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RIVERSIDE COUNTY FLOOD CONTROL
AND WATER CONSERVATION DISTRICT

CRWQCB - REGION 8
MES

FEB 18 2009

February 13, 2009

Mr. Gerard J. Thibeault, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, California 92501-3348

Dear Mr. Thibeault:

Re: Comment Letter – Renewal of Waste Discharge Requirements for the Tentative Order No. R8-2008-0030, NPDES No. CAS618030 Relative to Potential Application to Riverside County

The Riverside County Flood Control & Water Conservation District (District), the County of Riverside and the incorporated cities of Beaumont, Calimesa, Canyon Lake, Corona, Hemet, Moreno Valley, Murrieta, Perris and Riverside (Permittees) appreciate the opportunity to comment on the Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the incorporated Cities of Orange County, Tentative Order No. R8-2008-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff (Draft OC MS4 Permit). The following comments have been developed in consultation with and represent the views of the Riverside County Permittees.

Although the Draft OC MS4 Permit will only apply to Orange County Permittees, Regional Board staff has stated that certain provisions may serve as a model for the draft MS4 Permit that will be issued to the Riverside County Permittees; therefore, these comments principally address how the Draft OC MS4 Permit would impact the Riverside County Permittees and their associated compliance programs.

The 2002 Riverside County MS4 Permit and the associated compliance programs implemented by the Permittees have been effective in managing urban runoff quality in Riverside County and protecting receiving waters. Therefore, the Permittees oppose the use of the Draft OC MS4 Permit as an outright model for all three MS4 permits in the Santa Ana Region and request that Regional Board staff use the proposed revision of the 2002 Riverside County MS4 Permit that was submitted by the Permittees with the Report of Waste Discharge (ROWD) as the basis for developing the draft Riverside County MS4 Permit. Maintaining the 2002 Riverside County MS4 Permit structure will enable continuity of the Riverside County compliance programs and assist the Permittees in containing compliance costs. Compliance cost containment is particularly important considering the economic crisis, which is anticipated to continue well into the term of the 2009 Riverside County MS4 Permit. Building on the 2002 Riverside County MS4 Permit will continue to be protective of receiving water quality.

The economic crises and the impacts on Permittee funding sources will be a primary consideration during the term of the 2009 Riverside County MS4 Permit. The Permittees are currently implementing significant budget reductions and employee layoffs affecting vital basic services. Some of these basic services will be needed even more by those most impacted by the economic conditions. As MS4 permit compliance programs will be competing for finite resources with these services, it is anticipated that they will not be immune to reductions. Permittee efforts to develop new revenue sources for the NPDES MS4 programs have met with limited success (See Attachment B). It is unlikely new sustainable revenue sources will be generated in the near term and as previously noted, existing revenue sources have been significantly impacted by the deteriorating economic conditions. Under these circumstances, compliance with expanded permit requirements beyond current levels will likely require reduction or elimination of other compliance activities or receipt of Federal or State funding.

The District is also concerned that its limited participation in Orange County stakeholder meetings may be construed as tacit approval of the outcomes of those meetings. The purpose of the District's participation has only been to gain an understanding of the issues that may apply to Riverside County. Attendance should not be misinterpreted as active participation in the development or acceptance of provisions being drafted for the Orange County program. The Permittees expect the Regional Board to provide the same level of opportunity and time to participate in the review of the draft Riverside County MS4 Permit as afforded to the Orange County Permittees.

The following comments address the Permittees' general concerns with the major ramifications of using the Draft OC MS4 Permit as a model for the 2009 Riverside County MS4 Permit and the potential inclusion of the expanded program requirements in the 2009 Riverside County MS4 Permit.

The Basis for the Riverside County MS4 Permit should be the 2002 Riverside County MS4 Permit

In 2002 the Regional Board staff issued a draft MS4 Permit for Riverside County based on the MS4 Permit that had been adopted for Orange County. At a workshop in May 2002, the Riverside County Permittees objected to this approach, citing the significant differences between water quality conditions in Orange County and Riverside County, and the need to maintain existing compliance programs to provide continuity and contain compliance costs. The members of the Regional Board agreed and directed Regional Board staff to work with the Permittees to develop MS4 Permit requirements appropriate to Riverside County.

Following the workshop, the Permittees and Regional Board staff initiated over four months of intense negotiations leading to the Riverside County MS4 Permit that was adopted in October 2002. In this process, several Permittee representatives, including a Deputy County Counsel, met with Regional Board staff multiple times each week. In addition, the Permittee and Regional Board staff spent many hours outside of these meetings conducting research, drafting alternative permit text, and

reviewing proposed text. Virtually every word in every line of the Riverside County MS4 Permit was reviewed to ensure that findings and facts were substantiated, requirements were appropriate to the conditions and needs of Riverside County, existing compliance programs maintained, ambiguity of intent eliminated, content organized, redundancies eliminated and terms defined in a glossary. This process lead to an MS4 Permit that is superior relative to others in effect in California. At the hearing on October 25, 2002, the Regional Board, Regional Board staff and the Permittees were unanimous in praising the process and the resulting MS4 Permit and in supporting the adoption of the Riverside County MS4 Permit. This unanimous support is especially notable when one considers that all other MS4 permits issued in Southern California during that period were appealed and/or litigated.

The Draft OC MS4 Permit is based on the 2002 Orange County MS4 Permit. In addition to retaining many of the flaws that were eliminated in developing the 2002 Riverside County MS4 Permit, the Draft OC MS4 Permit is not appropriate to the water quality conditions or jurisdictional authorities in Riverside County, would require replacement and/or expansion of ongoing compliance programs and would impose substantial increased compliance costs without a demonstrated water quality need or benefit.

The 2002 Riverside County MS4 Permit Is Protective of Receiving Water Quality

The Riverside County Drainage Area Management Plan was updated to address the requirements of the 2002 Riverside County MS4 Permit. The revised programs are being implemented and have been effective in managing urban runoff and protecting receiving water quality. In fact, 155 chemical constituents, many of which are USEPA Priority Pollutants, have never been detected at Riverside County's monitoring stations since 2002. Bacteria and nutrients, the primary constituents of concern for the region, have adopted TMDLs and are currently in the implementation phases. The protection of receiving water quality is especially notable in light of the development activity that occurred in the Santa Ana Region since 2002.

In addition, the Permittees adopted and are implementing the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP) in large part to mitigate potential receiving water impacts associated with public and private development. This plan is based on a watershed scale analysis of critical habitat resources, a prioritization of resources based on value and a commitment to protect and maintain those resources deemed critical to sustaining Riverside County's unique environment. Since many of the most critical habitat areas are dependent on water, many of the proposed MSHCP lands significantly overlap with Riverside's remaining natural stream systems. In addition, the ongoing Special Area Management Plan watershed planning effort to protect critical Waters of the United States in Riverside County will also provide additional substantive protections for Waters of the United States. These existing and ongoing watershed based planning efforts will provide for substantive setbacks and natural buffers from existing receiving waters, protect high value aquatic habitat and achieve many other ends that are currently the goal of the intense discussions regarding Low Impact Development (LID) provisions in the Draft OC MS4 Permit. The

Permittees would expect that Riverside County's progressive activities to date would be recognized and reflected in the updated 2009 Riverside County MS4 Permit.

Expanded Compliance Program Requirements and Increased Costs cannot be Justified

As reflected in Attachment A, a number of the expanded program requirements proposed in the Draft OC MS4 Permit would be gratuitous if included in the Riverside County MS4 Permit: the requirements do not address identified water quality problems specific to Riverside County, or water quality problems that are not already effectively addressed by existing Riverside County Permit requirements and compliance programs. Further, the expanded compliance requirements would not increase the effectiveness of receiving water quality protection despite substantial increases in implementation costs.

Further, due to deteriorating economic conditions, all of the Permittees have been forced to reduce operating budgets and several have instituted layoffs. These actions are affecting all Permittee projects and services, including MS4 Permit compliance programs. The economic conditions are anticipated to continue until well into the term of the Riverside County MS4 Permit. During the term of the 2009 Riverside County MS4 Permit, the Permittees' objective will be to maintain the existing level of compliance activities. Except to the extent that the State will provide funds for implementation, no Permittee will be in a position to fund expansion of their compliance programs. As noted above, local funding for new or expanded compliance programs will likely require reduction or elimination of existing compliance activities and/or State or Federal funding.

Riverside County ROWD

On April 27, 2007 the Permittees submitted a ROWD to the Regional Board for renewal of the 2002 Riverside County MS4 Permit. In the ROWD, the Permittees provided a markup of the 2002 Riverside County MS4 Permit that identified applicable updates and enhancements. In addition, the markup included revisions that reflected Regional Board staff comments received by the Permittees during the term of the 2002 Riverside County MS4 Permit, including comments received at the January 22, 2007 ROWD kickoff meeting regarding topics such as low impact development, hydromodification, local implementation plans, etc. This document builds on the significant investments of time and resources made by the Permittees and the Regional Board in developing the 2002 Riverside County MS4 Permit. This proposed revision of the 2002 Riverside County MS4 Permit is the appropriate starting point for developing the draft Riverside County MS4 Permit.

In addition to the general concerns described above, Attachment A provides specific concerns with compliance requirements proposed in the Draft OC MS4 Permit as they may apply to the 2009 Riverside County MS4 Permit. This list of concerns is not comprehensive, but represents specific concerns that were identified in initial Permittee review comments. In addition, Attachment B includes information regarding the impact of the economic crises on funding sources and the Permittees' ability to finance permit compliance programs.

Re: Comment Letter – Renewal of Waste
Discharge Requirements for the
Tentative Order No. R8-2008-0030,
NPDES No. CAS618030 Relative to
Potential Application to Riverside County

Thank you for the opportunity to comment on the Draft OC MS4 Permit. As requested in the ROWD submitted in April 2007, we request that the draft Riverside County MS4 Permit be based on the 2002 Riverside County MS4 Permit. Further, we request that the 2009 Riverside County MS4 Permit limit expansion of compliance requirements and support existing compliance programs. We appreciate your consideration of our comments and look forward to meeting with Regional Board staff to identify where and how compliance requirements can be adjusted to maintain or materially enhance the effectiveness of the compliance programs consistent with reduced funding availability. If you have any questions regarding these comments, please contact Jason Uhley at 951.955.1273.

Sincerely,

WARREN D. WILLIAMS
General Manager–Chief Engineer

Attachment A – Comments
Attachment B – Funding Sources & Economic Projections

c: Riverside County Management Steering Committee
David Huff, Deputy County Counsel

AM:cw:bjp

ATTACHMENT A

Comments

The Draft OC MS4 Permit is ambiguous and subject to alternative interpretations. For example, numerous terms are used without definition. As described in the discussion of proposed Residential Program requirements below, the ambiguity can result in a wide range of interpretations that may not be consistent with the regulatory intent or the Permittees' understanding. The Permittees request that the proposed revision of the 2002 Riverside County MS4 Permit that was submitted with the ROWD be used as the basis for the 2009 Riverside County MS4 Permit and that the glossary from the 2002 Riverside County MS4 Permit be retained. The following comments address findings and requirements presented in the Draft OC MS4 Permit relative to their potential application to Riverside County.

Findings

- Finding 5 asserts that the Draft OC MS4 Permit does not constitute an "unfunded mandate". There may be clear examples where the permit is more stringent than the Clean Water Act (CWA) and, therefore, is potentially an unfunded mandate.

- Finding 62 asserts that the proposed 5% effective impervious area (EIA) limitation is well proven. However, there is no sound basis for this Finding. Contrary to the Finding, the Southern California Coastal Water Research Project (SCCWRP) study does not state that 5% EIA will prevent downstream impacts. The Permittees are not aware that the referenced study prepared by Dr. Richard Horner has been peer reviewed or published, or that this represents more than a statement of opinion of an individual professionally associated with the Natural Resources Defense Council. A far more rigorous peer-reviewed evaluation, including input from experts with a range of perspectives, would be expected prior to establishment of a policy with such far-reaching impacts on the delivery of housing, transportation projects and employment.

Section III - Discharge Limitations/Prohibitions

1) Section III.3 of the Draft OC MS4 Permit specifies that certain discharges are prohibited unless the Permittees make a determination that they are not substantial contributors of pollutants to the MS4s and receiving waters. Not only is this inconsistent with the exempted discharges provisions specified in Provision II.C. of the 2002 Riverside County MS4 Permit, it is inconsistent with the Federal Phase I stormwater regulations which only require that such flows be " . . . *addressed* where such discharges are identified *by the municipality* as sources of pollutants to waters of the United States: . . ."[1] It is important to note that the Federal regulations require the discharges to be addressed, not prohibited, and only where the municipality, not the administrator (i.e., the Regional Board), determines that they are a source of pollutants. In issuing the Phase I stormwater regulations, EPA stated:

[1] 40 CFR § 122.26(d)(2)(iv)(B)(1)

> . . . it is unlikely Congress intended to require municipalities to effectively prohibit individual car washing or discharges resulting from efforts to extinguish a building fire and other seemingly innocent flows that are characteristic of human existence in urban environments and which discharge to municipal separate storm sewers.

Item III.3.i.c requires the Permittees to prohibit irrigation water from agricultural discharges. However, § 502(14) of the Clean Water Act exempts agricultural stormwater discharges and return flows from irrigated agriculture from regulation under NPDES. Therefore, since the Regional Board has identified these discharges as a significant source of pollutants warranting prohibition, waste discharge requirements should be issued to agricultural operators to control these discharges to protect receiving water quality.

The Permittees would object to including Section III.3 of the Draft OC MS4 Permit in the 2009 Riverside County MS4 Permit.

2) As discussed in the 2007 ROWD and comment letter from the District regarding the De Minimus General Permit[2] the Permittees request that construction site dewatering be covered under the 2009 Riverside County MS4 Permit. The receiving water limitations incorporated into NPDES MS4 permits requires Permittees to ensure that discharges within their jurisdiction are protective of receiving waters. The Permittees request that Permittee construction dewatering activities be identified as an allowed non-stormwater discharge in the 2009 Riverside County MS4 Permit and provide appropriate exemptions from the De Minimus General Permit for Permittee construction activities.

Section IV - Receiving Water Limitations

The receiving water limitations as presented in Section IV of the Draft OC MS4 Permit are not adequately specific to discharges from activities or areas under the jurisdiction of the Permittees. In addition, the receiving water limitations require modification of the DAMP within 30 days of notification by the Executive Officer following determination that a discharge from the MS4 is causing or contributing to an exceedance of water quality standards. This is an unreasonably short period for revision of such a significant compliance document. The Permittees request that the Receiving Water Limitations specified in the 2002 Riverside County MS4 Permit be retained in the draft Riverside County MS4 Permit. These receiving water limitations:

- Exclude exceedances due to activities or areas not under the jurisdiction of the Permittees
- Provides 90 days for DAMP revision following notification by the Executive Officer
- Clarifies that the receiving water limitations apply to "Urban Runoff" as defined in the glossary.

[2] Comments on General Waste Discharge Requirements for Discharges to Surface Waters that Pose an Insignificant Threat (De Minimus) to Water Quality – Order No. R8-2009-0003, NPDES No. CAG998001, Riverside County Flood Control and Water Conservation District, January 7, 2009.

Section VIII.2 - Municipal Inspections of Construction Sites

1) Provision VIII.2 of the Draft OC MS4 Permit requires all sites for which building or grading permits have been issued and where activities include soil movement, uncovered materials storage and mixing of masonry materials to be tracked on a computer-based database system. The Permittees do not understand the purpose of this mandate as it appears to require recordkeeping without a purpose. The database would be required to include GIS compatible information for every construction site. However, the majority of these construction sites to be tracked are transitory. This requirement would mandate establishment or expansion of existing Permittee GIS systems. In some instances, Permittees do not have a GIS system and would be required to develop one to comply with this requirement. This would require budget increases to obtain and/or expand a GIS system, increase GIS system staffing and/or expand contract budgets for GIS services at a time when Permittee budgets are impacted and basic services are being reduced.

   Tracking of all construction sites on a computer-based database system is a substantial, unnecessary and costly burden for the Permittees. Additionally, this mandate expands the Construction Site Inspection program to sites less than one acre. The result will add soft and hard costs to property owners doing minor property repairs and other minor property improvements, e.g., lawn irrigation systems, footings for patio covers, garden and retaining walls, pools/spas, etc. Receiving water quality issues to warrant establishment of a sophisticated GIS-based database system do not exist in Riverside County. Moreover, there is no reason to expect that establishment and maintenance of such a costly system would meaningfully enhance receiving water quality protection. The Permittees request that this requirement to develop and implement computer-based systems to track GIS compatible information on all construction projects be excluded from the draft Riverside County MS4 Permit.

2) Section VIII.4.b of the Draft OC MS4 Permit requires each construction site inspection to include a documented review of the Erosion and Sediment Control Plan. In addition to requiring a significant increase in the level of training and expertise of construction site inspectors, this requirement will significantly increase the amount of time needed for each construction site inspection.

   Although increased developer fees may offset inspection costs for future plan checks and inspections, costs associated with developing new MS4 program elements cannot be recovered. Lack of revenues from development fees have resulted in layoffs of construction inspectors and plan check staff. Increasingly, the lack of work for remaining staff has resulted in subsidies from general funds and other revenue sources just to keep plan check and inspection services minimally functional. Requirements to unnecessarily enhance related NPDES MS4 programs would increase the burden on these other funding sources; making MS4 program expansions compete for funding needed to support other basic services. Therefore, costs for expanded plan check and inspection requirements will have a substantial impact on these funding sources during a period when development fee revenue to fund inspection and plan check activities and general fund revenues have plummeted.

The Permittees currently implement an effective construction inspection program that is protective of receiving water quality. Expansion of this program is not necessary. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

3) Section VIII.6 of the Draft OC MS4 Permit omits verbal warnings as an acceptable form of sanction at construction sites. The Riverside County Permittees have incorporated an Enforcement Compliance Strategy in the Construction element of the Drainage Area Management Plan (DAMP) that incorporates verbal warnings as an appropriate enforcement response based on specified guidance and inspector judgment. This provides the inspector flexibility to provide a range of enforcement responses depending on the situation. The Permittees request that verbal warnings be retained as an acceptable form of sanction in the Riverside County MS4 Permit.

Section IX - Municipal Inspections of Industrial Facilities

The Draft OC MS4 Permit requires maintenance of an inventory of industrial facilities within their jurisdiction on a GIS database. Data required to be maintained on this database includes, at minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken. Compliance with this requirement would be a significant and unreasonable financial burden on the Permittees. In some instances, Permittees would be required to develop a GIS system to comply with this requirement. Chronic problems impacting receiving water quality associated with industrial facilities have not been identified. Moreover, there is no reason to believe that establishment of such an elaborate GIS database would be more protective of receiving water quality than utilization of existing data management systems. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

Section X.1 - Municipal Inspections of Commercial Facilities

Section X.1 of the Draft OC MS4 Permit requires use of a GIS database for maintenance of an inventory of commercial facilities. In addition, the categories of commercial facilities covered under the commercial facilities inspection program would be significantly expanded from those facilities inspected under the Permittees' existing inspection programs. Not only would the requirement to develop GIS based inventory system and expansion of the commercial facility inspection program significantly increase the cost of this compliance program, the Compliance Assistance Program (CAP) would need to be abandoned and replaced. Further, chronic problems impacting receiving water quality associated with commercial facilities have not been identified. Moreover, there is no reason to believe that establishment of such an elaborate and expensive GIS database would be more protective of receiving water quality than the existing Permittee programs. The Permittees request that these requirements be excluded from the draft Riverside County MS4 Permit.

Section XI.4 - Residential Program

Section XI.4 of the Draft OC MS4 Permit requires Permittees to develop and implement control measures to minimize runoff from "common interest areas". It is not clear what is included in the definition of "common interest areas" or if this requirement applies to new development or also to retrofit of existing development (including public facilities) or what compliance measures are contemplated. As written, this requirement is ambiguous and may be subject to a wide range of interpretations. Therefore, the Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit. However, the Permittees are interested in working with the Regional Board and water purveyors to promote water conservation and other programs that will promote efficient irrigation and reduce landscape irrigation runoff from residential developments into the MS4.

Section XII - New Development (Including Significant Re-Development)

1) Frequent reference to incorporation and implementation of "LID principles" is made throughout Section XII. A clear goal and definition of these LID principles as they apply to the semi-arid climate of Orange County is needed to ensure a consistent understanding of compliance expectations. It is particularly important to ensure that these principles do not conflict with water conservation or urban density policies, objectives, or requirements. The Permittees note that the LID principles that may be applicable to Orange County may not be applicable to the warmer and more arid climate found in Riverside County. Such principles for Riverside County should be developed in cooperation with the Permittees.

2) Section XII.A.1 of the Draft OC MS4 Permit requires that a database be maintained to ensure (prior to issuance of any local permits or other approvals) that all construction sites required to obtain coverage under the State's General Construction Permit have filed a NOI. However, Section VIII.A.1 of the 2002 Riverside County MS4 Permit states that any project seeking discretionary approval or map must be conditioned requiring the applicant to obtain coverage under the State's General Construction permit and that the Permittees verify that this condition has been satisfied. This existing MS4 Permit requirement and the programs and procedures implemented by the Permittees to comply effectively promote compliance with the General Construction Permit without the additional expense of developing and maintaining yet another database.

   In many cases, Permittee approvals and permits are issued well in advance of initiation of construction activity. In some instances, approvals may be provided years before the initiation of construction. The State's General Construction Permit only requires submittal of an NOI 14 days prior to initiation of construction. This provision would impose additional costs on development activities in the form of payment of fees and implementation of monitoring and other activities to comply with the General Permit prior to initiation of construction, with no corresponding water quality benefit.

   The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

3) Section XII.A.4 of the Draft OC MS4 Permit requires in the first annual report a summary of the Permittees' review of watershed protection principles and policies in their General Plan and other related documents to ensure that LID and HCOC principles are properly considered and incorporated. Formation and facilitation of a TAC, drafting amendments, public noticing and required public hearings to resolve these issues will exceed the deadline and place the Permittees in an unavoidable violation of this permit provision. Further, the Permittees would note that the existing Western Riverside County Multiple Species Habitat Conservation Plan and proposed Special Area Management Plan already incorporates significant watershed protection principles and policies promoting low impact development. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

4) Section XII.B.2.b of the Draft OC MS4 Permit adds a category under New Development where subdivisions creating less than 10 lots or units, where the combined impervious surface area of the lots or units is equal to or greater than 10,000 sq. ft. would be subject to WQMP requirements. This new category is a significant expansion of the WQMP requirements in the 2002 Riverside County MS4 Permit. Significant water quality problems have not been associated with these types of developments that are not adequately managed by the Permittees' existing requirements. While requiring such projects to prepare WQMPs would not provide meaningful receiving water quality benefits, it would add significantly to project and project review costs. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

5) Section XII.B.2.i of the Draft OC MS4 Permit adds a category under New Development where streets, roads, highways and freeways of 5,000 sq. ft. of paved surface would be subject to WQMP requirements. This new category is a significant expansion of the WQMP requirements in the 2002 Riverside County MS4 Permit. This new requirement will delay or halt numerous road improvement projects, such as street widenings, that are intended to address existing safety concerns, the original purpose of the facility, and other transportation related improvements for increased safety/capacity, bikeways, and pedestrian facilities. These vitally needed projects would be delayed or halted due to increased design complexity and the need to acquire additional property. Further, the cost of even minor enhancements of the highway systems in Riverside County would be inflated by property acquisition, construction and ongoing maintenance costs.

   The existing local transportation system receives runoff from adjacent developed properties (including those developed prior to the adoption of the stormwater regulations) and undeveloped properties. Transportation projects would be required to not only treat runoff associated with the project, but also run-on from adjacent properties. Therefore, this proposed requirement would burden transportation projects with the cost to treat runoff from other pre-regulation developments, making many important projects economically infeasible. Not only would this prevent implementation of vitally needed transportation projects, but this would eliminate the economic stimulus that such projects may provide.

   The proposed requirement to prepare a WQMP for road projects 5,000 sq. ft. or more is inconsistent with requirements for the design of State highways. State highways are only required to incorporate treatment control BMPs where needed to comply with a TMDL or where a highway project will result in a net increase of one acre or more of impervious

surface.[3] There is no justification for imposing more restrictive requirements on local road projects than are imposed on State highway projects.

Runoff from transportation projects is effectively managed by the Permittees' existing compliance programs. While requiring transportation projects to also comply with WQMP requirements would not provide additional meaningful receiving water quality benefits, it would add significantly to project costs. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

6) Section XII.B.3 of the Draft OC MS4 Permit requires that WQMPs limit effective impervious area to 5% or less of the total project site. The Permit does not adequately define how effective impervious area is to be determined. Further, we are unaware of published field studies that provide empirical evidence supporting the use of the 5% effective impervious area concept on a project site basis. The Permittees do support the concept of using a prioritization requirement for the 85% treatment control requirement to ensure that LID BMPs that promote infiltration, reuse and/or evapotranspiration are required prior to considering classic treatment control technologies, with the following exceptions or caveats:

   a) The Permittees do not support separate tiers for infiltration, reuse and evapotranspiration BMPs. These BMPs should be defined and considered concurrently on a project-specific basis as part of a single tier. The Permittees believe that separate tiers for LID BMPs would unduly constrain the flexibility of BMP selection for development projects and potentially require the Permittees to approve BMPs that may not be optimal for the site conditions, leading to future maintenance, permit compliance and water quality problems. Further, cisterns and other capture and reuse technologies are not widely used in Riverside County and the lack of experience in implementation may lead to improper design, installation, public safety concerns, and resultant BMP failures if the technology was required to be implemented in an immediate and broad fashion. More fundamentally, some of these technologies, although practical in the Pacific Northwest and other areas experiencing temperate climates and higher annual precipitation, may not be practical given climactic conditions in Riverside County.

   b) Before a prioritization scheme can be supported by the Permittees, appropriate offramps must be developed to ensure that projects are not inappropriately burdened with infeasible or inappropriate BMPs. Offramps for local geologic and climactic conditions, potential groundwater limitations flow requirements of downstream habitat or wetlands, consideration of smart growth in lieu of LID, consideration of other regional approaches to WQMP compliance, and other appropriate factors should be incorporated to ensure that effective BMPs are selected to the Maximum Extent Practicable (MEP).

   c) The existing 85% Treatment Standard must continue to constitute the MEP standard for new development. This standard was established as a State-wide policy that has not been amended.

[3] Storm Water Quality Handbook: Project Planning and Design Guide, California Department of Transportation, May 2007, Section 4.

To presume that any portion of the 85% design volume that cannot be addressed through LID techniques must be mitigated offsite (as proposed by the National Resource Defense Council representative at the various meetings coordinated by The Irvine Company in Orange County to discuss the new development requirements) and in addition to 85% design volume treatment would move the Permit from a water quality based standard to a hydrologic control based standard. Such a requirement would establish and allocate quantities of water to receiving waters. The requirement to provide offsite mitigation not only exceeds the MEP requirement, but would also extend the requirements of the MS4 permit beyond the authority of the Clean Water Act. The Clean Water Act specifically exempts water management activities from regulation as noted in Section 102(g):

> "It is the policy of Congress that the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired by [the Act]. It is the further policy of Congress that nothing in this chapter shall be construed to supersede or abrogate rights to quantities of water which have been established by any State. Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water sources".
>
> Requirements mandating offsite infiltration of water to manage flow rates or volumes in streams are clearly water management activities. Permit requirements for offsite mitigation would be an unfunded state mandate. In addition, facts and findings justifying and supporting requirements for off-site mitigation above and beyond the 85% treatment requirement must be provided. The Permittees do not support the use of offsite mitigation as an additional requirement beyond the existing onsite treatment control policy established by the State Water Resource Control Board.

d) The Permittees insist that the Permit provide facts and findings supporting requirements to promote infiltration, reuse and/or evapotranspiration as the required first approach to BMP implementation for new development and redevelopment projects. These facts and findings must identify the specific existing receiving water quality problems to be addressed by these proposed requirements, how existing programs are not effective in addressing these problems and demonstrating that the proposed requirements will be more effective than existing requirements in protecting receiving water quality to address the problems. Such facts and findings must be specifically applicable to the climactic conditions in western Riverside County.

e) The Permittees also insist that the Permit recognize through facts and findings the potential impacts of onsite infiltration requirements on downstream habitat and wetlands areas that may be degraded by the loss of dry weather or wet weather flows from redevelopment projects or similar reductions caused by infiltration (and subsequent loss of runoff from small storm events) from new development projects and explicitly state that these actions are required to attain beneficial uses and are mandated by the Regional Board to meet the MEP standard.

7) Section XII.C.4. of the Draft OC MS4 Permit links treatment control substitution to the 5% effective impervious area requirement. As noted above, the Permittees do not support the use of this metric. The Permittees recommend this section be modified consistent with the intent of Comment No. 6) above.

8) Section XII.D of the Draft OC MS4 Permit addresses hydromodification. The Permittees and the Santa Ana Regional Board have both supported SCCWRPs efforts to develop hydromodification and have dedicated substantial resources toward the completion of the study. Because of existing and continued commitment to the SCCWRP study, the expected prioritization of LID as the primary method of treatment control, and the existing requirements in the Riverside County WQMP to assess and mitigate hydromodification requirements, the Permittees recommend the following approach to hydromodification mitigation be used in Riverside County:

   a) That the draft Riverside County MS4 Permit promote the use of a final hydromodification standard based on the findings and tools developed by SCCWRP as part of their ongoing hydromodification studies. It is our understanding that SCCWRPs approach will include recommendations for watershed-based analysis of areas susceptible to hydromodification. The Permittees support the use of a watershed based approach to identify and mitigate hydromodification impacts as it allows the Permittees to develop clear knowledge of the scope of the issue, to prioritize resources to addressing the issue, to ensuring that appropriate conditions are placed on new development projects and that appropriate tools are available to both developers and Permittees to ensure that proper hydromodification mitigation activities occur.

   b) That the draft Riverside County MS4 Permit continue to promote the use of the hydromodification mitigation requirements contained in the 2002 Riverside County MS4 Permit. The existing hydromodification requirements have been demonstrated to be effective and appropriate to the conditions in Riverside County and will be significantly reinforced by the focus on low impact development techniques proposed in the Riverside County ROWD. The LID requirements will further reduce and control incremental runoff volumes from new developments and retard times of concentration.

      Further, it is our understanding that the SCCWRP studies are projected to be completed within three years. By the time the 2009 Riverside County NPDES MS4 Permit is adopted, new interim criteria developed, training conducted and effective implementation of interim requirements accomplished, it is likely that SCCWRPs revised hydromodification criteria would be available for use. Continued implementation of the existing hydromodification criteria would avoid the additional Permittee costs and confusion of the regulated community that would be associated with implementation of interim requirements.

   c) The Draft OC MS4 Permit and pending 2009 Riverside County MS4 Permit facts and findings should also recognize that there are many terminus conditions that can limit the need to conduct hydromodification evaluations to the ocean. These interim terminus water bodies may include lakes, engineered or maintained flood control facilities, dams, natural geologic features, etc. The 2009 Riverside County NPDES

MS4 Permit should explicitly identify that Reach 3 of the Santa Ana River, Prado Dam, Lake Elsinore, Canyon Lake, Mystic Lake and similar waterbodies as appropriate terminus features and that Prado Dam is the final receiving water from the Santa Ana Region of Riverside County.

9) Section XII.E.1. of the Draft OC MS4 Permit states that the Permittees may establish an urban runoff fund to be used for water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. A similar provision was proposed by the Regional Board for inclusion in the 2002 Riverside County MS4 Permit. Riverside County Counsel strongly advised that this provision be eliminated due to administrative difficulties and the potential for abuse and conflict. The Permittees request that this provision be excluded from the draft Riverside County MS4 Permit.

10) Section XII.F.2 and XII.I.3 of the Draft OC MS4 Permit adds a requirement that the Permittees maintain a database to track all structural treatment control BMPs, including the location of BMPs and parties responsible for construction, operation and maintenance. It is not clear why it is necessary or beneficial to track the parties responsible for construction. Projects have been incorporating structural treatment control BMPs since the inception of the Riverside County MS4 Permit in 1990 and identification of existing facilities would be a formidable and expensive requirement. The Permittees request that requirements for tracking the parties responsible for construction of structural treatment control BMPs be excluded from the Riverside County MS4 Permit. However, if incorporated into the draft Riverside County MS4 Permit, the Permittees request that this requirement to develop a database for structural treatment control BMPs be revised to require tracking by site as opposed to by BMP and to grandfather exceptions for existing treatment control BMPs. In addition, the Permittees recommend prioritization based on site risk for business inspections. The Permittees request that this database be implemented one year following adoption of the 2009 Riverside County MS4 Permit.

11) Section XII.H of the Draft OC MS4 Permit requires the Permittees to establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or City and the information is conveyed to all appropriate parties when there is a change in project or site ownership. Please see comment to Section XII.F. 2 of the Draft OC MS4 Permit above. The additional tracking of recordation of easements and ownerships and verification of conveyance of project information to new owners would be labor intensive and costly. Current requirements for WQMP documentation in Riverside County are effective and it is unlikely that the additional commitment of resources to comply with the proposed requirement would provide meaningful improvements in receiving water quality. The Permittees request that this provision be excluded from the draft Riverside County MS4 Permit.

12) Section XII.I.3 of the Draft OC MS4 Permit also requires establishment of the database specified in XII.F.2. Please see comment to Section XII.F. 2 of the Draft OC MS4 Permit above.

13) Section XII.I.4 of the Draft OC MS4 Permit requires including a list of all structural treatment control BMPs approved, constructed and/or operating within each Permittee's jurisdiction in Annual Reports. This expansion of the Annual Reporting requirements will

be costly and there is no need for or water quality benefits that would be provided by this proposed requirement. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

14) Section XII.I.5 of the Draft OC MS4 Permit requires inspection of all public agency structural treatment control BMPs, and at least 50% of priority development project structural treatment control BMPs prior to the rainy season. There are many public agency structural treatment control BMPs within the Riverside County over which the Permittees have no authority to inspect or control. For example, the Permittees have no authority over Caltrans, school districts, water and wastewater districts and many other "public agencies". In addition, priority development projects implemented by electric and gas utilities, pipelines, railroads and other private organizations are not subject to Permittee inspection or control. These limitations should be recognized in the permit text. Further, the inspection frequency is excessive and costly given the large number of such facilities that will be required in Riverside County. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit. In cooperation with the Regional Board, the Permittees would be interested in exploring the feasibility of a self-certification program to be implemented by the owners or operators of these systems. Barriers to implementation of such a program may include ordinance requirements, staffing and other costs, and political issues.

Section XIV.11 - Municipal Facilities/Activities

Section XIV.11 of the Draft OC MS4 Permit requires the permittees to clean and maintain at least 80% of their drainage facilities on an annual basis, with 100% of the facilities included in a two-year period. The Permittees currently implement a flexible program that provides for resources to be focused on problem areas. This approach is effective in Riverside County and the imposition of a more rigid maintenance schedule would not provide improved effectiveness, and may be detrimental to receiving water quality protection. The Permittees request that this requirement be excluded from the draft Riverside County MS4 permit.

Section XVI.1 - 3 Training Program

1) Section XVI.1 - 3 of the Draft OC MS4 Permit significantly expands Permittee staff training requirements. Although further development of the training programs is an objective of the Riverside County Permittees, this will not be possible during the term of the 2009 Riverside County MS4 Permit without federal or state funding. The Permittees request that this requirement be revised in the draft Riverside County MS4 Permit to note that implementation will only be required if federal or state funding can be obtained for development and implementation. In particular, the requirement to issue a "Certificate of Completion" may trigger "meet and confer" requirements in employee bargaining groups that may result in significant labor costs to the Permittees. The existing employee training program is effective and no need for such a formalized certification process has been identified. The Permittees request that this requirement be excluded from the draft Riverside County MS4 Permit.

2) Section XVI.8 of the Draft OC MS4 Permit requires each Permittee to "have adequately trained all staff involved with stormwater related projects within 60 days from being

assigned duties". This is inconsistent with Permittee procedures and 2002 Riverside County MS4 Permit requirements for training and would impose an economic hardship on the Permittees. The Permittees request that this requirement be deleted from the draft Riverside County MS4 permit.

XVIII.A - Watershed Action Plans and TMDL Implementation

1) Section XVIII.A of the Draft OC MS4 Permit requires the Permittees to prepare Watershed Action Plans where total maximum daily loads (TMDLs) have not been developed. The Permittees would be required to:

   a. Identify impaired waters
   b. Monitor for pollutants causing impairment
   c. BMPs to target pollutants causing impairment

   This requirement would pre-empt the TMDL processes established by USEPA as well as task forces established in Riverside County. More flexible voluntary, risk-based, cost-efficient, and fiscally responsible opportunities for Permittees and the Regional Board to collaborate to address impaired waters would also be pre-empted.

   Development of Watershed Action Plans was proposed in the Orange County ROWD. However, the watershed conditions in Riverside County are distinctly different from those found in Orange County. Orange County has several separate and unique watersheds that discharge to the ocean. Riverside County has a single watershed – the Santa Ana River watershed that discharges to Prado Dam.

   Although it may be appropriate for Orange County to develop plans specific to each of their unique watersheds, the Permittees have been able to successfully incorporate permit wide programs into the DAMP to address TMDL impairments, 303(d) listed waterbodies and other constituents of concern. In each year's NPDES MS4 monitoring annual report, the Permittees summarize the constituents of concern impacting our receiving waters and identify DAMP program modifications that are proposed to address those constituents of concern. The adjustments are then incorporated directly into the DAMP as necessary. Unlike Orange County, Riverside County has not seen the need to subdivide our compliance activities by sub-watershed. Further, the Riverside County Permittees have developed their own TMDL task forces, IRWMs and administrative mechanisms that address these issues in a different manner.

   The Permittees request meetings with Regional Board staff to review existing Riverside County programs and how a requirement for Watershed Action Plans would be redundant to our existing administrative structures and processes. In the future, Riverside County Permittees may determine that there is a need to develop sub-watershed specific action plans, but the need to do this should be determined by the Permittees, not as a Permit requirement.

ATTACHMENT B

Funding Sources & Economic Projections

Funding Sources

The costs incurred by the Permittees in implementing the Santa Ana Regional DAMP fall into two broad categories:

- **Shared Costs**. These are costs that fund activities performed mostly by the District under the Implementation Agreements. These activities include coordinating the overall stormwater program, coordinating other interagency cooperative efforts such as the Compliance Assistance Program (CAP), participating in CASQA activities, representing Permittees at meetings of the Regional Board or State Board and other public forums; preparing and submitting compliance reports and other reports required under the MS4 Permit, conducting Urban Runoff monitoring and public education outreach programs, responding to Water Code Section 13267 requests, providing other program documentation, and coordinating consultant studies, Permittee meetings and training seminars.

- **Individual Permittee Costs for DAMP Implementation**. These are costs incurred by each Permittee for implementing within its jurisdiction the BMPs (drainage facility inspections for illicit connections/illegal discharges, drainage facility maintenance, drain inlet/catch basin stenciling, emergency spill response, street sweeping, litter control, public education, construction activity inspection, development of implementation plans, etc.) comprising the Santa Ana Regional DAMP.

Historically, the Permittees have employed several funding methods to finance their MS4 Permit compliance activities. Unfortunately, the mortgage crisis, collapse of the housing market and the economic recession has resulted in the cessation of virtually all development activity and has significantly reduced sales tax revenue. Property tax revenues have been reduced by the high level of foreclosure activity and reduced property values. Property tax revenues have been further reduced by homeowner requests for reassessments to reflect the reduced property values. The impact of these economic conditions on the Permittees in the Santa Ana Region has been particularly severe. As a result, funds typically provided by these funding methods has been severely reduced, and it is anticipated that this condition will continue for an indefinite period. The funding methods historically used and the effects of the economic situation on the availability of funds through these sources are summarized as follows:

- **Santa Ana Watershed Benefit Assessment Area**. In 1991, the District established the Santa Ana Watershed Benefit Assessment Area to fund its MS4 Permit compliance activities. Currently, the Benefit Assessment revenues fund the District's share of the area-wide MS4 Permit program activities and the District's individual compliance activities as a Permittee. Under the Benefit Assessment each parcel is taxed based on the impervious area of each parcel at a set rate established through Proposition 218. This rate has not been increased since 1991 and increases in revenues have resulted from increases in the number of contributing parcels resulting from New Development. In 2007/08 the

Santa Ana Benefit Assessment generated approximately $2,030,000 in revenue. These revenues are used to fund the District's compliance activities and the bulk of the administrative costs associated with the District's duties as Principal Permittee.

Outlook: The District expects at best to maintain, if not see temporary reductions in Benefit Assessment revenues due to the significant number of homes that are not paying property tax due to foreclosure. An increase in the established Benefit Assessment rate to compensate for these reductions would require approval of 2/3 of the voters or 50% of the property owners and is unlikely, especially in the current economic climate. An increase in the number of contributing parcels will not occur until the development industry recovers.

- **General Fund/Other Revenues**. The County and the Cities utilize general fund revenue to finance most of their MS4 Permit compliance activities. General fund revenue is generated by property tax, sales tax, and auto license taxes.

  Outlook: The Permittees expect a continued reduction in the funds available through General Fund/Other Revenues through at least FY 2009/2010. Although optimistic that conditions will begin to stabilize toward the end of 2009, the Permittees cannot speculate as to when revenues will recover to previous levels. Historically, the Permittees have investigated other funding sources, including a phone survey conducted by LESJWA with support from the District and the County of Riverside to evaluate the possibility of passing a new assessment to fund water quality improvements benefiting Lake Elsinore. The results of the survey found insufficient voter support for water quality related issues to move forward with a special election. The Permittees have also formed a finance committee which has met several times to educate our Permittees about actions that they can take to maximize revenues and potential alternative funding sources. These efforts met with some success, particularly in relation to maximizing fees for service; however significant new funding sources were not identified or available to the Permittees even during the more favorable economic conditions experienced during the term of the 2002 Riverside County MS4 Permit.

- **Fees**. Several Permittees charge fees for services such as inspections, plan check and other recoverable costs related to compliance with the 2002 Riverside County MS4 Permit. These fees cover both the direct and indirect costs associated with conducting these inspections/reviews including associated compliance tracking and reporting.

  Outlook: It is notable that, with the virtual collapse of the development industry in the Santa Ana Region, the fees received by the Permittees for review of new developments and construction inspections have been significantly reduced. With this reduced level of fee-based income, maintenance of the existing inspection and plan review programs will place a burden on overall funding of the compliance programs. The Permittees do not expect revenues from fees to recover until the development industry recovers. Even with recovery of the development industry, it is anticipated that revenues from fees will be reduced for the majority of the Cities within the Santa Ana Region and the County due to the reduced area remaining for development in their jurisdictions.

- **Grants.** The Permittees have actively pursued and, as available, used grants to fund compliance programs.

  Outlook: In December the State's budget crisis resulted in a directive to State agencies from the Department of Finance to halt projects that rely on bond funds, including those funded by Proposition 40, Proposition 50 or Proposition 84. The State of California is the primary source of grant funding for water quality projects. Future availability of funds to resume compliance projects funded by grants is uncertain.

It is clear that the current economic climate and that of the foreseeable future is creating a significant burden upon the Permittees that will make the continuance of all existing MS4 Permit compliance programs difficult. New funding sources or alternative combinations of funding sources will likely be required to ensure continued funding of even the current MS4 Permit compliance programs.

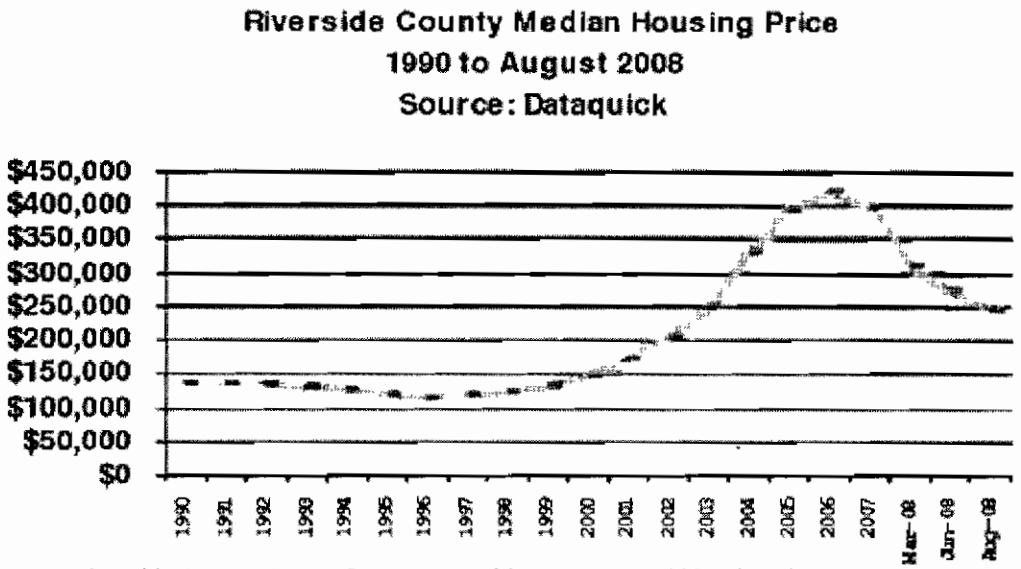
Economic Projections

According to Chicago Title, Southwest Riverside County has experienced a very significant increase in supply of single-family residential units on the market. As a result, housing price indicators are very negative. In the majority of the Southwest Riverside submarket, the pending price is less than closing price that suggests the weakness of the market. The October 2008 count of bank owned (REO) properties for Riverside County as a whole was 12,078. The number of foreclosures was 23,480. The presence of high levels of REO properties will continue to negatively affect the price line. In addition, the level of foreclosures is increasing. At the end of January 2009, 68% of the homes listed for sale are foreclosures or short sales.[4]

With regard to other sectors of the economy, Riverside County has taken a serious turn for the worst in 2008, with projections indicating that the severe downturn will continue through 2009 at the very least. The economic difficulties being faced in the Southwest Riverside submarket is the result of the dramatic downturn in the housing market in this area, the national financial turmoil, the worldwide credit crisis, and the increasing consumer debt crisis. According to Beacon Economics, a respected economics consulting firm in Los Angeles, Inland Southern California is clearly at the epicenter of this economic turmoil, with extremely high rates of unemployment at present. Unemployment rates in Inland Southern California are expected to reach 12.4% before this deep recession is over. Housing prices are expected to continue their precipitous decline from their peak levels in the two Inland Southern California counties through at least 2011. According to Dataquick, median home prices in Riverside County peaked at $415,000 in January 2007. At the end of this cycle, the median home price in Riverside County is expected to be $198,000. Figure 1 depicts the median housing price in Riverside County over the period 1990 to August 2008.

[4] Orange County Register, January 27, 2009, p. 11.

Figure 1. Riverside County Median Housing Price (1990 – August 2008)

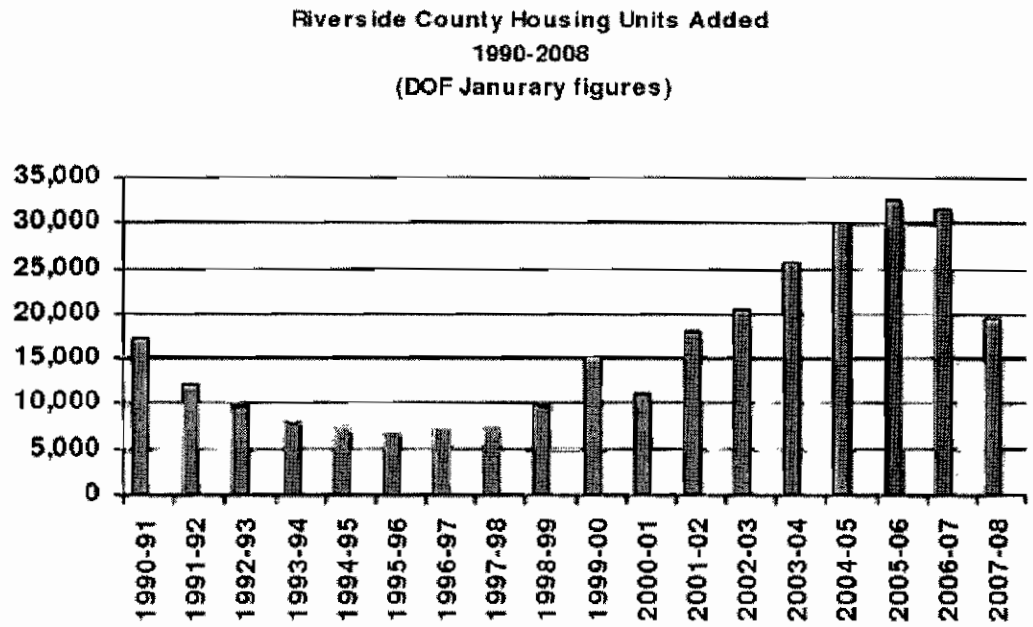


Source: Riverside County Center for Demographic Research. 2008. Riverside County Progress Report, pg 14.

Local Government sales tax revenues remained fairly stagnant through 2006 and began to decline in early 2007, according to Beacon. By the second quarter of 2008, the taxable sales in Riverside County declined by 7.7%. This will continue with taxable sales possibly bottoming out by 2010. These shocks are expected to continue and accelerate within the southwest Riverside County economy.

As a direct outcome of the current economy and the economic outlook into the term of the 2009 Riverside County MS4 Permit, the number of New Development proposals has plummeted and any significant rebound is not forecast. New and redevelopment projects will likely remain minimal. As shown in Figure 2, the number of housing units being added each year has dropped below the levels seen at any point in time during the 2002 Riverside County MS4 Permit. These numbers will likely continue to decrease for a significant portion of the new 2009 Riverside County MS4 Permit term.

Figure 2. Riverside County Housing Units Added (1990 – 2008)



Source: Riverside County Center for Demographic Research. 2008. Riverside County Progress Report, pg 12.

These economic issues and projections directly affect and limit both:

- The need for including enhanced new and re-development requirements in the 2009 Riverside County MS4 Permit, and

- The Permittees ability to fund, and even seek new funding sources for additional MS4 Permit requirements for new and re-development projects.

Therefore, the Permittees are not recommending and cannot financially support any significant increases to their Development Planning activities. Permittee specific projections are as follows:

County of Riverside

The County is operating with a structural deficit of $12 million and plans a 25% budget reduction from FY 2008/2009 through FY 2011/2012. The County's current budget of $4.7 billion represents a 5% reduction from the previous year and next year's budget is expected to be cut by 10%. These cuts are directly associated with the decline in property values caused by the high number of foreclosures. There are concerns about having to use discretionary funds to meet State mental health and social service mandates. In addition, the County is dependent on funds from Federal and Sstate sources. If during this time of economic crisis Federal and State funding sources are reduced or eliminated, any unfunded programs will be terminated. Only core County programs will continue.

The primary source of general fund revenue is from property taxes and sales tax. With the unprecedented number of foreclosures, reduced property values, and declining sales, general fund revenue is in a downward spiral. Another source of funding is through the

Solid Waste Tipping Fees paid at the County landfills. Volume is down 15% since 2006 with anticipated downward trend to 40% reduction in solid waste through 2014. Programs that are partially funded through tipping fee allotments will be impacted. Due to the declining economy the recycling market has collapsed. Virtually no recyclable materials are being shipped for reprocessing. This loss of revenue and increased disposal costs is further impacting the general fund.

Cuts of 25% for all Net County Cost general fund programs will translate into reduction of County services and elimination of unfunded State and Federal programs. Only core value programs will be provided (including public safety and fee programs).

The County has instituted a hiring freeze and required each department to create a report outlining the projected effects of the budget cuts. The County currently employs over 20,000 people, and layoffs are expected to result from the findings of these departmental reports. It is anticipated that this will impact program delivery for stormwater related activities. No County department will be able to sustain current staffing levels as they try to meet the 25% budget reduction strategy.[5] [6]

City of Menifee

The newly incorporated City of Menifee FY 2008/2009 initial budget was estimated from their comprehensive fiscal analysis that was submitted to the Local Agency Formation Commission during the incorporation process. Because of the economic uncertainty, and the fact that the City is only now beginning to staff positions, it is unknown what the immediate impact of the fiscal crisis will be. The County is responsible for assisting the City in meeting its MS4 Permit compliance requirements during the first year of incorporation which expires October 1, 2009. Currently, the level of property tax revenue that will be available to the City is uncertain. Funding for MS4 Permit compliance requirements was not explicitly budgeted. A financial hardship currently exists because of the costs associated with incorporation.

City of Murrieta

The City of Murrieta's FY 2008/2009 budget did not increase compared to FY 2007/2008. The City has identified a $3.3 million budget shortfall for the current fiscal year ending on June 30, 2009. This represents approximately 8.2% of the City's projected revenue which must be absorbed in five months. The shortfalls are primarily due to reduced sales tax and property tax revenues. Department heads are currently working on revised budgets to adjust for the loss in revenue.

Additional, budget cuts are anticipated for FY 2009/2010 because the immediate economic outlook is not good. There have been approximately 2,000 home foreclosures within the City. Sales tax revenue is estimated to drop 12.5%, property tax revenue will drop, and the State took approximately $525,000 out of redevelopment funds. Murrieta did not receive any vehicle licensing fees from the State and it appears likely that the State will take more

[5] "The Realities of Recession in California: A Statewide Report by U.S. Senator Barbara Boxer, December, 2008, p. 18.

[6] Riverside County Executive Office, January, 2008.

revenue from the Cities to solve its budget problems. New NPDES requirements that increase compliance costs will create a financial hardship for the City.

City of Riverside

The City of Riverside has seen declining general fund revenue over the last two fiscal years in virtually all categories. The City's most recent projection indicates that total general fund revenues for the current fiscal year will be under $200 million, down from a budget of $215 million as adopted, and $226.5 million in the prior fiscal year. This represents a decline over two fiscal years of approximately 12%. Specifically, property tax and sales tax revenue continue their decline, which is primarily attributable to decreased residential construction activity and in the case of sales tax declining automobile sales.

The decline in revenue has resulted in a corresponding reduction to general fund expenditures. Specifically, approximately 12% of the positions authorized for the general fund have been vacated and unfunded, either through transferring staff to other funds, attrition or limited layoffs of temporary and contract staff. Additionally, the level of service provided to the community in virtually all City departments has been reduced through funding reductions to items such as street maintenance, recreation programs and libraries, though great care has been taken to minimize the impact of cuts to the public. It is anticipated that in the near term the economic situation will not improve, and staff is preparing a budget for the upcoming fiscal year that anticipates further decreases in revenue.

City of Wildomar

The newly incorporated City of Wildomar FY 2008/2009 initial budget was estimated from their comprehensive fiscal analysis that was submitted to the Local Agency Formation Commission during the incorporation process. Because of the economic uncertainty, and the fact that the City is only now beginning to staff positions, it is unknown what the immediate impact of the fiscal crisis will be. The County is responsible for assisting the City in meeting its MS4 Permit compliance requirements the first year of incorporation that expires July 1, 2009. Currently, the level of property tax revenue that will be available to the City is uncertain. Funding for MS4 Permit compliance requirements was not explicitly budgeted. A financial hardship currently exists because of the costs associated with incorporation.

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Southern California Gas
GT16G3
555 Fifth Street
Los Angeles, Ca. 90013

Via Email
February 13,, 2009

Gerard J. Thibeault, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

SUBJECT: Written Comments on the proposed updated Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department and The Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff, ORDER No. R8-2008-0030, **NPDES No. CAS618030 Orange County**

Dear Mr. Thibeault;

We appreciate the opportunity to comment on the proposed updated Waste Discharge Requirements For the County of Orange, Orange County Resources and Development Management Department and The Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff, ORDER No. R8-2008-0030, NPDES No. CAS618030 Orange County.

Southern California Gas Company (SCG), a California regulated public utility, genuinely supports the Santa Ana Regional Water Quality Control Board and Staff (RWQCB) concerning the proposed revision to this important permit for water quality improvement. However, we have one issue of vital importance to SCG regarding the wording of an important section of the permit.

In permit Section III. 3. ii. a), the proposed revision to the Orange County MS4 Permit may appear to the municipalities as a mandate to **prohibit all** certain potable water discharges that are used for various purposes including hydrostatic test water for new piping, unless the water meets the stated RWQCB criteria. SCG requests that the wording in Section III. 3. ii, prior to subsection a), incorporate the exception for NPDES permits stated in Section III. 3. We suggest changing the wording in the heading for Section III. 3. ii to read: "The permittees shall prohibit the following categories of non-storm water discharges unless such discharges are authorized by a separate NPDES permit and/or the stated conditions below are met."

SCG considers the RWQCB NPDES De Minimus Permit an important tool to assist SCG in providing a cost effective, timely, safe, and reliable supply of natural gas to its customers, as SCG is legally required to do by the U.S. Department of Transportation ("DOT") and the California Public Utilities Commission ("CPUC"), while providing this service in an environmentally conscientious manner.

SCG has natural gas transmission and/or distribution pipelines and piping in every municipality within the Santa Ana Regional Water Quality Control Board (SWRCB) region. SCG routinely installs new pipelines and piping, or new sections of pipelines and piping to service new customers, or to maintain existing pipelines and piping. It is a requirement of both DOT and the CPUC that certain new pipelines and piping be pressure tested for safety. The only practical

means for this testing is to fill the pipelines with potable or other clean source of water, and then add air or nitrogen to raise the pressure to the required pressure testing standards. Adding air or nitrogen alone to the required pressure would be prohibitive on a cost and time basis, and disposal of the clean hydro-test water by other means is often cost prohibitive due to the volume of water required. SCG's hydrostatic test water discharges on new pipe have consistently met all current RWQCB De Minimus Permit parameter limits.

SCG also considers it vitally important that their pipeline and piping and other business activities that cross municipal and other local jurisdictional boundaries, be regulated as consistently as possible, minimizing the potentially numerous different, and potentially conflicting, construction requirements as a project proceeds from one local jurisdiction to the next.

For the purposes of removing a potential source of confusion and the provision of as much regulatory consistency as possible across the SCG service territory, SCG respectfully requests the insertion of the above clarifying wording in the aforementioned text.

Thank you for your consideration.

Sincerely,

/G. Scott Koken/

G. Scott Koken
Principal, Water Quality
Environmental Services
Southern California Gas Company
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CRWQCB - REGION 8
MA 3124
MES

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MCB

February 13, 2009

Mr. Michael J. Adackapara, Division Chief
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, California 92501

Subject: Tentative Order No. R8-2008-0030, NPDES No. CAS 618030

Dear Mr. Adackapara:

The City of Villa Park appreciates the opportunity to comment on Tentative Order No. R8-2008-0030, renewing waste discharge requirements for the discharge of urban storm water from areas of Orange County within the Santa Ana Region.

The City supports the Tentative Order's goal of protecting water quality standards of receiving waters. However, after reviewing the Order City Staff have identified a number of crucial general concepts, identified below, and have compiled a number of focused comments identifying items of concern (Attachment "A").

1. The Draft Order will significantly increase the administrative and financial burden associated with the program.
2. The Draft Order is overextending its regulatory reach into areas not legally within its or the permittee's control.
3. The Draft Order is creating a flawed basis for land development with the Effective Impervious Area and Hydromodification requirements.
4. The Draft Order is not taking into consideration available programmatic performance and environmental quality data provided by the Principle and Co-permittee's.

We hope that these comments and concerns are considered by the Regional Board before formally adopting Order No. R8-2008-0030, NPDES No. CAS 618030.

Sincerely,

Jason Carson
NPDES Coordinator

C: Don Powell, Interim City Manager
Jarad Hildenbrand, Assistant City Manager
Todd Litfin, City Attorney
Joe O'Neil, City Engineer

JIM RHEINS, Mayor • BILL MAC ALONEY, Mayor Pro Tem
DEBORAH PAULY, Councilwoman • BRAD REESE, Councilman • W. RICHARD ULMER, Councilman

Attachment: Comments Regarding Tentative Order No. R8-2008-0030, NPDES No. CAS 618030

Attachment "A"

Comments on Tentative Order No. R8-2008-0030, NPDES No. CAS 618030

VI. LEAGAL AUTHORITY/ENFORCEMENT

✓#2 Requiring the level of inspection authority described within this section of the Draft Order is viewed as a violation of the 4th Amendment of the U.S. Constitution.

Recommendation: Current legal authority inspection requirements should be maintained or item must be reworded to include the statement, "subject to restrictions of the Constitution".

✓ #6 Quarterly reporting of enforcement activity that administratively is a burdensome requirement that for medium to small cities with little to no staff resources is not viable.

Recommendation: Maintain current enforcement activity reporting requirements.

X. MUNICIPAL IINSPECTIONS OF COMMERCIAL FACILITIES

✓ #1 Quarterly updating of the commercial facilities database and the implementation of GIS tracking of commercial fixed facilities is a burdensome requirement that for medium to small cities with little to no staff resources is not viable.

Recommendation: Maintain current commercial facility tracking requirements.

✓ #1 No rational or technical findings are provided justifying an addition within the Draft Order of multiple categories of commercial facilities requiring inspections.

Recommendation: Maintain current commercial facility category list.

✓ #2 The minimum criteria requiring mandatory prioritization ranking percentages for commercial sites seems completely contradictory to the well established prioritization ranking criteria used in the existing permit. An unfair burden would be placed on both the public agency and those commercial business owners subject to random ranking increases to satisfy this requirement.

Recommendation: It is recommended that the current prioritization ranking criteria be maintained and that no random ranking increases be imposed.

#8 It is unrealistic to expect that over any period of time it would be possible for the principle permittee to notify all mobile businesses operating within the County of minimum source control and pollution prevention measures that they must develop and implement.

Recommendation: It is recommended that requirement be modified to read that ".....the principle permittee shall utilize all reasonable resources to notify mobile businesses....."

XI. RESIDENTIAL PROGRAM

The existing public education program implemented by the principle and co-permittee's has proven to be a very effective residential educational outreach program. Requiring a separate residential program would cause unnecessary duplication and burden.

Recommendation: That Section XI. RESIDENTIAL PROGRAM is removed from the Order completely.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

B.2.b Setting the square footage tolerance for subdivisions with less than 10 lots as low as 10,000 will require the inclusion of projects normally considered as deminimus water quality contributors.

Recommendation: That the current threshold of requiring residential development of 10 units or more is maintained and that the application of Low Impact Development (LID) principles is encouraged.

B.3.a Requiring within the permit that an Effective Impervious Area (EIA) of 5% be applied to land development projects within a Permittee or Co-Permittee's jurisdiction intrudes upon the Agency's Land Use Authority, in violation of the 10th Amendment of the United States Constitution.

Recommendation: That the section is omitted from the permit completely and that the application of Low Impact Development (LID) principles is encouraged or the item must be reworded to include the statement, "subject to restrictions of the Constitution.

B.3.c The existing Integrated Regional Watershed Management Program implemented by the principle and co-permittee's has proven to be a very effective integrated watershed approach program. Requiring a separate integrated watershed program would cause unnecessary duplication and burden.

Recommendation: That the Permittee's be directed to continue addressing watershed specific issues through existing watershed specific programs.

C. Requiring within the permit that LID site design principles be applied to land development projects within a Permittee or Co-Permittee's jurisdiction intrudes upon the Agency's Land Use Authority, in violation of the 10th Amendment of the United States Constitution.

Recommendation: It is recommended that the requirement be modified to state that "The permittee's shall encourage implementation of LID site design principles...."

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

#4 Define what are considered routine maintenance activities.

Recommendation: Routine maintenance activities may include but not be limited to street re-surfacing including removal and replacement of curb and gutter, routine building repair and alterations, landscape irrigation maintenance and repair, minor sewer and storm drain maintenance and replacement, and traffic control modifications.

XIV. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

#2 & 3 It is unfair to assume that all public agencies have industrial activities occurring within their boundaries and places an unfair burden in requiring responsible staff to prove competency through testing for activities they do not have.

Recommendation: It is recommended that the requirement be reworded to state that "The curriculum content should include those elements, listed below, that are applicable to that agency:"

Construction Industry Coalition on Water Quality

February 13, 2009

Michael Adackapara
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

RE: Tentative Order No. R8-2008-0030 (NPDES Permit No. CAS618030) Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department, and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff, Orange County

Dear Mr. Adackapara:

On behalf of the more than 3,000 member companies of the Construction Industry Coalition on Water Quality (CICWQ), we would like to thank the Santa Ana Regional Water Quality Control Board (Regional Board) for the opportunity to offer this public comment on the Draft Orange County Municipal Separate Storm Sewer System Permit, Tentative Order No. R8-2008-0030 (Draft Permit). We also appreciate the Regional Board's participation in the series of permit stakeholder meetings that we have had to date. This letter and attachments provide constructive suggestions that we have for the Draft Permit, and defines where we feel we have reached conceptual agreement on planning and land development provisions (most notably Low Impact Development and Hydromodification Control requirements) that have been discussed and debated thoroughly within a stakeholder group framework since December 2008.

I. Introduction

CICWQ is comprised of the four major construction and building industry trade associations in Southern California: the Associated General Contractors of California (AGC), the Building Industry Association of Southern California (BIA/SC), the Engineering Contractors Association (ECA) and the Southern California Contractors Association (SCCA). The membership of CICWQ is comprised of construction contractors, labor unions, landowners, developers, and homebuilders working throughout the region and state.

These organizations work collectively to provide the necessary infrastructure and support for the region's business and residential needs. Members of all of the above-referenced organizations are affected by the Draft Permit, as are thousands of construction employees and builders working to meet the demand for modern

infrastructure and housing in Orange County. Our organizations support efforts to improve water quality in a cost effective manner. Our comments and suggestions on the Draft Permit as well as our active involvement in the stakeholder group process reflect our commitment to protect water quality while at the same time preserve our member's economic viability in this difficult economic environment. Our membership has invested significant resources into developing sound engineering approaches for Low Impact Development (LID) stormwater management techniques and for hydromodification control, facilitating the appropriate application of these valuable approaches to water quality management. Our comments reflect this commitment to sound engineering practices and consideration of site-specific feasibility considerations.

II. Preliminary Statement

The stakeholder discussions have demonstrated that the new terms and provisions of the Draft Permit are not self-defining. They could potentially invite misunderstanding because different people might impute different meanings and definitions for the same terms. Regardless of this potential, we believe that considerable progress has been made, and that significant common ground is being found. Most importantly, we share the common goal of moving the permit program in the direction of LID Best Management Practices ("BMPs"), and we appreciate the need to avoid hydromodification impacts to sensitive stream channels. We agree that conventional stormwater BMPs should not be used as the primary BMP approach for a site unless it is plainly infeasible or undesirable due to ecological or other societal considerations (e.g. ultra high density project) to use LID BMPs. We also continue to favor regional BMPs and off-site solutions when they can be demonstrated to achieve a high environmental benefit, recognizing at the same time that these options cannot be mandated when they are not generally available, and may not be for some time.

We also believe that there are certain realities for which the Draft Permit must account, including the following principal points:

- A 2-year, 24-hour design storm volume for LID BMPs is not realistic, and should be replaced with a capture volume corresponding to the current criterion in the existing permit and the Drainage Areawide Management Plan (DAMP). Our understanding is that all those participating in the stakeholder process, including the agency and the Non-Governmental Organizations ("NGOs"), are in agreement on this point.

- A 95 percent non-effective impervious area ("EIA") requirement does not make sense given that LID BMPs should apply to 100 percent of the capture volume. In addition, the term "EIA" lacks a common, understandable and implementable definition, and is too vague and ambiguous to be used as a logical standard. There seems to be willingness on the part of the agency and the NGOs to consider a capture volume approach, without the complication and confusion created by appending EIA to it. The NGOs have acknowledged that EIA lacks meaning

without a design storm volume specified and clear criteria of what would be considered non-effective impervious area. This is an important acknowledgement, which we appreciate, as it tends to show that EIA as a stand-alone concept does not have value or relevance.

- Mandating the complete on-site retention of capture volume (i.e. runoff that never leaves as surface flows) is not a reasonable approach. Total, 100 percent retention remains a practical infeasibility in most circumstances, and is not a goal that can be achieved for most projects within any reasonable cost, despite best efforts. Thus, the retention BMPs of infiltration, harvesting, and evapotranspiration ("ET") may be fairly described as a favored first tier of LID BMPs, but they should not be universally mandated to the exclusion of all other options. While we understand that the NGOs would prefer to see the retention BMPs applied everywhere, and every project retain the entire capture volume on site, there seems to be some level of appreciation that this ideal is not possible, or even necessarily desirable, as a universal mandate.

- Biofiltration, bioretention, filter strips, and other BMPs based on using vegetation to promote stormwater treatment should be added to the suite of LID BMPs available to project proponents. These BMPs may be specified as a second tier, but project proponents should have considerable discretion to use these BMPs, and should not be required to apply for a feasibility exception to do so. The Regional Board and NGOs seem amenable to including these BMPs in the universe of LID, especially if projects must use underdrains in these features due to the feasibility and desirability of infiltration.

- The use of conventional BMPs as the principal approach for stormwater management should be a last resort, available only when objective infeasibility criteria are satisfied, and when off-site opportunities are not readily available. When LID BMPs are infeasible, and off-site opportunities are not available, the use of conventional BMPs that have been demonstrated to be effective on the pollutants of concern should be a compliance option.

- The approach to hydromodification control needs to be carefully considered on a watershed specific basis. Each stream or stormwater conveyance system is unique along with unique characteristics of the watershed. Hydromodification impacts can come from not just increasing runoff volumes, but also reduction in sediment supply from upland areas. Finally, many of Orange County's streams and stormwater conveyances are geomorphically stable and do not require hydromodification controls. Therefore, we recommend that hydromodification controls be targeted to those watersheds that drain to sensitive systems and that these controls over time be tailored to specific watersheds. There should be a provision that if a hydromodification plan is submitted for a project that provides a technically accurate hydromodification assessment and control plan, that project

can implement those provisions rather than any generalized non-watershed specific requirements.

Finally, we are enthusiastic about advancing a variety of leading-edge issues through a watershed master planning process. These plans would facilitate progress on unresolved issues related to science, technology and feasibility. On a much more granular basis than is available today, watershed-specific master plans can help determine appropriate project BMP requirements, retrofit BMPs, source controls, and other watershed efforts to address specific, receiving water beneficial uses.

Such plans hold the promise of a better path towards achieving water quality standards, replacing the relatively fractured, site-by-site, *ad hoc* approach of the current paradigm, with an overall scheme for water quality improvement. Watershed-specific master plans will provide project proponents with a level of certainty that does not presently exist and make cost-effective and environmentally-superior, regional and sub-regional water quality solutions available. Examples of issues to be explored include opportunities for harvesting, mapping of sensitive channels, determining areas where infiltration should be promoted, and compiling information on groundwater quality and contamination. There also could be added focus on an integrated approach to addressing impairment, and protecting high-quality, specially-protected areas.

III. Comments

What follows are our comments, organized into three sections and supported with attachments where noted: (1) comments on Finding No. 62; (2) comments on Section XII: New Development (Including Significant Redevelopment); and (3) comments on areas of conceptual agreement, where we list areas within the Draft Permit structure upon which the stakeholder group (and *ad-hoc* technical subgroup) reached general consensus.

A. Comments on Finding No. 62

CICWQ does not support this finding, the implications of it, and the utility of using EIA in defining "requirements for new development and redevelopment projects." The finding supports EIA as a performance standard in sizing and implementing LID BMPs, yet does not reflect the current state of knowledge concerning the much greater efficacy of other performance standards for sizing LID BMPs.

BIA/SC communicated with the U.S. Environmental Protection Agency (EPA) regarding their intent in using EIA as a performance standard in designing and implementing LID BMPs. While EPA supports the use of "clear, measureable, and enforceable requirements" for LID performance, such as limitations on EIA, EPA's letter to BIA/SC dated July 31, 2008 (Attachment 1) clearly states that "use of the 5% EIA requirement is not the only acceptable, quantitative approach for incorporating LID into renewed MS4 permits in southern California." The EPA further states that "we are open to other quantitative means for measuring how LID tools reduce storm water discharges."

Therefore, Finding No. 62 does not accurately reflect the position of EPA regarding its advocacy of clear, quantitative measures for LID BMP performance in MS4 permits such as volume capture or other more common engineering approaches to sizing storm water handling facilities.

Additionally, CICWQ is concerned by the reference to Dr. Richard Horner's case study analysis which the Regional Board is using to support the inclusion of the 5% EIA limitation as a criterion for LID BMP implementation. The Finding accurately points out that this was a "limited study." The Finding should also point out, however, this is not a peer-reviewed analysis and it relies on many coarse-level assumptions about key LID BMP sizing parameters, such as generous consideration of the availability of landscaping areas for LID BMP features within several types of development projects, optimistic infiltration scenarios, and non-representative soil condition assumptions (soil data taken from the San Fernando Valley) that are applied broadly across Ventura County. We are enclosing a critique of the hydrological aspects of the Horner Case Study prepared by Geosyntec, Inc., dated May 28, 2008 (Attachment 2).

Moreover, CICWQ has pointed out during the stakeholder meetings that a limitation on EIA as a performance standard for sizing LID BMPs has created widespread confusion and misunderstanding in the development and building industry with respect to the definition of EIA, what this standard would require, and the reason for it. Proposing EIA as a performance standard has also created confusion among stormwater professionals from the principal permittee and co-permittees and consultants who support them within Orange County and within Regional Board staff as well. It is quite clear from the recent stakeholder meeting discussion that EIA does not have an agreed upon, logical definition. It may be a valid scientific concept under uncontrolled conditions (where there are no BMPs), and one that has meaning on a watershed scale where its definition first appeared, but it does not have a useful or proper role in project-level engineering design or project feature performance assessment.

We suggest striking Finding No. 62 or, at a minimum, revising it to present a reasonable, accurate and complete discussion of the debate regarding the LID BMP performance standard protocol.

B. Comments on Section XI: New Development (Including Significant Redevelopment)

1. <u>LID BMPs Should Be Preferred</u>

The CICWQ membership is committed to using appropriate LID design features and LID BMPs in new and redevelopment projects. While LID BMPs have been demonstrated to be effective stormwater management tools, they should not be limited simply to those that reduce stormwater runoff via infiltration or harvesting alone. In fact, LID includes a range of measures which can be employed on most projects and others, such as infiltration and harvesting/reuse, which have less universal application.

Projects should prioritize the selection of LID BMPs that remove stormwater pollutants, reduce stormwater runoff, and promote groundwater infiltration (where appropriate and technically and economically feasible), ET, and harvesting and reuse in an integrated approach to protecting water quality and managing water resources. It is our understanding that this approach is fairly close to the Board's originally intended language. We recommend that hard feasibility criteria should be specified in the model WQMP/DAMP upon its renewal – such that developers should not be able to bypass implementation of appropriate LID BMPs.

2. It is Neither Feasible Nor Appropriate to Mandate Universal Infiltration, Universal Infiltration Plus Harvesting, or Universal Infiltration Plus Harvesting Plus ET

We agree that LID BMPs that retain stormwater on site should be used when feasible and promoted in the Draft Permit. We do not think, however, that such BMPs should be mandated as a condition of permit compliance to the complete exclusion of other options. Such an approach would impose a universal hydrology standard mandating the on-site retention of a certain volume of water, regardless of likely water quality implications. If such an approach were achievable on a widespread basis using techniques and engineering approaches that are practicable, even to the maximum extent, we would agree to the approach. We have deep concerns, however, that such is not the case. We also have concerns that this could lead to other environmental problems. The use of retention BMPs should be promoted as preferred, but should not be mandated absent including BMPs that employ vegetation.

Retention BMPs, mandated to the exclusion of other options, have limited present utility as explained below. These points are made to illustrate the importance of maintaining a concept of LID BMPs that is broader than just retention – not to discourage the use of retention BMPs where appropriate.

- Infiltration – Infiltration BMPs can be land-intensive unless underground injection control wells can be used and many developments would not move forward as site constraints can limit the availability of land to dedicate for infiltration. Many areas subject to the Draft Permit are underlain by perched groundwater that is shallow and degraded. Infiltrating in these areas can mobilize and exacerbate preexisting contamination, create rising groundwater that then interferes with land development, or other problems. Infiltration can cause changes to habitat type, and to the hydrology of ephemeral streams, should the duration of flows be extended. It also can result in geotechnical instability and increased seismic risk, when rising groundwater increases the potential for liquefaction. Many soils in the area are not amenable to infiltration, given content such as silts and clay. Forebay areas where groundwater replenishment already is occurring by water authorities are in distinct locations, which may not correspond to where new projects are planned. New projects do not have the means to

transport retained stormwater to these forebay areas where infiltration may be desirable. Water authorities already have located and developed the most favorable zones in the forebay areas for ongoing groundwater replenishment. These authorities may resist increased infiltration over pressure zones on the basis of contamination risk, and infiltration in the forebays, as interfering with their jurisdiction.

- Harvesting – Harvesting is limited by reuse option, social acceptability, competing policy goals, and economic considerations, including the need to demonstrate that the water quality benefits of this approach warrant the significant investment entailed. A significant obstacle to harvesting is the limited availability of reuse options, whether on a local or regional basis. There are very few projects where a project proponent has a water demand that can be satisfied with captured stormwater. Typically, there would have to be open space, parks or golf courses immediately nearby or associated with the project to make this option even possible. The demand must be relatively immediate after collection so that the cisterns can be evacuated and made available for the next storm. This is particularly important in Southern California, where storms characteristically sweep through the area in a series. It is not possible to build cisterns so large that they capture the volume from the entire storm series, and there is no need to irrigate in between such storms.

- Other reuse options are extremely limited. Health codes limit the ability to reuse the water for toilet flushing, and building codes impede the construction of projects with the plumbing to accommodate this approach.

- The social acceptability of harvesting has not been demonstrated. Some places like Bermuda have been harvesting water in cisterns for decades. But there is no such precedent or history in Southern California. Who is going to maintain cisterns, monitor them during weekends, holidays and vacations? These questions are particularly acute should cisterns be required of homeowners.

- Harvesting stormwater is a policy goal that is in direct conflict with the California Legislature's goals for reclaiming and reusing wastewater. Recycled water is used largely for irrigation purposes, and in rare instances for indoor toilet flushing. The region covered by the Draft Permit enjoys the environmental and water conservation benefits of water reclamation facilities, but the demand is insufficient and recycled water goes unused. Harvesting will compete with recycled water, and offset its use to some extent. When and where is this socially desirable?

- No one has yet to address the cost of harvesting water. Certainly, at some cost, harvesting is not practicable. What are the appropriate benchmarks against which to measure this aspect? Should harvesting stormwater be used only if it is

comparable in cost to reclaimed water? What if it is five times more expensive per acre foot to produce harvested stormwater? Should it be promoted under that circumstance? Since there has been no economic study, it is difficult to gage this aspect of practicability. But this certainly counsels in the direction of folding harvesting into a broader array of BMP options.

- Finally, where is the water quality demonstration that harvesting produced water quality benefits that are commensurate with the investment? Harvesting only postpones the introduction of the stormwater into the environment. How does that postponement compare with vegetation-based BMPs that reduce the pollutant load but do not affect the timing of the discharge to any material extent?

- Evapotranspiration – Opportunities to enhance ET should be considered, but maybe limited. In some cases, soil amendments such as compost may be able to increase infiltration or shallow soil saturation and drying potential. The potential for ET, however, may be limited by excess irrigation that occupies the ET component of the hydrologic cycle. There may be exotic ET BMPs that are in development. But, practicability limits the options that are available today.

For the Regional Board's consideration, we have attached a white paper on infiltration prepared by Geosyntec Consultants (Attachment 3). The paper provides background on infiltration considerations and identifies some of the key factors necessary in properly implementing a storm water infiltration strategy. Most, if not all, of the concepts contained in the white paper have been discussed during stakeholder meetings.

3. Permittees Should Not Be Required To Make Up Capture Volume Off Site Or Pay A Fee If They Cannot Retain Capture Volume On Site

Off-site options available for project applicants are extremely limited and, in many cases, illusory. The San Diego Creek watershed enjoys a Natural Treatment System ("NTS") that the Regional Board approved as a regional treatment BMP for purposes of the existing permit. Certainly, the new permit should preserve this designation, and encourage other regional projects, particularly those that address existing as well as new development. But, to date, the NTS is the only regional treatment BMP approved by the Regional Board, and its capacity to detain and treat stormwater already is limited. In addition, the approval process for the NTS was arduous, and may have discouraged other entities from proposing regional solutions.

Diversion to the sanitary sewer can be considered on a case-by-case basis, but requires separate permitting involving sanitation districts. Historically, sanitation districts have been reluctant to accept stormwater, and most have policies limiting how much stormwater they will take into their respective systems. Also, it is not clear that such diversions are environmentally desirable in comparison with other options, such as using on-site vegetation BMPs which keep water in local creeks and channels, but only after natural treatment.

In short, in some circumstances off-site options and fee-based programs may be available to support a mandate that would impose a mitigation obligation on a project proponent that cannot retain the entire capture volume on site. With that said, project proponents should be required to explore such options, and adopt them only when it is practicable to do so in light of the context.

Finally, it should be pointed out that such off-site programs likely would need their own entitlements and a large financing mechanism. In the case of the NTS, entitlement and permitting took years, and the funding mechanism required an act of the California Legislature. These facts should illustrate to the Regional Board that it cannot expect such programs to be available until well into this next permit cycle, at the earliest. Any attempt to mandate acceleration would be technology-forcing and not practicable. With that said, we in the private sector long have favored regional solutions and certainly intend to pursue their promise. This is an important element of our interest in watershed master planning.

4. Permittees Should Decide Whether LID BMPs Are Not Feasible and Whether and What Types of Conventional Treatment Can Be Used

We also recommend that the permittees, which are the entities armed with the most local knowledge and appreciation of circumstances, should decide whether LID BMPs are not feasible in particular contexts and where conventional treatment can be used. Using this system, the developer can then reasonably choose, based upon the context, which of the four types of LID BMPs to employ: infiltration, harvesting, ET, or vegetative/landscaping solutions including bioretention or biofiltration with underdrains, or appropriate conventional BMPs. This holistic, basket-type approach is more practical and it is more flexible than requiring permittees to install only LID BMPs that reduce runoff via retention.

5. At Least 12 Months Are Needed To Develop A WQPM Guidance Document on LID Principles

Given discussion at the stakeholder meetings, Orange County should be given at least 12 months to develop a WQMP guidance document on LID principles including BMP specification, feasibility criteria, and engineering sizing criteria. Six months is inadequate to prepare the necessary technical materials and educate the co-permittees and development community on new requirements.

6. WQMP Content Needs To Be Revised

CICWQ suggests deleting the content of Section XII(B)(3)(a) based on conceptual agreements reached with the ad-hoc technical sub-group and replacing it with a statement requiring that the WQMP include strict, clear, technical performance standards for sizing LID BMPs based on treating current volume requirements in the

current SUSMP/DAMP. (*See* below, Section C: Comments on Areas of Conceptual Agreement).

7. Capture Volume Should Be SUSMP Volume

CICWQ suggests deleting all references to limiting EIA to 5% or less in Section XII(C)(3) based on conceptual agreements reached with the ad-hoc technical sub-group. To reiterate, we suggest replacing it with a statement requiring that the WQMP include strict, clear, technical performance standards for sizing LID BMPs based on treating current volume requirements in the current SUSMP/DAMP (24-hour, 85th percentile storm event).

We are also concerned with the following statement that appears repeatedly in Section XII(C)(3)(a-d):

> "The pervious areas to which runoff from the impervious areas are connected should have the capacity to percolate at least the excess runoff from a two-year storm event."

This statement implies 100% capture and infiltration of the excess runoff from a 2-year storm event (or other storm event if substituted). As stated above in our general comments on Section XII, a requirement to capture and infiltrate and/or detain 100% of the water quality treatment volume is infeasible under many different circumstances. We suggest striking this sentence wherever referenced and alternatively include permit conditions concerning LID BMP volume capture sizing standards in the first paragraph of Section XII(C)(3). We are including as Attachment 4 a comparison table showing the requirements of a volume capture standards for LID BMPs based on preferentially treating the 24-hour, 85th percentile storm event and those in the Draft Permit.

CICWQ does not support using EIA as an off-ramp for substituting treatment control BMPs for LID BMPs per Section XII(C)(4)(b), and urges striking this reference.

8. Hydromodification Control Strategies Should Be Implemented Pursuant To Geosyntec White Papers

CICWQ has been working with an array of permittees and developers in southern California to devise appropriate hydromodification control standards for more than two years. We support the use of hydromodification control measures where appropriate and where downstream receiving water conditions warrant installation of on-site, off-site, and/or in-stream control facilities. For the Board's consideration we have attached a white paper on hydromodification control approaches prepared by Geosyntec Consultants (Attachment 5). This paper provides background on hydromodification control considerations and provides a series of recommendation regarding approaches the permittee could use to identify and map sensitive receiving water bodies and develop appropriate hydromodification control strategies. In the baseline period before watershed

or water body based standards are adopted, we recommend using control strategies as defined in Attachment 4. This table compares the approach recommended by CICWQ to that of the current Draft Permit requirements.

Finally, we recommend that permittees have the ability to prepare their own hydromodification control requirements/plan that is receiving water specific.

C. Comments on Areas of Conceptual Agreement

CICWQ was encouraged by the formation of a stakeholder group process in December 2008, on-going discussions, and the formation of an ad-hoc technical group to attempt to reach general agreement on principles for selecting and sizing LID BMPs.

Based on general areas of discussion during stakeholder meetings and during the sub-group conference call on 1/27/09 and 2/3/09, a summary of those discussions and a four point list of areas of conceptual agreement are included:

1. Performance standards for implementing LID BMPs other than a fixed effective impervious area (EIA) percentage (3-5%) are acceptable to Coastkeeper and NRDC if a technically equivalent standard can be identified.

2. Sizing LID BMPs to capture the 85th percentile storm event (current OC SUSMP/DAMP criteria for water quality volume) is an acceptable alternative to EIA as a performance standard provided that technically-based, strict, and clear feasibility criteria are developed for any project that cannot meet the LID BMP requirements.

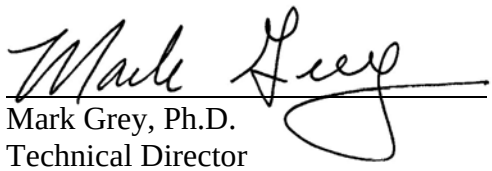
3. Prioritized LID/SUSMP BMPs for water quality volume capture are represented by: (a) infiltration, harvesting, or evapotranspiration BMPs; or (b) vegetated BMPs including bioretention and biofiltration. The water quality volume not captured by LID BMPs shall be treated consistent with SUSMP requirements. Note: There is debate regarding BMP selection options. Coastkeeper/NRDC support complete capture/accounting of the 85th% storm on site using LID BMPs from category (a) or meet off-site mitigation obligations; Permittees/CICWQ support complete treatment using category (a) and (b) BMPs.

4. If a project proponent cannot feasibly treat the SUSMP water quality volume using the prioritized application of LID/SUSMP BMPs on-site, then off-site mitigation of the remaining treatment volume must occur.

IV. Summary

CICWQ is pleased that an inclusive stakeholder process has ensued since the Draft Permit was first released in late November 2008. The process has shed significant light on areas where all stakeholders have common interests and common plans for tackling the pressing water quality improvement issues we all face. We will be an active participant in this group moving forward, and we trust that the Regional Board will continue to promote and engage in this process leading up to permit adoption. If you have any questions or want to discuss the content of our comment letter, please feel free to contact me at (909) 396-9993, ext. 252, (909) 525-0623, cell phone, or mgrey@biasc.org.

Respectfully,



Mark Grey, Ph.D.
Technical Director
Construction Industry Coalition on Water Quality

Public Works / Engineering

CRWQCB - REGION 8
MES

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February 13, 2009

Mr. Gerard Thibeault, Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

SUBJECT: COMMENT LETTER – DRAFT ORDER NO. R8-2008-0030 NPDES NO. CAS618030 (P.W. File No 1101.2)

Dear Mr. Thibeault:

The City of Tustin appreciates the opportunity to provide comments on the Santa Ana Regional Water Quality Control Board's Draft Order No. R8-2008-0030, as distributed in November 2008. The draft Tentative Order is indeed reflective of the recommendations made in the Report of Waste Discharge (ROWD), submitted by the Principal Permittee and Co-Permittees of North Orange County. However, the City of Tustin has a few concerns with the current draft. In addition to our concurrence with the comment letter submitted by the County of Orange, the City of Tustin would like to submit these additional comments for your consideration.

Comment #1: The potential for increased administrative burden from reporting requirements.

The City of Tustin echoes the County's comments regarding the increasing administrative burden on Co-Permittees with the new requirements in the draft Tentative Order. Like other Co-Permittees, over the years fiscal expenditures on the City's Storm Water NPDES program has steadily increased. Coupled with the current economic climate, state-wide budget cuts and hiring freezes, the increase in administrative requirements proposed by the draft Tentative Order may place a prohibitive strain on Cities to meet compliance objectives or compromise the goal of improving water quality.

The information submittals required in Section IX.6 and X.5, in particular, may prove to be a resource intensive endeavor. During the past fiscal year, the City invested significant funds and resources in the development of an electronic database to track and record information for the New Development Program, Existing Development Program, Construction Program, ID/IC Program, and the Municipal Program. To incorporate and maintain the additional functions outlined in the draft Tentative Order of those databases may prove to be resource intensive. Furthermore, to require Co-Permittees to provide their databases to the Regional Board may prove to be logistically difficult, as each Co-Permittee may be relying upon different software programs (or proprietary software), which may or may not be compatible with Regional Board systems. To convert such systems for compatibility may require significant costs to the Co-Permittees. The City therefore suggests that a spreadsheet with the information requested be submitted annually instead of the database itself.

SARB_011696

Comment #2: The addition of commercial facility categories for the commercial inspection program.

In Section X.1 of the draft Tentative Order, eleven (11) new categories of commercial facilities are subject to municipal inspections. As stated in the County's comments, no justification is provided by the Findings of the Tentative Order that support these eleven (11) commercial categories as posing a significant water quality threat to the MS4, thereby warranting their listing.

The City recognizes the importance of commercial inspections to the storm water program. This program has for the last several years provided an excellent opportunity for public outreach, and business owners/operators have benefited from this face-to-face interaction with City staff. However, with the City facing budget reductions and a reduced staff, the City will have a difficult time meeting the inspection requirements as presented in the draft Tentative Order. A sound basis for the inclusion of these eleven (11) new commercial categories should be established prior to their inclusion into the draft Tentative Order in light of these economic conditions.

Comment #3: Applying minimum percentages for high, medium, and low priority commercial facilities.

The new requirement to have 10% of commercial sites ranked "high", 40% ranked "medium", and the rest of the commercial inventory ranked low, as stated in Section X.2 of the draft Tentative Order appears arbitrary. The Findings do not provide any basis for these minimum criteria. The process of ranking commercial facilities should be based solely on their water quality threat. If a facility is ranked "low" based on the listed factors evaluated, it should be deemed as such. Furthermore, setting this minimum percentage penalizes Co-Permittees with a low population of commercial facilities with "high" pollution potential by imposing unwarranted inspections. This would further strain that City's resources. The City of Tustin suggests that the Tentative Order provide criteria for the proposed ranking.

Comment #4: The Residential Program proposed in Section XI.

The City agrees with the sentiments expressed in the County's comments regarding the proposed Residential Program in the draft Tentative Order. The obligation to require residents to implement BMPs to mitigate polluted storm water runoff discharges is contrary to the Public Education and Outreach program, which strives to engender environmental stewardship and to affect the public through behavior change. The City supports a Residential Program component to the draft Tentative Order, but recommends the program be driven or measured through behavior change and awareness, and not through requirements for BMP implementation.

Comment #5: LID requirements for 5% Effective Impervious Area (EIA) are not justified in the Proposed Permit and may discourage infill and redevelopment opportunities.

The City of Tustin had strong concerns with the 5% EIA requirements as stated in the first version of the draft Permit. The 5% EIA requirements as currently written inappropriately takes a watershed assessment tool and applies it to site-specific projects. Justification for this application is not provided and does not ensure the protection of water quality but significantly encroaches upon the municipality's land use discretion authority. The City recognizes this requirement may be appropriate for new master planned communities, but is not as appropriate for a City such as Tustin which is largely built out. For the City of Tustin, there is a significantly higher potential for higher density in-fill or redevelopment projects that can be developed in a much more sustainable way that reduces the carbon footprint of the site. Encouraging

sustainable redevelopment within the City is an important objective of the City and is consistent with other land use regulations such as AB 375. EIA requirements on high-density developments may not be feasible or appropriate in certain situations and may discourage redevelopment projects.

However, the City of Tustin has been encouraged by the efforts of the Principle Permittee staff, the Santa Ana Regional Board Staff, and local NGOs to sit down and develop an alternative approach. The watershed approach currently being developed by all parties appears to address the concerns of the City. The City is encouraged that the parties will continue to develop an alternative plan after this first draft comment deadline.

Consistent with the working group noted above, the City of Tustin strongly supports technically equivalent performance standards other than the EIA percentage (3-5%) for implementing LID BMPs. The City also wants to make note that the proposed changes to land development would require a period of time for the Permittees to develop technical resources and capacity to implement them. At a minimum, there should be at least a 12-month period after permit adoption before any new obligations take effect.

Comment #6: The source of selenium is a non-point source and should not be subject to the NPDES Permit.

Selenium is a naturally occurring element in the environment and occurs in the MS4 system by way of groundwater seepage or rising groundwater. In order to regulate selenium as a discharge as stated in the Tentative Order, it would need to originate from a point source and not the natural background. Since Selenium does originate from the natural background, it should be regulated as a non-point source under a load allocation which is defined as "the portion of a TMDL's pollution load allocated to a non-point source, storm water source for which an NPDES permit is not required, atmospheric deposition, groundwater, or background source." (See 40 C.F.R. Section 1302(f)).

The City of Tustin appreciates the opportunity to comment on this tentative order. The City looks forward to working with the staff of the Santa Ana Regional Board and of the County of Orange in implementing this fourth term permit. If you have any questions, please feel free to contact Mr. Alex Waite at (714) 573-3305.

Sincerely,

Tim D. Serlet, P. E.
Director of Public Works/City Engineer

c: Douglas S. Stack, Assistant Public Works Director
Doug Anderson, Transportation and Development Services Manager
Dana Kasdan, Engineering Services Manager
Alex Waite, Environmental Compliance Specialist

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

February 13, 2009

Michael Adackapara
Division Chief
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Re: Draft MS4 Permit for Orange County and Incorporated Cities within Orange County (NPDES Permit No. CAS618030)

Dear Mr. Adackapara:

The following are EPA Region 9's comments on the November 10, 2008 "First Draft" of the renewed Areawide Urban Stormwater Permit for Orange County and incorporated cities within Orange County within the jurisdiction of the Santa Ana Regional Water Quality Control Board.

EPA is generally supportive of the approach taken by the Santa Ana Regional Board in the draft permit. The following comments are informed by our review of other Municipal Separate Storm Sewer System (MS4) permits throughout our Region, and our review of the implementation of these permits via audits of nearly 50 MS4 programs.

The renewed Orange County MS4 permit will be the fourth permit issued for these municipal stormwater discharges. It is appropriate for the permit provisions to evolve based on lessons learned from past permits. The renewed permit is an opportunity to include clear permit provisions that support water quality benefits. Our comments concern two aspects of the draft permit.

1. Implementation of Low Impact Development (LID) Requirements

EPA agrees with the draft permit's approach for incorporating LID techniques, also known as green infrastructure. On a national level, EPA is advocating LID as an approach to stormwater management that is cost-effective, sustainable, and environmentally-sound. Ongoing efforts to promote the use of these techniques are described in EPA's January 2008 Action Strategy for Managing Wet Weather with Green Infrastructure. Materials regarding EPA's policies in this area can be found at: http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy.

On page 20 of 89 of the draft permit, Finding #62 states, "The USEPA has determined that by limiting the effective impervious area of a development site to 5% or less, downstream impacts can be minimized." While it is true that EPA agrees that limiting effective impervious area (EIA) to 5% or less will have positive impacts on water quality,

EPA has not made a determination that the 5% EIA concept is necessarily the only or always the best method to implement LID. We recommend replacing Finding #62 with the following:

> "USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of stormwater pollution that will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits such as aesthetics, recreation, and wildlife areas. EPA has reviewed studies[1] that have evaluated the % EIA concept and we believe that it is a reasonable and effective metric for incorporating LID principles into stormwater permits."

EPA's primary objective for incorporating LID into renewed MS4 permits, especially for those representing the fourth generation of permits regulating these discharges, is that the permit must include clear, measurable, enforceable provisions for implementation of LID. In our review of MS4 programs in our Region, we have found it common for permits to rely on the development of plans to achieve certain permit controls, rather than including clearly prescriptive requirements in the permits. While the permittees generally make significant and sincere efforts in their development of these plans, the plans often result in a reliance on qualitative provisions rather than specific measurable criteria. As a result, we've often found uncertainty among both the MS4 permittees and the permitting agencies as to specific permit controls. The incorporation of LID techniques into MS4 permits provides an opportunity to establish clear, measurable performance measures for the implementation of LID.

Section XII of the draft permit, entitled "New Development (Including Significant Re-Development)," appropriately sets a 5% EIA limit as a means for measuring the utilization of site controls, including LID techniques, for limiting stormwater runoff. This section of the draft permit also appropriately includes measurable requirements for controlling hydromodification by comparing post-development runoff to pre-development flows. EPA is in agreement with these permit provisions. While these approaches are not the only means available for including measurable requirements for the implementation of LID and the control of hydromodification in municipal stormwater permits to promote water quality improvements, EPA is supportive of the approaches you've chosen. We understand there is an alternative proposal to include a specific, measurable design storm volume which must be managed using LID techniques. Conceptually, we are supportive of such an approach, although we would be

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[1] See for example the analysis prepared by Dr. Richard Horner entitled "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

interested in reviewing specific permit language. We would not support replacing these approaches with qualitative provisions that do not include measurable goals.

We support the concept of alternatives and in-lieu programs for LID outlined in section XII.E. However, this section should be restructured to require that these waiver programs be approved prior to their utilization. If a permittee intends to grant waivers, they should be required to first establish the water quality credit system described in section XII.E.3. Section XII.E.3 should be moved to the beginning of section XII.E (thus renumbered as XII.E.1). The permit should require that any credit system that the permittees establish must (not "should") be submitted to the Executive Officer for review and approval. Any approved alternative programs should include measurable requirements, consistent with our comments above regarding the need for clear, measurable and enforceable permit conditions. In the section which is currently section XII.E.1 (which would become XII.E.2) the first sentence should be revised to note that if a BMP is not feasible, the permittee may grant a waiver pursuant to their approved Credit System.

2. Incorporation of Total Maximum Daily Loads (TMDLs)

The permit appropriately includes the relevant TMDLs, but the permit should more explicitly state that the wasteload allocations (WLAs) established by these TMDLs are intended to be enforceable permit effluent limitations and that compliance is a permit requirement. As a general matter, it is also our view that the permit language should clarify what monitoring will be done to determine compliance with WLAs. We recognize that the permit includes several different sections which describe monitoring efforts. However, with respect to the specific TMDLs described in section XVIII, the requirements for monitoring receiving waters (and end-of-pipe monitoring for sediments) are not always clear. If required monitoring to determine compliance with WLAs is specified in existing, separate monitoring plans, these existing plans should be clearly identified. With respect to existing plans, there should be confirmation that the plans clearly identify what monitoring will be conducted, and that monitoring results will enable the Board to clearly determine compliance with WLAs. If these referenced plans have not yet been prepared, the permit should contain required plan submittal dates, along with the expectations for the content of the plans to enable the Board to determine compliance with WLAs.

To further support WLA requirements in the permit, we recommend that Finding #52 for the permit include the following statement: "NPDES regulations at 40 CFR 122.44(d)(1)(vii)(B) require that permits be consistent with Waste Load Allocations (WLAs) approved by EPA. In the case of this permit, where there are EPA-approved TMDLs for waters in Orange County, this permit must incorporate provisions consistent with the WLAs associated with municipal stormwater, aka "urban runoff," from these TMDLs."

Section XVIII.B (technical TMDLs with no implementation plans)

i. Please note that the parenthetical statement in section XVIII.B.1.c should refer to paragraph 2, not paragraphs 4 & 5.

ii. In section XVIII.B.2, the permit references the Newport Bay/San Diego Creek organochlorine (OC) compounds TMDLs adopted by the Regional Board in September 2007. Despite having been adopted by the Regional Board, these TMDLs and the implementation plan have not yet been submitted to the State Board for approval. Until they are submitted to the State Board, and in turn approved by the State Board, OAL, and EPA, they are not applicable. Rather, the permit should recognize that the EPA TMDLs adopted in June 2002 are the currently applicable TMDLs.

iii. Based on our review of the Newport Bay/San Diego Creek TMDLs, it appears that the concentrations in Tables 1A/1B do not accurately reflect the WLAs for urban runoff in EPA's 2002 TMDLs. In addition to correcting these Tables, the permit should clarify that the WLAs are intended to be enforceable effluent limits. Compliance with the WLAs could be required in accordance with the time frame envisioned by the Board's implementation plan since this would be consistent with the intent of the EPA TMDLs.

iv. This section currently requires activities (the Regional Monitoring Plan (RMP) and Toxicity Reduction and Investigation Program (TRIP)) geared toward compliance with the Regional Board's as-yet unapproved OC TMDLs. These activities are similar to those contemplated for compliance with EPA's OC TMDLs. However, it should be confirmed that the monitoring results will enable determinations regarding compliance with the approved and currently applicable EPA TMDLs. Monitoring plans must clearly identify monitoring locations, the frequency of required monitoring, and required submittal of monitoring results. As recommended by the EPA TMDL, the monitoring plan should include water column and sediment monitoring. In addition, fish tissue monitoring should be included (if not already in the existing plan) since this was identified as an important environmental indicator in EPA's TMDL.

v. The permit should include conditions consistent with the WLAs for metals and selenium established by EPA in June 2002 for Newport Bay, San Diego Creek and the Rhine Channel. The description of the selenium TMDL for Newport Bay on page 67 describes selenium as naturally occurring. However, the TMDL suggests that selenium loads are made up of both naturally occurring and anthropogenic sources. The permit's required monitoring of selenium should not be limited to sources of naturally occurring selenium. Section XVIII.B.3 of the permit mentions that revised TMDLs for selenium are being developed by the Regional Board, but until the revised TMDLs and implementation plan are approved, the WLAs from the existing TMDLs are applicable. The EPA TMDLs for selenium and metals do not include a compliance deadline, but rather suggest a phased, iterative approach for compliance with the WLAs. Consistent with the recommendations of the EPA TMDLs, we suggest the permit require the

development and submittal of a compliance plan (with an implementation schedule) to the Board by the permittees. Detailed requirements for a monitoring program to determine compliance with the WLAs, including monitoring locations, frequency of sampling, and reporting should also be required.

vi. Section XVIII.B.3 of the permit refers to the activities and plans underway for revised nutrient TMDLs. We understand that these ongoing activities are focused on revisions to the nutrient TMDL implementation plan, not the TMDLs themselves. The permit should be corrected accordingly.

vii. Section XVIII.B.3 of the permit lays out an open-ended approach to the development of a monitoring plan for selenium and nitrogen. A specific deadline for the submittal of the monitoring plan should be included in the permit.

viii. We support the approach provided for incorporating the Coyote Creek WLAs, by establishing a date certain for submittal of a source control plan and monitoring plan. The permit should clarify the monitoring plan must include the frequency of sampling, and any other details to be required in using the collected data to determine compliance with WLAs.

Section XVIII.C (TMDLs beyond the permit term)

Tables 5a and 5b (in section XVIII.C.1) contain errors in that the first two rows of each table both include, "Total Maximum Daily Load for Fecal Coliform." It appears that one of these rows should present the WLA for urban runoff. The permit should also clarify that the urban runoff WLAs are intended to be permit effluent limits; we suggest that language be added to the permit such as: "The permittees shall comply with the wasteload allocations for urban runoff in Tables 5a and 5b in accordance with the deadlines in Tables 5a and 5b."

Section XVIII.D (TMDLs with compliance schedules within the permit term)

i. The permit (section XVIII.D.1) should clarify that the diazinon and chlorpyrifos WLAs are intended to be permit effluent limits; we would suggest that language be added to the permit such as: "The permittees shall comply with the following wasteload allocations in Tables 6a and 6b." Immediate compliance should be required unless an alternate date is provided in the implementation plan. We would also recommend that the fact sheet discuss the current compliance status of the permittees with the WLAs; given the phase-out of these pesticides within urban areas, compliance may have already been achieved.

ii. Regarding the nutrient TMDLs, the fact sheet (page 9) indicates the current and future targets for nutrients are already being met. In contrast, the permit (page 71) indicates that

the *overall* allocations have been met, leaving questions about the urban runoff WLA. Recent monitoring reports submitted to the Regional Board show that the urban runoff allocations for both the total nitrogen and total phosphorus loads are not currently being met. This discrepancy should be clarified in the fact sheet. Further, the permit should be clarified to indicate that the urban runoff WLAs in the Tables 7, 8 and 9 are intended to be permit effluent limits.

iii. Regarding the Newport Bay sediment TMDL, the permit should include firm dates for the submittal of monitoring data presenting the 10-year running averages.

Section XVIII.E.2 refers to "numeric effluent limits." For clarity, and for consistency with the rest of section XVIII, we suggest this be revised to: "Based on the TMDLs, numeric effluent limits have been specified to ensure consistency with the wasteload allocations."

We appreciate the opportunity to provide our views on this draft permit. If you'd like to discuss these comments, please contact John Tinger of the NDPES Permits Office at (415) 972-3518, or Eugene Bromley of the NPDES Permits Office at (415) 972-3510.

Sincerely,

Douglas E. Eberhardt, Chief
NPDES Permits Office

Bruce Fujimoto – SWRCB
Comments on Order R8-2008-0030, County of Orange MS4 permit

Page 31 – Section III. 3. ii. c) – This section contains a requirement to control the volume and velocity of dechlorinated swimming pool discharges to prevent resuspension of sediments. Is the intent to prevent resuspension of sediments in the receiving water, the MS4 or the BMP? I also recommend revise the heading of the paragraph to read "Swimming Pool Discharges" instead of "Dechlorinated Swimming Pool Discharges." This revision is not intended to change the meaning of the paragraph.

Page 48 – Section XII. B.3.) – Please specify whether the four items are goals or requirements. The use of the word "shall" suggests that they are requirements.

Page 55 – Section XII D.4. – It is stated that a 10% difference between the pre- and post-development hydrographs is insignificant, yet in Section XII.D.2.a) it is stated that 5% is the threshold of significance. Since this discrepancy does not appear to be intentional, it should be reconciled.

Page 57 – Section XII G. 3. – This requirement seems to imply that no one can occupy until a rain event has occurred. Is that the intent of this requirement?

Page 72 – Section XVIII D.3. – Table 9 – These footnotes appear to be incorrect. Please review them for accuracy.

CITY OF ANAHEIM
MAYOR CURT PRINGLE

February 24, 2009

Carol H. Beswick, Chair
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

Subject: **SARWQCB Order No. R8-2008-0030, NPDES No. CAS618030 Waste Discharge Requirements for the County of Orange and the Incorporated Cities of Orange County within the Santa Ana Region**

Dear Chair Beswick and Honorable Board Members:

We appreciate the opportunity to review the Santa Ana Region MS4 NPDES Permit ("Permit") which will soon be before your Board for consideration. Attached to this letter is a letter to Board staff which offers detailed comments and recommendations for the programmatic elements of this Permit.

This letter, however, is offered to highlight the City's concern over the economic impacts of many of the new proposed requirements. The positive impact to water quality achieved, for example, by expending significant expense in complying with the additional paperwork submittals or performing site inspections at sites with little or no potential impact to stormwater is questionable. The City strongly supports the goal of improving water quality but would suggest focusing efforts on items such as structural treatment controls which will have a tangible positive impact. Additionally, the City believes that the proposed significant redevelopment requirements would effectively put a stop to most affordable housing projects in Anaheim. Similar or even greater positive impacts could be achieved through less expensive regional controls and more flexible site specific onsite requirements.

Again, the City supports the goal of improving water quality, but with a commitment to ensuring responsible and effective use of our limited public resources. This City is appreciative of your consideration.

Sincerely,

Curt Pringle
Mayor

200 South Anaheim Boulevard, Anaheim, California 92805
(714) 765-5247 • FAX (714) 765-5164 • www.anaheim.net

CITY OF BUENA PARK

Department of Public Works
James A. Biery, Director

March 6, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Concurrence with Comment Letter Submitted by Mary Anne Skorpanich, Director of OC Watersheds Program

Dear Mr. Thibeault:

The City of Buena Park strongly concurs with the comments that were submitted to you on February 13, 2009, by the Director of the OC Watersheds Program regarding Tentative Order No. R8-2008-0030 No. CAS618030. As you are aware, the County of Orange, as Principal Permittee, worked together with the Co-Permittees to discuss and review the components of the Tentative Order and on the development of the referenced comment letter.

The City of Buena Park respectfully requests that the Tentative Order be revised for the following five key reasons, including that the new requirements:

- Are outside the scope of the authority given by the Federal Clean Water Act to the SARWQCB
- Lack sound technical basis
- Increase administrative burdens without scientific justification
- Over-extend the regulatory reach of local agencies
- Create new requirements for new development and re-development projects without justification

Each of these key reasons are thoroughly presented and discussed in the comment letter (attached), and for that reason I will not repeat them in their entirety. However, the City of Buena Park does specifically wish to object to the attempt by the Santa Ana Region to inappropriately implement a TMDL for a segment of the Coyote Creek that is not listed as an impaired water body. As indicated in Attachment A of the County comment letter, this is not permissible

under the Clean Water Act. The Santa Ana Region has not taken the steps necessary to list the upper reaches of the San Gabriel River as an impaired segment, nor has it proposed the upper reach for listing as impaired under section 303(d). Because the upper reach of Coyote Creek is not listed as an impaired segment, it is not appropriate to establish a TMDL for that segment. The Santa Ana Region must comply with established procedures to conduct a water body assessment for the segment, develop a load allocation and wasteload allocation for the segment, develop an implementation plan for meeting the allocations, amend the Santa Ana Basin Plan to incorporate the TMDLs, and allow public participation in the process. It cannot simply adopt the allocations and implementation plan developed by or for another Regional Board for a downstream waterbody.

The City of Buena Park continues to be fully committed to implementing an effective Stormwater Program. We share with the Santa Ana Region the goal of improving our environment and we look forward to working together with Board Staff and the stakeholders group to further refine the proposed Permit. I would be pleased to discuss this issue further. You may contact me at (714 562-3670.

Sincerely,

James A. Biery
Director of Public Works

cc: Rick Warsinski, City Manager
Mark Smythe, Senior Environmental Scientist, SARWQCB
Mary Anne Skorpanich, County of Orange

OC PublicWorks
Bryan Speegle, Director
Environmental Resources
2301 N. Glassell St.
Orange, CA 92865
Telephone: (714) 955-0600
Fax: (714) 955-0839

February 13, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2008-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

Thank you for the opportunity to comment on *Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department* (sic) *and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County* (Tentative Order No. R8-2008-0030). The County as Principal Permittee welcomes the opportunity to provide comments. The Permittees were involved in the development of these comments and the cities of Anaheim, Brea, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Laguna Hills, Placentia, Santa Ana, Seal Beach, Stanton, Tustin and Westminster have directed that they be recognized as concurring entities with this letter.

In summary, our comments conclude that the draft Tentative Order must be revised for five key reasons including that the new requirements:

- Are outside the scope of the authority given by the Federal Clean Water Act to the SARWQCB
- Lack sound technical basis
- Increase administrative burdens without scientific justification
- Over-extend the regulatory reach of local agencies
- Create new requirements for new development and re-development projects without justification.

The Orange County Stormwater Program (the "Orange County Program" or "Program") has been in existence under a National Pollutant Discharge Elimination System (NPDES) permit since 1990. This permit was re-issued in 1996 and 2002. In 2006, the Permittees submitted a Report of Waste Discharge (ROWD) in anticipation of permit renewal in 2007. The basis of this document was a comprehensive program assessment undertaken using a multiple lines of evidence approach, including audit findings, facilitated workshops, and the California Stormwater Quality Association (CASQA) Municipal Stormwater Program Effectiveness

Assessment Guidance. The ROWD identified many positive program outcomes and proposed changes and added program development commitments to the Drainage Area Management Plan (DAMP) where the assessments indicated the need for improvement.

In the ROWD and proposed plan (the 2007 DAMP), the Permittees committed to enhancing program implementation, developing BMPs for identified countywide water quality constituents of concern, and establishing a watershed-based approach to water quality planning and protection to complement the countywide management effort. While the Permittees want to commend your staff on both their efforts to incorporate the recommendations made in the ROWD into the Tentative Order and willingness to support the deliberations of the land development stakeholder group, a number of key concerns must be recognized. These concerns, which relate to the proposed new requirements intended to increase Permittee accountability, extend the regulatory reach of local jurisdictions, incorporate additional TMDLs, and create a new basis for the land development requirements of the Order, are now being significantly amplified by the worsening deterioration of the economy. Indeed, a significant number of Permittees have specifically expressed their concern regarding the creation of additional mandates at a time of forced staff reductions and increasingly severe fiscal circumstance.

The substantial body of programmatic performance and environmental quality data that informed the ROWD has since been augmented by two additional annual reports. While the Permittees believe that the additional reports largely affirmed the ROWD commitments, this comprehensive and augmented dataset presents a basis and an opportunity for a cooperative and informed consideration and resolution of the Permittees' concerns. In this regard, the current series of stakeholder meetings to discuss the Tentative Order's land development provisions, as well as the meeting with your staff on January 29, 2009, have been productive. We look forward to continuing to meet with you to discuss the areas of contention and to achieve a timely resolution. In the interim, we have summarized our overarching concerns with the Tentative Order as General Comments in this letter and provide additional comments and concerns in the following Attachments:

- Attachment A: Legal and policy issues and comments
- Attachment B: Technical comments and suggested revisions
- Attachment C: Monitoring and Reporting Program comments

GENERAL COMMENTS

I. Increasing Administrative Burden

At the inception of the Orange County Program the County of Orange, as Principal Permittee, and the 26 Permittees developed a DAMP to serve as the principal policy and programmatic guidance document. Since 1993, the DAMP has been modified through an adaptive management process to reflect the needs of the Permittees, ensure Permittee accountability, and deliver positive water quality and environmental outcomes. The DAMP now provides definitive guidance to each Permittee in the development of its Local Implementation Plan (LIP), which specifically describes how the Orange County Program will be implemented on a city/jurisdiction basis. Concurrently, the annual progress report has been developed into a rigorous systematic assessment of program effectiveness that is conducted at jurisdictional, watershed and countywide levels of resolution, using the CASQA Municipal Stormwater

Program Effectiveness Guidance, and with identified *headline measures* of programmatic performance. The Tentative Order requires additional reporting to the Regional Board staff. The Permittees believe that adjusting the existing reporting processes, rather than creating additional reporting requirements, is the most effective approach to increasing transparency and accountability. Such an approach also offers the additional potential benefit of identifying opportunities to reduce the administrative burden of the Program for both the Regional Board and for the Permittees.

II. Extending the Regulatory Reach of Local Jurisdictions

In the most recent annual report, the Permittees noted that over 30,000 industrial and commercial facilities in Orange County were subject to inspection for compliance with local water quality ordinances. Nonetheless, the Tentative Order includes new requirements that arbitrarily increase the universe of commercial facilities subject to inspection, mandates the annual inspection of treatment controls in completed land development and re-development projects, and more prescriptively turns the attention of the Permittees toward residences and mobile businesses. Key elements of this overarching concern are the significant resource implication for cities and the absence of technical justification.

The Permittees, in the detailed program assessment that preceded the ROWD, did not discern a rationale for a more inclusive inspection of commercial enterprise nor is one presented in the Findings of the Tentative Order. With land development projects, the installation and subsequent maintenance of treatment controls certainly needs to be verified. However, self certification is already a verification mechanism being used by Permittees and it and other third party verification mechanisms should not be precluded by the Order in exclusive favor of Permittee inspection. The current opportunity to strategically re-consider the use of inspection resources should be used to target and focus these activities rather than simply expand their scope. Furthermore, given the current state of the economy, the Permittees, like all municipalities, are facing shrinking budgets and the Regional Board should give great weight to the best use of limited resources in achieving water quality objectives.

The prescribed creation of a residential program also needs to be carefully considered. The effectiveness of *Project Pollution Prevention*, the public education and outreach initiative of the Orange County Program, has been validated by public opinion surveys that show incremental, but also statistically significant, increases in public awareness of stormwater issues and positive changes in protective behaviors. The new residential program requirements therefore appear duplicative of the current public education and outreach obligations that have already produced and continue to yield positive measurable outcomes. However, there is also a separate concern that prescribed efforts to "require residents to implement pollution prevention measures" (XI. 2) will engender resistance among some segments of the public and be counter-productive to long term efforts to engender stewardship. The justification for this additional program when current requirements have produced positive outcomes has not been provided and we recommend that it be deleted from the Tentative Order.

The last area of prescribed new regulatory oversight is mobile businesses. The Permittees have already produced educational materials for these businesses, cooperatively developed wash water disposal options with Orange County's sewering agencies, and coordinated on enforcement. The further required regulation of these businesses is a potentially resource Intensive undertaking that currently appears to lack a strong technical rationale.

III. Creating a New Basis for the Land Development Requirements of the Order.

The Model Water Quality Management Plan (WQMP) prepared for the Third Term Permit explicitly recognizes the channel stability implications of watershed urbanization and provides for this potential impact to be addressed as a hydrologic condition of concern. It also requires consideration of Site Design Best Management Practices (BMPs), now more commonly referred to as Low Impact Development (LID) BMPs. The commitment made in the ROWD was to adjust the Model WQMP to incorporate work being undertaken on hydromodification by the Southern California Coastal Water Research Project, which is still pending. Since that time, various hydrograph matching requirements have appeared in municipal stormwater permits, including the Tentative Order and an Effective Impervious Area (EIA) of 5% or less has appeared as a performance standard for land development.

The EIA requirement for land development is inappropriately establishing a watershed assessment metric as a site specific performance standard. It is also establishing an unreliable surrogate for flow reduction (see case study discussion in Attachment B) as the basis for conformance with the stormwater mandate. Moreover, there is currently no clear technical consensus on control standards for hydromodification (also noted in Attachment B). In addition, the Permittees believe that the highly urbanized condition of Orange County's watersheds in the Santa Ana Region needs to be carefully considered. Over the period of the next permit, new development will be composed almost entirely of infill or redevelopment projects that will subject to other mandated development standards intended to encourage denser development. These additional mandates will present a significant challenge to developing and implementing effective approaches to both LID and hydromodification for achieving prescribed levels of site performance and meaningful ecological outcomes.

The uncertainties and challenges noted above have been highlighted in the series of stakeholder meetings convened specifically to examine the land development provisions of the Tentative Order. This group's discussions, in which the County actively participates, have been helpful to facilitating broader understanding of the perspectives of key constituencies and productive in identifying a number of early general areas of agreement. While these general areas have already been discussed with you, they are reiterated below and endorsed as the basis for initial adjustments to the current land development provisions of the Tentative Order. The general areas of agreement, which may be "backstop" or "default" requirements until a watershed based standard can be developed either through a watershed specific plan or an updated watershed action plan, are:

1. Performance standards for implementing Low Impact Development BMPs other than an EIA percentage (3-5%) are acceptable if a technically equivalent standard can be identified.

2. Sizing LID BMPs to capture the 85th percentile storm event (current DAMP criteria for water quality volume) is an acceptable alternative to EIA as a performance standard provided that technically-based, strict, and clear feasibility criteria are developed for any project that cannot meet the LID BMP requirements.

3. Prioritized LID/SUSMP BMPs for water quality volume capture are represented by: a) infiltration BMPs; b) harvesting and reuse BMPs; c) vegetated (or evapotranspiration)

BMPs including bioretention and biofiltration. Water quality volume not captured by LID BMPs shall be treated consistent with DAMP requirements

It should also be noted that any new or revised obligations with respect to land development would require a minimum of at least 12 months for the Permittees to develop the technical resources and effectively implement new standards, including training and guidance for the development community.

IV. Using Available Programmatic Performance and Environmental Quality Data

In advance of preparing the ROWD the Permittees undertook a detailed program assessment drawing upon prior annual report findings, a comprehensive environmental quality database, audit findings, facilitated workshops, and the CASQA Municipal Stormwater Program Effectiveness Assessment Guidance. This assessment provided a strong technical basis for improvements to the Orange County Program recommended in the ROWD and which have been subsequently validated in later annual progress reports. These informational resources and, in particular, the environmental quality database, have been compiled at great expense and provide unique and site specific information on the state of Orange County's surface waters and the performance of the Orange County Program. Strong technical justification developed from the information that has been compiled over the last 18 years by the Permittees is needed to support requirements in the Tentative Order supplemental to the ROWD recommendations. New requirements must also be consistent with the federal stormwater regulations and within the scope of the Clean Water Act. The Tentative Order has attempted to step outside the scope of the authority provided by the Clean Water Act by including the regulation of non-point sources. The Permittees believe that these sections of the Tentative Order should be revised to be in compliance with the appropriate federal laws.

We appreciate the effort that you and Regional Board staff have devoted to the development of the fourth term permit for the Orange County Program. We look forward to meeting with you and the staff to quickly resolve the Permittees' concerns regarding the Tentative Order to ensure that it meets our mutual goals.

Thank you for your attention to our comments. If you have any questions or need additional information please contact Richard Boon at (714) 955-0670 or Chris Crompton at (714) 955-0630.

Sincerely,

Mary Anne Skorpanich
Director, OC Watersheds Program

cc: City Permittees

ATTACHMENT A

LEGAL ISSUES AND COMMENTS ON TENTATIVE ORDER NO. R8-2008-0030 NPDES NO. CAS618030

INTRODUCTION

Attachment A contains the principal legal comments of the County of Orange (the "County") on Tentative Order No. R8-2008-0030 dated November 10, 2008 ("Tentative Order").

The County has endeavored to provide a complete set of comments on the Tentative Order. However, the County reserves the right to submit additional comments relating to Tentative Order No. R8-2008-0030 and the supporting Fact Sheet/Technical Report to the Regional Board in the future.

COMMENTS

THE TENTATIVE ORDER IMPROPERLY ATTEMPTS TO PRESCRIBE CONDITIONS THAT GO BEYOND THAT REQUIRED BY FEDERAL LAW

The Tentative Order includes new requirements that are more demanding than those mandated by federal law. One specific example is the significant increase in the universe of commercial facilities subject to inspection. Federal Clean Water Regulations governing MS4 systems do not require operators of those systems to have an inspection program for construction, industrial, and commercial sites. For the Regional Board to include these new commercial facilities as part of the Permittees inspection program, the Regional Board must consider the economic effects of this expansion as stated by the California Supreme Court in ***City of Burbank v. State Water Resources Control Bd.*** (2005) 35 Cal. 4th 613. In that case, the Supreme Court stated that:

> "The federal Clean Water Act reserves to the states significant aspects of water quality policy (33 U.S.C. § 1251(b)), and it specifically grants the states authority to 'enforce any effluent limitation' that is not 'less stringent' than the federal standard (33 U.S.C. § 1370). It does not prescribe or restrict the factors that a state may consider when exercising this reserved authority, and thus it does not prohibit a state-when imposing effluent limitations that are more stringent than required by federal law-from taking into account the economic effects of doing so." (***City of Burbank***, 35 Cal. 4th at 627)

The mere fact that the State has the authority under section 402(p)(B) of the Clean Water Act to prescribe conditions in excess of those specifically enumerated by Congress or the U.S. EPA does not mean that those requirements automatically fall under the umbrella of federal regulation. To the extent that a requirement contained in the Tentative Order is more prescriptive or specific than those outlined in the Clean Water Act and accompanying

regulations, the Regional Board must comply with the statutory requirements set forth in the California Porter-Cologne Water Quality Control Act.[1]

Furthermore, Article XIII B, section 6 of the California Constitution requires the State to give funding to reimburse local governments for the costs associated with a new program or higher level of service mandated by the Legislature or any State agency. Cal. Const., art., XIII B, § 6. An exception is made for "mandates of . . . the federal government which, *without discretion*, require an expenditure for additional services or which *unavoidably make the providing of existing services more costly*." Cal. Const. art., XIII B, § 9(b) (emphasis added); ***Sacramento v. California (Sacramento II)***, 50 Cal. 3d 51 (1984). However, this exception applies only where "the State had no 'true choice' in the manner of implementation." ***Hayes v. Commission on State Mandates***, 11 Cal. App. 4th 1564, 1593-94 (1992) (citing ***Sacramento II***). As discussed above, the Tentative Order's new inspection requirements go beyond what is required under the Clean Water Act. Thus, to the extent the Regional Board chooses to exercise discretion to impose such requirements on the Permittees, it must comply with the prohibition against unfunded mandates set forth in the California Constitution.

THE TENTATIVE ORDER IMPROPERLY INTRUDES UPON THE PERMITTEES' LAND USE AUTHORITY IN VIOLATION OF THE TENTH AMENDMENT OF THE U.S. CONSTITUTION AND IMPOSES A PRESCRIPTIVE STANDARD AS TO COMPLIANCE WITH THE TENTATIVE ORDER

To the extent that the Tentative Order relies on federal authority under the Clean Water Act to impose land use regulations and dictate specific methods of compliance, it is in contravention to the separation of powers between the regional board and the local governments. Furthermore, to the extent the Tentative Order requires a Municipal Permittee to include Low Impact Development (LID) principles, specifically the 5% or lower Effective Impervious Area (EIA) standard, in local land use regulations, it also violates the Tenth Amendment of the U.S. Constitution. According to the Tenth Amendment:

> "The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people."

Article XI, section 7 of the California Constitution guarantees municipalities the right to "make and enforce within [their] limits all local police, sanitary and other ordinances and regulations not in conflict with general laws." The United States Supreme Court has held that the ability to enact land use regulations is delegated to municipalities as part of their inherent police powers to protect the public health, safety, and welfare of its residents. *See* ***Berman v. Parker*** (1954) 348

[1] The Porter-Cologne Water Quality Control Act requires that all regulations adopted pursuant to State law must be "reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." Water Code § 13000. Furthermore, any regulations relating to discharges must be based on water quality objectives that are "reasonably required for that purpose." Water Code § 13263. All water quality objectives adopted by the Regional Board must be reasonably achievable and take into account a variety of factors including, but not limited to, those factors enumerated in Water Code section 13241.

U.S. 26, 32-33. Because it is a constitutionally conferred power, land use powers cannot be overridden by State or federal statutes.

The requirement that an EIA of 5% or less be incorporated in all new development and significant redevelopment projects is a considerable encroachment upon the inherent police powers specifically delegated to municipalities. The Clean Water Act only grants the Regional Board authority to regulate the discharges of pollutants through the NPDES program. Flow or volume of water is not a pollutant under the Clean Water Act. Although stormwater runoff may contain pollutants, the attempted regulation of the volume and/or flow of stormwater runoff by an EIA of 5% or less through the Tentative Order is prescriptive and effectively a land use control. The Regional Board must stay within the scope of authority provided by the Clean Water Act. Finding A.3 of the Tentative Order requires the Permittees to reduce to the Maximum Extent Practicable (MEP), through the implementation of BMPs, the discharge of pollutants in urban stormwater from the MS4s in order to support attainment of water quality standards. A standard of 5% or less EIA does not give the Permittees flexibility in the methods of achieving the water quality objectives as contemplated by the Clean Water Act and the Findings of the Tentative Order. Moreover, Water Code Section 13360 prohibits the Regional Board from specifying the manner in which Permittees are to comply with the MEP standard. This standard is an impermissible mandate on how the Permittees are to comply with the MEP and the Regional Board needs to consider various methods or approaches to achieving the goal of reduction of pollutants in the stormwater runoff and not rely strictly on a prescriptive standard.

THE TENTATIVE ORDER IMPROPERLY ATTEMPTS TO REGULATE NON-POINT SOURCES IN VIOLATION OF THE CLEAN WATER ACT

A. The Source of Selenium in the MS4 is a Non-Point Source and Should Not Be Subject to the NPDES Permit

Selenium found in the MS4 occurs by way of groundwater seepage or "rising groundwater." In Part III.3.i.c of the Tentative Order discusses rising groundwater in the context of an illicit discharge/improper disposal aspect of the program in the Federal Regulations. (See 40 C.F.R. 122.26(d)(2)(iv)(B)). The stated expectation for this section is that any problematic pollutant sources would be dealt with by either the removal of the discharge or by requiring the discharger to obtain an individual NPDES permit. The key concept here is discharge. The Clean Water Act defines a discharge as "The term 'discharge of a pollutant' and the term 'discharge of pollutants' each means (A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.)."[2] For the addition of selenium to be a discharge, it would need to originate from a point source - i.e. there would need to be an individual or entity

[2] 33 USC 1362 (14) - The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

that the MS4 Permittees could require to obtain an individual NPDES permit to cease the illicit discharge.

The Clean Water Act regulations define a load allocation (LA) as "the portion of a TMDL's pollution load allocated to a non-point source, stormwater source for which an NPDES permit is not required, atmospheric deposition, groundwater, or background source." (See 40 C.F.R. Section 1302(f)). The seepage of groundwater into surface waters falls within this definition. Additionally, as selenium is a naturally occurring element and accumulated through natural processes, the source is natural background. And, per the State's Non-Point Source Policy, seepage of groundwater into surface water can be classified as a non-point source. Furthermore, Finding C.8 of the Tentative Order specifically states that, "[t]his order is intended to regulate the discharge of pollutants in urban stormwater runoff from anthropogenic sources and/or activities within the jurisdiction and control of the Permittees and is not intended to address background or naturally occurring pollutants or flows." Thus, the selenium attributed to non-point sources cannot be regulated by the Tentative Order. To the extent that the Regional Board believes that selenium can be attributed to a point source, these NPDES-regulated stormwater discharges must be addressed by the wasteload allocation (WLA) component of the TMDL. (See 40 C.F.R. § 130.2(h)).

Part XVIII.B.3 of the Tentative Order states:

> "A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. As long as the stakeholders are participating in and implementing the collaborative approach, if approved, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements."

The collaborative watershed approach is expected to be based on regional BMPs in order to address the diffuse nature of the non-point source rising groundwater as well as point sources where implementation of site-specific treatment controls is infeasible. Permittee participation in any program to address the rising groundwater LA of the TMDL will be on a voluntary basis.

B. Agricultural Sources are Non-Point Sources and are Not Subject to the NPDES Permit

Part III of the Tentative Order requires the Permittees to prohibit illicit/illegal discharges (non-stormwater) from entering into the MS4 unless they are authorized by NPDES permit or not prohibited in accordance with Section III.3 of the Tentative Order. Section III.3.i enumerates the specific discharges that are not prohibited unless they are substantial contributors of pollutants to the MS4 and the receiving waters. The Regional Board has included the discharge of "irrigation water from agricultural sources" in Section III.3.i.c.

The County opposes the inclusion of this phrase as worded. Agricultural sources are specifically excluded from the NPDES program as the definition of point source "does not include agricultural storm water discharges and return flows from irrigated agriculture." 33 U.S.C. Section 1362(14). The inclusion of irrigation water from "agricultural sources" goes beyond the requirements of federal law. The County requests that the Regional Board rely upon the authority of the Clean Water Act and include the discharges that are enumerated in 40 C.F.R. 122.26(d)(2)(iv)(B)(1) which specifically includes, "irrigation water" but not "irrigation water from agricultural sources."[3]

THE TENTATIVE ORDER IMPOSES INSPECTION REQUIREMENTS ON THE PERMITTEES THAT WOULD VIOLATE THE FOURTH AMENDMENT

Part VI.2 states:

> "The Permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments."

Through this statement, the Regional Board is requiring the Permittees to violate the Fourth Amendment's prohibition on illegal searches and seizures. The Fourth Amendment to the U.S. Constitution states:

> "The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated; and no Warrants shall issue but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized."

The Fourth Amendment is clear in its policy of protecting the security and privacy rights of individuals against unpermitted or unwarranted governmental invasions. The Permittees' ordinance cannot allow unpermitted entry into private property for the purpose of inspection or collection of evidence to ensure compliance with the Permittees' Water Quality Ordinance. Any entry into an industrial, construction or commercial establishment must be by permission of the

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[3] See 40 CFR 122.26(d)(2)(iv)(B)(1).
A description of a program, including inspections, to implement and enforce an ordinance, orders or similar means to prevent illicit discharges to the municipal separate storm sewer system; this program description shall address all types of illicit discharges, however the following category of non-storm water discharges or flows shall be addressed where such discharges are identified by the municipality as sources of pollutants to waters of the United States: water line flushing, landscape irrigation, diverted stream flows, rising ground waters, uncontaminated ground water infiltration (as defined at 40 CFR 35.2005(20)) to separate storm sewers, uncontaminated pumped ground water, discharges from potable water sources, foundation drains, air conditioning condensation, *irrigation water*, springs, water from crawl space pumps, footing drains, lawn watering, individual residential car washing, flows from riparian habitats and wetlands, dechlorinated swimming pool discharges, and street wash water (program descriptions shall address discharges or flows from fire fighting only where such discharges or flows are identified as significant sources of pollutants to waters of the United States); (emphasis added)

owner or through administrative warrant as provided for in the County's existing Water Quality Ordinance. The County requests that Part VI.2 be amended to state:

> "The Permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments."

THE TENTATIVE ORDER INAPPORPRIATELY IMPLEMENTS TMDLS DEVELOPED BY U.S. EPA FOR IMPAIRED WATER SEGMENTS IN THE LOS ANGELES REGION

Part XVIII.B.4 of the Tentative Order requires Permittees with discharges tributary to Coyote Creek or the San Gabriel River to meet WLAs for Coyote Creek. Part XVIII.B.5 requires the County, as Principal Permittee, to develop a monitoring program to monitor flows in Coyote Creek. The results are to be evaluated against numeric targets for Coyote Creek. (We refer to these two provisions as the "Coyote Creek TMDL provisions.") The Tentative Order does not indicate how the WLAs or numeric targets were developed. There is a reference in Part XVIII.B.1 to a Coyote Creek TMDL developed by U.S. EPA and the Los Angeles Regional Board. Presumably this refers to the TMDLs for Metals and Selenium for San Gabriel River and Impaired Tributaries established by U.S. EPA for the Los Angeles Region (the "San Gabriel River Metals TMDL").[4]

The County objects to the Coyote Creek TMDL provisions for several reasons. First, the provisions would essentially implement a TMDL for a segment of Coyote Creek that is not listed as impaired. That is not permissible under the Clean Water Act. Under the Clean Water Act and U.S. EPA's implementing regulations, states are to identify impaired water segments ("water quality limited segments" or "WQLS"), rank them in order of priority, and then establish TMDLs for those segments according to their ranking. *See, e.g.,* ***San Francisco Bay Keeper v. Whitman***, 297 F.3d 877, 880 (9th Cir. 2002). Coyote Creek is in the San Gabriel River watershed. Its upper reach is located in Orange County within the jurisdiction of the Santa Ana Regional Board. Its lower reach is in Los Angeles County within the jurisdiction of the Los Angeles Regional Board. The Los Angeles Regional Board has listed the lower reach as an impaired water segment under section 303(d) of the Clean Water Act.[5] The Santa Ana Regional Board, however, has not listed the upper reach as an impaired segment, nor has it proposed the

[4] Neither the Fact Sheet for the Tentative Order nor the Findings in the Tentative Order provide any detail on the Coyote Creek TMDL provisions. The Fact Sheet discusses the San Gabriel River Metals TMDL not in the TMDL section of the document but rather in a section titled "Sub-Watersheds and Major Challenges." The County agrees that attempting to implement and enforce a TMDL developed for one region by the Regional Board of another region would be a "major challenge."

[5] The Los Angles Regional Board's current "2006 CWA Section 303(d) List of Water Quality Limited Segments Requiring TMDLs" identifies 13 miles of Coyote Creek as impaired for various pollutants and stressors.

upper reach for listing as impaired under section 303(d). *See* Santa Ana Regional Board, **2006 CWA Section 303(d) List of Water Quality Limited Segments Requiring TMDLs.**

Because the upper reach of Coyote Creek is not listed as an impaired segment (*i.e.*, a WQLS), it is not appropriate to establish a TMDL for that segment.[6] The fact that the upper reach (nonimpaired) flows into the lower reach (impaired) of the Coyote Creek is irrelevant. If the Regional Board could establish WLAs for nonimpaired water segments simply because they flow into impaired segments, it would render meaningless the mechanism for listing water ***segments***, and then developing TMDLs for those ***segments***. *See, e.g.,* State Water Resources Control Board, ***Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List***, adopted September 30, 2004. Rather than calling for TMDLs on a segment by segment basis, under the Tentative Order's "tributary discharge" approach the Clean Water Act would simply have required TMDLs on a watershed-wide basis.

The second reason the County objects to the Coyote Creek TMDL provisions is that they effectively implement a TMDL where no implementation plan currently exists. As the Tentative Order acknowledges, there is no implementation plan for the Coyote Creek TMDL.[7] An implementation plan "describes the approach and required activities required to ensure that the allocations are met." *See* State Water Resources Control Board, ***Total Maximum Daily Loads (TMDL) Questions & Answers***, (April 2001). Until a TMDL, including an implementation plan, is incorporated into the Regional Board's Basin Plan, the TMDL is not enforceable. *Id.*

For other established TMDLs in the Santa Ana Region, where no implementation plan has been adopted, the Tentative Order simply requires that the Permittees continue participating in the development of the implementation plans. *See, e.g.,* Parts XVIII.B.1 and 3. For the Coyote Creek TMDL, however, the Tentative Order requires Permittees to develop and implement source control BMPs designed to meet the Coyote Creek WLAs and to monitor Coyote Creek flows and evaluate the results against Coyote Creek numeric targets for total recoverable metals. In other words, Permittees are required to effectively implement the Coyote Creek TMDL. However, unless a Coyote Creek TMDL is developed and incorporated into the Santa Ana Basin Plan, the Santa Ana Regional Board cannot require Permittees to implement the TMDL. Accordingly, the County objects to the Coyote Creek TMDL provisions.[8]

Finally, and related to the above grounds, the County objects to the Coyote Creek TMDL provisions to the extent the Regional Board appears to be attempting to adopt and implement a TMDL for the upper reach of Coyote Creek without going through the rigorous public process

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[6] States may adopt "informational" TMDLs for water segments not identified as impaired. These are "estimated" TMDLs, for the purpose of developing information only. *See* Clean Water Act Section 303(d)(3).

[7] As noted above, the Coyote Creek TMDL referenced in Part XVIII.B.1. of the Tentative Order presumably refers to the TMDLs for Metals and Selenium for San Gabriel River and Impaired Tributaries established by U.S. EPA for the Los Angeles Region.

[8] The Tentative Order provides that Permittees' source-control BMPs will be required "until a TMDL implementation plan is developed." As noted above, if the Santa Ana Regional Board amends its Basin Plan to incorporate a TMDL (including an implementation plan) for the upper reach of Coyote Creek, Permittees may be required to meet a waste load allocation to implement the TMDL. An implementation plan developed by the Los Angeles Regional Board for the lower reach of Coyote Creek and incorporated into the Los Angeles Basin Plan would be irrelevant to dischargers located in the Santa Ana region tributary to the upper reach of Coyote Creek.

required to establish and implement a TMDL. If the Regional Board intends to establish, implement, and enforce TMDLs for the upper reach of Coyote Creek, it needs to conduct a water body assessment for the segment, develop LAs and WLAs for the segment, develop an implementation plan for meeting the allocations, amend the Santa Ana Basin Plan to incorporate the TMDLs, and allow public participation in the process. *See* State Water Resources Control Board, ***Total Maximum Daily Loads (TMDL) Questions & Answers***, (April 2001). It cannot simply adopt the allocations and implementation plan developed by or for another Regional Board for a downstream waterbody.[9]

An example of how cross-jurisdictional TMDL development could occur is found in the San Francisco Regional Board's mercury TMDL for the San Francisco Bay. In that TMDL, the San Francisco Regional Board included a waste load allocation for sources within the Central Valley Region whose discharges are tributary to San Francisco Bay. However, at the same time, the Central Valley Regional Board was developing its own mercury TMDL for upstream water bodies. The San Francisco Regional Board's WLA for the Central Valley Watershed, in effect, represents the reduction that will be obtained once the Central Valley Regional Board's TMDL is implemented. In other words, the San Francisco Regional Board's allocation is more of an accounting mechanism that assures sources within the jurisdiction of the San Francisco Regional Board are credited with the reductions that will be obtained through the Central Valley Regional Board's TMDL once it is implemented.[10] The San Francisco Board did not attempt to enforce its WLA on Central Valley Region sources, nor did the Central Valley Regional Board simply adopt the San Francisco Board's allocation as its own.[11]

CONCLUSION

In summary, the Tentative Order has included requirements that are outside the scope of authority given to the Regional Board by the Clean Water Act's NPDES program. The goal of the Tentative Order is to reduce the discharge of pollutants in urban stormwater runoff to waters of the U.S. to the maximum extent practicable to protect water quality standards. The Regional Board must ensure that the requirements in the Tentative Order are not prescriptive and are in compliance with federal law. The County hopes that the Regional Board will consider the numerous methods in which compliance with the MEP standard can be accomplished and that

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[9] Both the Fact Sheet and the Findings state that Permittees are "expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed." In other words, they are "expected" to implement the Coyote Creek TMDLs developed for the Los Angeles region.

[10] San Francisco Regional Board staff refused to assign allocations to individual Central Valley sources, stating that "these sources are outside our jurisdiction, and the Central Valley Water Board is developing mercury TMDLs that will more effectively address these sources . . ." ***Staff Report, Proposed Amendment to the Water Quality Control Plan (Basin Plan) for the Sun Francisco Bay Region to Establish San Francisco Bay Mercury Total Maximum Daily Load (TMDL) and Implementation Plan***, Meeting Date: September 15,2004.

[11] Perhaps a better example of how to address waters crossing jurisdictional boundaries can be found in the Tennessee E. Coli TMDL approved by U.S. EPA. *See,* ***Total Maximum Daily Load (TMDL) for E. Coli in the South Fork Holston River Watershed*** (September 2006). The Tennessee TMDL identifies impaired waters in a portion of the watershed that is located in Virginia. Tennessee did not attempt to adopt a TMDL for the Virginia waters or impose allocations. Rather, it simply acknowledged the issue and indicated that Virginia is addressing it through its own TMDL for fecal coliform.

the Regional Board will not impose requirements that are appropriately handled through other regulatory mechanisms.

ATTACHMENT B

TECHNICAL ISSUES AND COMMENTS ON TENTATIVE ORDER NO. R8-2008-0030 NPDES NO. CAS618030

INTRODUCTION

Attachment B contains the principal technical comments of the County of Orange (the "County") on Tentative Order NO. R8-2008-0030 dated November 10, 2008 ("Tentative Order"). These comments are divided into three sections: (1) General Comments; (2) Findings; and (3) Sections. At times, the issues and concerns raised will pertain to more than one section of the Tentative Order.

The County has endeavored to provide a complete set of comments on the Tentative Order. However, the County reserves the right to submit additional comments relating to Tentative Order No. R8-2008-0030 and the supporting Fact Sheet/Technical Report to the Regional Board in the future.

GENERAL COMMENTS

TENTATIVE ORDER IS INCONSISTENT REGARDING THE NAMING OF THE PERMITTEES THAT ARE REGULATED

The Tentative Order inconsistently identifies the Permittees in three primary locations, a) the subject line in the Fact Sheet, b) the header in the Tentative Order, and c) the header in the Monitoring and Reporting Program (MRP). All references should consistently identify the Permittees as:

"The County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County within the Santa Ana Region"

FINDINGS

TENTATIVE ORDER REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

- **Maximum Extent Practicable (A.3., page 2)**
  The Tentative Order includes a definition of Maximum Extent Practicable (MEP) that is inconsistent with current case law, the Fact Sheet and the definition included in the current NPDES permit.

  The Fact Sheet States (VI., page 13):

  Maximum Extent Practicable (MEP) means to the maximum extent feasible, taking into account equitable considerations of synergistic, additive, and competing factors,

including but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

However, the Tentative Order states (A.3., page 2):

MEP is not defined in the Clean Water Act; it refers to management practices, control techniques, and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

By modifying the definition of MEP to include "and such other provisions as the Administrator or the State determines appropriate for the control of pollutants…", the Regional Board appears to have determined, contrary to current case law, that the discretion that the state has to use "such other provisions" is a part of the definition of MEP. However, we would strongly disagree with that interpretation and submit that this discretion is outside of the definition of MEP and, therefore, subject to California law.

Under federal law, municipal stormwater discharges must comply with section 402(p) of the Clean Water Act, which requires that cities reduce stormwater to the maximum extent practicable. (33 U.S.C. Section 1342(p)(3)(B)(iii)) Whenever a Regional Board imposes pollutant restrictions in a wastewater discharge permit more stringent than what federal law requires, California law requires the Board to take into account the public interest factors of Water Code section 13241, which includes economic factors and the cost of compliance. (City of Burbank v. State Water Resources Control Bd. (2005) 35 Cal.4th 613, 627.). Thus, if the Regional Board seeks to impose any requirements that go beyond those set forth in section 402(p), the Regional Board must evaluate the public interest factors in Water Code section 13241 prior to permit adoption.

As such, the County recommends that the Finding be modified as follows to be consistent with the Fact Sheet definition:

MEP is not defined in the Clean Water Act; it refers to management practices, control techniques, and system, design and engineering methods, ~~and such other provisions as the Administrator or the State determines appropriate~~ for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

- **Illegal Discharges Definition (N.70., page 22)**
  The explanation in Finding N.70, that the first term permit required the Permittees to: ... (2) eliminate illegal and illicit discharges to the MS4s…is incorrect. Section II. 9 of NPDES N. CA 8000180 established a responsibility for the Permittees to *Respond to emergency situations such as ..... illegal discharges/illicit connections*. Further, Section II.1. of this permit required the dischargers to *…prohibit illegal discharges*. In response

to these obligations, the Permittees developed and adopted local legal authority creating a prohibition on *illicit connections* and *prohibited discharges* (see Sec. 9-1-40. of the Codified Ordinances of the County of Orange for example). The Finding should be revised for consistency with this programmatic history and specific use of the terms *illicit connection* and *prohibited discharge* in Orange County.

- **Illegal Discharges Definition (N.70., page 22)**
  Finding N.70, for the first time, defines illegal discharges to include "any discharge (*or seepage*) to the municipal separate storm sewer that is not composed entirely of stormwater and not one of the authorized discharges" [emphasis added]. This is problematic for several reasons.

  First, this new definition of illegal discharges will significantly impact the Permittees' resources and does not fit within the context or intent of the illegal discharges/illicit connections (ID/IC) program. The Permittees have a program to address illegal discharges (Section 10 of the Drainage Area Management Plan and Local Implementation Plan). This comprehensive program includes procedures for detecting, responding to, investigating and eliminating these types of discharges in an efficient and timely manner. Including "seepage" in this definition means that the Permittees may now have to use a series of resource intensive investigations in order to detect these types of discharges within the channels and underground pipes. Further – they would then have to investigate these discharges, but do not have a way to eliminate them given that the discharges are resulting from groundwater seeping into the channels. Short of sealing the channel bottom and walls, which is not technically feasible, these types of discharges can not be eliminated. Thus, it is unclear how the Permittees can be expected to include this whole new category of passive, groundwater seepages into the ID/IC program and remain in compliance with the permit.

  Second, the inclusion of a new category of discharges, "seepage", seems counter to the definition of illicit discharges provided in Finding 11 on page 4. The definition states"Illicit discharge means any *disposal*, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance. [emphasis added]". This definition includes an intent to actively "dispose" of a material or waste. It does not seem to include passive groundwater seepage that enters the storm drain system.

  The County recommends that the Finding be modified as follows:

  Illegal discharge means any discharge ~~(or seepage)~~ to the municipal separate storm sewer that is not composed entirely of stormwater except for the authorized discharges listed in Section III of this permit. Illegal discharges include the improper disposal of wastes into the storm sewer system.

NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

- **Effective Impervious Area (L.62., page 19)**
  Finding 62 identifies that USEPA has determined that, by limiting the effective impervious area (EIA) of a development site to 5% or less, downstream impacts could be minimized. However, USEPA, in several statements made by Dr. Cindy Lin at the November 14, 2008 CASQA General Meeting, has recently suggested that the 5% EIA metric should only be considered as an example and that USEPA is open to consideration of other metrics for low impact development (LID).

  > "At EPA Region IX, we're strongly promoting LID strategies that lead to infiltration, evapotranspiration, capture and re-use of stormwater to maintain or restore natural hydrology and improve water quality."
  >
  > "We're encouraging permitting agencies to, as much as possible, incorporate LID provisions into MS4 permits with clear, measurable, and enforceable requirements."
  >
  > "The new MS4 permits should include quantitative requirements to enable all parties to clearly identify performance expectations for LID implementation and permit provisions should include specific enforceable and measurable requirements that will result in water quality improvement."
  >
  > "We completely understand that there is still the science going on, but it is now our job also to have some kind of a target goal and so, for us, even with Ventura County having a 5% effective impervious area, we're not saying that that is what you absolutely have to do. We are saying – here's an example of a draft permit with something that is specific, that's concrete, that's quantitative, that we can understand. That, later when we come back, we can say – did we meet this goal?"
  >
  > "Given your best judgment, your expert opinion, on what you experience and what you are seeing on the ground, what are those specific requirements you can give back to your Regional Board. We want to make sure that there is something workable. We are asking that you come to us and say – this is what we can do, this is what we can put in a permit."

  Further, at the same November 14, 2008 CASQA General Meeting the principal author of the cited Southern California Coastal Water Research Project (SCCWRP) study effectively refuted the notion that their work constituted advocacy for a 5% EIA performance standard for land development. These comments and observations point to the lack of a technical consensus on a performance standard for land development intended to produce urbanized landscapes that better mimic the hydrological response of undeveloped areas.

  The County would submit that, in order to resolve current uncertainty and ensure that the technically valid objectives for the land development program are established, there

needs to be an opportunity to continue to develop a contextual approach for Orange County through a stakeholder driven process that incorporates input from those engaged in design and implementation of LID based practices. In addition to resolving areas of technical uncertainty, such a process would also provide an opportunity to integrate stormwater management into efforts to comply with other mandates such as SB 375, which requires the development of sustainable community strategies, and AB1881, which focuses on water conservation. Alternative language for Finding 62. is provided below.

~~*62. The USEPA has determined that by limiting the effective impervious area of a development site to 5% or less, downstream impacts could be minimized (also see the SCCWRP study20). A limited study conducted by Dr. Richard Horner21 concluded that a 3% EIA standard for development is feasible in Ventura County. These principles are incorporated into requirements for new developments and redevelopment projects.*~~

62. *There are many different quantitative metrics and approaches that have been approved and/or are being considered throughout California and the country to ensure that LID-based principles are incorporated into development projects The variety of metrics and approaches is a result of the fact that this is a newly emerging area for stormwater programs and the uncertainty regarding the technical feasibility of implementation and the nexus to water quality benefits.*

Integration of LID into new and redevelopment stormwater standards has taken several forms including (but not limited to) peak flow controls, volume reduction, onsite retention, volume reduction tied to a pollutant load target, and impervious area reduction. Examples of each approach are provided below.

- *Peak flow controls - post-project/development is equal to or less than pre-project/development plus treatment control*

  Contra Costa County: Requires peak flow control (post-development ≤ pre-development) plus treatment control. Standards also prioritize the use of BMPs with the first preference being no net increase of impervious cover and second preference being the use of specified infiltration practices. The framework for compliance demonstration makes use of the preferred practices easier than conventional practices, such as detention basins. This requirement applies to both new development and significant redevelopment alike. Available at: www.cccleanwater.org/new-developmentc3/stormwater-c3-guidebook/.

- *Volume reduction – post-project/development stormwater runoff volumes be reduced to levels equal to or less than pre-project/development stormwater runoff volumes*

  Los Angeles County: Recently adopted an ordinance that requires that post-development stormwater runoff volumes be reduced to levels equal to or less than pre-development stormwater runoff volumes. This requirement applies to

both new development and redevelopment alike. Available at: http://planning.co.la.ca.us/spGreenBuildingProgram.htm.

- *Onsite retention - onsite retention of the volume from a specified design storm.*

  City of Santa Barbara: Requires the onsite retention of the runoff volume from 1-inch/24 hr storm. This requirement applies to both new and redevelopment and does not specify preference for low impact development strategies (e.g., possible that requirement could be met through use of detention basin or on-site retention. Available at: www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf

- *Volume reduction tied to a pollutant load target*

  State of Virginia: Virginia is considering the use of a volume reduction requirement tied to a target phosphorus load reduction. Developers must apply LID strategies to meet the target phosphorus load. If the target load cannot be met solely through the use of LID strategies, additional conventional BMPs (such as wet ponds) can be used to meet the remaining load requirement. Available at: www.cwp.org/Resource_Library/Center_Docs/SW/RRTechMemo.pdf.

- *Impervious area reduction - significant redevelopment projects reduce existing site imperviousness by some percentage (typically 10-20%).*

  State of Maryland: Requires that all significant redevelopment projects reduce existing site imperviousness by 20%. Where site conditions prevent the reduction of impervious area, BMPs (preference is stated for LID strategies) shall be implemented to provide treatment control for at least 20% of site imperviousness. A combination of impervious area reduction and treatment controls may be used. The State is in the process of revising the Maryland Stormwater Design Manual to better integrate LID strategies for new development. A summary of the redevelopment policy can be found at: www.mde.state.md.us/assets/document/Urban_redevelopment%202005.pdf.

In order to identify and implement the most appropriate metric and approach for development in the Orange County area, the permittees should utilize a stakeholder driven process and engage those experienced with LID design and implementation, those engaged in LID research, those engaged in review and approval of development projects, as well as other interested stakeholders including the Regional Board, and environmental groups.

- **Existing Model WQMP (L.63., page 20)**
  Finding 63 refers to the Model WQMP developed by the Permittees and the requirements for inclusion of site design, source control, and treatment control BMPs for new development and significant re-development projects. However, this discussion does not recognize the inclusion in the Model WQMP of *Section 7.II -3.2.4 Identify Hydrologic Conditions of Concern (HCOC)*. This section identifies the process to determine if a project site's hydrologic regime would be considered a condition that would have a significant impact on downstream natural channels and habitat integrity, alone or in conjunction with impacts of other projects. Where downstream conditions of concern have been identified, the project is required to maintain the pre-project hydrologic conditions affecting downstream conditions of concern by incorporating site design, source control, and treatment controls. Since adoption of the Model WQMP, new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. The County proposes a mapping effort to identify HCOC areas in the Santa Ana Region of Orange County while an appropriate LID metric is developed. This effort will provide a tool that project proponents can use to better comply with the existing HCOC requirements of the Model WQMP.

  The County recommends that additional language be added to Finding 63. to provide an interim measure and tool to protect susceptible areas while the development standards are being revised.

  Incorporated into the Model WQMP and required in the development of a WQMP for new development and significant re-development projects is Section 7.II -3.2.4 "Identify Hydrologic Conditions of Concern (HCOC)". An HCOC exists if a change to a project site's hydrologic regime would be considered a condition of would have a significant impact on downstream natural channels and habitat integrity, alone or in conjunction with impacts of other projects. Currently, new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. In the interim, while the development standards are being revised, the permittees will conduct an HCOC mapping effort in the first six months after adoption of the Order to identify HCOC areas in the Santa Ana Region of Orange County.

SECTIONS

DISCHARGE LIMITATIONS/PROHIBITIONS

- **"Presumption" and Public Education Requirements (III. 3. i. Page 30)**
  Consistent with the federal regulations and prior permits, Section III.3. of the Tentative Order notes that certain discharges need not be prohibited by the Permittees unless they are identified as a significant source of pollutants. The Tentative Order also notes in Section III.3. that changes to the list of exempted discharges (including changes made by the Regional Board) should be predicated on a finding that a particular type of discharge is a significant source of pollutants. There is no finding in the Tentative Order that justifies the requirement that all of these previously exempted discharges should now be presumed to be significant sources of pollutants until determined otherwise.

  The Tentative Order also requires the Permittees to incorporate public education and outreach activities directed at reducing certain categories of discharges even if they are not substantial contributors of pollutants to the MS4s and receiving waters (such as air conditioning condensate, passive footing drains, etc.). In the absence of any supportive finding regarding either of these new requirements, the Discharge Limitations/ Prohibitions section of the Tentative Order (Order No. R8-2002-0010)should be retained.

- **Categories of Discharges (III. 3. i. c. Page 31)**
  The Tentative Order includes a new category of discharge "irrigation water from agricultural sources". Although the discharge limitations/prohibitions have typically included a category entitled "landscape irrigation, lawn garden watering and other irrigation waters" the nexus to agriculture sources has never been made in previous permits and is counter to the federal regulations [40 CFR 122.26(d)(2)(iv)(B)(1)].

  The proposed inclusion of the new category is also inconsistent with the Findings and Fact Sheet, specifically:

  > Finding C.13, page 5 – "*Urban* activities also generate non-storm water discharges such as air conditioning condensate, *irrigation runoff*, individual residential car washing, etc., generally referred to as de minimus type of discharges." [emphasis added]
  >
  > Finding M.68, page 21 – "The MS4s generally contain non-storm water flows such as *irrigation runoff*, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows *generally referred to as de-minimus discharges*." [emphasis added]
  >
  > Finding S. 87, page 27 – "The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: *agriculture*, silviculture, *urban*, marinas, and hydromodification. *This*

> *order addresses the management measures required for the urban category*, with the exception of septic systems. Compliance with requirements specified in this Order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs. [emphasis added]
>
> Fact Sheet IV, page 6 – "In addition, there are storm water discharges from *agricultural land uses*, including farming and animal operations. However, *the CWA specifically excludes agricultural discharges from regulation under this program.*" [emphasis added]

The category "irrigation water from agricultural sources" needs to be deleted from the Tentative Order and, instead, be addressed through other regulatory mechanisms.

LEGAL AUTHORITY

- **Reporting (VI. 6, page 34)**
  The Tentative Order includes a section that requires the Permittees to report threats of potential violations of the Industrial or Construction General Permits. This requirement essentially requires the Permittees to make a determination regarding the compliance status of a regulated entity with these permits. Since the Permittees do not administer or enforce those permits, the only reporting that can be provided is with regard to conformance with local codes and ordinances. The Section should be modified as follows:

  6. The Permittees shall continue to provide notification to Regional Board staff regarding stormwater related information gathered during site inspections of industrial and construction sites ~~regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits~~. The notification shall include any significant ~~observed violations, or threat of potential~~ violations of the ~~General Permits~~ local codes and ordinances ~~(e.g., problematic housekeeping issues),~~ prior history of violations, any enforcement actions taken by the Permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

LITTER, DEBRIS AND TRASH CONTROL

- **Trash Characterization (VII. 5, page 36)**
  The Tentative Order requires each Permittee to undertake trash characterizations. The Section should be modified to identify this requirement as solely an obligation of the Principal Permittee.

MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

- **Types of Commercial Facilities (X.1, page 40 and 41)**

The Tentative Order adds 11 new categories of commercial facilities that will be subject to Permittees inspection. This new requirement, which represents a significant investment of resources for the Permittees, is not supported within the Findings or Fact Sheet. Although the Permittees agree that the commercial program and related inspections need to be continued during this permit term, it is critical that any new categories of commercial facilities that are added are documented as significant source of pollutants within this region. The new categories of commercial facilities should be deleted from the Tentative Order until such a time that these types of facilities have been determined to contribute a significant pollutant load to the MS4.

Commercial facilities may include, but may not be limited to:

~~*a) Transport, storage or transfer of pre-production plastic pellets.*~~
b) Automobile mechanical repair, maintenance, fueling or cleaning;
~~*c) Airplane repair, maintenance, fueling or cleaning;*~~
~~*d) Marinas and boat repair, maintenance, fueling or cleaning;*~~
~~*e) Equipment repair, maintenance, fueling or cleaning;*~~
~~*f) Automobile impound and storage facilities;*~~
~~*g) Pest control service facilities;*~~
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
~~*j) Cement mixing, concrete cutting, masonry facilities;*~~
~~*k) Building materials retail and storage facilities;*~~
~~*l) Portable sanitary service facilities;*~~
m) Painting and coating;
~~*n) Animal facilities such as petting zoos and boarding and training facilities;*~~
o) Nurseries and greenhouses;
p) Landscape and hardscape installation;
q) Pool, lake and fountain cleaning;
~~*r) Golf courses;*~~
s) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
t) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

- **Types of Commercial Facilities (X.1, page 40 and 41)**
The Tentative Order added the commercial facility category "transport, storage or transfer of pre production plastic pellets". While the Permittees understand the intent of the Regional Board in wanting to add these facilities to the program so that they are inspected, this category of facilities are better suited for the industrial program instead of the commercial program. In the Los Angeles Region, due to the types of facilities that typically handle pre-production plastic pellets, the stormwater inspection staff has inspected plastic products manufacturing facilities to determine compliance with the Industrial General Storm Water Permit. The County recommends that this category of facility be moved to the industrial program.

- **Inspection Frequencies (X.2, page 41)**
  The Tentative Order added a new requirement that, after the Permittees prioritize the commercial facilities for inspection based on the threat to water quality (based upon established criteria such as type of facility, location, potential for discharge, history of discharges, proximity and sensitivity of receiving waters, and materials used and generated at the site), there must be a minimum percentage allocation of the prioritized sites (10% high priority, 40% medium, and remaining % low) within the commercial facility inventory.

  There is no justification in the Findings or Fact Sheet for this designation. If the use of the prioritization system and/or criteria are viewed as problematic, then the Permittees would recommend that the Tentative Order address revisiting the existing system to fix potential flaws instead of arbitrarily assigning percentage breakdowns.

  The County recommends revising this language as follows:

  Each permittee shall conduct inspections of its commercial facilities as indicated below. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-stormwater discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 6 months of the adoption of this Order, the permittees shall review their existing prioritization system, criteria, and results based on the inspections, and determine if any modifications are necessary. The modifications shall be completed within 6 months of the determination and reported on in the annual report. ~~*The following minimum criteria must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality35; 40% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.*~~

- **Mobile Businesses (X.8, page 42)**
  The Tentative Order adds a new requirement to develop and implement a mobile business program for four (4) categories of mobile businesses including a) mobile auto washing/detailing, b) equipment washing/cleaning, c) carpet, drape, and furniture cleaning, and d) mobile high pressure or steam cleaning. The program must include the tracking, identification of BMPs for the mobile businesses, development of an enforcement strategy, a notification effort for all businesses, and the development of an outreach and education program.

  If the Tentative Order is going require the development and implementation of a significant new element of the commercial program, the Findings and Fact Sheet must also provide a technical basis for this addition. Mobile businesses present a unique regulatory challenge in stormwater regulation for several reasons including:

- The regular, effective practice of unannounced inspections is difficult to impossible to implement;
- Identifying mobile businesses is difficult because they are often not permitted or licensed; and
- Mobile businesses are transient in nature, advertise a mobile phone number as the only means of contact and may have a geographic scope of several cities or the entire region.

The Tentative Order should include language that limits the scope of the section until the costs and benefits of the program are better understood by allowing the Permittees to identify a mobile business category that may be a significant source of pollutants and develop a pilot regulatory program. The pilot program, to be completed in the first three years of the permit, would allow the Permittees to work together on a regional basis to develop and then implement an appropriate framework for addressing mobile business over the balance of the permit term.

Within 12 months of adoption of this order, the ~~principal~~ permittees shall develop a mobile business pilot program. The pilot program will address one category of mobile business, which may include: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape, furniture cleaning; or mobile high pressure or steam cleaning. The pilot program will include at least two (2) notifyications of the ~~all~~ individual ~~mobile~~ businesses operating within the County concerning the minimum source control and pollution prevention measures that they must ~~develop and~~ implement. ~~For purposes of this order, mobile businesses include: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape, furniture cleaning; and mobile high pressure or steam cleaning. The mobile businesses shall be required to implement appropriate control measures within 3 months of being notified by the permittees. Within 12 months of adoption of this order, the principal~~ The pilot program will also include the ~~permittee shall~~ development of an outreach and enforcement strategy to address mobile businesses. ~~Each~~ The permittees shall ~~also~~ develop and distribute ~~the~~ BMP Fact Sheets for the mobile business selected ~~es that has been developed by the permittees~~. At a minimum, the mobile business BMP Fact Sheets ~~/training program~~ should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedures for disposing of wastes generated ~~from each mobile business~~.

RESIDENTIAL PROGRAM

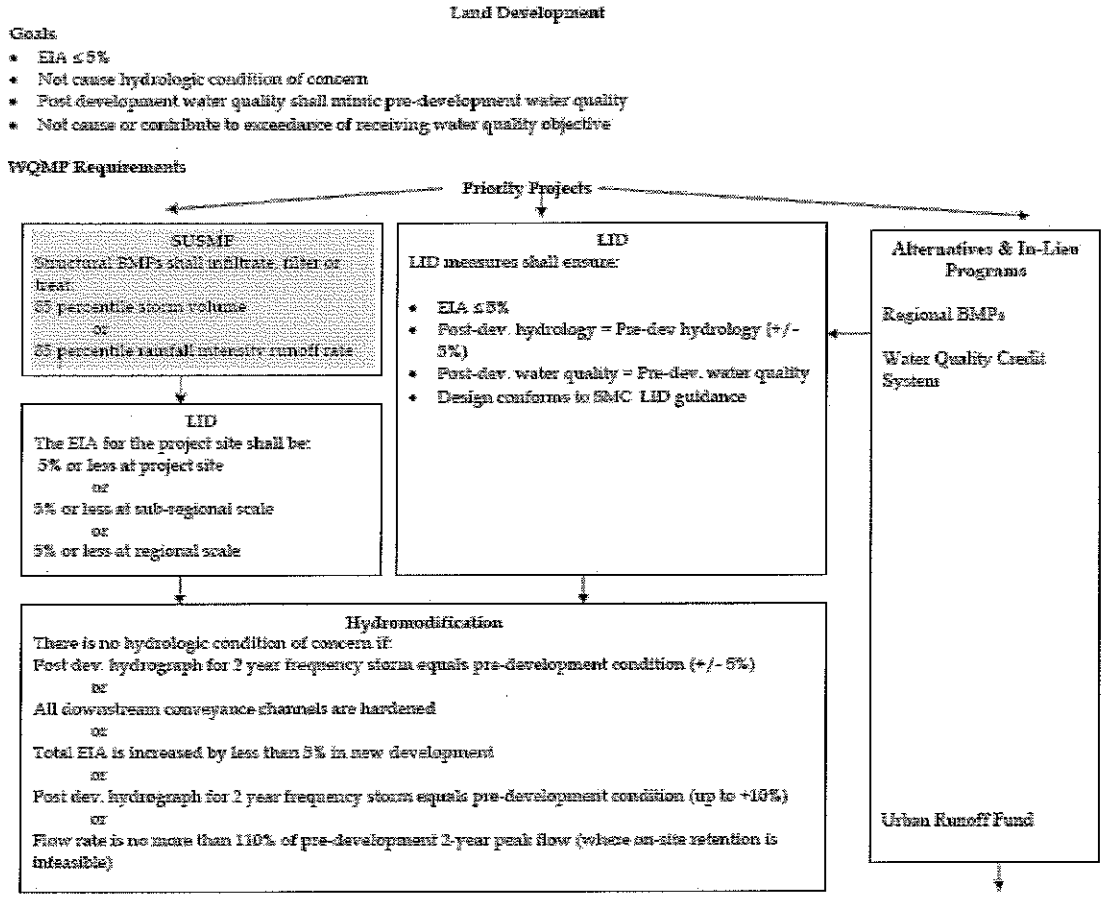
- **Pollution Prevention Measures (X.1.2, page 43)**
  The Tentative Order adds a new requirement for the development and implementation of a residential program to reduce the discharges from residential areas to the maximum extent practicable. Given the success of the Permittees' public education and outreach program – Project Pollution Prevention – which has demonstrably changed residents' awareness and behaviors in Orange County, this requirement appears duplicative of existing education and outreach efforts. However, there is also a concern that the

obligation to "require" residents to implement BMPs is contrary to current educational approaches which are striving to engender a stewardship ethic and may ultimately erode public support. If this section is retained, the County recommends that it be modified as follows:

> *2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage ~~require~~ residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program36 and USDA's Backyard Conservation Program.*

NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

The New Development provisions include significant new requirements related to SUSMP, LID and Hydromodification. The flow chart provided below is an attempt to graphically represent the County's understanding of and interplay between these provisions as currently written.



For the reasons stated in the comments related to Finding 62, the County believes that there is a vital need to develop a contextual approach to the revised land development provisions of the Tentative Order. Instead of seeking to establish a Countywide performance standard for land development upon permit adoption, these new requirements need to be developed in a stakeholder driven process with the goal of producing a substantially revised Model WQMP within 12-24 months. The elements of the revised Model WQMP would include an integration of SUSMP, LID and hydromodification requirements informed by consideration, on a watershed-by-watershed basis, of the opportunities and constraints presented by the urbanized landscape, water balance within each watershed, the ecological condition of individual stream systems, and other mandates (as previously noted) for more sustainable patterns of urban and sub-urban development. Provided in the sections below are the detailed technical comments that encompass the County's vision for New Development in the Orange County area.

The County is also concerned about the provision relating to pre-approved projects (XII. J, p. 58). Requirements for LID and hydromodification will need to be considered at the earliest stages of project conception and design and so those projects that are in the middle or nearing the end of project design but do not have an approved WQMP at the time of adoption of the

permit will be required to re-design the project, placing an undue burden on project proponents. Consequently, the County strongly recommends that the "grandfathering" provision of the current permit be used to avoid major disruption and undue burden to projects that are close to completion of their design phase.

A. GENERAL REQUIRMENTS

- **WQMP Guidance (XII.A.2., page 44)**
  Section XII.A.2. requires that the Permittees, within 6 months of adoption of the Tentative Order, develop a WQMP guidance document to more effectively ensure that water quality protection, including LID principles, are considered in the earliest phases of a project. The schedule for developing this guidance does not allow sufficient time to develop and institutionalize an effective guidance document through the necessary consultative stakeholder process. The Tentative Order should also therefore be modified to allow at least 12 months for each Permittee to revise its LIP at the same time to be consistent with the WQMP guidance.

  2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the permittees, shall develop a guidance document utilizing a stakeholder driven process for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. ~~The appropriate revisions to the DAMP to incorporate this guidance shall be submitted with the first annual report after adoption of this permit~~. Within ~~12~~ 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.

- **CEQA Document Preparation Review (XII.A.6, page 45)**
  Section XII.A.6 requires the Permittees to perform an annual review of their planning procedures and CEQA document preparation processes. Review of the planning procedures and the CEQA document preparation processes on an annual basis is unnecessary. The Tentative Order should be modified to require that a review of the planning procedures and CEQA document preparation processes should be completed concurrently with finalization of the revised land development provisions of the DAMP.

  6. The permittees shall ~~continue to~~ review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24 months after the adoption of the Order, ~~on an annual basis,~~ to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to stormwater quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:...

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOMENT/SIGNIFICANT REDEVELOPMENT)

- **Commercial and Industrial Developments (XII.B.2.(c), page 47)**
  Section XII.B.2.(c) lowers the threshold criterion for commercial and industrial developments to comply with WQMP requirements from 100,000 square feet to 10,000 square feet. The findings and fact sheet should explain the basis for lowering the threshold criterion.

- **Streets, roads, highways** – This provision especially the proposed LID requirement is particularly difficult for linear projects. In lieu of applying the LID requirement to streets, roads and highway the County suggests that these type of projects be required to incorporate where feasible EPA's *Managing Wet Weather with Green Infrastructure: Green Streets*.

- **Retail Gasoline Outlets (XII.B.2.(j), page 47)**
  Section XII.B.2.(j) includes, as a category of priority development projects, Retail Gasoline Outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day. However, the fact sheet does not provide any technical basis for inclusion of RGOs as a priority development project category. It should be noted that the DAMP already prescribes a suite of BMPs specific to RGOs. Subjecting RGOs to WQMP requirements imposes duplicity where it is not needed. Section XII.B.2.(j) should be removed from the Tentative Order.

- **WQMP Goals (XII.B.3., page 48)**
  Section XII.B.3. Identifies goals associated with WQMPs. However, these "goals" are currently written as specific requirements in a section that otherwise addresses project thresholds for WQMP preparation and numeric sizing criteria for treatment controls. The placement is confusing regarding how subsections a-d relate to each other and how they are to be addressed in Section XII.B.4 Treatment Control Sizing. Sections XII.B.3 (a), (b), and (c) should be relocated to a separate discussion of overall goals regarding introducing all the land development provisions of the Tentative Order.

- **Structural Infiltration BMPs (XII.B.5., page 49)**
  Section XII.B.5.(d) requires the vertical distance from the bottom of the infiltration system to seasonal high groundwater must be at least 10 feet. However, the Fact Sheet does not provide any technical basis for the distance of 10 feet. In fact, studies by NURP and Nightingale (1975; 1987a,b,c; 1989) and F. Napier (2008) have identified that pollutant removal occurs for most pollutants in the first several inches of soil. Furthermore the State Water Board is currently developing proposed regulations and waiver for onsite wastewater treatment plans (OWTS). These regulations may be relevant and provide a more technically based approach to protect groundwater from infiltration BMPs. The technical basis for the distance of 10 feet should be provided or the language should be revised to state that the vertical distance should be based on an adequate protection of groundwater defined as no impact to groundwater quality. Section

XII.B.5.(f) identifies that systems must not be used for areas of industrial or light industrial activity and areas subject to high vehicular traffic (25,000 or more daily traffic). Clarification of a definition of "light industrial" should be specified in the Tentative Order. The Fact Sheet does not provide any technical basis for the exclusion of high vehicular traffic of 25,000 or more daily traffic and thus should be removed.

- **Structural Infiltration BMPs (XII.B.7., page 50)**
  Section XII.B.7. appears to require that WQMPs are to be required for all non-priority projects. There are many types of non-priority projects, such as interior re-modeling, which do not meaningfully lend themselves to the preparation of a WQMP. The County requests that Section XII.B.7. be revised to be consistent with DAMP Section 7.6.2 which establishes the scope of project applicability with respect to WQMP requirements.

C. LOW IMPACT DEVELOMENT TO CONTROL POLLUANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT

- **LID Site Design Principles (XII.C.1., page 50)**
  Section XII.C.1. identifies a list of site design BMPs that should be taken under consideration during each phase of priority development projects. However, the list provided is a confusing mix of goals, tasks, and work products which does not provide a clear basis for compliance. The list needs to be revised with thought toward a potential future checklist of required considerations. Reference to accepted or forthcoming LID guidance, such as the USEPA LID Guidance or the future SMC Technical Guidance Manual, respectively, should also be considered.

- **LID Site Design Principles (XII.C.2., page 51)**

  It is not clear why the major discussion of LID includes prescribed source control BMPs. For the purposes of clarity, Section **XII.C.2** should be deleted.

- **LID & Effective Impervious Area (XII.C.3., page 51)**
  Section XII.C.3. requires the EIA for the project site shall be limited to 5% or less. However, consistent with the comments provided regarding Finding 62, the County would submit that EIA is not an appropriate project specific performance metric for LID. The County would submit that in order to ensure feasibility of compliance as well as water quality benefits associated with an LID metric that the Permittees develop an integrated and contextual approach focused on volume retention and reduction through a stakeholder process. This process would incorporate input from LID designers, academia engaged in LID research, municipal stormwater and plan check staff, and environmental groups to develop requirements that more effectively emphasize LID, can be feasibly implemented and is protective of water quality. The development of an appropriate LID metric is anticipated to require 12 months.

The County recommends that Section XII.C.3. be rewritten to provide for the development of a contextual approach for the Orange County permit. Alternative language for Section XII.C.3. is provided below.

Within 12 months from the date of adoption of this Order, the permittees shall identify a quantitative metric for incorporation of LID-based principles, update the new development standards, and adopt the new development standards to be in compliance with the development related requirements within the Order. In order to complete this, the principal permittee shall utilize a stakeholder driven process that includes, to the extent feasible, representatives from the permittees, LID designers, academia engaged in LID research, municipal plan check staff, Regional Board staff, and environmental groups. The development metric and approach, once agreed upon by the stakeholders, will be submitted to the Regional Board Executive Officer for approval.

Section XII.C.3. (a) identifies that pervious areas should have the capacity to percolate excess runoff from a two-year storm event. Percolation is not the only method for reducing the volume of runoff from a site and the Tentative Order should recognize the option for capture and onsite reuse.

Footnote 50 and 51 in sections XII.C.3. (a) and (b) refer to Footnote 38 which refers to the "Metropolitan Water District Evaluation of the Landscape Performance Certification Program" which appears to not be the correct reference.

- **Substitution of Treatment Controls for LID Measures (XII.C.4., page 53)**
  The County presumes that the intention of Section XII.C.4. is to allow project proponents to substitute LID measures for treatment controls if certain conditions are met and not the reverse substitution option currently prescribed by this section.

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION)

- **Hydrologic Conditions Assessment (XII.D.1., page 54)**
  Section XII.D.1. requires each priority development project to ascertain the impact of development on the site's hydrologic regime. This analysis should not be required if a hydrologic condition concern does not exist (i.e. downstream conveyance channels are engineered, hardened, and regularly maintained as identified in Section XII.D.2).

  Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event, except those projects that do not have a hydrologic condition of concern as identified in Section 2 below:

- **Hydrologic Conditions of Concern (XII.D.2.(c), page 54)**
  Section XII.D.2. (c) identifies that a hydrologic condition of concern is not present if the total effective impervious cover on a site is increased less than 5%. With respect to the hydrologic performance of a site, any performance metrics should be expressed in terms of runoff volume reduction.

- **Hydrologic Conditions of Concern (XII.D. page 54)**
  The County recommends that an additional provision be added to Section XII.D. Certain Permittees have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. In the interim, while an appropriate LID metric is developed, the Permittees will engage in an HCOC mapping effort to identify HCOC areas in the Santa Ana Region of Orange County. This effort will provide a tool that project proponents can use to comply with the HCOC requirements as part of the Model WQMP and provide an enhanced benefit to help maintain hydrologic conditions in those areas most susceptible to water quality degradation due to new development and significant redevelopment. The proposed language for the new provision Section XII.D.5. is:

  Within 12 months from the date of adoption of this order, the principal permittee shall develop a map to identify the HCOC areas in the Santa Ana Region of Orange County. This map will identify those areas susceptible to water quality degradation including downstream erosion and adverse impacts on physical structure, aquatic and riparian habitat due changes in the volume, peak discharge, and time of concentration for runoff associated with new development and significant re-development.

PUBLIC EDUCATION AND OUTREACH

- **Outreach Activities (XIII.4, page 59)**
  The Tentative Order added a new requirement that the Permittees conduct individual or regional workshops for various business-related sectors on an annual basis. However, past experience with these types of workshops has shown that it is very difficult to garner the support of the business community and to have them attend since they are concerned about time spent away from the office. Instead of spending the resources on the development and implementation of workshops, which are very time intensive for everyone, it is suggested that the Permittees explore other, alternative methods and provide outreach to the business sector through existing mechanisms including industry related events, chamber of commerce, etc. Thus, the County recommends that the section be modified as follows:

  > *4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities.* ~~*Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter.*~~ *The permittees shall propose, by July 1, 2010, the mechanisms that will be used to outreach to the above mentioned business-related sectors and the frequency at which the mechanisms will be utilized. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to*

these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

MUNICIPAL FACILITIES

- **Conveyance System Inspection (XIV, page 60)**
  The Tentative Order prescribes that stormwater conveyance systems be inspected annually. Following systematic, thorough and repeated inspection of the underground portions of the conveyance system during earlier permit terms, the County requests that the obligation to annually inspect conveyance systems apply only to the open channel portions of the system.

TRAINING

- **Training Program (XVI, page 62-63)**
  The Tentative Order prescribes that a schedule of training be delivered by the Principal Permittee an annual basis. Further to a specific ROWD commitment, the Permittees have developed a core competencies and skills based training program framework for 6 key areas of stormwater program functional responsibility predicated on a 2 year schedule for the development and delivery of a significantly revised training modules. The County requests that the training requirements be revised for consistency with this framework. In addition, the requirements should allow a Permittee to deliver its own equivalent training in lieu of receiving training from the Principal Permittee.

WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

- **Waterbodies with Technical TMDLs (B.3, page 66)**
  The Tentative Order includes a description of the selenium and nitrogen-related efforts within the watershed and describes the collaborative approach that has been utilized over the past 4 years. However, the section then goes on to describe what may occur if the stakeholders do not participate or if the collaborative approach "fails to achieve the TMDLs". Since the collaborative approach is designed to assist in addressing the rising groundwater source and the Regional Board may issue waste discharge requirements for rising groundwater if the Permittees do not attempt to mitigate this source, the County recommends that the section be modified as follows so that this direct cause and effect is more explicit:

  3. ..... Through the Nitrogen and Selenium Management Program, the watershed stakeholders are collaboratively developing comprehensive nitrogen and selenium management plans, which are expected to form the basis, at least in part, for a revised nutrient TMDL implementation plan and the selenium implementation plan. A collaborative watershed approach to implement the

nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected to continue. ~~As long as the stakeholders are participating in and implementing the collaborative approach, if approved, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay~~. The stakeholders' participation in and implementation of the collaborative approach will satisfy any wasteload allocations assigned to the permittees under this permit for compliance with the nitrogen and selenium TMDLs. In the event that ~~any of the stakeholders does not participate, or if~~ the collaborative approach is not approved or ceases to exist, ~~fails to achieve the TMDLs~~, the Regional Board ~~will~~ may exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

- **Numeric Effluent Limits (E, page 73) [Also addressed in Attachment A]**
  Although Section XVIII discusses the requirements for TMDLs including the related targets and wasteload allocations, section XVIII E incorrectly identifies that "numeric effluent limits" are included within the Tentative Order for the TMDLs. The County contends that this language is counter to the intent of the Tentative Order for the following reasons:
    - Numeric effluent limits are monitored at the end of pipe – section XVIII recognizes in numerous places that the monitoring for the TMDLs is within the receiving waters, not end of pipe
    - Numeric effluent limits are used to assess compliance with the Permit – if the discharger exceeds the effluent limit, they are out of compliance with the Tentative Order/requirement. However, the Tentative Order identifies within the Receiving Water Limitations (Section IV.) and Section XVIII.E. that compliance will be achieved through an iterative process with the application of more effective BMPs.

  Thus, the use of the term "numeric effluent limit" is incorrectly being used and should be replaced throughout the Fact Sheet, Findings and Tentative Order with "wasteload allocation" as follows:

  Fact Sheet –V., page 13
  The proposed order includes ~~numeric effluent limits based on the~~ wasteload/load allocations developed and approved by the Regional Board, State Board, Office of Administrative Law and the EPA.

  Fact Sheet – IX., page 17

  This order recognizes the significant progress made by the permittees during the first, second and third term permits in implementing the stormwater regulations. The permit also recognizes regional and innovative solutions to such a complex problem. For these reasons, the order is somewhat less prescriptive when compared to some of the MS4 NPDES permits for urban runoff issued by other Regional Boards. However, it incorporates an integrated watershed approach in

solving urban runoff related water quality and quantity issues. The proposed permit also includes ~~numeric effluent limits based on~~ wasteload/load allocations and an emphasis on implementation of low impact development principles. With these requirements, it should achieve the same or better water quality benefits because of the programs and policies already being implemented or proposed for implementation, including regional and watershed wide solutions.

The major requirements include: (1) Discharge prohibitions; (2) Receiving water limitations; (3) Prohibition on illicit discharges and illegal connections; (4) Public and business education; (5) Adequate legal authority; (6) Programs and policies for municipal facilities and activities; (7) Inspection Activities by the municipalities; (8) A program to address runoff from residential areas; (9) New development/re-development requirements including a requirement to fully implement low impact development principles and to minimize any hydrologic conditions of concern; (10) Waste load allocations for nutrients, sediment, and fecal coliform bacteria; metals, and pesticides, ~~including numeric effluent limits~~; and (11) Monitoring and reporting requirements.

Fact Sheet – IX., page 20

The proposed order includes special sections for the protection of impaired waterbodies. The 303(d) listed watebodies fall under the following four categories:

a. 303(d) listed with no TMDLs: The permittees are required to develop and implement pollutant-specific Watershed Action Plans to control the discharge of the pollutant causing the impairment.
b. 303(d) listed with a technical TMDL (no implementation plan): If the TMDL specifies a wasteload/load allocation for urban runoff or stormwater, the proposed order includes the appropriate load allocation ~~or a numeric effluent limit derived from it~~.
c. 303(d) listed with a TMDL implementation plan that has a compliance date beyond the permit term: The permittees are required to implement control measures to reduce the pollutant causing the impairment and monitor the progress towards achieving the wasteload allocation ~~target numeric effluent limit~~.
d. 303(d) listed with a TMDL implementation plan that requires meeting the target goals within the permit term: ~~Numeric effluent limits based on the~~ wasteload allocations are included in the proposed order.

Finding 72, page 23

This order includes wasteload allocations ~~numeric effluent limits~~ for those constituents for which the Regional Board has already established TMDLs. Consistent with the federal stormwater laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the

discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other sections as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

Waterbodies with Technical TMDLs (E, page 73)

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determination is based on monitoring within the receiving waters. For sediment TMDLs, compliance determination is based on end-of-pipe monitoring.

2. Based on the TMDLs, wasteload allocations ~~numeric effluent limits~~ are specified for most constituents. If the monitoring results indicate an exceedance of a wasteload allocation, ~~a violation of the numeric effluent limits,~~ the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

ATTACHMENT C

MONITORING AND REPORTING ISSUES AND COMMENTS ON TENTATIVE ORDER NO. R8-2008-0030 NPDES NO. CAS618030

INTRODUCTION

Attachment C contains the principal monitoring and reporting program comments of the County of Orange (the "County") on Tentative Order No. R8-2008-0030 dated November 10, 2008 ("Tentative Order").

The County has endeavored to provide a complete set of comments on the Tentative Order. However, the County reserves the right to submit additional comments relating to Tentative Order No. R8-2008-0030 and the supporting Fact Sheet/Technical Report to the Regional Board in the future.

COMMENTS

TRANSITION THE URBAN STREAM BIOASSESSMENT PROGRAM FROM A SOLELY NPDES SEMIANNUAL PROGRAM TO AN ANNUAL HYBRID PROGRAM

The Tentative Order requires continued implementation and evaluation of the Bioassessment element of the Monitoring Program (p. 85; III.1.f.). The County requests that this element of the monitoring program be revised to allow integration with the regional bioassessment monitoring initiative being coordinated by the Southern California Stormwater Monitoring Coalition through the Southern California Coastal Water Research Project (SCCWRP). The revision would transition the existing bioasessment monitoring to a program of annual surveys using Targeted (NPDES program) and Random (Regional program) sites.

ELIMINATE THE LAND USE CORRELATION PROGRAM ELEMENT

The Tentative Order requires continued implementation and evaluation of the Land Use Correlation element of the Monitoring Program (page 85; III.1.h). The County requests that the Land Use Correlation element be eliminated from the program for the following reasons:

- The most beneficial information from the Land Use Correlation program element has already been obtained from the development of the Hines Nursery/Northwood and Quail Hill areas of Irvine.
- The current monitoring locations in the drainage channels surrounding the former Tustin air station receive significant amounts of runoff from the adjacent neighborhoods. This interference effect makes assessment of the air station redevelopment difficult to isolate from ambient conditions. Further, downstream water quality has not shown any significant changes since development of the former Tustin air station began in early 2007.

REDUCE THE INLAND CHANNEL BACTERIOLOGICAL / PATHOGEN MONITORING PROGRAM

The Tentative Order requires continued implementation and evaluation of the Bacteriological / Pathogen Monitoring element of the Monitoring Program (page 85; III.1.e). Additional sampling of Newport Bay watershed sources began in 2005 at the request of the Regional Board for increased data collection to strengthen statistical power assessments of water quality conditions. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi Channel by both OC Environmental Health and the Orange County Program. This intensive monitoring requirement should now be reduced since almost four years of intensive data has been obtained.

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009~~8~~-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District ~~Resources and Development Management Department~~

and
The Incorporated Cities of Orange County w~~W~~ithin the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

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protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

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[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods~~, and such other provisions as the Administrator or the State determines appropriate~~ for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange ~~County Resources and Development Management Department (RDMD)~~, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange ~~RDMD~~ will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

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9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and ~~illegal~~~~illicit~~illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] ~~Illegal~~ Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

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Quality Inventory Reports to Congress cite urban runoff as a major source of beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

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E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect ~~illegal~~illicit discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 78~~9~~6 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control~~'s~~ system~~s~~ includes an estimated ~~400~~ 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within

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this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

<u>Inland Surface Streams</u>

Santa Ana River, Reaches 1 and 2

Aliso Creek (tributary to Santa Ana River)

Carbon Canyon Creek (tributary to Santa Ana River)

Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

Silverado Creek (tributary to Santiago Creek)

Black Star Creek (tributary to Santiago Creek)

Ladd Creek (tributary to Santiago Creek)

San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

San Joaquin Freshwater Marsh (tributary to San Diego Creek)

Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

Santa Ana Delhi Channel (tributary to Newport Bay)

Big Canyon Wash (tributary to Newport Bay)

Buck Gully

Los Trancos Creek

Coyote Creek (tributary to San Gabriel River)

Other tributaries to the above listed rivers, creeks and channels

<u>Bays, Estuaries, and Tidal Prisms</u>

Anaheim Bay and Seal Beach National Wildlife Refuge

Sunset Bay

Bolsa Bay and Bolsa Chica Ecological Reserve

Upper and Lower Newport Bay

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Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

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H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new

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developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants. The Regional Board recognizes that a watershed management program should integrate all related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary. The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues,

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such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The ~~While the~~ construction and industrial inspection programs in the third term permit had ~~followed~~ established criteria/examples. However, the commercial inspection program only included ~~and its list of business types requiring inspection was~~ a preliminary list of types of facilities to be inspected. Further r~~R~~efinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB 411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

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permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12.] The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13.]

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, "Management Guidelines for Use of Fertilizers and Pesticides". The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

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36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

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provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and ~~illegal~~illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

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Seal Beach (listed for enteroccocus, PCBs);

Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the ~~San Diego Creek/~~Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

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45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the ~~San Diego Creek/~~Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the ~~San Diego Creek/~~Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the ~~San Diego Creek/~~Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where

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necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

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52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.46(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA~~.....~~. This order requires the permittees to comply with the urban runoff/storm water wasteload allocations for both EPA-promulgated and Regional Board adopted/EPA approved TMDLs. ~~-~~Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, ~~-~~compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances~~,~~ and guidelines for the implementation of ~~minimum and~~ best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

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management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit ~~illegal and~~ illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that ~~is one of the most effective ways to~~ minimize ~~any~~ adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) ~~under the auspices of Storm Water Monitoring Coalition and in collaboration with~~and the California Storm Water Quality Association (CASQA), with

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

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funding from~~and~~ the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during ~~in~~ the earliest stages of planning such as site assessment, environment review and site planning. This manual ~~guidance document~~ will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the ~~guidance~~ manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mititgative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should ~~may~~ be considered. To the extent practicable, these LID BMPs must be implemented at the project site.

62. The USEPA has determined that ~~by~~ LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA ~~We~~ believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. ~~However, a~~A review of the analysis of the LID metrics in storm water permitting[25]and its critique[26]

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area ~~to 5% or less~~.

[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

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indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this –order concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be a better metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a~~limiting the effective impervious area of a development site to 5% or less, downstream impacts could be minimized (also see the SCCWRP study[28]). A limited study conducted by Dr. Richard Horner[29] concluded that a 3% EIA standard for development is feasible in Ventura County. The order se principles are incorporates~~d a volume capture metric based on the design volume specified in the WQMP. ~~into requirements for new developments and redevelopment projects.~~

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and ~~changes~~ the priority project threshold for commercial/industrial developments has been changed ~~to~~ 10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

[28] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area to 5% or less.

[29] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

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structural treatment control BMPs may not be necessary. The project WQMPs ~~for the project is~~ are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. T~~he t~~reatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc.~~.~~ If not properly designed and managed, these systems could be sources of groundwater pollution and could become a nuisance and/or cause the spreading of surface water pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 6~~5~~ could create a nuisance and/or habitat for vectors[30] (e.g., mosquitoes and rodents). Third

[30] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

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term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.~~.~~S.~~.~~ unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a ~~–~~number of NPDES permits[31] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the ~~San Diego Creek/~~Newport ~~Beach~~ Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate ~~illegal~~[32] ~~and~~ illicit discharges[33] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these

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[31] E.g., R8-2003-0061,as amended by R8-2004-0021.

[32] Illegal discharge means any discharge ~~(or seepage)~~ to the municipal separate storm sewer that is not composed entirely of storm water except for the authorized discharges listed in Section III of this permit. Illegal discharges include the improper disposal of wastes into the storm sewer system.

[33] Illicit Discharge means any discharge ~~(or seepage)~~ to the municipal separate storm ~~drain~~ system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

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requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,', resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,', for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The

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permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations ~~numeric effluent limits~~ for those constituents for which ~~the~~ either the U.S. EPA has promulgated or the Regional Board has ~~already~~ established TMDLs. Federal regulations (40 CFR 122.46(d)(vii)(B)~~…~~)) require the Permittees to comply with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have

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developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed

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inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

~~80.~~ Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal ~~or illicit~~ activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on ~~T~~the association between disease vectors, urban runoff, storm water treatment control and LID BMPs. ~~permittees are required to continue their efforts in public education programs.~~

81.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During

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the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ~~ILLEGAL~~ ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. ~~Illegal~~ Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect ~~illegal~~illicit discharges and illicit connections. The program also facilitates public reporting of ~~illegal and~~ illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate ~~illegal~~ illicitl discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit ~~illegal~~illicit connections and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

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86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the

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provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and ~~illegal connections~~illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.
7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.

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8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.
2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.

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3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, ~~illegal connections~~illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
   i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. ~~if they have been determined not to be substantial contributors of pollutants to the MS4s and the receiving waters.~~ The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
      a) Discharges composed entirely of storm water;
      b) Air conditioning condensate;
      c) Irrigation water ~~from agricultural sources~~;
      d) Passive foundation drains;
      e) Passive footing drains;

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f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Diverted stream flows;

i) Rising ground waters and natural springs;

j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

k) Flows from riparian habitats and wetlands;

l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5);

m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges unless the stated conditions are met:

a) The de minimus types of d~~D~~ischarges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

b) Discharges ~~–~~from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[34] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing ~~resuspension of sediments~~hydrologic conditions of concern in receiving waters.

~~b)~~c) Discharges from lawn watering and other irrigation runoff from non-agricultural operations[35]: These discharges shall be minimized through public education and water conservation efforts, as prescribed under Section XI, Residential Program.

[34] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[35] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

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~~c)~~d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[36] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent ~~resuspension of sediments~~causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

~~d)~~f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.
5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).
6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those ~~at~~ terms are ~~is~~ defined in Section 13050 of the Water Code.
8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.

[36] See previous footnote ~~25~~.

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2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.

3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

   d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

   So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not

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signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.

2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all ~~illegal connections~~illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. ~~The permittees' ordinance must include adequate legal authority to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments.~~ The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.

3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.

4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

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5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[37]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

   f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[38];

   g) Discharges of runoff from the washing of toxic materials[39] from paved or unpaved areas;

[37] State Board WQO No. 2006-0003.

[38] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

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h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/~~ILLEGAL CONNECTIONS~~ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all ~~illegal connections~~illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for ~~illegal connections~~illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any ~~illegal connections~~illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.

2. The permittees shall control, to the maximum extent practicable, the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.

3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/~~Illegal Connections~~llicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.

4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.

5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, t~~T~~he principal permittee~~s~~ shall characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the~~each~~ annual report.

[39] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

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6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.

7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.

2. Each permittee shall continue to maintain and update (at least on a biannual ~~quarterly~~ basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude [~~(~~in decimals]~~)~~ or NAD83/WGS84[40] compatible formatting ~~as identified by GIS for a spot within the site perimeter~~), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.

[40] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

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4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:

   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;

   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

   c) Visual observation for non-storm water discharges and potential pollutant sources;

   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work

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Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.

7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitutde/longitude (in decimals) or NAD83/WGS84[41] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.
3. Each permittee shall conduct industrial facility inspections, ~~-~~subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

[41] See Footnote ~~34~~38.

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4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.
5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period.

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction. As required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[42] compatible formatting is required. For water quality planning

[42] See Footnote ~~34~~38.

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purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

Commercial facilities may include, but may not be limited to[43]:

a) Transport, storage or transfer of pre-production plastic pellets.
b) Automobile mechanical repair, maintenance, fueling or cleaning;
c) Airplane ~~repair,~~ maintenance, fueling or cleaning;
d) Marinas and boat ~~repair,~~ maintenance, fueling or cleaning;
e) Equipment repair, maintenance, fueling or cleaning;
f) Automobile impound and storage facilities;
g) Pest control service facilities;
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
~~j) Cement mixing, concrete cutting, masonry facilities;~~
j) Building materials retail and storage facilities;
k) Portable sanitary service facilities;
l) Painting and coating;
m) Animal facilities such as petting zoos and boarding and training facilities;
n) Nurseries and greenhouses;
o) Landscape and hardscape installation;
p) Pool, lake and fountain cleaning;
q) Golf courses;
r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. The following minimum criteria must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[44]; 40% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its

[43] Mobile cleaning services are addressed in X.8, below.
[44] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

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ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.

4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.

5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.

7. All violations shall be notified as specified in Section XVII.

8. Within 12 months of adoption of this order, the ~~principal~~ permittee<u>s</u> shall <u>develop a</u> ~~notify all~~ mobile business <u>pilot program. es operati</u>The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or steam cleaning. The pilot program shall include at least two notifications of the individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. ~~ng within the County concerning the minimum source control and pollution prevention measures that they must develop and implement. For purposes of this order, mobile businesses include: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape, furniture cleaning; and mobile high pressure or steam cleaning. The mobile businesses shall be required to implement appropriate control measures within 3 months of being notified by the permittees.~~ The pilot program shall include outreach materials for the business and ~~Within 12 months of adoption of this order, the principal permittee shall develop~~ an enforcement strategy to address mobile businesses. The ~~Each~~ permittee<u>s</u> shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. ~~that has been developed by the permittees.~~ At a minimum, the mobile business Fact Sheets~~/training program~~ should include: laws and

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regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated. ~~from each mobile business.~~

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:
   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;
   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;
   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;
   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,
   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.
10. All commercial site inspectors shall be trained as specified in Section XVI.
11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period.

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s to the maximum extent practicable so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.
2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage ~~require~~ residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest

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research information, such as the UC Master Gardeners Program[45] and USDA's Backyard Conservation Program[46].

3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.

4. Within 18 months of adoption of this order, t~~T~~he permittees shall develop a pilot program to ~~and implement~~ control pollutant discharges from ~~measures for~~ common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[47] to encourage efficient water use and to minimize runoff[48].

5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[49].

6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.

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[45] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[46] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[47] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[48] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[49] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

2. Within 12~~6~~ months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. ~~The appropriate revisions to the DAMP to incorporate this guidance shall be submitted with the first annual report after adoption of this permit.~~ Within 18~~2~~ months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.

3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.

4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. The permittees shall ~~continue to~~ review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24 months after adoption of this order, ~~on an annual basis,~~ to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The

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permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance with the approved Model WQMP and shall incorporate LID principles in the WQMP.

   a. All significant redevelopment projects, where significant redevelopment is defined as priority development projects, which include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity

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required to protect public health and safety. Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b. Subdivisions creating 10 lots or units and more, and subdivisions creating less than 10 lots or units, where the combined impervious surface area of the lots or units is equal to or greater than 10,000 square feet. This includes single family residences, multi-family residences, condominiums, apartments, etc.

c. Commercial and industrial developments, which are not subdivisions, of 10,000 square feet or more. This includes non-residential developments.

d. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

e. Restaurants where the land area of development is 5,000 square feet or more.

f. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

g. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[50] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

h. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

i. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface[~~51~~] shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable. ~~. The WQMP should address the project area.~~ This category includes any paved surface used for the transportation of automobiles,

[50] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

[51] If a feasibility study indicates that it is not feasible to implement standard WQMP requirements due to unique constraints imposed on the project, alternatives acceptable to the Executive Officer must be implemented.

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trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

j. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

k. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[52] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

~~k.~~

~~WQMPs shall include BMPs for source control, pollution prevention, site design and structural treatment control BMPs (also see Section C, below). For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, and a funding source or sources for its operation and maintenance. WQMPs shall reflect consideration of the following goals, which may be addressed through on-site and/or watershed-based BMPs:~~

a) ~~The effective impervious area[53] (EIA) shall be limited to 5% or less of the total project site. Also see Section C, below.~~ Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

[52] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

[53] Effective impervious areas are those areas which are not connected to a pervious feature (such as a landscaped area, pervious concrete or asphalt surfaces with a sub-base of infiltration materials) and from where storm water runoff is conveyed to a storm water conveyance system or directly to waters of the US.

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e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

~~The project shall not cause a hydrologic condition of concern (see Section D, below).~~

~~Through an integrated watershed approach that integrates source control, pollution prevention, site design and structural treatment controls (if needed), the post-development runoff water quality and quantity shall mimic pre-development water quality and quantity.~~

~~The discharge of any listed pollutant[54] to an impaired waterbody on the 303(d) list shall not cause or contribute to an exceedance of receiving water quality objectives.~~

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

A. Volume

Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[55]; or,

2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

[54] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

[55] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

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OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

   b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

   c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050. ~~.~~

   d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

   e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

   f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[56].

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional

[56] This restriction applies only to sites that are known to have soil and groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

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treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for approval to the Executive Officer.~~.~~

2. The permittees shall incorporate LID site design principles to ~~that~~ reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration and treatment systems as close as possible to the source of runoff. Site design considerations shall include, but not be limited to:

   a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

   b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable concrete and porous asphalt; minimize pipes, culverts and engineered systems for storm water conveyance; utilize rain

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barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and ~~areas,~~ bio-filtration swales to replace curbs gutters and conventional storm water conveyance systems, ~~watershed-scale retrofits, etc.,~~ where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

3. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to the maximum extent practicable; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention. ~~**use of native vegetation to manage otherwise increased stormwater runoff volumes through returning rainfall to the atmosphere by evapotranspiration**~~

4. LID structural site design BMPs shall ensure capture of the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above.

5. The LID goal shall be to infiltrate, evapotranspire, harvest and beneficially reuse the design capture volume at the project site. Any volume that is not captured by the LID BMPs shall be treated using conventional treatment control BMPs in accordance with Section XII.B.4, above.

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~~5.~~6. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[57], New Urbanism[58] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

7. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality. If site conditions do not permit infiltration and/or harvesting and re-use of the design capture volume at the project site as close to the source as possible, the alternatives discussed below and the credits and in-lieu programs discussed under Section E, below, may be considered:

~~Site design BMP considerations shall include, but not be limited to:~~

~~b)Limit disturbance of natural water bodies and drainage systems; conserve natural areas; minimize paving, impervious areas and compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;~~

~~c)Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable concrete and porous asphalt; minimize pipes, culverts and engineered systems for storm water conveyance; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;~~

[57] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[58] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

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d)Preserve wetlands, riparian corridors, natural waterbodies, natural drainage systems and vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

e)Use of water quality wetlands, bioretention areas, biofiltration swales, watershed-scale retrofits, etc., where such measures are likely to be effective and technically and economically feasible;

f)Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

g)Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

h)Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on site hydrologically functional landscape controls; and

i)Integrate Watershed Action Plans and TMDL Implementation Plans into the sites conceptual WQMP.

2.The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a)Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b)Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c)Minimize storm water contact with pollutant sources;

d)Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e)Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances; and

f)Minimize the alteration of natural flow regime as discussed under Section XII.D.

3. Through implementation of appropriate site design, source control, pollution prevention and other LID principles, the EIA for the project site shall be limited to 5% or less. This EIA goal should be accomplished by implementing LID measures at the project site as close as possible to the source of storm water runoff. The goal of LID is to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative source control and site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality. Even though the LID principles are universally applicable, there could be constraining factors such as: soil conditions including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater

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~~levels, soil contaminants (Brown field developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit oriented developments), etc. In such cases, the LID principles could be integrated into other programs such as: Smart Growth[59], New Urbanism[60] or regional or sub-watershed management approaches. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The pollutants in post development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources. If site conditions do not permit~~ infiltration ~~and/or harvesting and re-use of the design capture volume at the project site as~~achieving the goal of 5% EIA ~~close to the source as possible, of excess storm water generation[61], the alternatives discussed below and the credits and in-lieu programs discussed under Section E, below, may be considered:~~

a) Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or ~~percolate~~harvest and re-use at least the design capture volume~~excess runoff[62] from a two-year storm event~~.

b) Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume ~~achieve the 5% EIA for the entire project~~ through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from ~~connected~~ impervious areas should have the capacity to infiltrate and/or harvest and re-use~~percolate~~ at least the design capture volume~~excess runoff[63] from a two-year storm event~~.

[59] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[60] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

[61] Excess storm water runoff = volume of post-development runoff minus pre-development runoff for a 2-year 24-hour storm event. This is mostly the runoff from impervious areas and excess runoff due to changes in site conditions, such as soil compaction, eliminating vegetative cover, etc..

[62] See Footnote 38

[63] See Footnote 38.

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c) Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume~~excess runoff from the pervious areas of the entire development~~. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use~~percolate~~ at least the design capture volume~~excess runoff~~[64] ~~from a two year storm event. (~~. (Also see discussion on hydrologic conditions of concern, below.)

d) Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use ~~percolate~~ at least the design capture volume~~excess runoff~~[65] ~~from a two-year storm event~~ from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

~~4.A combination of preventative and mitigative LID techniques may be substituted for t~~The ~~treatment control BMPs specified under Section XII.B.4 provided the~~ permittees may allow a project proponent to substitute treatment ~~control BMPs for LID measures if the following conditions are met:~~

~~a)~~The project proposes to implements applicable site design and source control ~~BMPs;~~

~~b)~~The ~~design capture volume is infiltrated and/or harvested and re-used at the project site~~EIA for the project site is limited to 5% or less~~;~~

~~c)~~The post-development site hydrology (including runoff volume and time of concentration[66]~~,~~) is not significantly different from pre-development hydrology (a difference of 5% or less is considered insignificant)~~;~~

~~d)~~The project proponent has included an analysis that indicates that post-development runoff water quality is equal to or better than pre-development runoff water quality; and

~~e)~~The permittee(s) establishes a mechanism to verify that the LID measures are designed, constructed and operated in accordance with acceptable engineering practices or in accordance with the LID Guidance Manual for Southern California

[64] See Footnote 38.

[65] See Footnote 38.

[66] Time of concentration is defined as the time after the beginning of rainfall when all portions of the drainage basin are contributing simultaneously to flow at the outlet.

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~~developed by the Southern California Coastal Water Research Project (currently being developed).~~

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[67])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

   e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected. These conveyance channels should not include any waters of the U.S.

   c) The site infiltrates ~~total effective impervious cover on a site is increased by less than 5% in new development projects. In considering the effective impervious cover, the impervious areas that are directly connected to a storm water conveyance system should be included, and those areas that are connected to pervious areas with a capacity to percolate~~ at least the runoff from a two-year storm event. ~~, need not be considered.~~

      The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency

[67] Hydromodification is the alteration of natural flow characteristics.

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storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees have the option to address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan that integrates water quality, hydromodification, water supply, and habitat. The Watershed Master Plan may be prepared for the whole watershed or for sub-watersheds. The Plan should include a map to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and specify hydromodification management standards for each sub-watershed. In the preparation of this Plan or plans, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; and (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board. The Watershed Master Plan or the sub-watershed plans shall be submitted to the Executive Officer for approval.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, ~~the permittees may grant~~ a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer ~~Regional Board~~ in writing. ~~within 30 days.~~ Waivers shall only be granted with prior approval from the Executive Officer.

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2. ~~If it is determined by the Executive Officer~~ Regional Board ~~that waivers are being inappropriately granted, this order may be reopened to modify these waiver conditions.~~ The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for ~~approved~~ water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

~~2.~~3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.

~~3.~~4. The permittees may establish a water quality credit system for alternatives to ~~evapotranspiration,~~ infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID~~, ,~~ ~~-~~hydromodification and treatment control BMPs ~~, and infiltration requirements~~ should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

   a) Redevelopment projects that reduce the overall impervious footprint

   b) Brownfield redevelopment

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c) High density developments (>7 units per acre)

d) Mixed use and transit-oriented development (within ½ mile of transit)

e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses

f) Regional treatment systems with a capacity to treat flows from all upstream developments

g) Contribution to an urban runoff fund (see 1, above)

h) Offsite mitigation or dedications within the same watershed

i) City Center area

j) Historic Districts and Historic Preservation areas

k) Live-work developments

l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

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I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.

2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.

3. The permittees shall develop a database with information regarding each structural treatment control BMP. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.

4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.

5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 50% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within a two year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. ~~as of the date of adoption of this order.~~ The above provisions shall be implemented to the maximum extent practicable for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for

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certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.
2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.
3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.
4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The

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outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.

2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.

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3. The permittees shall conduct inspections of open channel systems ~~municipal facilities~~ at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:

   a) Parking facilities;

   b) Flood management and storm water conveyance systems (open channels);

   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and

   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.

4. All applicable public agency staff shall be trained as specified under Section XVI.

5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:

   a) Conduct annual integrated pest management self-audits;

   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

   c) Provide proper training to municipal and contract staff involved in the above activities;

   d) Within six months of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within six months of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own

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evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.

13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.

14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.

2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.

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3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.
2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training (Certificate of Completion).

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4. At least every ~~on a~~two years, ~~n annual basis,~~ the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections.

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2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. ~~Currently~~ E~~e~~xisting Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.

2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

1. Implementation plans are being developed for the following TMDLs:

   a) Metals (San Diego Creek and Newport Bay)

   b) Metals (Rhine Channel)

   c) Organochlorine compounds (San Diego Creek and Newport Bay, also see Paragraph~~s~~ 2~~4 & 5~~, below)

   d) Selenium (San Diego Creek and Newport Bay)

   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)

   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)

   As required under a consent decree, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay that included TMDLs for ~~selenium,~~ metals, organochlorine compounds, selenium and organophosphate pesticides. As noted in the Findings, the Regional Board adopted TMDLs, including an implementation plan, for the organophosphate pesticides diazinon and chlorpyrifos. The diazinon and chlorpyrifos TMDLs have been fully approved and are now being implemented. The Regional Board adopted

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TMDLs, including an implementation plan, for organochlorine compounds in September 2007. The Regional Board adopted organochlorine -TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. It has not been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed.~~,~~ ~~and TMDLs are under implementation for diazinon and chlorpyrifos.~~ Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs. The permittees within the ~~San Diego Creek~~Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. However, until Regional Board adopted TMDLs for the organochlorine compounds, metals and selenium are approved by the State Board, the~~California~~ Office of Administrative Law (OAL), and the EPA, ~~approves the Regional Board adopted TMDLs, these~~ EPA promulgated TMDLs (see a-f, above) are the applicable TMDLs for these waterbodies. The permittees in the Newport Bay Watershed shall comply with the EPA-promulgated wasteload allocations in Tables 1 A/B/C, 2 A/B/C/D and 3.

Tables 1 A/B/C – Urban Runoff Waste Load Allocations for Metals (TMDLs promulgated by U.S. EPA)[68]

A- San Diego Creek and Tributaries – Concentration based TMDL

	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)

[68] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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0.0171 kg/yr	5.66 kg/yr

Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[69]

A- San Diego Creek and Tributaries

Total DDT	Chlordane	Dieldrin	PCBs	Toxaphene
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	Chlordane	PCBs
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	Chlordane	Dieldrin	PCBs
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	Chlordane	Dieldrin	PCBs
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries (TMDL promulgated by U.S. EPA)[70]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

2. For the organochlorine compounds TMDLs, the Regional Board has adopted an implementation plan. That plan requires approvals from the State Board, ~~the~~ O~~ffice of~~ A~~dministrative~~ L~~aw~~ and the EPA. Once approved by the State Board, OAL, and EPA, the Regional Board TMDL will replace the TMDLs promulgated

[69] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[70] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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by EPA. ~~The organochlorine compounds TMDLs have not been submitted the State Board for its approval.~~ The urban runoff wasteload allocations in those TMDLs are presented in Table 4. The permittees in the Newport Bay Watershed shall comply with the WLAs in Table 4 and the water column targets in Tables 5 A/B. ~~-~~The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated a Toxicity Reduction and Investigation Program (TRIP) consistent with the implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, t~~T~~he permittees shall evaluate the monitoring results with the ~~following~~ targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations. Tables 6 A/B have EPA-promulgated WLAs for toxic pollutants for San Diego Creek and Newport Bay. The permittees in the Newport Bay Watershed shall comply with the WLAs specified in Tables 6 A/B.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Pesticides (TMDLs approved by Santa Ana Regional Water Quality Control Board)[71]

	Total DDT	**Chlordane**	**Total PCBs**	**Toxaphene**
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.7 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

Tables ~~1~~5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[72]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l

[71] From Resolution No. R8-2007-0024, Table NB-OCs-10

[72] From Resolution No. R8-2007-0024, Table NB-OCs-4

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Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

Table 62 -– Allocations for San Diego Creek and Newport Bay WatershedWater Column Targets from

from the the

EPA-Promulgated Informational TMDLs for Toxic PollutantsChlordane and PCBs[73][74]

A- Sand Diego Creek and Tributaries

	Chlordane	DDT (including dicofol)	Total PCBs	Dieldrin	Toxaphene
Urban Runoff WLAAcute Criterion	2.4 µg/l	302.8 g/yr	177.7 g/yr	183.4 g/yr	6.2 g/yr
B- Upper Newport Bay					
Urban Runoff WLA	120.5 g/yr	207.4 g/yr	609.7 g/yr		
Chronic Criterion	0.0043 µg/l		0.014 µg/l		
Human Health Criterion	0.00059 µg/l		0.00017 µg/l		

3. In conjunction with watershed stakeholders, Regional Board staff is in the process of developing recommendations for revisions to the nutrient TMDLs and to the EPA promulgated –TMDLs for selenium, and is formulating a selenium

[73] From Resolution No. R8-2007-0024, Table NB-OCs-5

[74] U.S. EPA Region 9, Total Daily Loads for Toxic Pollutants, San Diego Creek and Newport Bay, California, June 14, 2002.

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TMDL implementation plan. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of ~~anthropogenic activities, specifically,~~ changes in the hydrologic regime as the result of extensive drainage modifications. ~~and is partitioned into groundwater through natural groundwater flow and through modifications to the natural hydrologic regime.~~ Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive nitrogen and selenium management plans, which are expected to form the basis, at least in part, for a revised nutrient TMDL implementation plan and the selenium implementation plan. A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one~~three~~ month~~s~~ after approval of the TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, ~~collaborative approach, if approved,~~ they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

4. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with ~~be designed to meet~~ the following wasteload allocations:

Table 7~~3~~ – Municipal Storm Water Wasteload Allocations

Coyote Creek

	Copper	Lead	Zinc

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Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

5. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table ~~7~~84 – Numeric Targets - Coyote Creek
(total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[75]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

Dry Weather limit for copper is based on CTR saltwater criterion in San Gabriel River estuary

C. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 9~~5a~~A – Fecal Coliform TMDL and AllocationsLoads for Newport Bay

To be achieved no later than December 30, 2013

Urban Runoff Waste ~~Total Maximum Daily~~ Load		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.

[75] Based on saltwater CTR criterion.

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Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2013	
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 9B~~5b~~ – Fecal Coliform TMDL and Allocations~~Loads~~ for Newport Bay

Before December 30, 2019

Urban Runoff Waste~~Total Maximum Daily~~ Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

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The permittees shall comply with the wasteload allocations for urban runoff in Tables 9a and 9b in accordance with the deadlines in Tables 9a and 9b. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans ~~DAMP~~ to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing ~~a~~ source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve~~six~~ months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.

3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 10~~6a~~A and 10~~6b~~B are extracted from the Implementation Plan[76]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 10 A and B.

Table 10~~6A~~a

Diazinon and Chlorpyrifos Allocations for San Diego Creek

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Actue	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6
Load Allocation	72	45	18	12.6
MOS	8	5	2	1.4

[76] Attachment to Resolution No. R8-2003-0039

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~~TMDL~~TMDL	**80**	**50**	**20**	**14**

MOS=Margin of safety; Chronic means 4-consecutive day average

Table 10~~6b~~B

Chlorpyrifos Allocations for Upper Newport Bay

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1
Load Allocation	18	8.1
MOS	2	0.9
~~TMDL~~TMDL	**20**	**9**

MOS=Margin of safety; Chronic means 4-consecutive day average

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall comply with the waste load allocations for urban runoff in Tables 9A and 9B. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 11~~7~~ - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[77]

[77] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

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Nutrient ~~TMDL~~TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[78]	2007 Summer Allocation (Apr-Sept)[79]	2012 Winter Allocation (Oct-Mar)[80]
Newport Bay Watershed	lbs/year TN[81,82]	lbs/season TN	lbs/season TN	lbs/season TN
Wasteload Allocation				
Urban runoff	277,131[83]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 12~~8~~ - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[84]

	2012 Allocation lbs/day TN[85]
~~TMDL~~TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

[78] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[79] See previous footnote ~~54~~.

[80] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[81] TIN = (NO3+NH3).

[82] TN = (TIN + Organic N).

[83] Estimated annual average (summer and winter loading).

[84] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[85] Compliance to be achieved no later than December 31, 2012~~this date~~. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

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Table 139 - Annual Total Phosphorous Load Allocations For The Newport Bay Watershed[86]

	2002 Allocation lbs/year TP[8712]	2007 Allocation lbs/year TP[6128]
TMDLTMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 11, 12 and 13 in accordance with the schedules in Tables 11, 12 and 13. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campusthe end-of-pipe, from representative MS4 systems, starting from year 2000 and based on a 10-year running average. The data from this monitoring is towill be submitted with each annually on February 27. report, on November 15th, starting in 2010.

[86] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[87] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[88] See previous footnote

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5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determination is based on monitoring within the receiving waters. For sediment TMDLs, compliance determination is based on ~~end-of-pipe~~ monitoring in the Creek.~~.~~

2. Based on the TMDLs, ~~numeric~~ effluent limits have been ~~have been~~are ~~specified~~ to ensure consistency with the waste~~-~~load allocations~~for most constituents~~. If the monitoring results indicate an exceedance ~~, violation~~ of the wasteload allocations~~numeric effluent limits~~, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:

   a) Review of the formal training needs of municipal employees

   b) Review of coordinating meeting/training for the designated NPDES inspectors.

2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.

3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.

4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.

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2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:

   a) Each permittee's expenditures for the previous fiscal year,

   b) Each permittee's budget for the current fiscal year,

   c) A description of the source of funds, and

   d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.
5. Within six months of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.

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6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014~~XXXXXXXX~~ and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge

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requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:

a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;

b) Changes in land use and/or population including land use map updates;

c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).

3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on April 24, 2009~~XXXXXXXXXX~~.

_____

Gerard J. Thibeault
Executive Officer

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To be provided at a later date.

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Order No. R8-2008-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities
Area wide Urban Storm Water Runoff

Attachment "B"

To be provided at a later date.

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Order No. R8-2008-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

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Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

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State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2008-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County w~~W~~ithin the Santa Ana Region
Areawide Urban Storm Water Runoff

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I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

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determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

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f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

~~h)Land Use Correlations: The permittees continue to gather additional data for determining the effects of land use on the quality of receiving waters and the impact of development on sediment loading within receiving waters.~~

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

   a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

   b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program

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has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format

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for all data transfer so that data can universally be shared and evaluated from various programs.

V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report

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Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual Report

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Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

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Ordered by_____
Gerard J. Thibeault
Executive Officer

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

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plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

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b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

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facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of beneficial use impairment. Urban area runoff may contain[9] elevated levels of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

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pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

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[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

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a) A summary of status of current Storm Water Management Program;

b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

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19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

    Inland Surface Streams

    Santa Ana River, Reaches 1 and 2

    Aliso Creek (tributary to Santa Ana River)

    Carbon Canyon Creek (tributary to Santa Ana River)

    Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

    Silverado Creek (tributary to Santiago Creek)

    Black Star Creek (tributary to Santiago Creek)

    Ladd Creek (tributary to Santiago Creek)

    San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

    San Joaquin Freshwater Marsh (tributary to San Diego Creek)

    Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

    Santa Ana Delhi Channel (tributary to Newport Bay)

    Big Canyon Wash (tributary to Newport Bay)

    Buck Gully

    Los Trancos Creek

    Coyote Creek (tributary to San Gabriel River)

    Other tributaries to the above listed rivers, creeks and channels

    Bays, Estuaries, and Tidal Prisms

    Anaheim Bay and Seal Beach National Wildlife Refuge

    Sunset Bay

    Bolsa Bay and Bolsa Chica Ecological Reserve

    Upper and Lower Newport Bay

    Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

    Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

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Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin)

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includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

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27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants. The Regional Board recognizes that a watershed management program should integrate all related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary. The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and

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efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB 411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

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32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12.] The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13.]

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, "Management Guidelines for Use of Fertilizers and Pesticides". The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

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leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

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38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

    Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

    Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

    Seal Beach (listed for enteroccocus, PCBs);

    Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

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Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be

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conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation

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of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.46(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

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order requires the permittees to comply with the urban runoff/storm water wasteload allocations for both EPA-promulgated and Regional Board adopted/EPA approved TMDLs. Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

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57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

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are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mititgative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. To the extent practicable, these LID BMPs must be implemented at the project site.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25]and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

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concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be a better metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to 10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues.

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However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of groundwater pollution and could become a nuisance and/or cause the spreading of surface water pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

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of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

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problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.46(d)(vii)(B)) require the Permittees to comply with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of

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increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

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78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide

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24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic

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framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicitl discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the

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California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

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PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.
7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.

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3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.
2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.

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3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.

   i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.

      a) Discharges composed entirely of storm water;

      b) Air conditioning condensate;

      c) Irrigation water;

      d) Passive foundation drains;

      e) Passive footing drains;

      f) Water from crawl space pumps;

      g) Non-commercial vehicle washing;

      h) Diverted stream flows;

      i) Rising ground waters and natural springs;

      j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

      k) Flows from riparian habitats and wetlands;

      l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5);

      m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

      n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

   ii. The permittees shall prohibit the following categories of non-storm water discharges unless the stated conditions are met:

      a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

      b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and

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pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

c) Discharges from lawn watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be minimized through public education and water conservation efforts, as prescribed under Section XI, Residential Program.

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.

5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

[33] See previous footnote.

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6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.
8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.
2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.
3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:
   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;
   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;
   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

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d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.

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3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.

4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[34]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

[34] State Board WQO No. 2006-0003.

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d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[35];

g) Discharges of runoff from the washing of toxic materials[36] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.

2. The permittees shall control, to the maximum extent practicable, the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks,

[35] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

[36] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

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and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.

3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.
4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.
6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.
7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.
2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location

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(latitude/longitude [in decimals] or NAD83/WGS84[37] compatible formatting), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.
4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:
   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;
   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);
   c) Visual observation for non-storm water discharges and potential pollutant sources;
   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,
   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.
5. At a minimum, the inspection frequency shall include the following:
   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

[37] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

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b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.
7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitutde/longitude (in decimals) or NAD83/WGS84[38] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of

[38] See Footnote 38.

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Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.

3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.

5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.

6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.

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8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period.

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction. As required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

   Commercial facilities may include, but may not be limited to[40]:

   a) Transport, storage or transfer of pre-production plastic pellets.
   b) Automobile mechanical repair, maintenance, fueling or cleaning;
   c) Airplane maintenance, fueling or cleaning;
   d) Marinas and boat maintenance, fueling or cleaning;
   e) Equipment repair, maintenance, fueling or cleaning;
   f) Automobile impound and storage facilities;
   g) Pest control service facilities;
   h) Eating or drinking establishments, including food markets and restaurants;
   i) Automobile and other vehicle body repair or painting;
   j) Building materials retail and storage facilities;
   k) Portable sanitary service facilities;
   l) Painting and coating;
   m) Animal facilities such as petting zoos and boarding and training facilities;
   n) Nurseries and greenhouses;
   o) Landscape and hardscape installation;
   p) Pool, lake and fountain cleaning;
   q) Golf courses;
   r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
   s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the

[39] See Footnote 38.

[40] Mobile cleaning services are addressed in X.8, below.

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permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. The following minimum criteria must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[41]; 40% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.
4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or

[41] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

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steam cleaning. The pilot program shall include at least two notifications of the individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:

   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;

   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period.

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s to the maximum extent practicable so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should

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include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[42] and USDA's Backyard Conservation Program[43].

3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[44] to encourage efficient water use and to minimize runoff[45].
5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[46].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

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[42] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[43] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[44] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[45] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[46] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.

2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.

3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.

4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24 months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings

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of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance with the approved Model WQMP and shall incorporate LID principles in the WQMP.

   a. All significant redevelopment projects, where significant redevelopment is defined as priority development projects, which include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance

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activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b. Subdivisions creating 10 lots or units and more, and subdivisions creating less than 10 lots or units, where the combined impervious surface area of the lots or units is equal to or greater than 10,000 square feet. This includes single family residences, multi-family residences, condominiums, apartments, etc.

c. Commercial and industrial developments, which are not subdivisions, of 10,000 square feet or more. This includes non-residential developments.

d. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

e. Restaurants where the land area of development is 5,000 square feet or more.

f. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

g. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[47] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

h. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

i. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

[47] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

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j. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

k. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[48] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

A. Volume

Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

[48] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

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1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[49]; or,

2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

   b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

   c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

[49] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

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d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[50].

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for approval to the Executive Officer.

2. The permittees shall incorporate LID site design principles to reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration and treatment systems as close as

[50] This restriction applies only to sites that are known to have soil and groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

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possible to the source of runoff. Site design considerations shall include, but not be limited to:

a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable concrete and porous asphalt; minimize pipes, culverts and engineered systems for storm water conveyance; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales to replace curbs gutters and conventional storm water conveyance systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

3. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-

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structural measures, e.g., preservation of natural features to the maximum extent practicable; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

4. LID structural site design BMPs shall ensure capture of the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above.

5. The LID goal shall be to infiltrate, evapotranspire, harvest and beneficially reuse the design capture volume at the project site. Any volume that is not captured by the LID BMPs shall be treated using conventional treatment control BMPs in accordance with Section XII.B.4, above.

6. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[51], New Urbanism[52] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

7. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality. If site conditions do not permit infiltration and/or harvesting and re-use of the design capture volume at the project site as close to the source as possible, the alternatives discussed below and the credits and in-lieu programs discussed under Section E, below, may be considered:

3.

a) Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains

[51] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[52] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

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to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

b) Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

c) Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

d) Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[53])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

[53] Hydromodification is the alteration of natural flow characteristics.

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c) Changes in time of concentration;

d) Potential for increases in post development downstream erosion; and,

e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected. These conveyance channels should not include any waters of the U.S.

   c) The site infiltrates at least the runoff from a two-year storm event.

   The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees have the option to address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan that integrates

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water quality, hydromodification, water supply, and habitat. The Watershed Master Plan may be prepared for the whole watershed or for sub-watersheds. The Plan should include a map to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and specify hydromodification management standards for each sub-watershed. In the preparation of this Plan or plans, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; and (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board. The Watershed Master Plan or the sub-watershed plans shall be submitted to the Executive Officer for approval.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.

2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

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3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.
4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:
   a) Redevelopment projects that reduce the overall impervious footprint
   b) Brownfield redevelopment
   c) High density developments (>7 units per acre)
   d) Mixed use and transit-oriented development (within ½ mile of transit)
   e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses
   f) Regional treatment systems with a capacity to treat flows from all upstream developments
   g) Contribution to an urban runoff fund (see 1, above)
   h) Offsite mitigation or dedications within the same watershed
   i) City Center area
   j) Historic Districts and Historic Preservation areas
   k) Live-work developments
   l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.

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2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.
3. The permittees shall develop a database with information regarding each structural treatment control BMP. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance

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verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.

4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.
5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 50% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within a two year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented to the maximum extent practicable for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.
2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.
3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes

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to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.

4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of

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the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.
2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.
3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:
   a) Parking facilities;
   b) Flood management and storm water conveyance systems (open channels);
   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and
   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.
4. All applicable public agency staff shall be trained as specified under Section XVI.
5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:
   a) Conduct annual integrated pest management self-audits;
   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;
   c) Provide proper training to municipal and contract staff involved in the above activities;

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d) Within six months of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within six months of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.

13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance

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contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.

14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.

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2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training (Certificate of Completion).
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.

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8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections.
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

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1. Implementation plans are being developed for the following TMDLs:
   a) Metals (San Diego Creek and Newport Bay)
   b) Metals (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay, also see Paragraph 2, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)

   As required under a consent decree, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay that included TMDLs for metals, organochlorine compounds, selenium and organophosphate pesticides. As noted in the Findings, the Regional Board adopted TMDLs, including an implementation plan, for the organophosphate pesticides diazinon and chlorpyrifos. The diazinon and chlorpyrifos TMDLs have been fully approved and are now being implemented. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. The Regional Board adopted organochlorine TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. It has not been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. However, until Regional Board adopted TMDLs for the organochlorine compounds, metals and selenium are approved by the State Board, the Office of Administrative Law (OAL), and the EPA, the EPA promulgated TMDLs (see a-f, above) are the applicable TMDLs for these waterbodies. The permittees in the Newport Bay Watershed shall comply with the EPA-promulgated wasteload allocations in Tables 1 A/B/C, 2 A/B/C/D and 3.

Tables 1 A/B/C – Urban Runoff Waste Load Allocations for Metals

(TMDLs promulgated by U.S. EPA)[54]

A- San Diego Creek and Tributaries – Concentration based TMDL

[54] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

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Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[55]

A- San Diego Creek and Tributaries

Total DDT	**Chlordane**	**Dieldrin**	**PCBs**	**Toxaphene**
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	**Chlordane**	**PCBs**
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	**Chlordane**	**Dieldrin**	**PCBs**
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	**Chlordane**	**Dieldrin**	**PCBs**
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

[55] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[56]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

2. For the organochlorine compounds TMDLs, the Regional Board has adopted an implementation plan. That plan requires approvals from the State Board, OAL and the EPA. Once approved by the State Board, OAL, and EPA, the Regional Board TMDL will replace the TMDLs promulgated by EPA. The urban runoff wasteload allocations in those TMDLs are presented in Table 4. The permittees in the Newport Bay Watershed shall comply with the WLAs in Table 4 and the water column targets in Tables 5 A/B. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated a Toxicity Reduction and Investigation Program (TRIP) consistent with the implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations. Tables 6 A/B have EPA-promulgated WLAs for toxic pollutants for San Diego Creek and Newport Bay. The permittees in the Newport Bay Watershed shall comply with the WLAs specified in Tables 6 A/B.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Pesticides (TMDLs approved by Santa Ana Regional Water Quality Control Board)[57]

[56] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[57] From Resolution No. R8-2007-0024, Table NB-OCs-10

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	Total DDT	**Chlordane**	**Total PCBs**	**Toxaphene**
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.7 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[58]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l
Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

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Table 6 – Allocations for San Diego Creek and Newport Bay Watershed from the EPA-Promulgated TMDLs for Toxic Pollutants[59]

A- Sand Diego Creek

	Chlordane	DDT (including dicofol)	PCBs	Dieldrin	Toxaphene
Urban Runoff WLA		302.8 g/yr	177.7 g/yr	183.4 g/yr	6.2 g/yr
B- Upper Newport Bay					

[58] From Resolution No. R8-2007-0024, Table NB-OCs-4

[59] U.S. EPA Region 9, Total Daily Loads for Toxic Pollutants, San Diego Creek and Newport Bay, California, June 14, 2002.

Urban Runoff WLA	120.5 g/yr	207.4 g/yr	609.7 g/yr		

3. In conjunction with watershed stakeholders, Regional Board staff is in the process of developing recommendations for revisions to the nutrient TMDLs and to the EPA promulgated TMDLs for selenium, and is formulating a selenium TMDL implementation plan. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive nitrogen and selenium management plans, which are expected to form the basis, at least in part, for a revised nutrient TMDL implementation plan and the selenium implementation plan. A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one month after approval of the TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

4. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with the following wasteload allocations:

Table 7 – Municipal Storm Water Wasteload Allocations

Coyote Creek

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	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

5. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 8 – Numeric Targets - Coyote Creek (total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[60]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

Dry Weather limit for copper is based on CTR saltwater criterion in San Gabriel River estuary

C. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 9A – Fecal Coliform TMDL and Allocations for Newport Bay To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL

[60] Based on saltwater CTR criterion.

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Fecal Coliform	As soon as possible, but no later than December 30, 2013	for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 9B – Fecal Coliform TMDL and Allocations for Newport Bay Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables 9a and 9b in accordance with the deadlines in Tables 9a and 9b. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and

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Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.

3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 10A and 10B are extracted from the Implementation Plan[61]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 10 A and B.

Table 10A

Diazinon and Chlorpyrifos Allocations for San Diego Creek

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Actue	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6
Load Allocation	72	45	18	12.6
MOS	8	5	2	1.4
TMDL	**80**	**50**	**20**	**14**

MOS=Margin of safety; Chronic means 4-consecutive day average

[61] Attachment to Resolution No. R8-2003-0039

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Table 10B

Chlorpyrifos Allocations for Upper Newport Bay

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1
Load Allocation	18	8.1
MOS	2	0.9
TMDL	**20**	**9**

MOS=Margin of safety; Chronic means 4-consecutive day average

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall comply with the waste load allocations for urban runoff in Tables 9A and 9B. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 11 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[62]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[63]	2007 Summer Allocation (Apr-Sept)[64]	2012 Winter Allocation (Oct-Mar)[65]

[62] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

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Newport Bay Watershed	lbs/year TN[66,67]	lbs/season TN	lbs/season TN	lbs/season TN
Wasteload Allocation				
Urban runoff	277,131[68]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 12 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[69]

	2012 Allocation lbs/day TN[70]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table 13 - Annual Total Phosphorous Load Allocations

[63] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[64] See previous footnote.

[65] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[66] TIN = (NO3+NH3).

[67] TN = (TIN + Organic N).

[68] Estimated annual average (summer and winter loading).

[69] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[70] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

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For The Newport Bay Watershed[71]

	2002 Allocation lbs/year TP[72]	2007 Allocation lbs/year TP[73]
TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 11, 12 and 13 in accordance with the schedules in Tables 11, 12 and 13. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

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[71] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[72] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[73] See previous footnote

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1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determination is based on monitoring within the receiving waters. For sediment TMDLs, compliance determination is based on monitoring in the Creek.
2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
    a) Review of the formal training needs of municipal employees
    b) Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.
3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
    a) Each permittee's expenditures for the previous fiscal year,
    b) Each permittee's budget for the current fiscal year,

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c) A description of the source of funds, and

d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.
5. Within six months of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.

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7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:
   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for

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additional source control and/or structural BMPs, any proposed pilot studies, etc.;

b) Changes in land use and/or population including land use map updates;

c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).

3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on April 24, 2009.

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Gerard J. Thibeault
Executive Officer

To be provided at a later date.

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Order No. R8-2008-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities
Area wide Urban Storm Water Runoff

Attachment "B"

To be provided at a later date.

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Order No. R8-2008-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

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Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

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State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2008-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

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I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

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determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

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f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

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c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

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V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual

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		Report

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Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

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Ordered by_____
Gerard J. Thibeault
Executive Officer

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for
Environmental Protection

3737 Main Street, Suite 500, Riverside, California 92501-3348
Phone (951) 782-4130 • FAX (951) 781-6288
www.waterboards.ca.gov/santaana

Arnold Schwarzenegger
Governor

March 25, 2009

TO: The Attached Mailing list

RENEWAL OF WASTE DISCHARGE REQUIREMENTS FOR THE COUNTY OF ORANGE, ORANGE COUNTY FLOOD CONTROL DISTRICT AND THE INCORPORATED CITIES OF ORANGE COUNTY, TENTATIVE ORDER NO. R8-2009-0030, NPDES NO. CAS618030, AREAWIDE URBAN STORM WATER RUNOFF

Enclosed is a copy of the second draft of tentative Order No. R8-2009-0030, NPDES No. CAS 618030. This order renews waste discharge requirements for the discharge of urban storm water from areas of Orange County within the Santa Ana Region. This item will be considered by the Regional Board at a public hearing during the regularly scheduled April 24, 2009 Board meeting, to be held at the Santa Ana City Council Chambers. An agenda announcement for this meeting will be posted on our website by April 2, 2009 at: http://www.waterboards.ca.gov/santaana/board_info/agendas/2009_agendas.shtml.

The major changes from the first draft of the tentative order are:

1. In the New Development/Re-development Section, Section XII of the tentative order: The 5% EIA requirement for determining compliance with the low impact development and hydrologic conditions of concern has been replaced with a design criteria based on the 85th percentile capture volume.

2. In the Watershed Action Plans and TMDL Implementation Section, Section XVIII: EPA promulgated TMDLs have been incorporated.

We have made other changes based on the written comments we received and the discussions at the stakeholder meetings. We have posted two versions of the tentative order on our website. All the changes are documented in the version "markup" and the second version is a clean copy of the tentative order.

While there is opportunity for comments to be made up to the time of the public hearing, for the accuracy of the record, all comments should also be submitted in writing. We will provide written response to all comments received at this office by COB April 9, 2009. Comments received after that deadline will be responded to during the public hearing. All comments received by April 9, 2009 will also be considered for the formulation of the draft permit that will be forwarded to the Regional Board two weeks prior to the Board

meeting date. In the interest of time, we request that all comments be submitted electronically to Marc Brown at: mbrown@waterboards.ca.gov

To be notified of future information regarding this permit, please sign on to our E-mail notification list (select "Storm Water – Orange County Municipal") at http://www.waterboards.ca.gov/resources/email_subscriptions/reg8_subscribe.shtml

If you have any questions, please call me at (951) 782-3238, Mark Smythe at (951) 782-4998, or Marc Brown at (951) 321-4584.

Sincerely,

Michael J. Adackapara
Division Chief

Enclosures: Mailing List, Fact Sheet, and Tentative Order No. R8-2009-0030

April 8, 2009

Via electronic mail

Ms. Carole H. Beswick and Members of the Board
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Re: Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2009-0030

Dear Chair Beswick and Members of the Board:

We write on behalf of the Natural Resources Defense Council ("NRDC") and Orange County Coastkeeper ("Coastkeeper"). We have reviewed Tentative Order No. R8-2009-0030, NPDES Permit No. CAS618030—the latest draft of the Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and The Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Storm Water Runoff NPDES Permit, released on March 25, 2009 ("Tentative Order"). We appreciate the opportunity to submit the following comments on the Tentative Order.

I. Introduction.

NRDC and Coastkeeper are concerned that the Tentative Order still requires clarification and improvement of key provisions. The Tentative Order, as currently written, is headed in the right direction but does not yet ensure that pollution from stormwater runoff will be reduced to the maximum extent practicable ("MEP") or to meet water quality standards. These concerns are reflected especially in the Tentative Order's low impact development ("LID") provisions, which require clearer articulation of a specific performance standard and certain delineation on when and how alternative compliance measures can be implemented. As we have indicated in previous comment letters, we strongly support LID because it is the most effective means of addressing the water quality and quantity problems associated with urban runoff, and believe that LID techniques are required by the Clean Water Act's MEP standard for pollution reduction because of their practicability, low cost, and superior performance relative to conventional BMPs. Currently, the Tentative Order's language needs to be tightened to

ensure the proper implementation of LID practices, which we think can be accomplished with important but discrete edits (which we have attached in the form of a redline of relevant LID language now contained in the Tentative Order).

The need to clarify the LID section of the Tentative Order is reinforced by other Clean Water Act requirements which are not adequately implemented currently by the provisions of the Tentative Order (which we address starting in Section III of this letter). The Tentative Order fails to adequately implement the Clean Water Act's ("CWA") requirement that permits incorporate TMDL waste load allocations ("WLAs") as enforceable permit limitations, as well as critical CWA requirements with regard to prohibitions against new sources or new dischargers of pollutants to impaired waterbodies and the discharge of non-stormwater to the MS4 system. Each of these problem areas highlights not only the need to revise the Tentative Order to bring it into accord with the requirements of federal law, but also the need to ensure that the Tentative Order's New Development requirements practicably maximize pollution control to enable the Tentative Order overall to adequately condition the discharge of water pollution to waters of the United States consistent with all relevant provisions of the CWA.

II. The New Development Section of the Tentative Order Requires Revision to Effectuate Regional Board Staff's Intent and to Meet the MEP Standard.

The New Development (Including Significant Re-Development) section ("New Development section") is particularly critical for addressing the root causes of stormwater pollution, which is why we have focused significant attention in our comments here and in our previous letter[1] on these requirements. As the U.S. Environmental Protection Agency ("U.S. EPA") has noted:

> Most stormwater runoff is the result of the man-made hydrologic modifications that normally accompany development. The addition of impervious surfaces, soil compaction, and tree and vegetation removal result in alterations to the movement of water through the environment. As interception, evapotranspiration, and infiltration are reduced and precipitation is converted to overland flow, these modifications affect not only the characteristics of the developed site but also the watershed in which the development is located. Stormwater has been identified as one of the leading sources of pollution for all waterbody types in the United States. Furthermore, the impacts of stormwater pollution are not static; they usually increase with more development and urbanization.[2]

[1] Letter from NRDC to Santa Ana Regional Water Quality Control Board re: Comments on Draft Order R8-2008-0030 (February 13, 2009) ("February 13th Letter").

[2] U.S. Environmental Protection Agency (December 2007) *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, at v.

Our concerns with the New Development section fall into the following three main categories:[3]

- The Tentative Order's performance requirement for the implementation of LID needs clarification;

- The public must be involved in decisions related to the permittees' establishment of critical standards and plans that implement the Tentative Order; and

- The Regional Board must clarify and limit the Tentative Order's alternative compliance provisions so that they meet the MEP standard and are based on scientific, not anecdotal, considerations.

A. The Tentative Order's Performance Requirement for the Implementation of LID BMPs Needs Clarification to Meet the MEP Standard and Effectuate Regional Board Staff's Apparent Intent.

While we continue to support an effective impervious area ("EIA") limitation as a performance standard for implementing LID BMPs, we can also support a technically equivalent alternative standard, which would ensure that the permit in fact reduces stormwater pollution to the maximum extent practicable. In the Tentative Order, Regional Board staff have eliminated the EIA standard and have created, instead, what appears to be an onsite retention-based standard. (*See* Tentative Order ¶¶ XII.C.2 through XII.C.5.) In concept, we believe that this standard (as encapsulated in provision XII.C.5) could accomplish the same objectives as the EIA limitation that we have advocated and supported in other locations within California through the work of Dr. Richard Horner.[4] The wording and structure of the Tentative Order, however, are not entirely clear, and certain revisions are needed to properly implement the new volumetric retention standard and to ensure that the Tentative Order meets the MEP standard.[5]

The necessity of including strong, numeric performance standards for post-construction stormwater BMPs has become evident across the country. As we mentioned

[3] We have submitted a redline of the Tentative Order's New Development section and recommend that the Regional Board implement these revisions to clarify the permit's requirements and ensure that it meets the MEP standard.

[4] *See* NRDC, February 13th Letter.

[5] In this vein, we note that the Tentative Order's findings highlight the extent to which a lack of clarity and specificity has led to lackluster results and poor implementation of effective stormwater management BMPs. *See* Tentative Order findings 64 and 71.

in our February 13th Letter, agencies from the U.S. EPA to the California Ocean Protection Council and the State Water Resources Control Board have studied and advocate such standards. Indeed, the U.S. EPA recently commented on the draft San Francisco Bay regional stormwater permit and reiterated the need for a "**clear, measureable performance standard to require landscape-based treatment, on-site retention, and/or storage for re-use**," even threatening to "consider objecting to the permit" if the San Francisco Regional Board does not include "additional, prescriptive requirements" in the permit.[6] Given this emphasis on capturing and infiltrating, harvesting, or evapotranspiring stormwater onsite, we believe that retention of the design storm volume is necessary to meet the MEP standard. With the revisions outlined below, the Tentative Order's performance standard will implement EPA's recommendations for clear metrics and be similar to—if somewhat less stringent than—the other examples from around the country that we cited in our February 13th Letter.[7]

First, the Low Impact Development section (provision XII.C) should, at the outset, set forth the performance requirement for LID BMPs so that this critical metric clearly applies to the implementation of post-construction stormwater management BMPs. In the redline that we are submitting with this letter, we have distilled (as provision XII.C.2) the onsite volumetric retention requirement that is evidently intended for implementation through the various provisions of this section. We have clarified that, as currently described in provision XII.C.5 (which, along with provision XII.C.4, we eliminated and made part of provision XII.C.2), permittees must require onsite retention of the design storm volume through infiltration, evapotranspiration, or harvesting and reuse. We have also more explicitly linked the Tentative Order's Alternatives and In-Lieu Programs section (XII.E) to the performance requirement by noting that any portion of the design storm volume not retained onsite must be mitigated elsewhere, while any surface runoff up to the design storm volume must be treated with LID or conventional BMPs before discharge. These revisions reflect comments of the U.S.EPA, which has stated that "in order to incorporate clear, enforceable, LID requirements" in permits, the permit should "clarify that regulated projects must utilize LID design elements to ensure onsite management of stormwater" without the use of "qualifiers such as 'to the extent feasible and 'as practicable,'" and that "[a]ny runoff that is not managed by these LID

[6] Letter from Douglas E. Eberhardt, U.S. EPA, to Dale Bowyer, San Francisco Regional Water Quality Control Board (April 3, 2009), at 1 (emphasis added).

[7] We are enclosing a relevant study recently conducted by Dr. Horner, which compares evaporation potential and rainfall in various locations around the country that have implemented onsite retention standards similar to the standard in the Tentative Order. Dr. Horner's research demonstrates that these national standards are equally applicable to Southern California and, in fact, Southern California has relatively better opportunities to practicably implement stringent LID requirements because of its favorable rainfall pattern.

design elements must be addressed" by offsite, equivalent or in-lieu provisions.[8] The Tentative Order suggests this structure, and we have made it clear.

Second, the hierarchy for LID implementation (provision XII.C.7) should clarify that evapotranspiration BMPs are an acceptable means of meeting the performance standard. LID features, such as green roofs, frequently result in considerable evapotranspiration, and these options should not be precluded since they allow developers additional flexibility in meeting the performance standard while preventing pollutants from entering receiving waters.

The Tentative Order, and our advocacy for LID practices that retain stormwater onsite through infiltration, harvesting and reuse, or evapotranspiration, thus ensuring that pollutant loads do not reach receiving waters, is most consistent with LID principles and goals. Others have advanced interpretations of "LID" that include the use of treat-and-discharge systems, but these systems are not as effective as retention practices because the discharged water may still contain pollution, even if it is attenuated. Our interpretation of "LID" is consistent with the U.S. EPA's: "LID comprises a set of approaches and practices that are designed to reduce runoff of water and pollutants from the site at which they are generated. By means of infiltration, evapotranspiration, and reuse of rainwater, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water."[9]

B. Various Provisions in the New Development Section Fail to Specify that the Public Must Have an Opportunity to Review and Comment on Documents that Implement Critical Aspects of the Tentative Order.

The Tentative Order appropriately requires Regional Board approval for many of the documents that the permittees will have to create to implement critical aspects of the Tentative Order. We generally object to the approach of deferring key aspects of the Permit to the future as we believe it is not permissible under the Clean Water Act. However, at bare minimum, the public must be meaningfully involved in the approval process of any deferred programmatic element because the effectiveness of the Tentative Order will be determined in large part through the various documents and as yet undeveloped programs required by the Tentative Order. *Environmental Defense Center, Inc. v. U.S. E.P.A.* highlights the legal necessity of meaningful regulatory entity review *and* public involvement during the process of establishing stormwater requirements. ((9th Cir. 2003) 344 F.3d 832.) "[S]tormwater management programs that are designed

[8] Letter from Douglas E. Eberhardt, U.S. EPA, to Dale Bowyer, San Francisco Regional Water Quality Control Board (April 3, 2009), at 2.

[9] U.S. Environmental Protection Agency (December 2007) *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, at iii.

by regulated parties must, in every instance, be subject to meaningful review by an appropriate regulating entity . . . Congress identified public participation rights as a critical means of advancing the goals of the Clean Water Act in its primary statement of the Act's approach and philosophy." (*Id*. at 856.)

To effectuate this purpose of the CWA, we have suggested in our redline various revisions to allow for public participation whenever the permittees are required to submit critical documents and plans to the Regional Board for approval. The provisions in question are: (1) the update of the WQMP (provision XII.C.1); (2) the creation of Watershed Master Plans (provision XII.D.5); (3) the technical infeasibility criteria (provision XII.E.1); (4) the waiver system permitted by provision XII.E.1; and (5) the "water quality credit system" pursuant to provision XII.E.4. These provisions relate to the establishment of requirements that play a central role in determining how effectively the permit will reduce stormwater pollution. Without allowing the public to participate in the development of these documents and plans, the public will be precluded from meaningful involvement in setting the criteria that govern the permittees' implementation of the Tentative Order's broad requirements.

In addition, some of these provisions, particularly the water quality credit provisions, are new and require a much better factual basis since they have the potential to significantly impact the level of water quality control. The creation of such a program is not merely an administrative detail that can be left to development by permittees. We believe, for this reason, that the credit system should be deleted and deferred until the Regional Board has developed additional information and clearer, technically-based support for the structure of such a program. This is particularly true because the watersheds regulated by the Tentative Order contain impaired waters, which draws into question the legality of a credit system.

C. The Tentative Order Needs to Clarify, Impose Limitations on, and Better Integrate the Alternatives and In-Lieu Programs Section.

While NRDC and Coastkeeper support the concept of allowing equivalent alternative compliance (through offsite mitigation or in-lieu payments for public stormwater mitigation projects) in situations of technical infeasibility, the Tentative Order's alternative compliance provisions currently do not include the necessary clarity and limitations. Additionally, the other provisions of the New Development section must reference the alternative compliance provisions wherever they come into play so as to delineate clearly the interplay between relevant provisions. As explained in our previous comment letter, certain revisions are required.[10]

Accordingly, we have redlined this section to address concerns related to: (1) clarifying that the "urban runoff fund" is intended to collect in-lieu payments from developments that are granted waivers for technical infeasibility and that do not

[10] NRDC February 13th Letter, at 6-8.

undertake their own offsite mitigation projects; (2) specifying that developments receiving waivers must achieve, in the aggregate, equivalent or greater pollution reduction compared to onsite implementation of the required BMPs; (3) preventing "water quality credits" from exceeding 33% of the volumetric retention requirement of provision XII.C.2 (in our renumbering); (4) ensuring that any credits granted are based on scientific evidence demonstrating that the developments eligible for credits in fact result in absolute reduction of stormwater pollution as a result of the factor(s) that make them eligible for credits; and (5) the credits are proportional to those watershed benefits. These revisions are critical to ensure that the permittees properly implement the alternative compliance provisions and actually reduce pollution to the maximum extent practicable and meet water quality requirements.

D. Additional Structural Concerns.

In our February 13th letter, we identified additional LID-related provisions that were in need of revision. Not all of these concerns have been addressed, including: the Tentative Order's exemption of projects from hydromodification requirements based on whether they discharge to certain types of channels; the Tentative Order's prohibition of infiltration devices where seasonal high groundwater is within 10 feet of the bottom of the device; and inconsistency in the language of the applicability provision that governs redevelopment projects. We reiterate these concerns here and urge the Regional Board to revise the Tentative Order accordingly.

We also note the following concerns, which require clarification in the Tentative Order.

First, provision XII.C.6 mentions that "the LID principles could be integrated into other programs, such as: Smart Growth, New Urbanism or regional or sub-watershed management approaches." (Tentative Order ¶ XII.C.6.) While the Tentative Order discusses regional or sub-watershed management approaches, it never explains how smart growth or new urbanism concepts could accommodate the LID principles outlined in the Tentative Order. As the Tentative Order currently reads, the permittees could potentially misunderstand their obligation to implement LID requirements and misconstrue generic attempts to pursue compact growth as alleviating their need to comply with this Board's permit requirements.

Second, the New Development section's applicability criteria (XII.B.2) do not clearly identify an overall, "catchall" category for new development projects that are subject to the Tentative Order's requirements. We have inserted the corresponding provision from the San Francisco Bay region draft stormwater permit and deleted provisions that were redundant vis-à-vis this new provision. This change is necessary to ensure that the Tentative Order clearly identifies the overall applicability of the New Development section's requirements to new development itself.

III. The Tentative Order Fails to Explicitly State that Waste Load Allocations From Applicable TMDLs Must be Enforceable Permit Limitations.

TMDLs represent numerical calculations of the maximum amount of a pollutant that a waterbody impaired under section 303(d) of the CWA can receive and still meet water quality standards, and TMDLs allocate that amount of pollution to discharges from the pollutant's sources. TMDLs establish WLAs—or the maximum amount of a pollutant that each point source discharger may release into a particular waterway—which constitute a form of water quality-based effluent limitation. (*See* 33 U.S.C. 1313(d)(4)(A); 40 C.F.R. § 130.2.) Once a TMDL has been adopted, NPDES permits are required to include WLAs and contain effluent limitations and conditions consistent with the assumptions and requirements of the TMDL from which they are derived. (40 C.F.R. § 122.44(d)(1)(vii)(B).)

The Tentative Order incorporates numeric WLAs for TMDLs applicable to the permittees in Section XVIII. TMDLs for nutrients, fecal coliform, sediment, and diazinon and chlorpyrifos, are currently in the implementation phase for Newport Bay or San Diego Creek. Numerous other TMDLs established by either U.S. EPA or the Regional Board have been developed but are not yet subject to implementation plans. (*See* Tentative Order ¶ XVIII.B.1.)[11]

While the Tentative Order states that permittees "shall comply" with allocations for established TMDLs,[12] and that for all TMDLs except sediment in Newport Bay, a "compliance determination is based on monitoring within the receiving waters," we are concerned that the permit appears to allow permittees to "comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs." While the Regional Board argues that implementing BMPs may serve as a means of achieving WLAs, U.S. EPA policy requires that a permit "demonstrate that the BMPs are expected to be sufficient to comply with the WLAs."[13] There is nothing in

[11] Implementation plans are currently being developed for TMDLs for metals, organochlorine compounds, and selenium in San Diego Creek and Newport Bay; Metals in the Rhine Channel; and copper, lead, and zinc in Coyote Creek. (Tentative Order ¶ XIII.B.1.)

[12] *See, e.g.*, Tentative Order Section XVIII ("permittees in the Newport Bay Watershed shall comply with the EPA-promulgated wasteload allocations" for metals and organochlorine compounds in San Diego Creek, Newport Bay, and the Rhine Channel); *id*. ("The permittees in the Newport Bay Watershed shall comply with the WLAs for" organochlorine pesticides, water column targets, and toxicity requirements for San Diego Creek and Newport Bay); *id*. (permittees shall comply with WLAs for diazinon or chlorpyrifos in Newport Bay and San Diego Creek).

[13] Letter from Douglas E. Eberhardt, U.S. EPA, to Dale Bowyer, San Francisco Regional Water Quality Control Board (April 3, 2009), at 6.

the Tentative Order or its supporting documents to demonstrate that the management practices it requires will result in compliance with the WLAs, or even that the management practices were designed to do so, or address specific pollutants of concern, in the first place. The U.S. EPA has pointed out that "given the uncertainties in the performance of many of the BMPs commonly used for stormwater pollution control, it is often difficult to make such a determination."[14] Thus, the Tentative Order must explicitly state that implementation of the BMPs it mandates does not in itself constitute compliance with the WLAs. Effectively, the permit should "explicitly state that the wasteload allocations (WLAs) established by . . . TMDLs are intended to be enforceable permit effluent limitations and that compliance is a permit requirement."[15] Finding 52 of the Tentative Order discussing TMDL implementation should be revised accordingly, and the Tentative Order's provisions implementing TMDLs amended as a whole to address these concerns.

IV. The Tentative Order Allows the Discharge of Pollutants from New Dischargers and Sources.

Approval of the Tentative Order will authorize the discharge of pollutants to impaired waterbodies from "new sources" or "new dischargers" in violation of the CWA's implementing regulations. 40 C.F.R. § 122.4(i) explicitly prohibits discharges from these sources, stating that:

> No permit may be issued:
>
> … (i) To a new source or a new discharger, if the discharge from its construction or operation will cause or contribute to the violation of water quality standards. The owner or operator of a new source or new discharger proposing to discharge into a water segment which does not meet applicable water quality standards or is not expected to meet those standards … and for which the State or interstate agency has performed a pollutants load allocation for the pollutant to be discharged, must demonstrate, before the close of the public comment period, that:
>
> (1) There are sufficient remaining pollutant load allocations to allow for the discharge; and
>
> (2) The existing dischargers into that segment are subject to compliance schedules designed to bring the segment into compliance with applicable water quality standards.

[14] *Id.*

[15] Letter from Douglas E. Eberhardt, EPA, to Michael Adackapara, Santa Ana Regional Water Quality Control Board (February 13, 2009), at 3.

(40 C.F.R. § 122.4(i).) Under 40 C.F.R. § 122.2, a "new discharger" is defined as "any building, structure, facility, or installation: (a) From which there is or may be a 'discharge of pollutants;' . . . (c) Which is not a 'new source;' and (d) Which has never received a finally effective NDPES permit for discharges at that 'site.'" (40 C.F.R. § 122.2.) A "new source" is defined as "any building, structure, facility, or installation from which there is or may be a 'discharge of pollutants . . .'" that may be subject to applicable standards of performance under section 306 of the Clean Water Act. (40 C.F.R. § 122.2.) Thus, the Tentative Order may not authorize the development or redevelopment of any building or structure, including, without limitation, a new subdivision, industrial facility, or commercial structure within the permittees' jurisdiction if runoff from the new discharge adds any pollutant to discharges from the MS4 that "will cause or contribute to the violation of water quality standards" for a waterbody impaired for that pollutant. Furthermore, the applicant for the permit must prove the availability of any exception to this provision, as set forth above.

In *Friends of Pinto Creek v. U.S. E.P.A.*, the Ninth Circuit Court of Appeals vacated an NPDES permit issued by the U.S. Environmental Protection Agency to a new discharger on the grounds that the permittees' "discharge of dissolved copper into a waterway that is already impaired by an excess of the copper pollutant" would violate the CWA. ((9th Cir. 2007) 504 F.3d 1007, 1011.) Citing to 40 C.F.R. § 122.4(i), the court stated that "The plain language of the first sentence of the regulation is very clear that no permit may be issued to a new discharger if the discharge will contribute to the violation of water quality standards." (*Id*. at 1012.) The court noted that a single exception to this rule exists where a TMDL has been performed, and the "new source can demonstrate that, under the TMDL, the plan is designed to bring the waters into compliance with applicable water quality standards." (*Id.*) Thus, where no TMDL has been completed for a specified waterbody and pollutant, new discharges that add pollutants that will cause or contribute to a violation of water quality standards are prohibited absolutely. Further, the court in *Friends of Pinto Creek* observed that unless a TMDL explicitly provides that existing discharges into the impaired waterbody are "subject to *compliance schedules* designed to bring the segment into compliance with applicable water quality standards," issuance of a permit for new discharge was also prohibited under 40 C.F.R. § 122.4(i). (*Id*. at 1013.) In effect, a permit for new discharges may not be issued, even when a TMDL for the relevant pollutant exists, unless it firmly establishes that "there are sufficient remaining pollutant load allocations under existing circumstances." (*Id*. at 1012.) For the reasons set forth below, under the holding in *Friends of Pinto Creek*, the Regional Board is prohibited from approving a permit that allows new sources or discharge of any pollutant to waterbodies already impaired by that pollutant, unless the Tentative Order demonstrates that an existing TMDL specifically provides sufficient waste load allocations for the discharge.

The Tentative Order states that "The 2006 State water quality assessment listed a number of waterbodies within the Region under Section 303(d) as impaired waterbodies,"

(Tentative Order finding 40),[16] and that "[f]or many of these impaired waterbodies, one of the listed causes of impairment is urban runoff." (*Id*.) Among waters under the permittees' jurisdiction the Tentative Order specifically identifies the following as listed as impaired by urban runoff:

- San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);
- San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);
- Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);
- Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);
- Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);
- Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);
- Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);
- Seal Beach (listed for enteroccocus, PCBs);
- Silverado Creek (listed for pathogens, salinity, TDS, chlorides);
- Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);
- Peters Canyon Channel (listed for DDT, toxaphene);
- Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);
- Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);
- Bolsa Chica State Beach (listed for copper and nickel);
- Buck Gully Creek (listed for total and fecal coliform); and
- Balboa Beach (listed for dieldrin, DDT, PCBs).

(Tentative Order finding 40.) The Tentative Order fully acknowledges that the pollutants listed as impairing these waterbodies are known contaminants within stormwater in the Santa Ana Region, and that "Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters." (Tentative Order finding 31.) Notably, "The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations" for both wet and dry weather conditions. (Tentative Order finding 32.) The 2006 Report of Waste Discharge for the permittees demonstrates that California Toxics Rule criteria are exceeded for metals, which may include copper, nickel, and zinc, are exceeded in both wet and dry weather conditions.[17]

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[16] *See also*, 2006 CWA Section 303(d) List of Water Quality Limited Segments.

[17] Orange County Watershed and Coastal Resources Division (July 21, 2006) Report of Waste Discharge, at 11-10 – 11-12.

These findings are further borne out by research that has consistently "identified stormwater runoff as a major contributor to water quality degradation in urbanizing watersheds."[18] Studies have repeatedly shown that "Stormwater runoff typically contains dozens of pollutants that are detectable at some concentration," including "sediment, nutrients, metals, hydrocarbons, bacteria and pathogens, organic carbon, MTBE, pesticides, and deicers."[19] In particular, studies show that "zinc, copper and cadmium pollution [were] found in urban runoff;"[20] that "[m]icrobial pollution" such as bacteria, protozoa, and viruses "is almost always found in stormwater runoff;"[21] that "cars and other vehicles contributed 75 percent of the total copper load to the lower San Francisco Bay through runoff;"[22] and that "insecticides such as diazinon and malathion were commonly found in surface water and stormwater in urban areas … with urban runoff being the primary transport mechanism into urban streams."[23]

New discharges will only increase the mass of these pollutants entering impaired receiving waters. In fact, the Tentative Order explicitly acknowledges that "[u]rban development increases population density and pollutant sources such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash." (Tentative Order finding 54.) The U.S. EPA echoes these conclusions, stating that "the impacts of stormwater pollution are not static; they usually increase with more development and urbanization."[24]

As no TMDLs have been adopted and fully implemented as yet to address water quality impairments formally identified by the Regional Board and U.S. EPA and caused

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[18] Earl Shaver et al. (2007) *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, North American Lake Management Society, at 3-46.

[19] Center for Watershed Protection (March 2003) *Impacts of Impervious Cover on Aquatic Systems*, at 55.

[20] Earl Shaver et al. (2007) *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, North American Lake Management Society, at 3-48.

[21] *Id*. at 3-49.

[22] NRDC, *Stormwater Strategies: Community Responses to Runoff Pollution*, at Chapter 2, *available at* http://www.nrdc.org/water/pollution/storm/stoinx.asp.

[23] Earl Shaver et al. (2007) *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, North American Lake Management Society, at 3-54.

[24] U.S. Environmental Protection Agency (December 2007) *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, at v.

by many pollutants, including certain organochlorine compounds in San Diego Creek and Newport Bay, and metals, bacteria, PCBs, and pesticides in other Santa Ana region waterbodies,[25] any new discharge of these pollutants from increased urbanization would violate the terms of 40 C.F.R. § 122.4(i) and the court's holding in *Friends of Pinto Creek*. Such discharges are prohibited.

Even where TMDLs have been adopted and have implementation plans in effect for the Santa Ana Region, such as for sediment, fecal coliform, diazinon and chlorpyrifos, and nutrients for the Newport Bay watershed or San Diego Creek, following the court's holding in *Friends of Pinto Creek*, a permit allowing new dischargers or sources of these pollutants could be approved and issued only in the event that the applicable TMDL explicitly establishes that: (1) existing discharges into the impaired waterbody are "subject to *compliance schedules* designed to bring the segment into compliance with applicable water quality standards;" and (2) additional allocations are available for the specified waterbody. (*Friends of Pinto Creek*, 504 F.3d at 1013.) The Tentative Order does not establish that such allocations exist and are available. As a result, new discharges of these or other contaminants for which a TMDL has been established to impaired waterbodies are prohibited.

We stress that these concerns highlight the need for the Tentative Order to contain both clearly articulated performance standards for LID-based retention of storm water onsite and strict limitations on the use of alternative compliance measures in order to address water quality problems associated with urban runoff. One critical means of ensuring that runoff from new sources or dischargers will not contribute additional pollutants to an impaired waterbody is to mandate the proper implementation of LID practices through the imposition of either an EIA standard or an equivalent onsite-retention standard.

V. The Tentative Order Fails to Include Provisions that Effectively Prohibit all Non-Stormwater Discharges, as Required by the Clean Water Act.

Federal law requires that MS4 permits "shall include a requirement to effectively prohibit non-stormwater discharges into the storm sewers." 33 U.S.C. § 1342(p)(3)(B)(ii). However, the Tentative Order states that certain types of non-storm discharges are "exempt" from this requirement "unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants." (Tentative Order ¶ III.3.i.) This exception violates the clear language of the CWA and its implementing regulations. Section 402(p)(3)(B)(ii) of the CWA requires that permits for discharge from municipal sewers "effectively prohibit non-stormwater discharges," 33 U.S.C. § 1342(p)(3)(B)(ii), and does not create any authorization for exemption of such discharges.

[25] *See,* Tentative Order, at 14-15; 2006 CWA Section 303(d) List of Water Quality Limited Segments.

The Tentative Order states that under "Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B),"[26] an MS4 Permit must "prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in [the] Discharge Prohibitions." (Tentative Order finding 68; *see also*, *id*. ¶ III.1.) Therefore, the Tentative Order claims, certain specified categories of non-storm discharges "need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants." However, section 402(p) places a clear, mandatory duty on the permittee to prohibit non-stormwater discharges to the MS4 system. The permittee, or Regional Board, has no discretion to deviate from this requirement. In ascertaining the meaning of a statute, construction must begin with the text. (*Duncan v. Walker* (2001) 533 U.S. 167, 172.) "If there is no ambiguity, then we presume the lawmakers meant what they said, and the plain meaning of the language governs." (*Day v. City of Fontana* (2001) 25 Cal.4th 268, 272.) There is no ambiguity present in the CWA's requirement that a permit "effectively prohibit non-stormwater discharges," and the Tentative Order's provision of categorical exceptions stands in clear violation of its terms.

Further, the Tentative Order's attempt to allow exemptions to the prohibition against non-stormwater discharges to MS4 systems is not supported by regulations under 40 C.F.R. § 122.26(d)(2)(iv)(B)(1), as the Tentative Order implies. This provision merely states the circumstances under which a permittee must specifically design a program to prevent certain illicit discharges: "the following category of non-storm water discharges or flows shall be addressed where such discharges are identified by the municipality as sources of pollutants to waters of the United States." (40 C.F.R. § 122.26(d)(2)(iv)(B)(1).) The cited regulation, providing for an enforcement program to "prevent illicit discharges," simply does not support the construction, stated in the Tentative Order, that such non-stormwater discharges need not be prohibited. (*See* Tentative Order ¶ III.1.) Even if the regulations allowed some conditional exemption, they do not provide that non-stormwater discharges are permissible when they fall into a specified category and are not "a *significant* source of pollutants." (Tentative Order ¶ III.3.i (emphasis added).) The regulations explicitly state that the identified non-stormwater discharges "shall be addressed where such discharges are identified by the municipality *as sources of pollutants to waters of the United States*" in any quantity, whether or not it is considered significant. 40 C.F.R. 122.26(d)(2)(iv)(B)(1).

Indeed, the interpretation adopted in the Tentative Order is not found in the plain language of the regulation, and the Order's provisions place the regulations in direct conflict with the overlying statute. A clear reading of the regulation, and one that elaborates on Section 402(p)(3)(B)(ii) of the CWA rather than contradicting it, is that while non-stormwater discharges must be prohibited by the text of the CWA, illicit discharge enforcement programs need only specifically address the enumerated list of

[26] The specific section of the regulations discussing categories of non-stormwater discharges to be addressed is located at 40 C.F.R. § 122.26(d)(2)(iv)(B)(1).

non-stormwater discharges set forth in the regulations where such discharges have been identified as a source of pollutants. As such, we urge the Regional Board to revise the Tentative Order such that it is consistent with both the regulations and the statute they purport to implement.

Even if the permittees were afforded authority under 40 C.F.R. § 122.26(d) to exempt non-stormwater sources from the discharge prohibitions required by the CWA, the Tentative Order unlawfully allows the exemption of non-stormwater discharges in multiple circumstances. Included in the Tentative Order's list of exempt, or conditionally exempt discharges are:

- Discharges from lawn watering and other irrigation runoff from non-agricultural operations;
- Dechlorinated swimming pool discharges;
- Construction dewatering wastes;
- Irrigation water;
- Non-commercial vehicle washing; and
- Other types of discharges identified and recommended by the permittees and approved by the Regional Board.[27]

(Tentative Order ¶ III.3.i-ii.) Of particular concern is the Tentative Order's exemption of irrigation water, and conditional exemption of discharges from lawn watering and other irrigation runoff from non-agricultural operations even though pollutants from theses sources are a known, significant source of impairment to waters in the Santa Ana region. A finding that these discharges are "not []sources of pollutants to receiving waters" as required under 40 C.F.R. 122.26(d)(2)(iv)(B)(1), or even that they are not "a significant source of pollutants" as the Tentative Order would set as the standard for discharge under provision III.3.i, is simply unlawful, and would be inconsistent with facts in the record.

First, a non-source of pollutants finding would stand contrary to extensive research that has proved the opposite: studies have consistently shown that non-stormwater discharges from irrigation water or lawn water are a significant source of pollutants for which Santa Ana region waters are impaired. As the Tentative Order duly notes, "Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas." (Tentative Order finding 35.) Further, garden use has been identified generally as one of the main sources of pesticides

[27] 40 C.F.R. 122.26(d)(2)(iv)(B)(1), which identifies the specific categories of discharge that "shall be addressed," does not include any provision allowing for "Construction dewatering wastes" to be considered as an exception to the requirement that non-storm discharges be prohibited, or for the permittees or Regional Board to identify and exempt "Other types of discharges." These non-stormwater discharges must be prohibited under both the CWA and its implementing regulations.

found in urban streams.[28] Lawns have additionally been identified as a "hot spot" for nutrient contamination in urban watersheds—lawns "contribute greater concentrations of Total N, Total P and dissolved phosphorus than other urban source areas … source research suggests that nutrient concentrations in lawn runoff can be as much as four times greater than other urban sources such as streets, rooftops or driveways."[29] Thus, any claim that irrigation water is unequivocally not a source of pollutants to receiving waters cannot be sustained. As a result, this exemption should be removed from the Tentative Order.

Second, to the extent that the Tentative Order purports to utilize the implementation of "public education and water conservation efforts" (Tentative Order ¶ III.3.ii.C), as a means of authorizing the conditional exemption of potentially, or in fact actually, polluted lawn watering and other irrigation runoff water, there has been no showing that the Residential Program measures required by the Tentative Order under Section XI are sufficient to meet the regulatory requirements of the CWA or will ensure that these discharges are not a source of pollutants. The requirements of this section, such as that permittees "evaluate the applicability of programs such as the Landscape Performance Certification Program to encourage efficient water use and to minimize runoff" (Tentative Order ¶ XI.4) are vague and fail to set out any measurable requirement, further underscoring that these provisions are not tantamount to actions that will result in non-stormwater irrigation flows free of pollutants as required under 40 C.F.R. § 122.26(d). The Tentative Order does not provide evidence to support a contention that such measures will either effectively prohibit such discharges or even allow water quality standards to be met. Indeed, they echo proposals that have been introduced in previous permits throughout California and that have been tried—and failed—to prevent impacts to receiving waters from irrigation runoff.[30]

In total, the Tentative Order's approach does not equal the CWA's mandate that permittees "effectively prohibit non-stormwater discharges into the storm sewers."

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[28] Earl Shaver et al. (2007) *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, North American Lake Management Society, at 3-54.

[29] Center for Watershed Protection (March 2003) *Impacts of Impervious Cover on Aquatic Systems* at 69; *See also*, H.S. Garn (2002) *Effects of lawn fertilizer on nutrient concentration in runoff from lakeshore lawns, Lauderdale Lakes, Wisconsin*. U.S. Geological Survey Water-Resources Investigations Report 02-4130. In an investigation of runoff from lawns in Wisconsin, runoff from fertilized lawns contained elevated concentrations of phosphorous and dissolved phosphorous.

[30] *See, e.g.*, Order No. R8-2002-0010 NPDES Permit No. CAS618030, at 32 ("permittees shall develop BMP guidance for the control of those potentially polluting activities not otherwise regulated by any agency including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for . . . commercial landscape maintenance.")

(33 U.S.C. § 1342(p)(3)(B)(ii).) Given the overwhelming evidence that pollution from pesticides, nutrients and other contaminants constitutes a serious and ongoing problem in receiving waters under the jurisdiction of the permittees, the conditional exemption of irrigation or lawn watering from prohibitions against non-stormwater discharge violates the clear requirements of the CWA and its implementing regulations.

As with our comments in Section IV, we underscore that these concerns emphasize the need for LID-based onsite storm water retention requirements, since these approaches will reduce non-storm water runoff from new development to zero when properly implemented.

VI. The Permit Application Is Incomplete for Failure to Include an Assessment of Controls.

The permit application is significantly incomplete, as it fails to include information required under 40 C.F.R. § 122.26(d)(2) that is necessary to ensure that the selection of controls for reducing the discharge of pollutants is not arbitrary and capricious. A permit application for discharge from a large- or medium-sized MS4 must contain an assessment of controls, including "[e]stimated reductions in loadings of pollutants from discharges of municipal storm sewer constituents from municipal storm sewer systems expected as the result of the municipal storm water quality management program." (40 C.F.R. § 122.26(d)(2)(v).) Neither the application, the Tentative Order, nor the Fact Sheet includes any required information or other discussion of the amount of pollution that will be reduced through its controls. The approval of the Tentative Order without this information fundamentally violates basic precepts of administrative procedure, not only because required evidence in the record is lacking, but also because the findings and related subfindings in the record are therefore devoid of necessary guideposts as to why and how provisions were included or rejected; the Tentative Order does not provide sufficient evidence to demonstrate that the selected management practices are adequate to meet relevant requirements and water quality standards.

While prior EPA guidance states that, "as a practical matter, *most* first-time permit application requirements are unnecessary for purposes of second round MS4 permit application;" it does not state that all such information is unconditionally unnecessary. (61 F.R. 41698 (emphasis added).) The omitted pollutant reduction estimates represent a fundamentally different type of information from that required by *most* of the other provisions of 40 C.F.R. § 122.26(d)(2), such as identifying already identified "major outfalls," for which repeating the exercise "would be needlessly redundant," especially "where it has already been provided and has not changed." (61 F.R. 41698.) Instead, the required pollutant load reduction estimates are self-evidently relevant to crafting and assessing the core requirements of the new permit. Such estimates are an essential means of determining whether or not the permit will ensure that water quality standards will be met and what improvements can be expected; they are not merely an administrative detail that has no effect on the permit's functionality. While the Permit purports to require (or at least suggest) that permittees include estimates of

pollutant load reductions in their annual reports (Tentative Order, Monitoring and Reporting Program No. R8-2008-0030, ¶ IV.2.b), this provision for annual reporting does not constitute compliance with the Tentative Order's *application* requirements

This information is further indispensible when, as here, the Tentative Order and the provisions included in it represent a substantial change from the previously adopted 2000 permit.[31] The Tentative Order therefore represents "changed" information, for a permit that will largely determine the level of urban runoff control in most of the Santa Ana region. Given this change, the necessity of basing the Tentative Order on information about its estimated efficacy should be clear, and the tentative Order and application revised to include the required estimates.

VII. Conclusion.

We urge the Regional Board to improve the Tentative Order in the ways specified prior to its adoption. We appreciate staff's efforts to date during the adoption process and would be pleased to respond to any questions they may have about our comments.

Sincerely,



David S. Beckman
Bart Lounsbury
Noah Garrison
Natural Resources Defense Council

[31] For example, the Tentative Order eliminates the EIA standards present in Order No. R8-2002-0010.

April 9, 2009

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RE: Order No. R8-2009-0030 (NPDES Permit No. CAS618030) Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department, and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff, Orange County

Dear Mr. Adackapara:

Thank you for this opportunity to response to the draft tentative Orange County Municipal Separate Storm Sewer System Permit, Tentative Order No. R8-2009-0030 ("Draft Permit") released on March 24, 2009. The comments herein are those of (i) Building Industry Association of Southern California, Inc. ("BIA/SC"); and Building Industry Legal Defense Foundation ("BILD"), each of which represents the homebuilding industry or related construction and land development industries within the Southern California region that includes north Orange County.

BIA/SC is a nonprofit trade association representing more than 1,700 member companies, which together have more than 100,000 employees. BILD is a non-profit mutual benefit corporation and wholly-controlled affiliate of BIA/SC. BILD's purposes are to monitor legal and regulatory conditions for the construction industry in Southern California and intervene as appropriate. BILD focuses particularly on litigation and regulatory matters with a regional or statewide significance to its mission.

We remain very concerned about some key aspects the Draft Permit. Even though some objectionable aspects of the earlier drafts have been removed or corrected, we remain concerned that the tentative permit would in fact damage the land use development process and substantially harm the overall economy of north Orange County. Therefore, we must express our disappointment that the Draft Permit still fails to reflect the best policy options, despite our industry's efforts to bring science, reason and experience to help craft reasonable and practicable requirements in the new MS4 permit.

Our comments are as follows:

1. Some stakeholders have persistently distorted the meaning of the "hortatory" (i.e., merely *encouraging* or exhorting) "maximum extent practicable" language from 33 U.S.C. section 1342(p)(3)(B)(iii).

Some stakeholders, and in particular representatives of Natural Resources Defense Council, Inc. ("NRDC"), have made representations in connection with the formulation of and debate about the Draft Permit, effectively saying that the Board's rejection of particular control measures would not meet the "maximum extent practicable" mandate set forth in 33 U.S.C. section 1342(p)(3)(B)(iii). Sometimes, NRDC will point to the conclusions of an academic from one corner of the nation, or to the regulatory experiments in another part of the nation, and essentially argue that any and all measures thus indicated are proven "practicable," and therefore must be imposed by the Board here.

It is true that the federal law at issue – 33 U.S.C. section 1342(p)(3)(B)(iii) – generally directs the Board (as the U.S. E.P.A. Administrator's surrogate) to "require controls to reduce the discharge of pollutants to the maximum extent practicable...." However, this introductory "maximum extent practicable" directive is merely "hortatory" (meaning it merely *encourages* or exhorts action) rather than mandatory (indicating any legally enforceable mandate). *See Rodriguez v. West*, 189 F.3d 1351, 1355 (Fed. Cir. 1999) (holding that the express "maximum extent possible" directive of former 38 U.S.C. section 7722(d) was "hortatory rather than to impose enforceable legal obligations"). Because the language is introductory and hortatory, it does not require the Board to impose any and all possible requirements. Instead, the directive is merely a charge to go forth, balance interests, and require *some* reasonable controls.[1]

Our reading of the relevant federal statute is bolstered by the remainder of 33 U.S.C. section 1342(p)(3)(B)(iii). Immediately following the introductory "maximum extent practicable" language is this: "including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State [here, the Board] ***determines appropriate*** for the control of such pollutants." (Emphasis added.) Thus, the federal statute merely instructs the Board here, as the E.P.A.'s surrogate, to *exercise its broad discretion* (within bounds of reason – of course).

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[1] *See Conservation Law Foundation v. Evans*, 360 F.3d 21, 28 (1st Cir. 2004):

> [The environmentalist plaintiffs] essentially call for an interpretation of the statute that equates "practicability" with "possibility," requiring [the agency] to implement virtually any measure ... so long as it is feasible. Although the distinction between the two may sometimes be fine, there is indeed a distinction. *The closer one gets to the [environmentalists'] interpretation, the less weighing and balancing is permitted.* We think by using the term "practicable" Congress intended rather to allow for the application of agency expertise and discretion in determining how best to manage ... resources.

(Emphasis added.)

The federal courts consistently have ruled that the 33 U.S.C. section 1342(p)(3)(B)(iii) directive is one mandating only the reasonable exercise of broad discretion – nothing more. *See Arkansas v. Oklahoma*, 503 U.S. 91, 105 (1992) ("Congress has vested in the [EPA or a surrogate state] broad discretion to establish conditions for NPDES permits."); *Natural Resources Defense Council, Inc. v. U.S. E.P.A.*, 96 F.2d 1292, 1308 (9th Cir. 1992) ("NRDC contends that EPA has failed to establish substantive controls for municipal storm water discharges as required by the 1987 amendments. *Because Congress gave the administrator discretion to determine what controls are necessary, NRDC's argument fails.... Congress did not mandate a minimum standards approach or specify ... minimal performance requirements.*" (emphasis added)); *Defenders of Wildlife v. Browner*, 191 F.3d 1159, 1166-67 (9th Cir. 1999) ("Under [the MEP standard set forth in Clear Water Act section 402(p)(3)(B)(iii)], the EPA's choice to include [or exclude] ... limitations in [NPDES] permits [for MS4s] was within its discretion."); *City of Abilene v. U.S. E.P.A*, 325 F.3d 657, (5th Cir. 2003) ("The plain language of [CWA section 402(p)] clearly confers broad discretion on the EPA [or a surrogate state agency] to impose pollution control requirements when issuing NPDES permits").

Given a proper understanding of the law, 33 U.S.C. section 1342(p)(3)(B)(iii) merely mandates that the Board here must take evidence and then exercise its *broad discretion* concerning permit conditions. Certainly, the Board and staff do not need to bow to every whim transported here from far away.

2. The Draft Permit's failure to recognize and countenance Low Impact Development *filtration* practices is seemingly a radical and unsound departure from Clean Water Act goals and established land use doctrines.

One aspect of the Draft Permit is especially radical and objectionable – at least it could possibly be read as such if not properly clarified. That is the low impact development criteria discussed in Section XII.C (5) and (7) on page 53. Particularly, these provisions can be read to indicate that the permit requirements for development or redevelopment could be met only by designing and constructing for the on-site retention – for infiltration, evapotransporation or on-site reuse – of the volume of a design storm. Notwithstanding the appendage of mitigation options where infeasibility exists, as proposed, the cited provisions would seemingly impose, for the first time, a generally-applicable requirement that ***no water (from a design storm) should leave a parcel that has been developed or redeveloped.***

This requirement seemingly flies in the face of recognized low impact development (LID) strategies, which generally aim to have LID undertaken so that the pre-construction flows of storm waters are maintained, matched, or reasonably approximated. For example, the U.S. E.P.A. last month issued its new definition of LID, which states clearly that the use of LID best management practices (BMPs) for ***filtration*** **(i.e., not merely *infiltration*)** is appropriate – and repeats the basic goal of trying to maintain pre-construction hydrology. As proposed, however, the language of the Draft Permit generally rules out the use of LID BMPs for *filtration*, and requires instead designs for the *retention* of all storm water for a design storm.

Therefore (again, unless the Draft Permit is better clarified), the draft provisions seemingly rule out the use of LID BMPs for filtration – and instead require, as a general proposition, that no storm water (except in the largest rains) can leave a developed or redeveloped parcel. If this is indeed intended, it is a radical measure that should not be undertaken. It would violate millennia (literally) of civil law concerning the unconstrained flow of rain water (called "diffuse surface water"). Specifically, the law in California – which itself is derived from the laws of the ancient Roman Empire – generally favors what is called the "***natural flow doctrine***," which states that diffuse surface flows should be permitted to flow to their natural water course. *See Gdowski v. Louie*, 84 Cal.App.4th 1395, 1402 (2000) ("California has always followed the civil law rule. That principle meant 'the owner of an upper … estate is entitled to discharge surface water from his land *as the water naturally flows*. As a corollary to this, the upper owner is liable for any damage he causes to adjacent property *in an unnatural manner*.... In essence each property owner's duty is to leave the natural flow of water undisturbed.'" – emphasis added by the court, quoting *Keys v. Romley*, 64 Cal.2d 396, 405-06 (1966)).

The "natural flow doctrine" has been altered by the California courts in recent decades – in order to facilitate reasonable land development and protect local governments and land owners. Replacing the natural flow doctrine is a ***modern reasonableness test***. Property owners (both public and private) may alter the natural flow of diffuse and/or discrete surface water, but only if they are reasonable when doing so and downstream owners can effectively trump the reasonable efforts of the upstream owner only if they (the downstream owners) in turn take reasonable defensive steps. *See, e.g., Locklin v. City of Lafayette*, 7 Cal.4th 327, 337 (1994).

Juxtaposed against both the natural flow doctrine and the modern reasonableness test is a third, less favored doctrine, called the "***common enemy doctrine***." The common enemy doctrine stands for three propositions, that (i) individual property (development) rights are paramount, (ii) in developed and developing areas, both diffuse and discrete surface water is a common scourge, and (iii) each property owner may act "for herself or himself" and take steps to alter the natural or unnatural flow of such waters for the protection of his or her property, without regard for the effect on neighbors. *See Skoumbas v. City of Orinda*, 165 Cal.App.4th 783, 792 (2008). Although the common enemy doctrine is sometimes still applied other states – particularly in urbanized and suburban areas, the common enemy doctrine has been the focus of strong criticism from progressive courts, environmentalists, academics, and concerned policy makers because of the obvious and very negative implications for the broader community and for the preservation and restoration of natural flows. *See, e.g., Keys v. Romley*, 64 Cal.2d 396, 400-03 (1966) (Mosk, J., concurring).

Of these three doctrines (the *natural flow* doctrine, the *common enemy* doctrine, and the *modern reasonableness* test), the natural flow doctrine – which seeks to *maintain the natural flows* of diffuse and discrete surface water – is the doctrine that conforms best to the federal Clean Water Act's overarching objective to "restore and *maintain*" the natural integrity of waters.[2] *See* 33 U.S.C. section 1251. Accordingly, we would, of course, expect the Board and

[2] *See* S. Rep. No. 92-414, 92 Cong. 2d Sess., 2 U.S. Code Cong. & Adm. News '72 3668,

the non-governmental organizations that purport to defend natural resources to strongly prefer the *natural flow doctrine*, and to deviate from it (if at all) only as reasonably necessary to accommodate competing societal goals.

Rather than favor the natural flow doctrine, however, the Draft Permit – with its seeming refusal to allow the *filtration* of diffuse surface water and its discharge across property lines – could be read to establish a brand new and entirely different doctrine, a "***universal retention doctrine***," standing for the strange proposition that no diffuse surface water should leave any parcel that has been developed or redeveloped, except in very large storms. (Or, alternatively, if that standard cannot be met for feasibility reasons, then the land owner must pay to mitigate off-site by applying the same new universal retention doctrine to someone else's land.)

If it were the intent of the Board's staff to propose such a universal retention doctrine, such a radical step should not be taken without much more discussion, study, and major revision. Nonetheless, we see the hint of such a doctrine both in the Draft Permit language – Section XII.C(5) and (7) are at best ambiguous in this regard – and certainly in the urgings of NRDC. We are baffled by the fact that any group such as NRDC, which purports by its very name to *defend natural resources*, would turn its back on the *natural flow doctrine*, rather than seek to maintain or approximate the natural flows or diffuse and discrete surface waters to the extent and wherever practicable. But that is what has happened here, even though the U.S. E.P.A. and others are presently urging that suburban and exurban developers should seek to maintain or approximate – to the extent practicable – natural flows. Most notably, the US EPA defines LID as follows:

> *A comprehensive stormwater management and site-design technique.* ***Within the LID framework, the goal of any construction project is to design a hydrologically functional site that mimics predevelopment conditions****. This is achieved by using design techniques that infiltrate,* ***filter****, evaporate, and store runoff close to its source.* (emphasis added)
>
> http://cfpub1.epa.gov/npdes/greeninfrastructure/information.cfm#glossary

We respectfully urge the Board and staff to reject any embrace (ambiguous or otherwise) of a new *universal retention doctrine.* We urge instead appreciation of the *natural flow doctrine* or, better yet, the *modern reasonableness test* applied with ever-evolving and progressive standards of reasonableness. We suspect that the U.S. E.P.A. would similarly urge abandonment of a universal retention proposition (assuming the E.P.A. representatives are fully aware and fathom the policy implications of the proposal). In addition, we have only barely discussed this new, general universal retention doctrine with the appropriate individuals at the California Department of Fish and Game and the U.S. Fish and Wildlife Service. We found that they were not aware of the implications of the Draft Permit. The few officials with whom we spoke

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3674 (1992) ("The Committee believes the restoration of the natural chemical, physical, and biological integrity of the Nation's waters is essential."); H.R.Rep. No. 92-911, p. 76 (1972) (""the word 'integrity' ... refers to a condition in which the natural structure and function of ecosystems is [are] maintained.").

indicated their view that any lack of attention to natural flows would raise issues about stream health, especially where water courses might be starved of storm flows in all but the larger storms. Therefore, we urge the Board's staff to thoroughly discuss the new and generally-applicable universal retention policy with your fellow agency counterparts, and then remove any preference for or generally-applicable use of the universal retention doctrine from the eventual permit revisions.

3. We continue to seek more and better integration between the MS4 permit requirements and the land planning and approval processes required by the California Environmental Quality Act (CEQA).

As our industry representatives have noted before, California law has long established CEQA as the mechanism for evaluating – and mitigating – the environmental impacts of land development. The CEQA process evaluates all environmental impacts and provides a consistent process for their mitigation, with opportunity for input from a wide cross-section of agencies and public interests. Moreover, CEQA continues to evolve as science and policy imperatives drive it to do so. For example, several years ago, green house gas emissions were never a focus of CEQA; now they certainly are.

By establishing any fixed, inflexible numeric standards for low impact development, the Draft Permit trumps all other considerations (environmental and otherwise) and improperly shifts land use approval authority to the Regional Water Quality Control Board. Although the Draft Permit may refer to waivers or exceptions for infeasibility, the Draft Permit provides no clear process for this site-specific evaluation by the co-permittees and exceptions where the permit requirements are unreasonable, infeasible or suboptimal.

CEQA could – and we maintain should – be utilized to integrate low impact development and grading considerations into the project approval process in ways heretofore not applied. This would allow for the appropriate evaluation of water quality impacts in the context of all other environmental impacts. Perhaps more significantly, it would integrate the consideration of low impact development techniques into the land use planning process at the time of project design and development – rather than the all-too-common current occurrence where these techniques are evaluated after substantial approvals are in place and changes are difficult to retro-fit. Using CEQA as the tool to accomplish the integration of low impact development techniques would be achieved if the numeric standards were established as presumptive thresholds of environmental significance, which would significantly increase the level of analysis of water quality impacts – at the time when changes are most likely to be accommodated. We offer more detailed analysis of this approach in the accompanying attachment, which is – again – the CEQA integration proposal that we have lodged before. The CEQA integration approach would achieve the Board's goals of appropriate attentiveness and reasonable consistency between jurisdictions and permits, while maintaining the ability to make local decisions appropriate for the jurisdiction's environmental circumstance.

* * * * *

Since the first draft was released, the BIA and its industry affiliates have been active participants and contributors to the creation of new and improved MS4 permit. We continue to believe that rational, *implementable* permit requirements are critical to achieving great progress concerning water quality and our environment. We hope that these comments are received in the manner in which they are intended – to continue the discussion of how we can create a workable permit that improves water quality to the maximum extent practicable. We remain committed to a positive dialog with the Board and its staff – one that will result in an informed, balanced and effective permit.

Thank you for your consideration of these comments.

Sincerely,

Andrew R. Henderson
Vice President and General Counsel,
Building Industry Association of Southern California
and General Counsel,
Building Industry Legal Defense Foundation

cc: Dr. Mark Grey

Construction Industry Coalition on Water Quality

April 9, 2009

Michael Adackapara
Santa Ana Regional Water Quality Control Board
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RE: Order No. R8-2009-0030 (NPDES Permit No. CAS618030) Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department, and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff, Orange County

Dear Mr. Adackapara:

On behalf of the more than 3,000 member companies of the Construction Industry Coalition on Water Quality (CICWQ), we would like to thank the Santa Ana Regional Water Quality Control Board (Regional Board) for the opportunity to offer this public comment on the second Draft Orange County Municipal Separate Storm Sewer System Permit, Tentative Order No. R8-2009-0030 (Draft Permit) released on March 24, 2009. This letter and attachments provide additional, constructive suggestions that we have for the Draft Permit in addition to those we made to the Regional Board on February 13, 2009.

As currently drafted, we cannot support adoption of the permit because certain portions of the language can be misinterpreted to prohibit any discharge of surface water runoff. This is inconsistent with our months of negotiations in which we agreed the private and public development community would maintain the ability to employ a variety of Low Impact Development (LID) best management practices (BMPs). The Regional Board has never suggested that zero discharge of the design capture volume is required to achieve compliance and we trust this is not the intent of the current version of the permit. This requirement runs counter to our understanding of the outcome of the stakeholder discussion process and endorsement of consensus points regarding the flexibility to use the full range of LID BMPs to handle the design storm volume, not just those that hold all the water on-site. And as we point out below, this redefinition of LID and narrow interpretation of LID BMP implementation is not a technically or economically feasible alternative and has serious implications for redefining California water law. We will be following up with additional information for the Regional Boards consideration leading up to the permit hearing scheduled for April 24, 2009.

I. Introduction

CICWQ is comprised of the four major construction and building industry trade associations in Southern California: the Associated General Contractors of California (AGC), the Building Industry Association of Southern California (BIA/SC), the Engineering Contractors Association (ECA) and the Southern California Contractors Association (SCCA). The membership of CICWQ is comprised of construction contractors, labor unions, landowners, developers, and homebuilders working throughout the region and state.

These organizations work collectively to provide the necessary infrastructure and support for the region's business and residential needs. Members of all of the above-referenced organizations are affected by the Draft Permit, as are thousands of construction employees and builders working to meet the demand for modern infrastructure and housing in Orange County. Our organizations support efforts to improve water quality in a cost effective manner. Our comments and suggestions on the Draft Permit as well as our active involvement in the stakeholder group process reflect our commitment to protect water quality while at the same time preserve our member's economic viability in this difficult economic environment. Our membership has invested significant resources into developing sound engineering approaches for Low Impact Development (LID) stormwater management techniques and for hydromodification control, facilitating the appropriate application of these valuable approaches to water quality management. Our comments reflect this commitment to sound engineering practices and consideration of site-specific feasibility considerations.

II. Preliminary Statement

First, we are encouraged that the Regional Board revised Finding No. 62 to address the concerns of the regulated community regarding the utility of using Effective Impervious Area (EIA) limitations as a stand alone Low Impact Development (LID) best management practice (BMP) performance and sizing standard. We are also encouraged that the Regional Board included in Draft Permit Section XII, C. No. 3 a priority LID BMP selection procedure and that water quality mitigation may be achieved by using biotreatment or other vegetated LID BMPs within that priority framework. Despite these changes, we have identified several crucial remaining concerns regarding the specific permit language that appears to further constrict, rather than expand and promote, the use of all types of LID BMPs to their full extent. Moreover, the content in some parts of Section XII, C. following item No. 3 appears to conflict with the priority selection process and suite of available LID BMPs used for water quality mitigation.

The language in the current Draft Permit, while clearly specifying a volume capture approach to sizing LID BMPs, introduces an incorrect definition of LID through restrictive application of BMPs to only those that infiltrate, harvest and use rainwater, and/or evapotranspire all of the captured water (See Draft Permit Section XII, C. Nos. 5 and 7). In other words, permit language now requires that projects would be limited to zero discharge of a design storm volume with no runoff whatsoever allowed.

The US EPA defines LID as follows:

> *A comprehensive stormwater management and site-design technique. Within the LID framework, the goal of any construction project is* ***to design a hydrologically functional site that mimics predevelopment conditions.*** *This is achieved by using design techniques that infiltrate,* **filter**, *evaporate, and store runoff close to its source.* (emphasis added)
>
> http://cfpub1.epa.gov/npdes/greeninfrastructure/information.cfm#glossary .

Mandating the complete on-site retention of any sizable storm volume (i.e. runoff that never leaves as surface flows) is not a reasonable approach and the Draft Permit attempts in places to redefine the allowable site design elements necessary to implement this concept. The Draft Permit may implement LID in a way that is contrary to the EPA definition of LID by restricting BMPs to those that only achieve zero discharge—not allowing any BMPs that appropriately "filter" runoff, such as bioretention cells or other vegetated LID BMPs. Total, 100-percent retention remains impractical and unwise in most circumstances, and is not a goal that can be achieved for most projects within reasonable costs, despite best efforts. Moreover, such a mandate abandons the goal to mimic predevelopment conditions to the extent practicable, as EPA encourages.

In our prior comment letter, we documented and supported the significant concerns we have with a universal mandate to infiltrate stormwater into the ground and showed the clear limitations on feasibility. Here, we provide, in Attachment 1, a comprehensive analysis done by Geosyntec Consultants of the feasibility of implementing rainfall and stormwater harvesting systems and the utility of these systems in achieving pollutant load reductions from stormwater runoff as compared to use of all types of LID BMP features. This document and follow up correspondence with Geosyntec shows that harvesting alone may result in poor water quality treatment performance relative to a well designed system of LID BMPs that includes all types of BMPs, not just those that capture and retain stormwater. This document also identifies the current institutional barriers--code requirements--that will need to be adjusted long before total rainwater capture systems can be considered feasible in any practical sense.

To CICWQ, the retention BMPs of infiltration, harvesting, and evapotranspiration ("ET") may be described as a first tier of LID BMPs, but they should not be universally mandated to the exclusion of all other options. As the EPA definition of LID indicates, biofiltration, bioretention, filter strips, and other BMPs based on using vegetation to promote stormwater treatment via filtration are fundamental to LID implementation. These BMPs may be specified as second tier options (although they best mimic pre-development conditions), but project proponents should have considerable discretion to use these BMPs, and should not be required to apply for a feasibility exception to do so.

The use of conventional BMPs (structural treatment installations) as the principal approach for stormwater management should be a last resort, available only when objective infeasibility criteria are satisfied, and when off-site opportunities are not readily available. When LID BMPs are infeasible, and nearby off-site options are not available, the use of conventional BMPs that have been demonstrated to be effective on the pollutants of concern should be a compliance option.

The NGOs assert that the OC MS4 permit is too permissive in its application of LID BMPs or in the volume of water that must be collected. Moreover, they point to other locations around the U.S. where these more constrictive BMP measures are required and where larger volumes of water are presumably collected in them. A review and analysis of the documents referenced by NRDC prepared by Geosyntec Consultants (Attachment 2) shows that in all cases, none of the LID BMP sizing provisions appear in an adopted permit, so the actual utility, practicability, and on the ground

results of the permit conditions remains to be seen. In addition these programs do not: a) generally mandate zero discharge through application of only infiltration or rainfall harvest and use LID BMPs, and b) require large volumes of water (in excess of 1-inch for example) to be collected in infiltration or harvest and use LID BMPs regardless of feasibility. We recognize and appreciate that these programs provide constructive approaches for consideration, yet their direct transfer to permit content for Orange County is inappropriate. Also included for the Regional Boards consideration as Attachment 3 is a critical evaluation requested by the US EPA concerning the content of the Draft Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act. None of the documents cited by NRDC have been adopted for implementation.

CICWQ is supportive of the hydromodification control approach defined in Draft Permit Section XII, D. Hydrologic Conditions of Concern. However, we are very concerned about the language in Section D. 2. (b), as it removes any possible exclusion of a hydrologic condition of concern by limiting exempt conveyance channels to only those that are not waters of the U.S. This is a troublesome change in permit content and one that our membership cannot accept. Our interpretation of this revision is that it disables the LID requirements, including water quality volume mitigation requirements, by expanding the volume of water a project must handle and may render all the good work done on LID BMP selection and sizing irrelevant. We respectfully request a clear waiver process for those projects discharging into channels that are significantly hardened. In our specific comments below we provide alternative permit language.

III. Specific Comments on the Draft Permit

There are several references within *Section XII. New Development Including Significant Redevelopment. C. Low Impact Development to Control Pollutants in Urban Runoff From New Development/Significant Redevelopment* where CICWQ finds the definition of LID BMPs being narrowly interpreted to include only those that infiltrate, harvest and use rainfall, or evapotranspire. Below we identify those areas and suggest alternative language.

Content of Item No. 2. CICWQ suggests editing the third sentence in Item No. 2 as follows (edits underlined):

> *The design strategy shall be to maintain or replicate, to the extent practicable, the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration, and treatment systems as close as possible to the source of runoff.*

By changing this sentence, the Regional Board makes clear that the project developer will, to the extent practicable, make all efforts to mimic pre-development hydrologic conditions and that the project developer has in their toolbox all available LID BMPs consistent with the US EPA definition of LID.

Content of Item No. 5. CICWQ suggests changing the content of the first sentence in Item No. 5, as it narrowly defines the conception of allowable LID BMPs for the collection and treatment of the design capture volume and restricts the options available to the project proponent to comply with the provisions of the Draft Permit, Section XII, C. The sentence should be redrafted as follows (edits underlined):

> *The LID goal shall be to infiltrate, evapotranspire, harvest and beneficially reuse, or filter the design capture volume at the project site unless an infeasibility determination is made using the factors listed in No. 6 below.*

Content of Item No. 7. Here again, the language in the second sentence is narrowly defining the range of LID BMPs to those that only infiltrate, harvest and beneficially use rainwater, or evapotranspire runoff at the exclusion of those LID BMPs that use vegetation and other biological treatment means to filter stormwater runoff. The sentence should be redrafted as follows (edits underlined):

> *If site conditions do not permit infiltration, harvesting and reuse, evapotranspiration, or filtration using biofiltration or bioretention of the design capture volume at the project site as close to the source as possible, the alternatives discussed below and the credits and in-lieu programs discussed under Section E, below, may be considered:*

Content of Item No. 7 (a)-(d). The last sentence of each paragraph (a)-(d) reads as follows:

> *(a) The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and reuse at least the design capture volume.*
>
> *(b) The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate and/or harvest and reuse at least the design capture volume.*
>
> *(c) The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and reuse at least the design capture volume.*
>
> *(d) The pervious areas to which the runoff from the impervious areas are connected should have the capacity to at least the design capture volume from the entire tributary area.*

CICWQ recommends that the sentence read as follows within each subsection (a)-(d) to make it clear that all LID BMPs of variable scale are preferred for collecting and treating the design capture volume:

> *The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and reuse, or treat at least the design capture volume.*

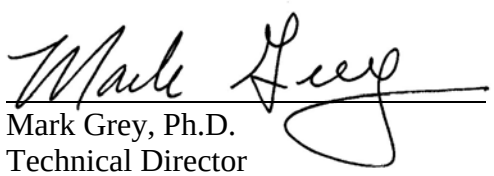
CICWQ, while supportive of the engineering approach to hydromodification control in the Draft Permit, is troubled by the removal of any possible exclusion of a hydrologic condition of concern by limiting exempt conveyance channels to only those that are not waters of the U.S. To our knowledge, most if not all existing hardened conveyance channels in Orange County are considered as being within waters of the U.S. By default, this would require all projects to comply with Section D, Hydrologic Conditions of Concern. We prefer much of the original language contained in the first Draft Permit which reads:

> *(b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened, and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected.*

IV. Summary

The second Draft Permit released for Orange County contains significant improvements from the first draft released in November 2008, but concerns on our part remain because of the restrictive language that redefines LID narrowly and removes any possible hydromodification control exemptions. CICWQ respects the difficult decisions the Regional Board must make concerning the sweeping changes this permit introduces for the building industry, yet we must urge you to go beyond the technical arguments presented here and consider the cost and practical feasibility considerations of these new permit provisions (zero discharge mandate) that appear to be wholly unsupported. Given the restrictive conception of LID that the permit introduces, the net result of implementation we believe will fall far short of the Regional Board's expectations because development will be hindered, not enhanced by current permit provisions and water quality will not improve. If you have any questions or want to discuss the content of our comment letter, please feel free to contact me at (909) 396-9993, ext. 252, (909) 525-0623, cell phone, or mgrey@biasc.org.

Respectfully,



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Memorandum

Date:	9 April 2009
To:	Mark Grey, Director of Environmental Affairs Building Industry Association Of Southern California
From:	Eric Strecker, Aaron Poresky, and Daniel Christensen
Subject:	Rainwater harvesting and reuse scenarios and cost considerations

SUMMARY

The purpose of this memo was to investigate two hypothetical scenarios involving rainwater harvesting and reuse in newly developed residential neighborhoods in Orange County, California. These scenarios include an on-lot harvesting and re-use and community-scale harvesting and re-use. The community system was also modeled using SWMM to assess its potential benefits using some simplifying assumptions, and general findings are presented in a brief discussion. Lastly, the Appendix, prepared by Dr. Mark Grey, provides an analysis of the institutional and building code issues for constructing rainwater harvesting and resuse systems in California.

For the on-lot scenario, a 1000 to 1300 gallon tank would capture 0.8 inches of runoff depending on the impervious area used to fill the tank. Depending on the assigned water usages (outdoor or indoor + outdoor), the drawdown time of the tank could vary from 7 to 21 days. A single house rain harvesting system for this scenario would cost approximately $4,900. For the 100 acres neighborhood scenario, a 1.3 million gallon storage basin would capture 0.8 inches of runoff from 60% of the total area of the catchment (impervious area). Depending on the assigned water usages (outdoor or indoor + outdoor), the drawdown time of the basin could vary from 10 to 45 days (longer drawdown time due to inclusion of street runoff). This system would cost approximately 1.65 million dollars. The cost estimates found herein are for new developments and are rough guesses due to unaccounted items and other ancillary costs.

For the same neighborhood scenario, long-term (40 year period) modeling results show that 32% of the total runoff could be captured and used if only toilet flushing were used. If toilet flushing and outdoor irrigation were used, the system could capture and reuse about 55% of the total runoff. Under both usage scenarios, significant volumes of runoff would bypass the storage tank (or cause overflow) from 50 to 70 percent of the runoff or more would be expected to bypass.

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BACKGROUND

Stormwater storage and re-use is a general description referring to the capture and storage of runoff and subsequent re-use of that water. Such a system could take a variety of forms. In the case of urban residential development, the typical storage component consists of some form of an enclosed tank or "cistern" that accepts runoff from roof drains or neighborhood storm drains. Some level of treatment (e.g. screening, filtration, etc.) is typically required upstream of the cistern to prevent the introduction of debris into the system. In addition, some form of treatment would be required, depending on the planned use. Potential re-use demands in residential neighborhoods are generally limited to irrigation of lawns and landscaped areas and/or to meet non-potable demands in homes such as toilet/urinal flushing (EPA 2008). The list below outlines the general materials needed for a reuse system for a single family household.

- Downspouts/Piping to Cistern: Typically a cistern is located near or directly under the downspout and minimal piping is needed. However, if driveway, patio and walkway water is to be collected on a lot, then additional collection and piping systems would be needed. The tank in this case would likely require deeper burial to be able to accept ground level runoff.
- Collection Filters: Fine mesh can be placed over the downspouts to prevent debris from clogging gutters and downspouts and entering the cistern. Filters with finer particle extraction capability, also known as "roof washers", can also be placed at top of the downspout to filter finer particles. (Figure 1a). For inlets from other areas such as driveways, filter materials can be integrated with the inlet and in fact would be more critical than for downspouts as debris quantities would be expected to be larger from ground level.
- First flush diverter: Typically this is a vertical pipe located before the cistern that traps the first flush volume using a ball float helping to prevent built-up contaminants entering the tank. The length and size of the vertical pipe determine the amount of water that will be diverted. A weep hole at the bottom of the vertical pipe empties the trapped first flush water. (Figure 1b). Another option would be to allow the tank to fill and then either divert via an overflow in the incoming pipe system or via a tank overflow.
- Tank/Cistern: Structure receives and stores impervious runoff (typically from roofs) and is design to store a certain volume of runoff to meet water use demands. (Figure 2a)
- Insect tank screens: Any open entrance to the tank should be covered with a fine mesh insect screen to prevent mosquitoes and pests from entering the cistern. (Figure 2b)
- Pump: A pump is used to force water to treatment system as appropriate and then toilets and/or irrigation system.
- UV treatment: Some regulations may require UV treatment for indoor non-potable water reuse or if water is re-introduced into a pressurized irrigation system. Another option would be to have a separate non-pressurized (low-pressure) irrigation system.
- Piping: Additional pipelines (purple lines) inside the house and to the irrigation system are needed to ensure the non-potable water does not mix with potable water.

- Backflow valve: This valve is a safety measure to ensure non-potable water does not mix with the potable water lines. An air-gap may also be used or in addition to a backflow valve.
- Potable water use failsafe system: A potable water line should be in place as a backup in case the non-potable reuse system fails or empties. This requires a double-line system and all measures should be taken to prevent non-potable water from mixing with potable water lines.
- Stencils: All non-potable water outlets should be clearly labeled as a "non-potable" source.

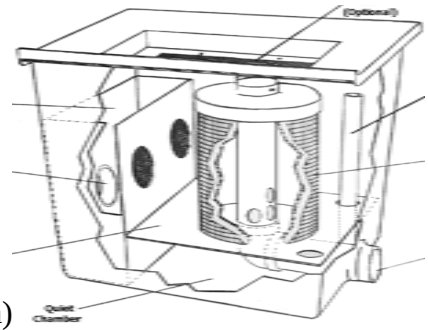
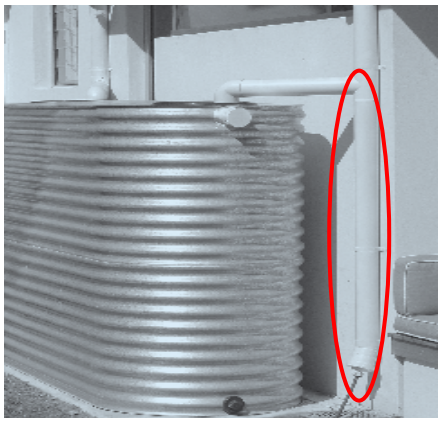
a)  b) 

Figure 1. a) Downspout filter or "roof washer"; b) First Flush Diverter

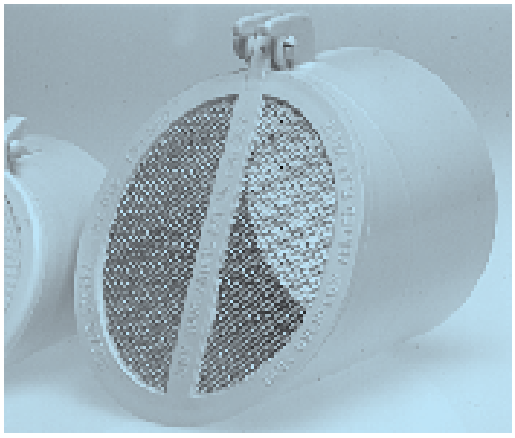
a)  b) 

Figure 2. a) Cisterns; b) Insect screen

The critical factor in performance of storage and re-use systems lies in the integration of the magnitude and pattern of inflows and outflows with storage volume. For example, if inflow and outflow are well-matched and fairly constant, the system will require a small storage volume. If inflows and outflows are well-matched in total volume but come at different times, a larger storage volume may be required to match supply with demand. In the case of storage and re-use as a means of "disconnecting" impervious area, the most important requirement is that cistern has sufficient capacity and ability to regenerate this capacity, such that the system captures a significant portion of runoff on an average annual basis. If demand for harvested water during

the period of high runoff is small compared to the overall runoff volume, then the system may not be able to perform its intended function of capturing a significant volume of runoff.

Two scenarios that were used for a general analysis are presented below. The first is a single family home scenario and the second is a 100-acre residential development. For the single family home scenario, two situations are analyzed: 1) only runoff from the roof-top drains to the cistern, and 2) runoff from the roof and additional impervious areas (driveway and patio) drains to the cistern. For the 100-acre residential development, runoff from the entire catchment, including the streets, sidewalks, driveways and roofs and pervious area was considered. The second scenario was also modeled using SWMM to ascertain long-term hydrology benefits.

HYPOTHETICAL SINGLE HOUSEHOLD SCENARIO

A simple single household example of rainwater harvest and reuse is provided to outline rough estimates of water demand and tank drawdown times that could be expected from a typical reuse system on a newly developed residential lot found in Orange County. This analysis uses the simple rational method to calculate runoff volumes and require tank size following the methods outlined in the "New Development and Significant Redevelopment" chapter in the DAMP. Runoff coefficients dependent on imperviousness found in the DAMP document were used in the runoff calculations. A total lot area of 0.1 acres with 69% impervious area was assumed. This imperviousness is based on 2,400 sq ft of roof area, 600 sq ft of other impervious area (driveway, sidewalks and patio), and the remaining 1,356 sq ft of pervious area. A rainfall depth of 0.8" was used to size storage units. This depth represents approximately the 85th percentile, 24 hour rainfall depth for large parts of Orange County. Two storage rainwater collection and storage scenarios were analyzed: 1) only runoff from the roof of the house drains to the cistern, and 2) runoff from the roof and additional impervious areas (driveway and patio) drains to the cistern.

Two reuse demand scenarios were considered: 1) reuse for internal demand only (i.e. toilet flushing), and 2) reuse for internal and external (i.e. irrigation) demand combined. Demand for toilet flushing and outdoor use per household were assumed to be 65 gal/day and 77 gal/day, respectively. The estimate for toilet flushing use was derived from an estimate of 18.5 gal/person/day (AWWARF 1999) and an assumed average occupancy of 3.5 people per house. For outdoor demand, the average use rate for May, September and December was estimated to be 113 gal/day for 2000 square feet of landscape area in the Irvine region (IRWD 2009). Since the majority of rain in Orange County occurs between November and March, the average of May, September and December demand likely over-estimates the demand for harvested rainwater during the months when rainwater is available for harvesting. The average outdoor demand (113 gal/day/2000sqft) was linearly scaled to the equivalent outdoor demand for the assumed 1,356 square feet of pervious area per lot used in this study, yielding 77 gal/household/day.

Based on the capture and storage scenarios and re-use scenarios described above, approximate average drawdown rates were estimated. Drawdown rates are important to the performance of stormwater BMPs because they affect how much storage capacity can be regenerated to capture

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runoff in subsequent storms. Table 1 shows the characteristics of the hypothetical lot and resulting cistern volume and drawdown times.

Table 1: Single household rainwater harvesting system attributes used for analyses.

	Roof Runoff	Roof + Other Impervious area	
Lot Characteristics			
# houses	1	1	
Total lot area	0.1	0.1	acres
Impervious area of roof	2400	2400	ft2
Other impervious area	600	600	ft2
Pervious area	1356	1356	ft2
% total impervious area of lot	69%	69%	
% of impervious area to cistern	80%	100%	
Runoff Coeff. for impervious area	0.9	0.9	
Storage Tank Sizing			
Storm Depth	0.8	0.8	inches
Vol Cistern	144	180	ft^3
	1,077	1,346	gal
	0.0033	0.0041	acre-ft
Demand Calculations			
People/ house	3.5	3.5	
Toilet use/capita	18.5	18.5	gal / day
Toilet use/house	65	65	gal / day
Outdoor / house	77	77	gal / day
Drawdown Times			
Toilets only	17	21	days
Both Toilets & Outdoor uses[1]	7.6	9.5	days

Per the calculations reported in Table 1, the drawdown time of a household cistern is expected to range from approximately 8 to 21 days. Note that these calculations assume that outdoor demand is immediately present following a storm event; likely an over-estimate due to rainfall soaking of landscaped areas and the prevalence of back-to-back storms in Southern California. From a runoff reduction perspective, a user would like to empty the cistern relatively quickly so

[1] Outdoor demand assumes that irrigation demand is immediate; more sophisticated modeling could be completed to more accurately characterize irrigation demand, but for purposes of this analyses, it has been assumed to be immediate. This likely significantly overstates the demand for irrigation.

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that adequate storage is available for the next storm. Conversely, from a water reuse perspective, a user would likely desire the tank to empty slowly so that demand could be met for a longer period with the captured stormwater.

HYPOTHETICAL 100 ACRE NEIGHBORHOOD SCENARIO

A newly developed neighborhood example of rainwater harvest and reuse is provided to outline rough estimates water demand and tank/basin drawdown time that could be expected from a larger centralized reuse system found in Orange County that would capture runoff from the entire catchment (including streets, driveways, and pervious areas if they are contributing). This analysis uses the simple rational method to calculate the runoff to size the volume for storage system following the methods outlined in the "New Development and Significant Redevelopment" chapter in the DAMP 2003 to size the cistern volume. A total tributary area of 100 acres with 60% impervious area was assumed. Assuming the same 0.1-acre lots as above at a density of 4.5 du/ac, the total acreage covered by residential lots would be 45 acres. This leaves approximately 27.5 ac of roads and 27.5 ac of common areas, parks and open space to yield 60 percent neighborhood-wide imperviousness.. Based on 1,356 sf of pervious area per lot and 450 lots in the neighborhood, 14 acres of pervious area would be located on private lots and the remaining 36 acres of pervious area would be contained in parks, open space, and greenways. A rainfall depth of 0.8" was used to size the neighborhood storage unit as this depth represents approximately the 85th percentile, 24 hour rainfall depth for large parts of Orange County.

The same water demand estimates as the lot scenario were used to develop the neighborhood scenario. Off-lot pervious area was assumed to be irrigated at the same rate per square foot as on-lot pervious area. Table 2 shows the characteristics of the neighborhood tributary area and resulting cistern volume and drawdown times.

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Table 2: Neighborhood rainwater harvesting system attributes used for analysis.

Tributary Area Characteristics		
# houses	450	
Impervious area	60	acres
Pervious area	40	acres
% impervious	60%	
Composite Runoff Coeff. C	0.60	
Storage Tank Sizing		
Storm Depth	0.8	Inches
Cistern / Basin Volume	174,000	ft^3
	1,300,000	Gal
	4.00	acre*ft
Reuse Demand Calculations		
People per house	3.5	
Toilet use per capita	18.5	gal / day
Toilet use per house	65	gal/ day
Outdoor demand per 2000 sf of pervious area	113	gal / day
Total toilet demand	29250	gal / day
Total outdoor irrigation demand	98500	gal / day
Total toilet + irrigation demand	127750	gal / day
Drawdown Time		
For Toilets	45	Days
Both Toilets & Outdoor[2]	10	Days

BASIC COST CONSIDERATIONS

Cisterns may take a variety of shapes and forms, thus costs may vary substantially by project. Likewise, the appurtenances required to convey water to the tank and supply the building demand are likely to be affected by project-specific factors. Finally, there are a variety of treatment systems that could be considered. Therefore, only a rough estimate of costs for storage and re-use systems in newly developed houses or neighborhoods can be made herein. The basic cost items that will be considered include: collection tanks, filters, UV treatment, 1st flush

[2] Outdoor assumes that irrigation demand is immediate; more sophisticated modeling could be completed to more accurately characterize irrigation demand, but for purposes of this analyses, it has been assumed to be immediate. This likely significantly overstates the demand for irrigation.

diverters, inlet piping and filters; pumps and appurtenances; the incremental cost of a dual plumbing system, and installation. The limited implementation of storage and re-use systems of the sort being considered herein allows limited basis for comparison to actual projects. Table 3 shows an itemized cost list for rainfall harvesting items.

Table 3: Rainwater harvesting items and prices

Item	Description	Cost	Reference/Source
TANKS			
Galvanized steel	200 gal	$225	Fairfax County, 2005
Polyethylene	165 gal	$160	Fairfax County, 2005
Fiberglass	350 gal	$660	Fairfax County, 2005
Plastic	800 gal	$400	Plastic-mart.com
Plastic	1100 gal	$550	Plastic-mart.com
Plastic	1350	$600	Plastic-mart.com
Plastic cone	1500 gal w/metal stand	$1500	Plastic-mart.com
Plastic	2500 gal	$900	Plastic-mart.com
Plastic	5000 gal	$3000	Plastic-mart.com
Plastic	10000 gal	$6000	Plastic-mart.com
Dry Det. Basin(1997)[3]	$C = 12.4V^{0.760}$: for 1 ac-ft	$41,600	stormwatercenter.net
Below Ground Vault[4]	$C = 38.1 (V / 0.02832)^{0.6816}$	$55,300	fhwa.dot.gov
Concrete	1,000,000 gal above g. (O&P)	$548,000	RSMeans
Steel	1,000,000 gal above g. (O&P)	$467,000	RSMeans
TREATMENT			
UV (house-scale)	Whole system - 12 gpm	$700-$900	rainwatercollection.com
UV bulb	Life: 10,000 hrs or 14 months	$80-$110	rainwatercollection.com
UV (neighborhood-scale)	Whole system - 200 gpm	$10,000	Bigbrandwater.com
Downspout filter	Placed in Gutter	$20 - $500	many online
1st Flush Diverter	Vertical pipe w/ ball float	$50-$100	raintankdepot.com
PUMP	1 hp (all in one package)	$575 - varies	rainwatercollection.com

[3] This dry detention cost equation is based on Brown and Schueler, 1997, where C is the construction, design and permitting cost and V is the volume (cu-ft) need to control the 10-year design storm. In this case, the 0.8" storm runoff volume was used in place of the 10-yr design storm volume.

[4] This below ground storage vault equation is based on Weigand et al., 1986, where C is the construction cost estimate in 1995 dollars and V is the runoff volume (cubic meters) of the maximum design event frequency, taken to be the 0.8" storm for this study.

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Item	Description	Cost	Reference/Source
PIPING (Purple)			
to Tank (lot)	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
to House (lot)	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
to Tank (neighbor.)	Concrete: 6” – 18” (O&P)	$15-$30 /LF	RSMeans
to House (neighbor.)	HDPE- 4” – 10” (O&P)	$11-$27 / LF	RSMeans
to Irrigation	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
Backflow prev. valve	Each	$100-$200	web
STENCILS	Non-potable water	----	
INSTALLATION	Percentage of material cost	40 % – 50%	

A rough cost estimate for the hypothetical examples can be developed using the table above. Table 4 summarizes the potential costs for the single household (lot), and Table 5 summarizes the potential costs for neighborhood. For the neighborhood scenario, the pipe (purple) lengths were estimated using measurements along the centerline of streets from a similar size neighborhood in Irvine.

According to Table 4, the total cost of the single household rainwater harvest and reuse system would be approximately $4900, not including design, permitting, and contingency costs which could run from another 30 to 70 percent of the material and installation costs. Table 5 shows the total cost for the neighborhood scenario is approximately $1.65 million, not including design, permitting, and contingency costs which could run from another 30 to 70 percent of the material and installation costs. This would equate to roughly $3660 per house, most of the saving being found in the total cost of the tanks verse a large central storage unit.

Table 4: Rainwater harvesting materials cost for single household scenario

Item	Description	Cost
TANKS		
Plastic	1100 gal and 1350 gal	$550
TREATMENT		
UV	Whole system - 12 gpm	$800
UV bulb	Life: 10,000 hrs or 14 months	$80-$110
Downspout filter	Placed in Gutter	$250
1st FLUSH DIVERTER	Vertical pipe w/ ball float	$100
PUMP	1 hp (all in one package)	$575
PIPING (Purple)		
to Tank (lot)	PVC: 2”-6” (O&P) 20ft	$8 / LF
to House (lot)	PVC: 2”-6” (O&P) 50ft	$8/ LF
to Irrigation	PVC: 2”-6” (O&P) 50ft	$8 / LF
Backflow prev. valve	each	$200
STENCILS	Non-potable water	----
INSTALLATION	40% of material cost	$1400
TOTAL		**$4,900**

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Table 5: Rainwater harvesting materials cost for neighborhood scenario

Item	Description	Cost	Units Assumed
TANKS			
Dry Det. Basin(1997)	$C = 12.4V^{0.760}$	$119,000	174,000ft^3
Below Ground Vault	$C = 38.1 (V / 0.02832)^{0.6816}$	$142,000	174,000ft^3
TREATMENT			
UV - neighborhood	Whole system - 200 gpm	$10000	
Catch basin filters	1 every 2 acres	$2000	50 catch basins
PUMP		$50,000	
PIPING (Purple)			
to Tank (neighbor.)	Concrete: 6" – 18" (O&P)	$15-$30 /LF	$23 - 14000 ft
to House (neighbor.)	HDPE- 4" – 10" (O&P)	$11-$27 / LF	$19 - 14000 ft
to Irrigation	PVC: 2"-6" (O&P)	$2-$12 / LF	$8 - 60 ft /house
Backflow prev. valve	each	$100-$200	$200 per house
STENCILS	Non-potable water	----	
INSTALLATION	40% of material cost	$470,000	
TOTAL		**$1,650,000**	

Note that there would also be on-going operation and maintenance costs for operation of both neighborhood and on-lot systems. These costs would include electricity, filter maintenance, operator for the neighborhood system, on-going training for home operators or contract maintenance and other on-going costs (periodic replacements/repairs, etc.).

ASSESSMENT OF HYDROLOGIC IMPACTS OF CISTERNS FOR NEIGHBORHOOD SCALE

Four community-scale residential re-use scenarios were analyzed based upon the above description of the 100-acre residential catchment. The four scenarios included:

A. Storage sized for 0.8" storm event and water reuse for toilet flushing only,
B. Storage sized for 0.8" storm event and water reuse for toilet flushing and outdoor uses,
C. Storage sized for 1.6" storm event and water reuse for toilet flushing only,
D. Storage sized for 1.6" storm event and water reuse for toilet flushing and outdoor uses,

Each scenario was modeled over a long period to better understand the potential hydrology performance of runoff storage and re-use systems in Orange County, California. Simplified representations were used for catchment runoff, cistern storage and re-use demands from toilet flushing and irrigation.

The Laguna Beach rainfall gage was used as a representative rainfall record for large parts of Orange County. The Laguna Beach gauging station is located in the City of Laguna Beach. The

gauge elevation is 210 ft above mean sea level (AMSL). Reuse demand inputs were generated from IRWD estimates of indoor demand and irrigation demand. Results of this effort include the overall stormwater capture efficiency achieved in each scenario and the portion of residential demand that could be supplied by rainwater harvesting (RH).

METHODOLOGY

This section describes the methodology used to estimate system performance.

Model Selection

The EPA Stormwater Management Model (SWMM) Version 5.0 was used for continuous simulation analysis of the various facility configurations. SWMM is a dynamic rainfall-runoff simulation model used for single event or continuous simulation of runoff from primarily urban areas. The model accounts for various hydrologic processes that combined to produce stormwater runoff from urban areas. The model also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures (USEPA, 2008). SWMM was selected because of its proven capabilities in simulation of urban hydrology and hydraulics, and its flexibility in representing the proposed systems. Although in this case, SWMM was used with some simplifying assumptions, it could be used with in a more sophisticated modeling approach to account for such factors as irrigation demand based upon available evapotranspiration rates, etc. that would allow for a more accurate analysis of irrigation demand then conducted in this simplified analysis.

Model Input Parameters

Table 6 shows the input parameters used to represent the tributary area to the re-use facilities. In addition, information from Tables 1 and 2 was used to characterize the attributes of each of the scenarios.

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Table 6. Baseline SWMM Inputs - Hydrology

Parameter	Value	Units	Source/Rationale
Rainfall	Laguna 2 NCDC record (1952-1993)	in/hr	Representative of rainfall pattern at project locations; long period of record; good resolution; minimal missing data
Imperviousness	60	%	Consistent with hypothetical scenarios described in memo.
Slope	0.03	ft/ft	Includes roofs, lawns, streets, and sidewalks.
Impervious Roughness	0.01	-	Literature[1] (not sensitive to analysis)
Pervious Roughness	0.1	-	Literature[1] (not sensitive to analysis)
Impervious Depression Storage	0.02	inches	Literature[1] (sensitive to analysis, selected conservatively)
Pervious Depression Storage	0.10	inches	Literature[1] (sensitive to analysis, selected conservatively)
Ksat	0.15	in/hr	Literature[1] (representative of B/C soils) (moderately sensitive to analysis
IMD	0.25	in/in	Literature[1] (representative of B/C soils) (moderately sensitive to analysis, not highly variable)
Suction Head	8	inches	Literature[1] (representative of B/C soils) (not sensitive to analysis)
% of Imp area w/o DS	25%	-	SWMM default (moderately sensitive to analysis)
Path Length	500	ft	Typical of urban development
Routing	Imp and Perv routed directly to outlet	-	Conservative representation; in reality some imperviousness will be routed over pervious area, resulting in diminished volumes for small storm events
Dry Weather Flow	Assumed to be zero	cfs	Based on use of efficient irrigation methods

1 – Based on James and James, 2000.

Hydrology Validation

Average annual runoff coefficients recommended by the OC DAMP Table A-1 were compared to model results. For 60% impervious areas, the DAMP Table 1 recommends a runoff coefficient of 0.60. The SWMM model computed a long-term runoff coefficient of 0.58. This is believed to be adequately close for the purposes of this analysis.

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Facility Representation

The storage and re-use systems were simulated as a simple underground storage feature (zero evapotranspiration) with multiple outlets to represent various types of re-use demand. The following assumptions were used:

- Storage volume was simulated per the hypothetical scenarios described in the memo. The baseline design storm depth was 0.8 inches for calculating the size of the storage facility. A scenario was also simulated that included twice as much storage (i.e. a 1.6 inch design storm).
- Toilet flushing was assumed to be the only indoor demand for harvested rainwater and was simulated as a constant use rate. It is acknowledged that toilet flushing will exert a time-dependent demand, most notably on a daily patter, however average rates were deemed acceptable for the modeling effort given the time scale of facility drawdown being considered (greater than 5 days).
- Irrigation demand was assumed constant within a single day, but to vary seasonally based on irrigation use data from IRWD's website (Table 2). The simulations did not account for reduced irrigation demands following wet periods that likely would significantly extend the storage drawdown times for irrigation use. Therefore, this analysis likely over predicts the effectiveness of the system in reducing runoff when irrigation is included.

Table 7: Landscape irrigation rates by month for IRWD service area (IRWD)

Month	Gal/mo per 2000 sf of landscaping	Gal/day per 2,000 sf of landscaping
Mar	3000	100
July	7500	250
Sept	5300	177
Dec	1900	63

Irrigation demand was interpolated between the monthly averages from Table 2 to yield monthly average values. The same yearly pattern of irrigation demand was assumed through the entire simulation period, though it is acknowledged that irrigation demand will vary by year (as well as following wet periods).

- An overflow weir was simulated to represent the condition in which the cistern is full and additional runoff bypasses the facility.

The simulation was run for 1952 through 1993 at 15-minute computational timesteps and one-hour reporting steps. Cumulative volumes were totaled and processed.

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SUMMARY OF RESULTS

Table 3 provides a summary of key inputs and results for 42 years of continuous simulation.

Table 8: Key Inputs and Results

Key Inputs and Results	Units	Scenario			
		A	**B**	**C**	**D**
		Toilet Flushing Only, 0.8" design storm	Toilet Flushing + Irrigation, 0.8" design storm	Toilet Flushing Only, 1.6" design storm	Toilet Flushing + Irrigation, 1.6" design storm
Design Storm for Tank Volume	inches	0.8	0.8	1.6	1.6
Tank Volume	cf | ac-ft | MG	174,000 | 4.0 | 1.3		348,000 | 8.0| 2.6	
Indoor Use Rate	cfs | gpd	0.0428 | 27,700			
Avg Ann Outdoor Use Rate (varies by month)	cfs | gpd	-	0.195 | 126,000	-	0.195 | 126,000
Average Annual Drawdown Time	days	47	8.5	94	17
Average Stormwater % Capture and Reuse	%	32%	55%	41%	68%
Avg Annual Volume of Stormwater Reused	MG | CCF	5.2 | 6,950	8.8 | 11,800	6.5 | 8,700	10.9 | 14,620

DISCUSSION

The modeling results illustrate several key concepts:

- Capture efficiency increases with higher use rate and larger volumes. Higher use rate serves to make more volume available for subsequent storms, while larger volume allows more water to be stored for use longer after the end of rainfall.
- The amount of runoff captured on an average annual basis by a DAMP sized cistern and used is on the order of 30 to 55%, and is likely closer to the 30 to 40 percent range due to optimistic irrigation demand assumptions. Therefore if no other treatment of runoff was provided, the system would leave about 60 to 70 percent of runoff untreated.
- Doubling the tanks size increases the percent capture, but at much less of a rate then the same percentage increase in size of the storage volume (i.e. double the volume with about a 10 percentage point increase in percent capture).

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- Although the single lot scenario was not modeled, due to the fact that it does not include streets, the percent capture of runoff from a neighborhood with on-lot systems would be less overall than the community scenario due to street runoff not being included.

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APPENDIX – RAINWATER HARVESTING AND REUSE CODE ANALYSIS

Prepared by Mark Grey, Director of Environmental Affairs Building Industry Association of Southern California

The purpose of this document is to identify the California building codes that may govern design, installation and operation of rainwater harvesting and reuse systems (RHR) in new and redevelopment projects. This document may also aid in identifying relevant code sections for existing building retrofit to accept RHR.

Regulatory Background

California building and public safety codes do not explicitly recognize RHR or provide definitions for "rainwater" or "stormwater" and instead address plumbing and mechanical system criteria and use of appropriately treated wastewater effluent to protect public health. Plumbing and health and safety code adaptations to using treated wastewater effluent generally began in the early 1990s, with modifications made thereafter at various times. Neither the Uniform Plumbing Code nor the International Plumbing Code addresses the use of RHR.

Three California Code of Regulations sections govern direct reuse of treated wastewater effluent:

Title 24—Building Standards Code (plumbing code)

Title 22—Social Security (recycled water quality standards)

Title 17—Public Health (public water system cross-connection and backflow prevention)

Title 24 contains California building standards including the plumbing code (Chapter 16). Within Chapter 16, requirements for designing and installing dual-plumbed systems to accommodate treated wastewater effluent are found in Appendix J. Interestingly, Appendix J has never been formally adopted within Title 24 by the California Building and Standards Commission (CBSC) and serves as a guidance document. As of April 2009, the CBSC is considering incorporation of graywater recycling system installation standards into Appendix J. In any case, the mechanical design and installation of on-site (project level) or sub-regional or regional water treatment systems and their associated piping and pumping requirements would be governed under California plumbing code found in Title 24.

Title 22 contains the water quality standards for treated wastewater effluent used for dual plumbed systems within residential and commercial buildings and direct reuse of treated effluent for ground water recharge or for landscaping. Recycled water used within buildings for toilet flushing and urinals, or for most landscaping applications must meet disinfected tertiary recycled water standards. Less stringent disinfection standards are in place for other outdoor uses such as roadway landscaping. There are multiple water treatment technologies capable of

meeting Title 22 requirements (CDPH, 2009). Two general classes exist: filtration and disinfection. Filtration technologies generally include granular media, cloth media, or membrane systems. Disinfection technologies include ultraviolet, pasteurization, or ozone/peroxide systems. An important project level planning consideration arises when capture and storage projects intend to use storage facilities in excess of 100,000 gallons or piping systems greater than 16 inches in diameter. Use of these large storage or conveyance systems triggers California Environmental Quality Act compliance.

Title 17 contains cross-connection and backflow prevention requirements where the treated wastewater effluent meeting Title 22 water quality standards is dual plumbed into potable water systems.

Integration of rainfall harvesting and reuse systems into existing California code structure

Given that state codes do not explicitly recognize rainfall or stormwater which is collected from roof areas or other impervious surfaces and stored and/or treated for use, discretion in plumbing and treatment system component approval will likely reside at the county or city level or both through local codes and ordinances. Few case studies are available for California, but available sources suggest multiple permits will be necessary from the local permitting authorities. These permits are required for installation of piping and mechanical systems (such as treatment) within the building footprint and envelope and below ground around the perimeter of the building site.

From a code transfer standpoint, California plumbing code (Title 24, Chapter 16) and cross connection/backflow system design standards (Title 17, Chapter 5) appear to be directly transferrable to RHR. Likewise, California Title 22, Division 4 Environmental Health standards would always apply to treated rainfall or stormwater serving dual plumbed systems (for toilet and urinal use within the building envelope). Title 22 standards for irrigation use also appear to be generally applicable; uncertainty arises for small single family homes or other buildings where only roof runoff will be collected and used for landscape supply only. Cross connection and backflow protection is always required whenever a recycled (presumably rainwater or stormwater) water source is integrated into the existing potable water system to meet indoor or outdoor demand.

Case Studies and National Code Guidance Documents on Rainwater Harvesting

City of San Francisco, California. The City of San Francisco amended its plumbing code in 2005 to allow individual property owners to direct rainwater to alternative locations such as rain gardens, rain barrels, and cisterns. Both landscaping and toilet flushing uses are allowed. To install such a system, an applicant must obtain a plumbing permit and a building permit, and if the system will include pumps, be located on a roof, or will be

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located underground, additional permits are necessary. If the rainfall collection system is not connected to the existing plumbing system, then permits are not necessary.

Oregon Building Codes Division. Oregon Smart Guide: Rainwater Harvesting. The Oregon Building Codes Division allows collection of roof runoff only for rainfall harvesting. A project applicant must obtain approval from the local authority having building code jurisdiction. Systems must be designed according to Appendix M.

Santa Fe County, New Mexico. Rainwater Catchment System Ordinance. This is a county ordinance that requires installation of rainwater catchment systems for all commercial and residential development from one to four dwellings. Cisterns are required to be designed to capture 1.5 gallons per square foot of roof area. Water collected must be directed to landscape irrigation.

Texas Water Development Board. Rainwater Harvesting Potential and Guidelines. The Texas State Board of Plumbing Examiners governs plumbing regulations in Texas. According to the document, most communities in Texas follow either the Uniform Plumbing Code or International Plumbing Code. Neither code structure addresses rainwater harvesting.

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Technical Guidance on Implementing
Section 438 of the Energy Independence and Security Act

INTRODUCTION

In December 2007, Congress enacted Energy Independence and Security Act. Section 438 of that legislation establishes strict stormwater runoff requirements for Federal development and redevelopment projects. The provision reads as follows:

> **"Storm water runoff requirements for federal development projects.** The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

The intent of Section 438 of the Energy Independence and Security Act (EISA) is to require federal agencies to develop and redevelop applicable facilities in a manner that reduces stormwater runoff and associated pollutant loadings in order to protect or restore the waters of the U.S. Until recently, stormwater programs established under the Clean Water Act Amendments of 1987 have been administered to control traditional pollutants that are commonly associated with municipal and industrial discharges, e.g., nutrients, sediment, and metals. Increases in runoff volume and peak discharge rates have been regulated through State and local flood control programs. Although these programs have merit, knowledge accumulated during the past 20 years has led stormwater experts to the conclusion that conventional approaches to control runoff have not resulted in adequate protection of the nations water resources (National Research Council, 2008).

Stormwater management practices, e.g., extended detention ponds, that have been designed to reduce peak flows and trap pollutants entrained in the runoff have been proven to inadequately protect receiving waters both in terms of maintaining stream channel stability and the biotic integrity of the waterbody. What research has shown is that the use of conventional stormwater management practices fails to achieve the desired management goals and as a result there is an increased incidence of runoff events that have flow volumes and runoff rates that are erosive and detrimental to the stability of the stream. In addition, the higher volumes and velocities also cause and carry increased pollutant loadings (Shaver, et al., 2007; Holz testimony, 2008; Horner testimony, 2008). A 2008 National Research Council report on urban stormwater confirmed the shortcomings of current stormwater control efforts. Three of the report's findings on stormwater management approaches are particularly relevant (National Research Council, 2008).

1. Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds;
2. Stormwater control measures such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use

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planning can dramatically reduce the volume of runoff and pollutant load from new development; and

3. Stormwater control measures that harvest, infiltrate, and evapotranspire stormwater are critical to reducing the volume and pollutant loading of small storms.

Purpose and Organization of this Guidance

The purpose of this document is to provide guidance and background information on Section 438. The document contains guidance on how compliance with Section 438 can be achieved, measured, evaluated, and reported. In addition, information detailing the rationale for the stormwater management approach contained herein has been included.

The following information is presented within this document:

Part I: Implementation Framework

A. Background
B. Benefits and outcomes of the new stormwater performance requirements
C. How to meet the requirements of Section 438
D. Applicability and definitions
E. Complying with the performance requirement
F. Calculating the 95th percentile rainfall event

Part II: Case Studies on Capturing the 95th Percentile Storm Using Onsite Management Practices

Case studies representing typical Federal installations have been included. The case studies were selected to demonstrate the feasibility of providing adequate stormwater control for a range of site conditions and building designs. Each case study includes a description of a method that can be used to determine the design objectives of the project based on controlling the 95th percentile storm. Examples of on-site technologies and practices have also been provided. The case studies are intended to provide examples of modeling procedures that can be used to quantify treatment system performance and processes for assessing sites and determining appropriate control techniques.

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Part I: Implementation Framework

A. BACKGROUND

This section contains background on the causes and consequences of stormwater discharges, solutions that can be used to address the causes and consequences of stormwater discharges and how to implement those solutions to comply with Section 438 of EISA.

Alterations to Natural Hydrology and the Impact on Stormwater Runoff

In the natural, undisturbed environment rain that falls is quickly absorbed by trees, other vegetation, and the ground. Rainfall that is not intercepted by leaves infiltrates into the ground or is returned to the atmosphere by the process of evapotranspiration. Very little rainfall becomes stormwater runoff, and runoff generally only occurs with larger precipitation events. Traditional development practices cover large areas of the ground with impervious surfaces such as roads, driveways, sidewalks, and buildings. Once such development occurs, rainwater cannot infiltrate into the ground and as a result, runs off the site at rates and volumes that are much higher than would naturally occur. Under developed conditions runoff occurs even during small precipitation events that would normally be absorbed by the soil and vegetation. The collective force of the increased runoff scours streambeds, erodes stream banks, and causes large quantities of sediment and other entrained pollutants to enter the water body each time it rains (Shaver, et al., 2007; Booth testimony, 2008).

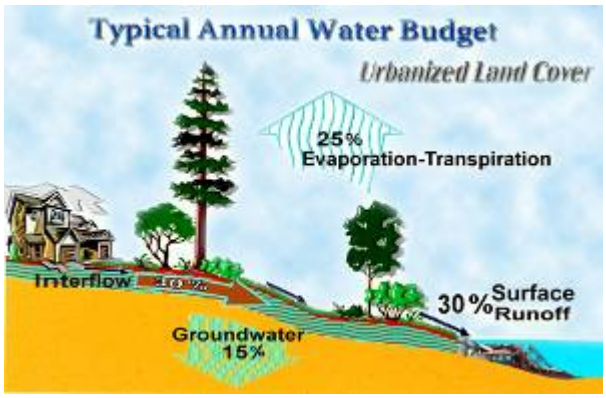
As watersheds are developed and impervious surfaces increase in area, the hydrology of the watersheds fundamentally changes over time which results in degraded aquatic ecosystems. In recognition of these problems, stormwater managers employed extended detention approaches to mitigate the impacts of increased runoff peak runoff rates. However, wet ponds and similar practices inadequately protect downstream hydrology because of the following inherent limitations of these conventional practices (National Research Council, 2008; Shaver, et al., 2007):

- Poor peak control for small, frequently-occurring storms;
- Negligible volume reduction; and
- Increased duration of peak flow.

Detention storage targets relatively large, infrequent storms, such as the two and 10-year/24-hour storms for peak flow rate control. As a result of this design limitation, flow rates from smaller, frequently-occurring storms typically exceed pre-development levels and result in flows erosive to stream channel stability (Shaver, et al., 2007). Section 438 is intended to address the inadequacies of the historical detention approach to managing stormwater and promote more sustainable practices that have been selected to maintain or restore predevelopment site hydrology.



Pre-development Hydrology. *Courtesy of C. May, University of Washington.*



Post-Development Hydrology. *Courtesy of C. May, University of Washington.*

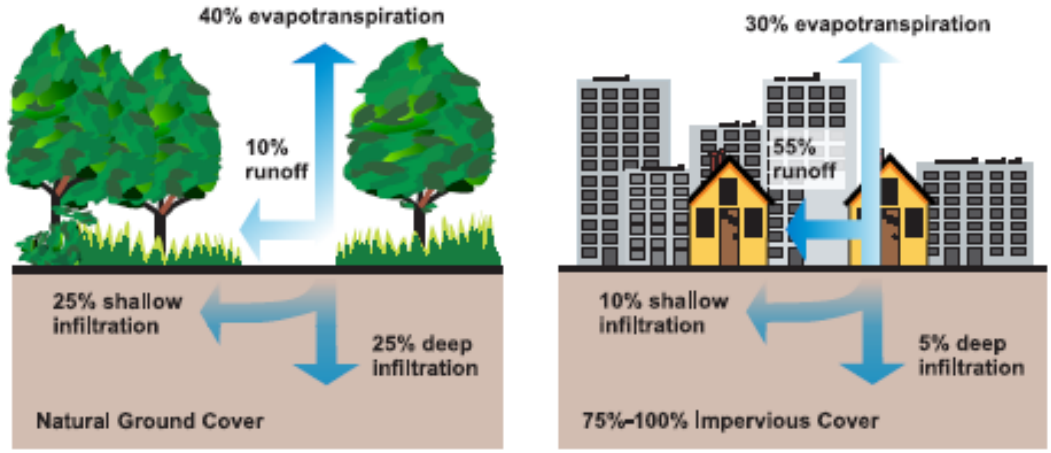


Figure 1. Pre-Development and Post-Development Hydrology. (USDA).

Land cover changes including increased imperviousness, soil compaction, loss of vegetation, and loss of natural drainage patterns result in increased runoff volumes and peak runoff rates. The cumulative impacts of the land cover changes result in alterations of the natural hydrology of a site, which disrupts the natural water balance and changes water flow paths. The consequences of these impacts include:

1. *Increased volume of runoff*. With decreased area for infiltration and evapotranspiration due to development, a greater amount of rainfall is converted to overland runoff which results in larger stormwater discharges.
2. *Increased peak flow of runoff*. Increased impervious surface area and higher connectivity of impervious surfaces and stormwater conveyance systems increase the flow rate of stormwater discharges and increase the energy and velocity of discharges into the stream channel.
3. *Increased duration of discharge*. Detention systems generate greater flow volumes for extended periods. These prolonged higher discharge rates can undermine the stability of the stream channel and induce erosion, channel incision and bank cutting.

4. *Increased pollutant loadings*. Impervious areas are a collection site for pollutants. When rainfall occurs these pollutants are mobilized and transported directly to stormwater conveyances and receiving streams via these impervious surfaces.
5. *Increased temperature of runoff*. Impervious surfaces absorb and store heat and transfer it to stormwater runoff. Higher runoff temperatures may have deleterious effects on receiving streams. Detention basins magnify this problem by trapping and discharging runoff that is heated by solar radiation (Galli, 1991; Schueler and Helfrich, 1988).

The resulting increases in volume, peak flow, and duration are illustrated on a hydrograph, which is a representation of a site's stormwater discharge with respect to time. The hydrograph below reflects the impacts of development on runoff volume and timing of the runoff. Individual points on the curve represent the rate of stormwater discharge at a given time. The graph shows that development and corresponding changes in land cover result in greater discharge rates, greater volumes, and shorter discharge periods. In a natural or pre-development condition, runoff rates are slower and occur over a longer time period. The predevelopment peak discharge rate is also much lower than the post-development peak discharge rate due to attenuation and absorption by soils and vegetation. In the post-development condition there is generally a much shorter time before runoff begins because of increased impervious surface area, a higher degree of connectivity of these areas and the lost of soils and vegetative cover that slow or reduce runoff.

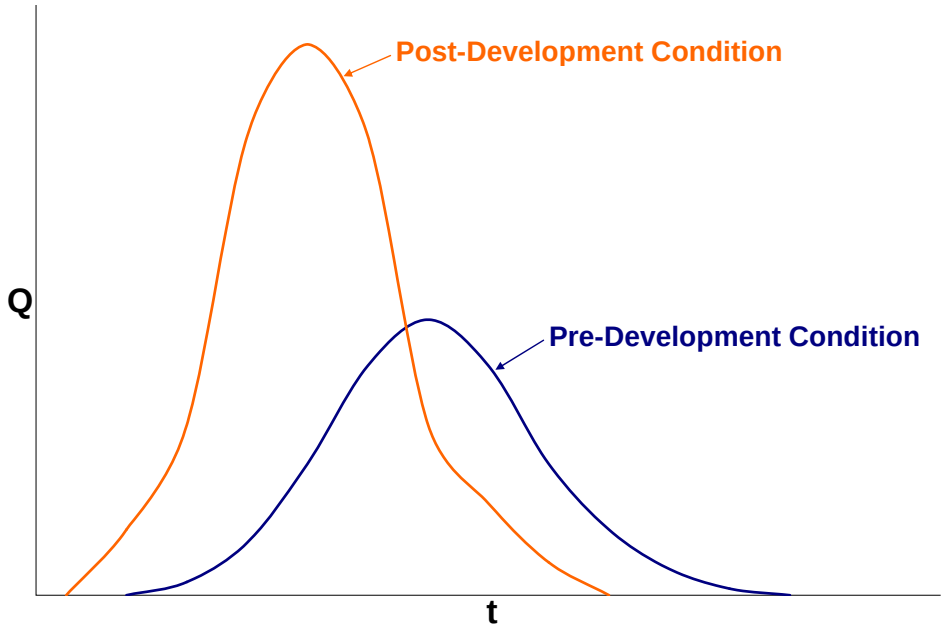


Figure 2. Post-Development Hydrograph.
(Q = volumetric flow rate; t = time)

In addition to the problems caused by stormwater and nonpoint source runoff, many older cities (including many of the largest cities in the United States), have combined sewage and stormwater pipes that frequently overflow due to precipitation events. By the late 20th century, most cities that attempted to reduce sewer overflows did so by separating combined sewers, expanding treatment capacity or storage within the sewer system, or by replacing broken or decaying pipes. However, these practices can be enormously expensive and take decades to

implement. Moreover, piped stormwater and combined sewer overflows (CSOs) may also, in some cases, have the adverse effect of upsetting the hydrological balance by moving water out of the watershed, thus bypassing local streams and ground water.



Figure 3. Stream Displaying the Effects of Stormwater Runoff and Channel Downcutting.

The Solution: Preserving and Restoring Hydrology

A new approach has evolved in recent years to eliminate or reduce the amount of water and pollutants that run off a site and ultimate are discharged into adjacent waterbodies.

The fundamental principle is to employ systems and practices that use or mimic natural processes to 1) infiltrate and recharge, 2) evapotranspire, and/or 3) harvest and reuse precipitation near to where it falls to earth.

Green infrastructure practices include a wide variety of practices that utilize these mechanisms. They can be used at the site, neighborhood and watershed/regional scales. In this document the focus is on site-level practices, which is most consistent with the terms used in Section 438: "project", "facility", and "property."

The purpose of the new approach is to replicate pre-development hydrology to protect and preserve both the water resources onsite and those downstream. For example, if prior to development, five (5) percent of the annual rainfall runs directly into the stream and the remainder infiltrates into the ground or is evapotranspired into the air, then the post-development goal should be to limit runoff to five (5) percent while maintaining the correct aquifer recharge rate. This has the benefit, in most cases, of delivering water to the stream at approximately the same rate, volume, duration and temperature as the stream had evolved to handle most effectively and safely. The result will be to eliminate or minimize the erosion of streambeds and streambanks, significantly reduce the delivery of many pollutants to water bodies, and retain historical instream temperatures.

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Restoring or maintaining pre-development hydrology has emerged as a control approach for several reasons. Most importantly, this approach is intended to directly address the root cause of impairment. Current control approaches have been selected in an attempt to control the symptoms (peak flow, and excess pollutants), but this strategy is largely ineffectual because of the scale of the problem, the cumulative impacts of multiple developments and the need to manage both site and watershed level impacts. With current approaches, it is also difficult to adequately protect and improve water quality because the measures employed are not addressing the main problem which is a hydrologic imbalance.

Designing facilities based on the goal of maintaining or restoring predevelopment hydrology provides a site specific basis and objective method with which to determine appropriate practices to protect the receiving environment.

Using pre-development hydrology as the guiding control principal also allows the designer to consider climatic and geologic variability and tailor the solutions to the site and geographic location. Thus the need for a one size fits all approach is rendered unnecessary since the design objective is dictated by the pre-development site conditions and not a solution based on ease of administration. Instead of prescribed approaches dictating discharge volumes or flow rates, site assessments of historical infiltration and runoff rates will inform the designer and provide the basis for a suitable design. The use of this approach will minimize compliance complications that may arise from prescriptive designs approaches which do not account for the variability of precipitation frequencies, rainfall intensities and land cover and soil conditions that influence infiltration and runoff.

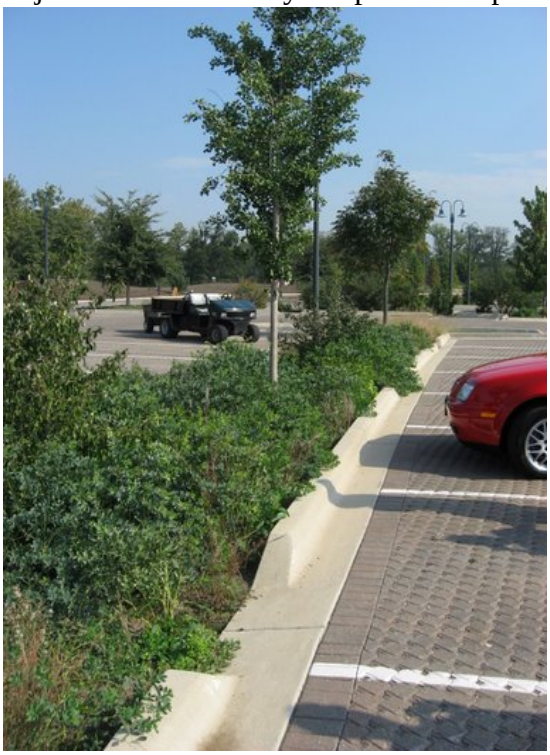

Figure 4. Parking lot bioswale and permeable pavers in Chicago.

This approach also helps to prevent and reduce pollutant loadings to both groundwater and surface waters. Traditional stormwater controls typically are designed to reduce the concentration of pollutants in runoff without addressing the increased volume of stormwater discharged from developed areas. Although removal of pollutants is an important aspect of stormwater management, the larger problem resulting from increased flow volumes and rates often overshadows the gains achieved by a pollutant focused approach. Even with stormwater controls and high rates of pollutant removal, absent volume reductions, urban areas will contribute more pollution than pre-development conditions making it difficult to achieve water quality standards. Table 1 below highlights this condition with the familiar example of the runoff from a one-acre meadow and one-acre parking lot after one-inch of rain.

Table 1. Runoff Volume and Pollutant Load from One-Acre Parking Lot with Treatment and Meadow for a One-Inch Rain Event (Schueler and Holland, 2000)(Wisconsin DNR, 2008).

Land Use	Pollutant	Concentration (mg/L)	% Removal	Effluent Concentration (mg/L)	Runoff Volume (gal)	Pollutant Load (lbs)
Paved Parking Lot with Treatment	TSS	130	80	26	25,800	5.6
Meadow		25	0	25	1,600	0.34

The data in the table show that even when treatment measures were used to reduce discharge (effluent) pollutant concentrations to levels similar to pre-development conditions, the large increase in runoff volume due to the parking lot caused a pronounced increase in total pollutant loadings. To maintain predevelopment pollutant loadings, the designer has two main choices, i.e., reduce pollutant loadings by designing the site and treatment systems to mimic the pre-development hydrology of the site or significantly raise the pollutant removal rates (% removal) to almost irreducible levels using very effective and probably expensive practices.

B. Benefits and Outcomes of the New Stormwater Performance Requirements

Implementation of these new stormwater performance requirements provides numerous environmental and economic benefits in addition to reducing the volume of sewer overflows and runoff:

Benefits to Water Resources:

- *Cleaner Water.* The use of plants, soils and water reuse practices can reduce stormwater runoff volumes and pollutant loadings and the frequency and magnitude of combined sewer overflows (volume and pollutant loading reductions). These practices are part of a larger set of practices called Green Infrastructure.
- *Clean and Adequate Water Supplies.* Green infrastructure approaches using soil based vegetated infiltration systems can be used to recharge groundwaters and maintain stream base flow. By recharging groundwater aquifers, aquatic ecosystem health is maintained and base flows are increased which helps ensure more constant flows for drinking water withdrawals. Harvesting and reusing rainwater also reduces the need to use potable water for all uses and can reduce both the infrastructure and energy needed to treat and transport both drinking water and stormwater.
- *Source Water Protection.* Green infrastructure practices provide pollutant removal benefits, thereby providing some protection for both ground water and surface water sources of drinking water. In addition, green infrastructure provides groundwater recharge benefits.

Green infrastructure for managing wet weather is a set of management approaches and technologies that utilize and/or mimic the natural hydrologic cycle processes of infiltration, evapotranspiration and reuse. Green infrastructure practices include green roofs, trees and tree boxes, rain gardens, vegetated swales, pocket wetlands, infiltration planters, porous and permeable pavements, vegetated median strips, reforestation and revegetation and protection of riparian buffers and floodplains. Green infrastructure can be used almost anywhere soil and vegetation can be worked into the urban or suburban landscape. Green infrastructure includes decentralized harvesting approaches such as rain barrels and cisterns that can be used to capture and re-use rainfall for watering plants or flushing toilets.

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Other Social and Environmental Benefits:

- *Cleaner Air.* Trees and vegetation improve air quality by filtering many airborne pollutants and can help reduce the amount of respiratory illness (Vingarzan and Taylor, 2003).
- *Reduced Urban Temperatures.* Summer city temperatures can average 10ºF higher than nearby suburban temperatures (Casey Trees, 2007). High temperatures are also linked to higher ground level ozone concentrations. Vegetation creates shade, reduces the amount of heat absorbing materials and emits water vapor – all of which cool hot air (Grant, et al., 2003). Reductions in impervious surface and the use of light colored pervious surfaces (e.g., permeable concrete) also can mitigate urban temperatures.
- *Moderate the Impacts of Climate Change.* Climate change impacts and effects vary regionally, but green infrastructure techniques can provide adaptation benefits for a wide array of circumstances. They can be used to conserve, harvest and reuse water, to recharge groundwaters and to reduce surface water discharges that could contribute to flooding. In addition, there are mitigation benefits such as reduced energy demand and carbon sequestration by vegetation.
- *Increased Energy Efficiency.* Green space helps lower ambient temperatures and, when incorporated on and around buildings, helps shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. Diverting stormwater from wastewater collection, conveyance and treatment systems can reduce the amount of energy needed to pump and treat the water. Energy efficiency not only reduces costs, but also reduces generation of greenhouse gases.
- *Community Benefits.* Trees and plants improve urban aesthetics and community livability by providing recreational and wildlife areas. Studies show that property values are higher when trees and other vegetation are present. Increased green space also has public health benefits and has been shown to reduce crime and associated the associated stresses of urban living.



Figure 5. Rainwater cistern.

C. HOW TO MEET THE REQUIREMENTS OF SECTION 438

"Section 438. Storm water runoff requirements for federal development projects. The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

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Compliance with Section 438 of the EISA can be achieved through either of the two performance requirements described below. The intention of the statute is to preserve or restore site hydrology during the development or redevelopment process. To be more specific, this requirement is intended to maintain stream flows that are protective of aquatic biota, stream channel stability, and historical aquifer recharge rates such that receiving waters are not negatively impacted by changes in runoff temperature, volumes, durations and rates. It should also be noted that a performance based approach was selected in lieu of a prescriptive requirement in order to provide site designers maximum flexibility in selecting control practices appropriate for the site. Described below are the two options site designs can use to comply with Section 438.

Option 1: Control of the 95th Percentile Rainfall Event

Design, construct, and maintain stormwater management practices that manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 95th percentile rainfall event. This objective shall be accomplished by the use of practices that infiltrate, evapotranspire and/or harvest and reuse rainwater. The 95th percentile rainfall event is the event whose precipitation total is greater than or equal to 95 percent of all storm events over a given period of record. For example, to determine what the 95th percentile storm event is in a specific location, all 24 hour storms that have recorded values over a 20 or 30 year period would be tabulated and a 95th percentile storm would be determined from this record, i.e., 5% of the storms would be greater than the number determined to be the 95th percentile storm. Thus the 95th percentile storm would be represented by a number such as 1.5", and this would be the design storm. The designer would then select a system of practices that infiltrate, evapotranspire or harvest and reuse this volume. Methods and data used to estimate the 95th percentile event are discussed in Part II of this document.

This approach has been selected because it directly addresses the statutory requirements to restore and maintain predevelopment hydrology for duration, rate and volume of stormwater flows. The 95th percentile storm event was selected because this storm size approximates the predevelopment hydrologic conditions, i.e., only large storms typically generate runoff. In addition, this approach was selected because it employs natural treatment and flow attenuation methods that are presumed to have existed on the site prior to human disturbance. Because this approach necessitates the use of practices that generally preclude extended detention, it will also typically address the issue of maintaining predevelopment temperatures. However, in cases where there are discharges to cool water streams or other sensitive receiving waters, additional care should be taken to ensure that stormwater discharges do not result in thermal impacts (Schueler and Helfrich, 1988).

One hundred percent (100%) of the volume of water from storms less than or equal to the 95th percentile event shall not be discharged to surface waters except in cases where the discharge of harvested and reused runoff is authorized or allowed to be discharged into sanitary treatment systems such as those owned and operated by a publicly owned treatment works (POTW). For example if runoff is captured for nonpotable uses such as toilet flushing or other uses that are not irrigation related, these waters potentially could be discharged into the sanitary sewer system. Preferred mechanisms for controlling discharges from storms greater than the 95th percentile event shall be through overflow or diversion for the volume that exceeds the 95th percentile

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amount. Because standard underdrains typically discharge from smaller storms as well, underdrain designs, if employed, should ensure adequate retention capacity for the 95th percentile event volume. For structures such as roofs and paved surfaces that can increase the temperature of stormwater runoff, materials that minimize temperature increases (e.g., concrete vs. asphalt; vegetated roofs) should be considered and used as appropriate.

Table 2. Example 95th Percentile Storm Events for Select U.S. Cities (adapted from Hirschman and Kosco, 2008).

City	95th Percentile Event Rainfall Total (in)	City	95th Percentile Event Rainfall Total (in)
Atlanta, GA	1.8	Kansas City, MO	1.7
Baltimore, MD	1.6	Knoxville, TN	1.5
Boston, MA	1.5	Louisville, KY	1.5
Buffalo, NY	1.1	Minneapolis, MN	1.4
Burlington, VT	1.1	New York, NY	1.7
Charleston, WV	1.2	Salt Lake City, UT	0.8
Coeur D'Alene, ID	0.7	Phoenix, AZ	1.0
Cincinnati, OH	1.5	Portland, OR	1.0
Columbus, OH	1.3	Seattle, WA	1.6
Concord, NH	1.3	Washington, DC	1.7
Denver, CO	1.1		

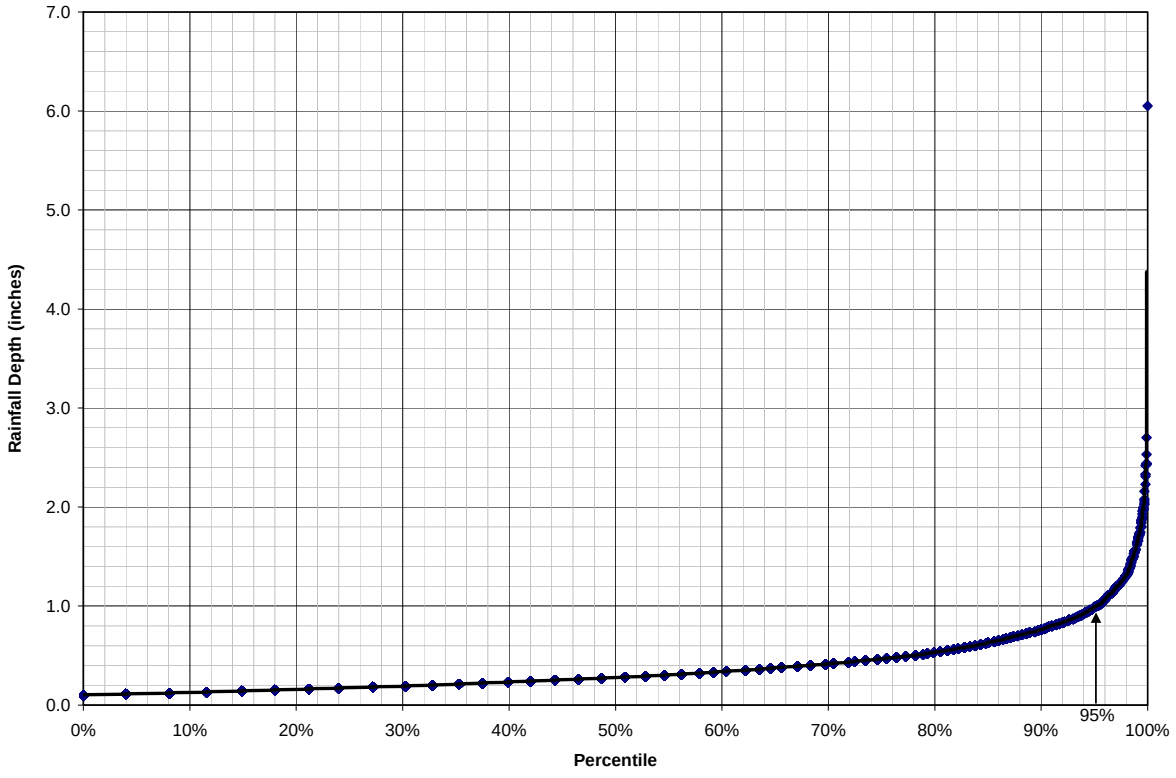


Figure 6. Rainfall Frequency Spectrum showing the 95th percentile rainfall event for Portland, OR (~1.0 inches)

Calculating the 95th Percentile Rainfall Event
Section F of this guidance contains information on how to calculate the 95th percentile rainfall event for a specific area. A long-term record of daily rainfall amounts (ideally, at least 30 years) is needed to calculate the 95th percentile rainfall.

Option 2: Hydrologic Analysis
Design, construct/implement, and maintain stormwater management practices that preserve the pre-development runoff conditions following construction. The post-construction rate, volume, duration and temperature of runoff shall not exceed the pre-development rates and the predevelopment hydrograph for 1, 2, 10, 25, 50 and 100 year storms should be replicated through site design and other appropriate practices. These goals shall be accomplished through the use of the infiltration, evapotranspiration, and/or rainwater harvesting and reuse. Defensible and consistent hydrological assessments and modeling methods should be used and documented. Additional discussions of appropriate methodologies to use in assessing and modeling site hydrology have been included in the technical sections of this document.

Exceptions
If options 1 or 2 cannot be met using combinations of approaches that are technically feasible, alternative procedures should be developed and followed to meet the intent of Section 438. For an exception to apply the facility owner/operator must demonstrate why it is not possible to comply with either option 1 or 2. In doing so, the owner/operator should identify the factors that preclude the use of options 1 and 2 and document any of the factors listed below (or others) that are relevant to and prevent the achievement of these two options.

- The conditions on the site preclude the use of infiltration practices due to the presence of shallow bedrock, contaminated soils, near surface groundwater or other factors such as underground facilities or utilities.
- The design of the site precludes the use of soil amendments, plantings of vegetation or other designs that can be used to infiltrate and evapotranspirate runoff.
- Water harvesting and reuse are not practical or possible because the volume of water used for irrigation, toilet flushing, industrial make-up water, wash-waters, etc. is not significant enough to warrant the design and use of water harvesting and reuse systems.
- Modifications to an existing building to manage stormwater to meet options 1 or 2 are not feasible due to structural or plumbing constraints or other factors as identified by the facility owner/operator.

An exception may also be granted if it is determined that compliance with the Section 438 requirements would result in the retention and or use of stormwater on the site such that an adverse water balance impact may occur to either or both the receiving surface waterbody or groundwater.

In cases where the facility has a defensible exception and can provide adequate documentation of site conditions or other factors that preclude compliance with options 1 or 2, stormwater practices must be designed, built and maintained to infiltrate, evapotranspire and/or harvest and use the maximum amount of stormwater technically feasible. The difference between this

volume and the 95th percentile rainfall event volume must be treated, as necessary, to ensure no increase in receiving stream temperature and no increase in the peak runoff rates of stormwater leaving the site such that no adverse effects to channel stability occur.

Each Agency or Department is responsible for ensuring compliance with Section 438. The final design and as-built drawings of each facility shall be reviewed by a registered professional engineer. The Agency or Department shall develop and maintain documentation of the following design criteria:

- Site evaluation and soils analysis
- Calculations for the 95th percentile rainfall event or the pre-development runoff volumes and rates to identify the volume of stormwater requiring management
- The site design and stormwater management practices employed on the site
- Design calculations for each stormwater management practice employed
- The respective volume of stormwater managed by each practice
- Operations and maintenance protocols for the stormwater management system

The submitted documentation shall provide the necessary detail to demonstrate compliance and operation of stormwater management practices for the entire site.

Determination of Maximum Extent Technically Feasible

Compliance with Section 438 requires that stormwater management measures are implemented to the maximum extent technically feasible (METF) to maintain or restore the pre-development hydrology conditions specifically with respect to temperature, rate, volume, and duration of flow. To meet these performance requirements stormwater control practices that are effective in reducing the volume of stormwater discharge must be used. To meet the intent of the statute, the Federal facility must use all known, available and reasonable methods of stormwater retention and/or reuse to prevent the off site discharge of stormwater runoff consistent with the performance standard. In cases when a facility seeks or claims an exception, it is expected that there will be a serious and documented attempt to comply.

For projects where an exemption from the Section 438 requirements is necessary due to technical infeasibility, the designer must document and quantify, to the satisfaction of the agency or department, that the processes of infiltration, evapotranspiration, and harvesting and reuse have been used to the METF, and that full employment of these types of controls are infeasible due to site constraints. Documentation should include, but may not be limited to, engineering calculations, geologic reports, hydrologic analyses, and site maps. A determination that the performance requirements specified in options 1 and 2 cannot be met on site must include analyses that rule out the use of an adequate combination of infiltration, evapotranspiration, and reuse measures. Examples of where site conditions may prevent the full employment of appropriate management techniques include a combination of: small project sites where the lot is too small to accommodate infiltration practices adequately sized to infiltrate the volume of runoff from impervious surfaces, soils that cannot be sufficiently amended to provide for the requisite infiltration rates, situations where site use is inconsistent with the capture and reuse of stormwater or other physical conditions on site that preclude the use of plants for

evapotranspiration or bioinfiltration. Note that a single one of these characteristics is very unlikely to preclude meeting the performance standard, but a combination of factors may.

D. APPLICABILITY AND DEFINITIONS

Applicability

1. Who is a **"Sponsor"** of a project?

Section 438 applies to the "**sponsor** of any development or redevelopment project involving a Federal facility . . . ." Section 438 requires that the "sponsor . . . shall use . . . strategies for the property to maintain or restore . . . the predevelopment hydrology. . . ." The "sponsor" should generally be regarded as the Federal department or agency that owns, operates, occupies or is the primary user of the facility and has initiated the development or redevelopment project. If the Federal agency hires another entity to perform activities such as site construction or maintenance, the agency should nonetheless be regarded as the sponsor and be responsible to assure compliance with the requirements of Section 438. Within this legal context, the agency is free to contract out various duties and responsibilities that are associated with achieving compliance.

2. What is a "**Federal facility**?

Section 438 provides that its requirements apply to the "sponsor of any development or redevelopment project involving a **Federal facility** . . . **."** Section 401(8) of EISA states: "The term `Federal facility' means any building and lands associated with a development or redevelopment project that are constructed, renovated, leased, or purchased in part or in whole for use by the Federal Government."

3. What is a **"footprint**"?

Section 438 provides that its requirements apply to a "federal facility with a **footprint** that exceeds 5000 square feet". Consistent with the purpose of Section 438 to preserve or restore predevelopment hydrology, the term "footprint" includes all hard surfaces that are constructed as part of the facility, including the building, foundations, access roads, fire lanes, driveways, alleys, walkways, sidewalks, patios, decks, and porches. In addition, consistent with the purpose of Section 438, "footprint" also includes other areas that have been disturbed and modified in a manner that changes the infiltrative and evapotranspirative characteristics of the landscape so that the hydrologic regime of the site is altered, e.g., soil compaction, tree cutting and paving with impervious materials.

4. What is "**the property**"?

Section 438 provides that the project sponsor "shall use site planning, design, construction, and maintenance strategies for the **property** to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the **property".** This clause has been interpreted to mean that the entire site is available to implement the appropriate green

infrastructure practices necessary to ensure that the site as a whole functions hydrologically in a manner equivalent to the pre-development (i.e., natural condition) hydrology of the site.

Definitions

95th percentile rainfall event. A rainfall event that is greater than 95% of all rainfall events over a period of record (this period of record should typically be > 30 years unless such data do not exist), **excluding small rainfall events that are 0.1 of an inch or less**. Note: Small rainfall events less than 0.1 of an inch or less have been excluded from this analysis because in general this volume does not result in any measureable runoff due to absorption, interception and evaporation by permeable, impermeable and vegetated surfaces.

Federal facility. The term federal facility means any building and associated land areas that are constructed, renovated, leased, or purchased in part or in whole for use by the Federal Government as defined in §410(8) of the Energy Independence and Security Act.

Development or re-development. For the purposes of this provision this term applies to any action that results in the alteration of the landscape, e.g., grading, construction of buildings and hardscapes, removal of vegetation, soil compaction, etc. such that the changes affect runoff volumes, rates and velocities and infiltration and evapotranspiration patterns. To further clarify the applicability of this requirement, the development or re-development footprint of the project includes all areas physically disturbed by the project activities and does not just include the typical "footprint" or foundation area of the structures and buildings. Examples of projects that would fall under this definition include parking lots or structures that are being reconstructed or replaced. Typical patching or superficial resurfacing of parking lots or other travel areas would not fall under this requirement.

Pre-development hydrology. The predevelopment hydrologic condition of the site is the combination of runoff, infiltration and evapotranspiration rates and volumes that typically existed on the site before human induced land disturbance occurred. In practice, determining the predevelopment hydrology of a given site can be difficult if development has already occurred or there is no suitable reference site. As a result, reference conditions for typical land cover types in the locality often are used to approximate what fraction of the precipitation ran off, soaked into the ground or was evaporated from the landscape. The use of reference conditions can be problematic if suitable data are not available or unique site conditions exist that do not fit within a typical land use cover type for the area, e.g., meadow or forest. The intent of Section 438 is not to restore the site to pre-Columbian conditions, but to develop or redevelop the site to ensure that there is a stable hydrologic regime that protects groundwater and surface waters. It should also be emphasized that the performance based approach in Option 1 is intended to be a surrogate for determining the predevelopment reference condition and this standard can be used in cases where it is difficult or infeasible to identify the relevant reference conditions for the site.

E. COMPLYING WITH THE PERFORMANCE REQUIREMENT

Controlling 100 percent of all rainfall events equal to or less than the 95th percentile rainfall event was selected as the first compliance option because small, frequently-occurring storms account for a large proportion of the annual precipitation volume, and the runoff from those storm events also significantly alters discharge frequency, rate and temperature.



Figure 7. Bioretention facility in Oregon.

The runoff produced by these small storms and the initial portion of larger storms, has a strong negative cumulative impact on receiving water hydrology and water quality. In areas that have been developed, runoff is generated from almost all storms, both small and large, due to the impervious surfaces associated with development and the loss of soils and vegetation. In contrast, natural or undeveloped areas discharge little or no runoff from small storms because the rain is absorbed by the landscape and vegetation. Studies have shown that increases in runoff event frequency, volume and rate can be diminished or eliminated through the use of green infrastructure designs and practices, which infiltrate, evapotranspire and capture and use stormwater.

This option was selected because it is a straightforward approach to meet the intent of Section 438 in contrast to Option 2 which requires the designer to conduct a detailed hydrologic analysis of the site and model potential outcomes based on site specific conditions.

Designers opting to use Option 1 would need to do the following:

1) calculate or verify the precipitation amount from the 95th percentile storm event (this number would be typically expressed in inches, e.g., 1.5", and

2) Employ on-site stormwater management controls that infiltrate, evapotranspire or harvest and use the appropriate design volume.

The 95th percentile event can be calculated by using the following procedures below (summarized from Hirschman and Kosco, 2008, *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program*, Center for Watershed Protection):

- Obtain a long-term rainfall record from a nearby weather station (daily precipitation is fine, but try to obtain at least 30 years of daily record). Long-term rainfall records can be obtained from many sources, including NOAA at www.nesdis.noaa.gov

- Remove data for small rainfall events that are 0.1 inch or less and snowfall events that do not immediately melt from the data set. These events should be deleted since they do not typically cause runoff and could potentially cause the analyses of the 95th percentile storm runoff volume to be inaccurate.
- Using a spreadsheet or simple statistical package, sort the rainfall events from highest to lowest. In the next column, calculate the percentage of rainfall events that are less than each ranked event (event number/total number of events). For example, if there were 1,000 rainfall events and the highest rainfall event was a 4" event, then 999 events (or a percentile of 999/1000, or 99.9%) are less the 4" rainfall event.
- Use the rainfall event at 95% as the 95th percentile storm event.

Option 2 allows the designer to conduct a full hydrologic analysis to determine the pre-development runoff conditions instead of using the estimated volume approach of Option 1. If the designer elects to use Option 2, the designer would then identify and model appropriate land uses for the pre-development condition of the site and quantify that the post-development runoff volume and peak flow discharges are equivalent to pre-development conditions.

Common Practices to Comply with Section 438

Although Congress did not prescribe specific practices to be used to comply with Section 438 it can be inferred that one of the goals of the Act was to promote the use of innovative stormwater management approaches, designs and practices that better protect receiving water quality, flow regimes and provide other important environmental benefits. Green infrastructure practices are preferred practices, to be supplemented with or replaced with conventional controls when site specific conditions dictate.

The green infrastructure management approaches and technologies that Federal agencies would typically use enhance and/or mimic the natural hydrologic cycle processes of infiltration, evapotranspiration, and reuse. Green infrastructure approaches include biological systems and engineered systems. These include but are not necessarily limited to:

- Green roofs
- Trees and tree boxes
- Rain gardens, bioretention, and infiltration planters
- Vegetated swales and bioswales
- Pocket wetlands
- Permeable pavements
- Reforestation/revegetation
- Protection and enhancement of riparian buffers and floodplains
- Rainwater harvesting for reuse (e.g., irrigation, HVAC make-up, non-potable indoor uses).

Green infrastructure practices were selected to achieve the intent of the Act for the following reasons:

- cost effectiveness
- overall environmental performance

- pollutant loading reduction capability
- pollution prevention focused
- effectiveness in managing runoff volumes and rates
- energy efficient and energy conservative
- appropriate in a wide range of site condition and locations
- appropriate for new development and redevelopment projects
- appropriate at multiple scales of development, e.g., site, neighborhood, region

For more information on specific green infrastructure practices and how they function, visit: http://www.epa.gov/greeninfrastructure and www.epa.gov/nps/lid.



Figure 8. Disconnect downspout discharging to planter box.

Cost of Compliance

The cost of complying with Section 438 may require the use of approaches and techniques that initially may be more costly to design and implement. It is anticipated that as the expertise of the implementing agency or department increases and the demand for green infrastructure materials and equipment increases that the overall costs of the projects will be lower or equivalent to the costs of constructing conventional stormwater practices. Initial studies conducted by EPA and others suggest that the use of green infrastructure practices can be cost competitive. Recent evaluations of green infrastructure projects have identified opportunities for cost savings because of reduced infrastructure and site preparation demands. In addition, longer term studies have indicated that green infrastructure practices are continuing to gain cost efficiency as they are adopted more widely and with greater frequency thus reducing overall implementation costs.

In *Reducing Stormwater Costs through LID Strategies and Practices* (EPA 841-F-07-006, December 2007 - available for download at www.epa.gov/nps/lid), EPA examined 17 case studies in which conventional development costs were compared to green infrastructure costs. In the great majority of cases, the green infrastructure approach was between 15 and 80 percent cheaper and in some cases significantly they were less expensive because the incremental costs of implementing green infrastructure practices were more than offset by the cost reductions achieved by their use and management. Significant cost savings that were identified in the report include:

- Elimination or reduction of detention ponds
- Elimination or reductions of stormwater and CSO treatment and conveyance systems such as pipes, storage structures, stormwater treatment devices, and other related stormwater infrastructure

- Narrower streets with reduced material demands
- Fewer square yards of sidewalks
- Reduced land purchases for stormwater control structures

In addition, other benefits were achieved through the use of green infrastructure such as more beneficial uses of land previously dedicated to stormwater devices, increased livability and higher property values.

F. CALCULATING THE 95TH PERCENTILE RAINFALL EVENT

A long period of precipitation records, i.e., a minimum of 10 years of data, is needed to determine the 95th percentile rainfall event for a location. Thirty years or more of monitoring data are desirable to process an unbiased statistical analysis. The National Climatic Data Center (NCDC) provides long-term precipitation data for many locations of the United States. You can download climate data from their website (http://www.ncdc.noaa.gov) or by ordering compact discs (NOTE: The NCDC charges a fee for access to their precipitation data). Local airports, universities, water treatment plants, or other facilities might also maintain long-term precipitation records. Data reporting formats can vary based on the data sources. In general, each record should include the following basic information:

- Location (monitoring station)
- Recording time (usually the starting time of a time-step)
- Total precipitation depth during the time-step

In addition to the above information, a status flag is sometimes included to indicate data monitoring errors or anomalies. Typical NCDC flags include A (end accumulation), M (missing data), D (deleted data), or I (incomplete data). If there are no flags, the record has passed the quality control as prescribed by the NCDC and has been determined to be a valid data point.

There are several steps of data processing to determine the 95th percentile rainfall event using a spreadsheet. These steps are summarized below:

1. Obtain a long-term 24-hr precipitation data set for a location of interest (i.e., from the NCDC website).

2. Import the data into a spreadsheet. [Data / Import External Data / Import Data]

3. Rearrange all of the precipitation records into one column if the original data set has multiple columns of precipitation records.

	A	B	C	D
1	Date	Prcp		
2	1/2/1921	0.05		
3	1/3/1921	0		
4	1/4/1921	0		
5	1/5/1921	0.33		
6	1/6/1921	0.08		
7	1/7/1921	0.08		
8	1/8/1921	0.19		
9	1/9/1921	0		

4. Review the records to identify if there are early periods with a large number of flagged data points (e.g., erroneous data points). Select a long period of good recording data that represents, ideally, 30 years or more of data. Remove all of the extra data (if not using the entire dataset).

5. Remove all flagged data points (i.e., erroneous data points) from the selected data set for further analysis.

6. Remove small rainfall events (typically less than 0.1 inches), which may not contribute to rainfall runoff. These small events are categorized as depressional storage, which, in general, does not produce runoff from most sites.

	A	B	C	D
1	Date	Prcp		
2	1/5/1921	0.33		
3	1/8/1921	0.19		
4	1/14/1921	1.04		
5	2/6/1921	0.12		
6	2/11/1921	0.63		
7	2/20/1921	1.33		
8	2/28/1921	0.43		
9	3/3/1921	0.13		

Note: Steps 4 through 6 can be processed by applying data sort, delete and re-sort spreadsheet functions. [Data / Sort]

7. Calculate the 95th percentile rainfall amount by applying the PERCENTILE spreadsheet function at a cell: [=PERCENTILE(precipitation data range,95%)]

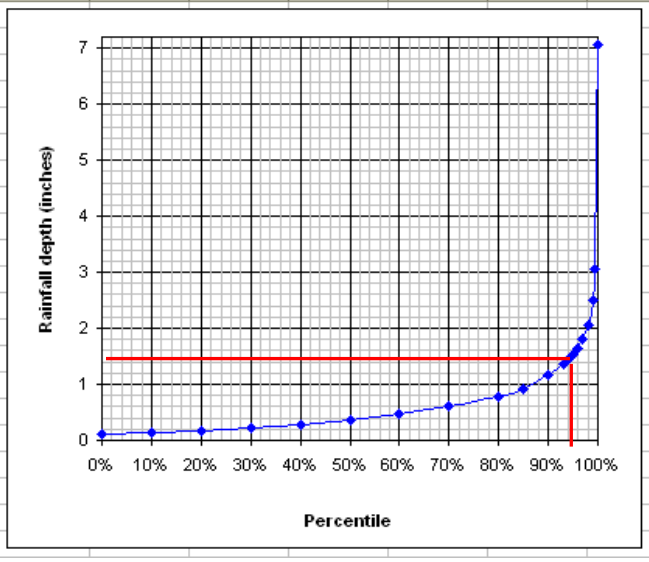
	A	B	C	D	E	F
1	Date	Prcp				
2	1/5/1921	0.33		=PERCENTILE(B:B,95%)		
3	1/8/1921	0.19		1.52		
4	1/14/1921	1.04				
5	2/6/1921	0.12				
6	2/11/1921	0.63				
7	2/20/1921	1.33				
8	2/28/1921	0.43				

Note: The PERCENTILE function returns the nth percentile of value in the entire precipitation data range. We can use this function to decide the 95th percentile storm event that captures all but the largest 5% of storms.

8. The 95th percentile rainfall event can also be determined graphically. Derive a table showing percentile versus rainfall depth to draw a curve shown as shown below. The PERCENTILE spreadsheet function can be used for each selected percent. It is recommended to include at least 6 points between 0% and 100% (several points should be between 80% and 100% to draw an accurate curve).

	A	B	C	D	E	F	G
1	Date	Prcp		Percentile	Rainfall		
2	1/5/1921	0.33		0%	=PERCENTILE(B:B,D2)		
3	1/8/1921	0.19		10%	=PERCENTILE(B:B,D3)		
4	1/14/1921	1.04		20%	=PERCENTILE(B:B,D4)		
5	2/6/1921	0.12		30%	=PERCENTILE(B:B,D5)		
6	2/11/1921	0.63		40%	=PERCENTILE(B:B,D6)		

	A	B	C	D	E
1	Date	Prcp		Percentile	Rainfall
2	1/5/1921	0.33		0%	0.1
3	1/8/1921	0.19		10%	0.13
4	1/14/1921	1.04		20%	0.17
5	2/6/1921	0.12		30%	0.22
6	2/11/1921	0.63		40%	0.28
7	2/20/1921	1.33		50%	0.36
8	2/28/1921	0.43		60%	0.46
9	3/3/1921	0.13		70%	0.6
10	3/9/1921	0.31		80%	0.79
11	3/13/1921	0.46		85%	0.93
12	3/25/1921	0.47		90%	1.16
13	3/28/1921	0.12		93%	1.35
14	4/1/1921	0.36		94%	1.44
15	4/9/1921	0.69		95%	1.52
16	4/15/1921	0.24		96%	1.65
17	4/17/1921	0.32		97%	1.82
18	4/18/1921	0.55		98%	2.068
19	4/23/1921	0.69		99%	2.508
20	4/24/1921	0.19		99.5%	3.049
21	4/30/1921	1.44		100%	7.06



Use the spreadsheet software to create of plot of rainfall depth versus percentile, as shown above. The 95th percentile storm event should correlate to the rainfall depth calculated in step 7, however the graph can be used to calculate rainfall depths at other percentiles (e.g., 50%, 90%).

Part II: Case Studies on Capturing the 95th Percentile Storm Using Onsite Management Practices

INTRODUCTION

This section contains eight case studies that are intended to be representative of the range of projects that are subject to the requirements legislated in Section 438 of the Energy Independence and Security Act. The facility examples in the case studies were selected to illustrate project scenarios for differing geographic locations, site conditions, and project sizes and types. As noted in Part I, all projects with a footprint greater than 5,000 square feet must comply with the provisions of Section 438. This means that both new development and redevelopment projects must be designed to infiltrate, evapotranspirate, and/or harvest and reuse runoff to the maximum extent technically feasible (METF) to maintain or restore the pre-development hydrology of the site. In this guidance, METF has been interpreted to mean the onsite control and management of all storms up to and including the 95th percentile storm event.

Given the site-specific nature of individual projects, the case study scenarios described herein do not include site specific design features such as runoff routing, specific site infiltration rates, the structural loading capacity of buildings, etc. in terms of stormwater practice selection.

It should be noted that an example of Option 2, which requires a detailed hydrologic analysis, has not been provided in this document because of the complexity of factors and the lack of general applicability such an analysis would have.

Background

Numerous approaches exist for determining the volume of runoff to be treated through stormwater management. Controlling stormwater runoff from all events up to and including the 95th percentile rainfall event was selected as Option 1 because small, frequently-occurring storms account for a large proportion of the annual precipitation volume. Using green infrastructure practices to control both the runoff produced by small storms and the first part of larger storms can reduce the cumulative impacts of altered flow regimes on receiving water hydrology, e.g., channel degradation and diminished baseflow. For the purposes of this guidance, control of all storms up to and including the 95th percentile storm event is analogous to maintaining or restoring the predevelopment hydrology with respect to the volume, flow rate, duration and temperature of the runoff for most sites.

Determination of the 95th Percentile Rainfall Event

The 95th percentile rainfall rainfall event was determined using the long-term daily precipitation records from the National Climate Data Center (NCDC, 2007). By analyzing the frequency and rainfall depths from daily rainfall records over 24-hour periods, the 95th percentile storm event can be determined. From a frequency analysis viewpoint, the 95th percentile event is the storm event that is greater than or equal to 95% of all storms that occur within a given period of time. Regional climate conditions and precipitation vary across the U.S. Because of local values, it is essential that the implementing agency or department establish the 95th percentile storm event for

the project site since the control volume may vary depending on local weather patterns and conditions.

Onsite Stormwater Management Practice Determinations

For the purposes of the case study scenarios, the following four categories of practices were selected as the most appropriate practices for implementing Section 438 requirements: bioretention, permeable pavements and pavers, cisterns, and green roofs. These practices were selected based on known performance data and cost. For each case study, the same hierarchy of selection criteria was used, i.e., the most cost effective practices were considered before other practices were considered. Bioretention practices were considered first because these systems generally have the lowest cost per unit of stormwater treated (Hathaway and Hunt, 2007). Thus, if the bioretention system could not be designed to adequately capture the desired runoff volume, permeable pavement and pavers, cisterns, and green roofs were considered in that order based on relative cost. In most cases a combination of practices was selected as part of an integrated treatment system. It should be noted that all treatment systems were designed to accomplish the goal of capturing the 95th percentile rainfall event onsite. Examples of onsite stormwater management practices selected for each site are presented in the results section. For the Boston, MA site, it was assumed that bioretention was not feasible in order to simulate a situation where space was severely limited; as a result, interlocking modular pavers were selected as the most cost effective stormwater management to capture the requisite design volume. To further illustrate the range of site conditions designers may encounter, and how site conditions impact the selection of appropriate control options, Scenario #3 (Cincinnati, OH) was re-analyzed as Scenario #8. In Scenario #8, it was assumed that the site had clay soils and low infiltrative capacity. Given these site conditions, the range of potential control options was more limited and a combination of modular paving blocks, a green roof, and cisterns was ultimately selected based on cost and site suitability factors.

For purposes of these modeling exercises, a number of assumptions were associated with each category of practice. These assumptions are not necessarily an endorsement of a particular design paradigm, but rather to keep a somewhat conservative cap on the scenarios in order to demonstrate feasibility of the approach. For example, bioretention retrofits can and should often be located in prior impervious locations; however, in all modeled scenarios bioretention was restricted to currently landscaped areas. The assumptions were:

- **Bioretention areas**: It is assumed bioretention practices would be installed within currently landscaped pervious areas or that pervious areas would be created for bioretention cells. While termed bioretention, these systems are designed to provide infiltration as well as temporary storage. Bioretention areas would be designed to store up to 10 inches of runoff depth from contributing areas (see Appendix A). The conceptual design of this storage depth would occur within the media and/or could be included as ponded storage. Further design storage beyond the 10 inches would be acceptable (and encouraged) above the media on a site by site basis with ponded depth generally not to exceed 12 inches.

  Uniform infiltration was assumed across the entire base of the bioretention cell. No additional media underneath the amended soils were included in the designs with

infiltration rates in this layer governed by the *in situ* soils. Underdrains were not modeled directly but could be applied at the point of storage overflow (at a design depth of 10 inches). This approach was selected to maximize infiltration benefits of these systems. The intent was to provide maximum storage and opportunities for infiltration processes over a pass-through or filtration system which can occur when using an underdrain at the base of the bioretention cell. Because standard underdrains typically discharge from smaller storms as well, underdrain designs, if employed, should ensure adequate retention capacity for the 95th percentile event volume.

The bioretention footprint for modeling purposes was calculated as one uniform area that did not include side slopes. There is an expectation that actual bioretention cell construction would be distributed throughout the site with targeted locations based on hydrology (natural flow paths) and soils with greater infiltrative capacity. Side slopes may increase the surface excavation area required to accommodate the footprint and freeboard of these systems depending on the design or the bioretention system.

- **Porous pavement**: Infiltration was modeled for the entire porous pavement area with drainage pipes used only as overflow outlets. This design was chosen to maximize infiltration capabilities of the system. While many types of porous pavement systems are can be used, modular block type pavers were generally applied in this design category under the assumption that they typically include sufficient volumetric storage in the media layer. Depending on design, other types of porous pavement applications can include similar volumetric storage with equal or improved load bearing benefits.

  For these systems, an equivalent of 2 inches of design storage depth was assumed. This design depth could be achieved by specifying 10 inches of media depth that had 20% void space. Similarly, this could be achieved by designing six inches of media depth above the bottom surface, with specified media containing 33% void space. This alternative would have the overflow outlet at the six inch depth providing an equivalent water storage depth of 2 inches.

  The soils under the paver blocks may require or be subjected to some compaction for engineering stability. As a result, infiltration into underlying soils was modeled conservatively by applying the minimum infiltration rate for each soil type (see Appendix A).

  Generally, porous pavement is not recommended for high traffic areas or loading bays. Because of this the scenarios assumed that only a percentage of total parking and road areas on a site can be converted to porous pavement. The assumed maximum percentage applied in the scenarios was set at 60% of the total paved area.

- **Cistern**: Cisterns were modeled in cases where green roofs were not feasible or where it was necessary to include additional storage volume to meet the goal of on site rainfall runoff capture. The sizes of cisterns would be calculated by site-specific rainfall, site specific spatial and structural conditions, use opportunities and rates, and consideration of cost per volume of storage. For simplicity, cistern volume was reported as a total

volume. This total volume could be subdivided into any number of cisterns to provide the total necessary storage but should be relative to the impervious area and runoff quantities which will flow to the cistern. Consideration of the most efficient cost per volume storage would need to be considered on a site by site basis (see Appendix A).

- **Green roof**: Frequently, green rooftop area is limited by structural capacity. In addition, other rooftop equipment may need to be accommodated in this space including HVAC systems and air handlers. For this reason, and to provide a somewhat conservative rate of application, it was assumed for these modeling analyses that up to 30% of a roof's impervious area could be converted into a green roof. Green roof area was assumed to have 1 inch of total effective stormwater storage, i.e., a 2.5 inch media depth with 40% void space (see Appendix A).

General Approach

Using site aerial photos, spatial analysis should be conducted to estimate the land cover types and areas for each site. The surface conditions of each site can be digitized using GIS techniques. Alternatively, CAD drawings can be used to estimate the surface area of each land cover type. The schematic in Figure 9 illustrates the processes used for selecting and determining the overall size of stormwater management practices for each site.

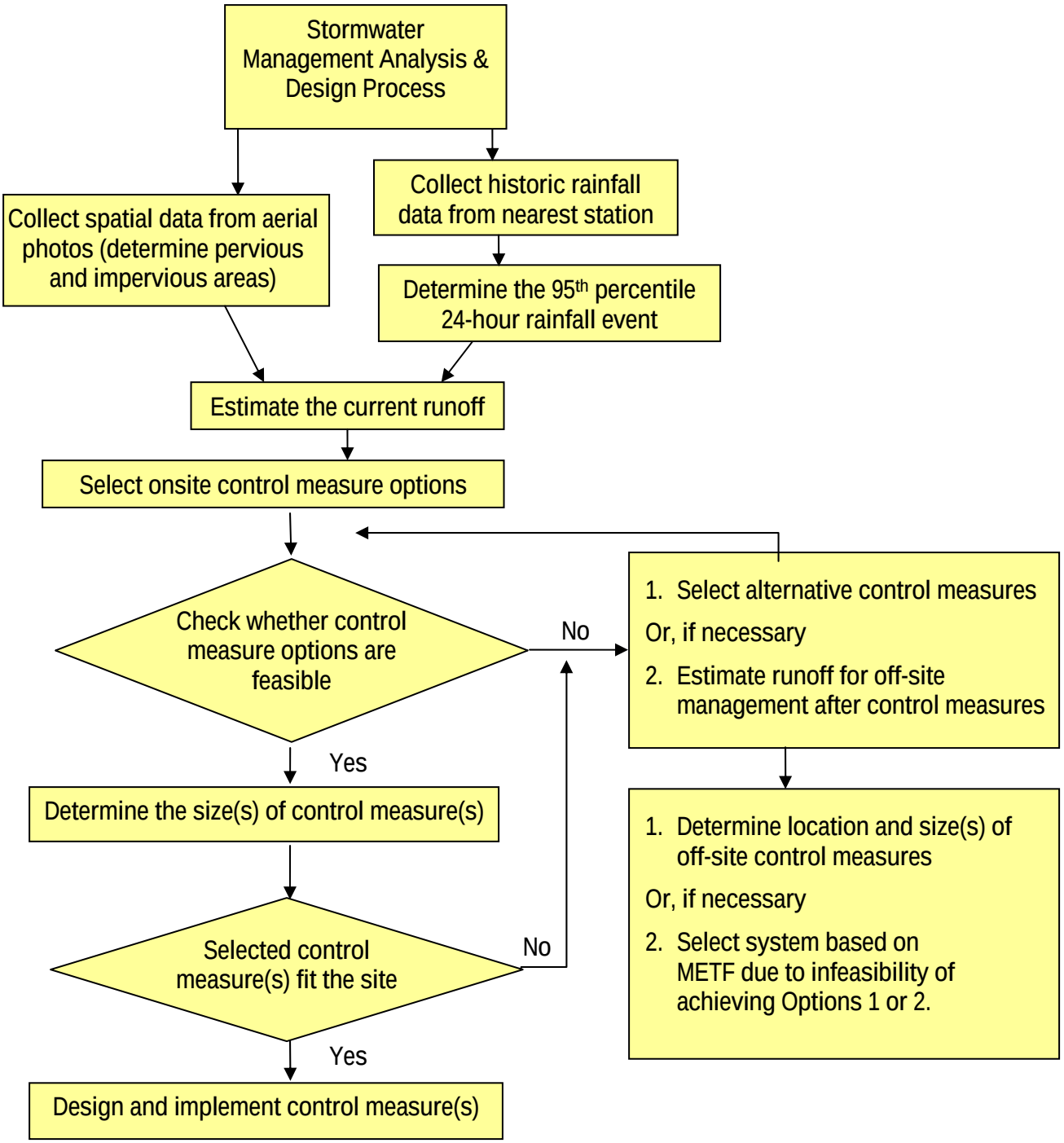


Figure 9. Flow chart depicting the process for determining control measures using the 95th percentile, 24-hour, annual rainfall event.

The following steps provide more detailed information on acquiring and calculating the necessary data to complete the processes indicated in Figure 9. This methodology was used in the scenario analyses that follow.

Collecting spatial data for a site

1. Collect an aerial orthophotograph for the desired site.
2. Digitize land use/land cover conditions using GIS techniques. If CAD drawings of the site exist, they can be used to estimate land cover area (pervious, impervious).
3. Categorize the digitized or planned land use/land cover based on surface hydrologic conditions, e.g., rooftop, pavement, and pervious/landscaped area.
4. Estimate the size of each land use/land cover category (polygon).

Determining the 95th percentile, 24-hr rainfall event

1. Obtain a long-term 24-hr precipitation data set for the location of interest (i.e., from the NCDC website or other source)
2. Import the data into a spreadsheet. *In MS Excel* [Data / Import External Data / Import Data]
3. Rearrange all of the precipitation records into one column if the original data set has multiple columns of precipitation records
4. Remove all flagged data points (i.e., erroneous data points) from the selected data set for further analysis
5. Remove small rainfall events (typically less than 0.1 inches) that may not contribute to rainfall runoff. These small storms often produce little if any appreciable runoff from most sites and for modeling purposes are typically considered as volume captured in surface depression storage.
6. Calculate the 95th percentile rainfall volume by applying the PERCENTILE spreadsheet function at a cell. The PERCENTILE function returns the nth percentile value in the entire precipitation data range. This function can be used to determine the 95th percentile storm event that captures all but the largest 5% of storms. *In MS Excel* [PERCENTILE(precipitation data range,95%)]

Placing onsite control measures to capture the 95th percentile rainfall event

1. Collect spatial data for a site, e.g., rooftop, pavement, and pervious areas as above.
2. Check soil type (USDA mapping, borings, or on-site testing) for the site to determine infiltration parameters. For this modeling, many of the assumptions that pertain to generalized soils groups and their infiltration properties come from the EPA Stormwater Management Model (SWMM 4.x) manual (see Appendix A).
3. Determine the current runoff volume that would occur during a 24 hour period by applying the 95th percentile rainfall to the existing site conditions (land use and soil properties) as above using a hydrologic model (such as TR-55 or SWMM). For this analysis, it is assumed that the rainfall amount is distributed over a 24 hour period. Actual rainfall event duration (and intensity) was not considered for rainfall runoff (however, timing was considered when modeling infiltration).
4. Determine flow paths so that management practices placements are in locations where flows can be intercepted and routed to practices (Note: This step was not included in the scenario exercises). Because this is a site specific effort and may require detailed topographic information or further surveys this would be a task to be completed onsite and therefore is not included as a part of the modeling scenario effort.

5. Select onsite control practices to capture the current 95th percentile runoff event; base the selection of appropriate options on site conditions, areas available for treatment options, and other factors such as use and other constraints.

Note: The steps above have been generalized for the purposes of this guidance. It is recommended that a qualified professional engineer determine or verify that stormwater management practices are sized, placed, and designed correctly. It should also be noted that the methodology to determine rainfall amount was subject to a 24 hour time period based on daily records. Actual rainfall events may have been shorter or longer time periods. Similarly, for modeling purposes, the 24 hour rainfall amount was distributed to pervious and impervious areas (and management practices) as a uniform event occurring during a 24-hour period. A large dataset (greater than 50 years) was used to reasonably represent rainfall depth not necessarily rain event depth. It stands to reason that more frequent, shorter duration precipitation events are better represented than less frequent, longer duration precipitation events.

Modeling Scenarios

Seven locations were selected for the 8 case studies as shown in Figure 10 and Table 3. Case study numbers 3 and 8 were both developed based on the Cincinnati, Ohio facility, although the site parameters were altered to represent differing site conditions and design constraints. Annual average rainfall depths for these locations range from 7.5 inches to 48.9 inches. Analyses of the 95th percentile rainfall events for these locations produced rainfall depths that range from 1.00 inch to 1.77 inches (Table 3).

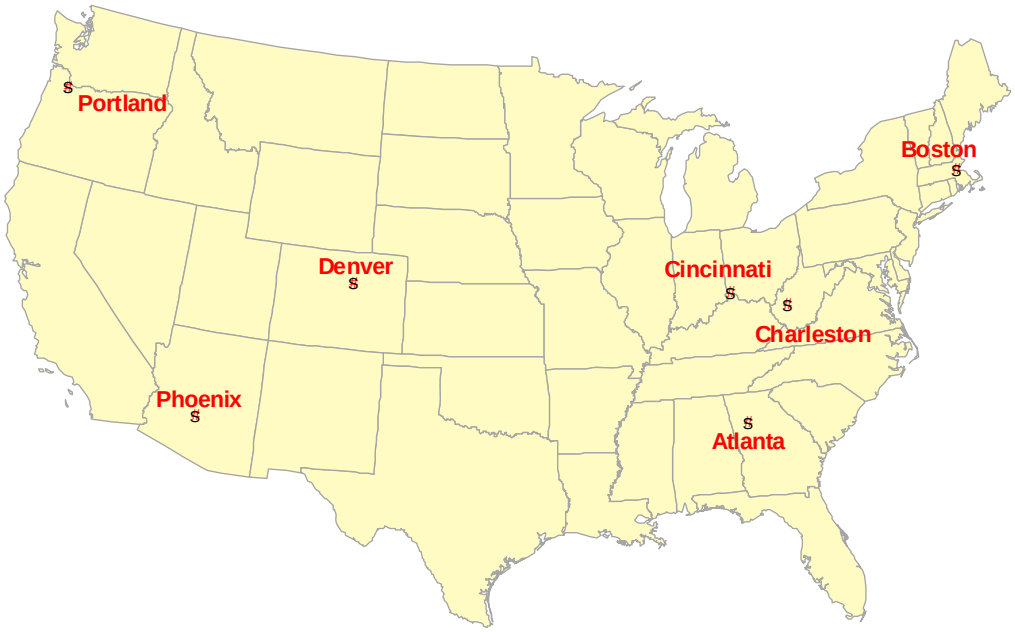


Figure 10. Locations for Analyzing Onsite Control Measures.

The government facilities in the 8 case studies were selected because they represent generic sites from the major climatic regions of the U.S. These facilities also were selected because the sites

have a range of site characteristics that can be used to illustrate different site designs and stormwater management options, e.g., pervious, roof, and pavement areas (Table 4). Site sizes ranged from 0.7 to 27 acres with percent site imperviousness area ranging from 47% to 95% of the site. Aerial photos of the sites are included along with site specific rainfall runoff and soil results.

Table 3. Summary of Rainfall Data for the Seven Locations.

No	Location	NCDC Daily Precipitation Data		Rainfall Depth (inches)	
		Period of record	Coverage	Annual average	95th percentile rainfall event
1	Charleston, WV	1/1/1948 - 12/31/2006 (59 yrs)	99%	43.0	1.23
2	Denver, CO	1/1/1948 - 12/31/2006 (59 yrs)	96%	15.2	1.07
3	Cincinnati, OH	1/1/1948 - 12/31/2006 (59 yrs)	96%	36.5	1.45
4	Portland, OR	1/1/1941 - 12/31/2006 (66 yrs)	98%	35.8	1.00
5	Phoenix, AZ	1/1/1948 - 12/31/2006 (59 yrs)	99%	7.5	1.00
6	Boston, MA	1/1/1920 - 12/31/2006 (87 yrs)	99%	41.9	1.52
7	Atlanta, GA	1/1/1930 - 12/31/2006 (77 yrs)	100%	48.9	1.77

The results of the spatial analyses were summarized and divided into three land cover categories; rooftop, pavement, and pervious area, as shown in Table 4.

Table 4. Summary of Land-use Determinations of the Study Sites.

No	Location	Facility Spatial Info (acres)				Site Imperviousness
		Rooftop	Pavement	Pervious	Total	
1	Charleston, WV	0.1	0.4	0.2	0.7	73%
2	Denver, CO	0.5	1.9	2.0	4.5	55%
3	Cincinnati, OH	1.6	8.0	9.4	19	51%
4	Portland, OR	8.8	16.9	1.3	27	95%
5	Phoenix, AZ	0.2	0.7	1.1	2	47%
6	Boston, MA	0.9	1.5	1.1	3.5	69%
7	Atlanta, GA	3.9	10.8	6.2	21	70%

Methods for Determining Runoff Volume

Direct Determination of Runoff Volume

Runoff from each land cover was estimated using a simplified volumetric approach based on the following equation:

$$Runoff = Rainfall - Depression\ Storage - Infiltration\ Loss$$

Again, this methodology does not consider routing of runoff; therefore slope is not considered when calculating on a volumetric basis.

Infiltration loss is calculated only in pervious areas (e.g., there is no infiltration in impervious areas). In this analysis, infiltration was estimated using Horton's equation:

$$f = f_{min} + (f_{max} - f_{min})\, e^{-k\,t}$$

where, f = infiltration rate at time t (in/hr)
f_{min} = minimum or saturated infiltration rate (in/hr)
f_{max} = maximum or initial infiltration rate (in/hr)
k = infiltration rate decay factor (/hr) and
t = time (hr)

Infiltration loss for the 24-hr rainfall duration was estimated by the following equation with assumptions of a half hour Δt and uniform rainfall distribution in time:

$$Infiltration\ Loss = \sum (f \cdot \Delta t)$$

To more accurately describe the dynamic process of infiltration associated with Horton's equation, infiltration loss was integrated over a 24-hour period using a half hour time step while applying the maximum and minimum infiltration rates (in/hr) with time using the appropriate soil decay factor. The results of this process are further illustrated in Appendix A.

In cases where sites had limited physical space available for stormwater management, a series of practices was used (e.g., treatment train) to simulate the runoff and infiltrative behavior of the system. For example, if there was inadequate area and infiltrative capacity to infiltrate 100 percent of the 95th percentile storm event within a bioretention system another onsite management practice was selected to manage the runoff that could provide the necessary capacity not available by another treatment system. In this manner, excess runoff was routed to another management practice in the series of treatment cells where possible.

Two types of soils were considered for every site: hydrologic soil group B and C (except for scenario 8 in which hydrologic soil group D was used). Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and either loamy sand or sandy loam textures with some loam, silt loam, silt, or sandy clay loam soil textures placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam soil textures with some clay, silty clay, or sandy clay textures placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (USDA-NRCS, 2007). The application of these hydrologic soil groups was intended to give reasonable and somewhat conservative estimates of infiltration capacity.

General hydrologic parameters in this analysis were assumed as follows (see Appendix A for citations of assumptions):

- Depression storage (or initial abstraction)
    - Rooftop: 0.1 inches
    - Pavement: 0.1 inches
    - Pervious area: 0.2 inches

- Horton Infiltration parameters
    - Hydrologic Soil Group B
        - Maximum infiltration rate: 5 in/hr
        - Minimum infiltration rate: 0.3 in/hr
        - Decay factor: 2 /hr
    - Hydrologic Soil Group C
        - Maximum infiltration rate: 3 in/hr
        - Minimum infiltration rate: 0.1 in/hr
        - Decay factor: 3.5 /hr
- Design storage assumptions of control measures
    - Bioretention: up to 10 inches
    - Green roof: 1 inch (2.5 inches deep media with 40% void space)
    - Porous pavement: 4 inches (10 inches deep media with 40% void space)

Other Modeling Methods for Estimating Runoff Volume

Runoff from a site after applying the 95th percentile storm can be estimated by using a number of empirical, statistical, or mathematical methods. Several methods were considered in this analysis. The Rational Method can be used to estimate peak discharge rates and the Modified Rational Method can be used to develop a runoff hydrograph. The NRCS TR-55 model can be used to predict runoff volume and peak discharge. TR-55 can also be used to develop a runoff hydrograph. The EPA Stormwater Management Model (SWMM) can be used to simulate rainfall-runoff, pollutant build-up and wash-off, transport-storage-treatment of stormwater flow and pollutants, backwater effects, etc. for a wide range of temporal and spatial scales. The SWMM model can be fit to model a small site with a distributed system. Hydrologic Simulation Program – Fortran (HSPF, USDA) is a watershed and land use based lumped model that can be used to compute the movement of water and pollutants when evaluating the effects of land use change, reservoir operations, water quality control options, flow diversions, etc. In general, regionally calibrated modeling parameters are applied into HSPF. QUALHYMO is a complete hydrologic and water quality model, which can be used to factor in snowmelt, soil moisture conditions or to simulate system behavior based on infiltration and ET, groundwater storage tracking, baseflow and deep volumetric losses, and other variables.

Many of the existing tools for analyzing distributed systems use some part or all of the principles or formulae of the modeling approaches highlighted above. For example, the Emoryville spreadsheet control measure model (Emoryville, CA) uses a runoff coefficient (i.e., Rational Method) for analyzing lot-level to neighborhood-scale control measure sizing. The Green Calculator (Center for Neighborhood Technologies) estimates the benefit of onsite green infrastructure options on a neighborhood-scale by applying the curve numbers (i.e., TR-55) and the Modified Rational Method. The Northern Kentucky Spreadsheet Tool uses a TR-55 based approach for control measure sizing on neighborhood or site level spatial scales. The WWHM (Western Washington Hydrology Model) is a regionally calibrated HSPF model intended for use in sizing stormwater detention and water quality facilities to meet the Washington State Department of Ecology standards. WBM-QUALHYMO is a Canadian model used in

conjunction with the Water Balance Model (WBM). This model can be used to continuously simulate stormwater storage routing, stream erosion, drainage area flow routing, and snowmelt runoff (and ultimately freeze-thaw). Table 5 contains a summary of these different methods based on generic modeling features.

Table 5. Potential Methods for Analyzing Control Measures.

Model Considerations		Rational Method	TR-55	SWMM	Direct Determination	HSPF	QUALHYMO
Temporal scale	Single Event	Yes	Yes	Yes	Yes	Yes	Yes
	Continuous Simulation	No	No	Yes	Possible	Yes	Yes
Spatial scale	Lot-level	Yes	Yes[b]	Yes	Yes	No	No
	Neighborhood	Yes	Yes	Yes	Yes	Possible	Possible
	Regional	Yes	Yes[c]	Yes	No	Yes	Yes
Outputs	Peak Discharge	Yes	Yes	Yes	No	Yes	Yes
	Runoff Volume	Yes	Yes	Yes	Yes	Yes	Yes
	Hydrograph	Yes[a]	Yes	Yes	No	Yes	Yes
	Water Quality	No	No	Yes	Possible	Yes	Yes

[a] Modified Rational Method

[b] No less than 1 acre.

[c] No more than 25 square miles (up to 10 subareas).

From the viewpoint of modeling both lot-level and neighborhood scale projects, the Rational Method, NRCS TR-55, SWMM, and Direct Determination approaches were selected for use in scenario analyses. Strength and weakness of these methods are presented below:

Table 6. Comparison of modeling approaches for determining runoff volume.

Method	Strengths	Weaknesses
Direct Determination	• **Methodology for runoff determination is same as SWMM** • **Models basic hydrologic processes directly (explicit)** • **Simple spreadsheet can be used**	• **Direct application of Horton's method may estimate higher infiltration loss, especially at the beginning of a storm** • **Does not consider flow routing**
Rational Method	• **Method is widely used** • **Simple to use and understand**	• **Cannot directly model storage-oriented onsite control measures**
TR-55	• **Method is widely used** • **Simple to use and understand**	• **May not be appropriate for estimating runoff from small storm events because depression storage is not well accounted for**
SWMM	• **Method is widely used** • **Can provide complete hydrologic and water quality process dynamics in stormwater analysis**	• **Needs a number of site-specific modeling parameters** • **Generally requires more extensive experience and modeling skills**

Each method requires specific modeling parameters for estimating runoff from a site. Runoff coefficients for the Rational Method are assumed to be 0.9 for rooftop and pavement areas, and

0.1 and 0.135 for Group B and C soil pervious areas, respectively (Caltrans, 2003). The slope of the pervious area was assumed to be an average of 2%. Applying these runoff coefficients for each surface, the overall area-weighted runoff coefficient can be determined.

When applying the NRCS TR-55 method, Curve Numbers (CNs) must be determined for each drainage area. For rooftop and pavement areas the CN was assumed to be 98, and pervious area CN was determined on the basis of the hydrologic soil group and the status of grass cover condition. Curve numbers for pervious areas were assumed to be 61 and 74 for Group B and C soils, respectively, with an assumption of over 75% grass cover. The overall CN can be estimated by using an area-weighted calculation (USDA-SCS, 1986).

In SWMM modeling, infiltration was modeled using Horton's equation. The same infiltration parameters and depression storage values used in the direct determination method of runoff treatment volume described earlier were applied to the SWMM analyses. The average slope of the pervious area was again assumed to be 2%. The same uniform rainfall distribution and time step was applied for the SWMM model runs. To verify the assumption that uniform distribution occurred, NRCS 24-hour rainfall distribution was modeled using SWMM.

Modeling Results

Stormwater management practice sizes were determined using the direct determination approach to capture the volume of runoff generated in a 95th percentile rainfall event at each location. Total acreage, impervious area, the 95th percentile rainfall event, the current expected runoff for the 95th percentile rainfall event, and the future runoff with stormwater management controls were reported for each site. Results were summarized for the two soil types (three soil types for scenarios #3 and #8 in Cincinnati). The spatial location of onsite control measures was also illustrated in the site aerial photo figures. Note that site practices were placed only on undeveloped or landscaped areas without regard for true flow paths or technical feasibility. It may be preferred to place practices in existing impervious areas, if possible.

To compare other approaches of runoff estimation, alternate methodologies were also employed for three scenarios. TR-55 was used for Scenario #1 (Atlanta), the Rational Method was applied to Scenario #2 (Denver), and the SWMM was run for Scenario #7 (Charleston).

For flood control purposes, TR-55 was used to model the 10 year frequency design storm for each site under the assumption that all stormwater management practices were in place. The 10-year design storms were selected from the NRCS TR-55 Manual (USDA, 1986) for both the Eastern U.S. and the Western U.S. Precipitation Frequency Maps (http://www.wrcc.dri.edu/pcpnfreq.html). The 10-year frequency design storm was selected because it represents a common design standard used by state and local governments in order to manage peak rates of runoff and prevent flooding.

Scenario #1 - Charleston, WV

A 0.7-acre site with 73% impervious area was selected from Charleston, West Virginia (Figure 11). If the 95th percentile rainfall event (1.23 inches) occurred on the existing site (i.e., with no control measures), 0.82 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.03 acres if hydrologic soil group B is present, or 0.06 acres if hydrologic soil group C (Table 7) is the predominant soil type on the site. Assuming that bioretention practices are placed in areas that are currently pervious or landscaped, a total of 0.2 acres of pervious area would be available for the placement of bioretention systems. The effective design storage depth within the designated bioretention area was assumed to be 8 inches.



Figure 11. Actual Site and Onsite Control Measures (Charleston, WV)

Table 7. Estimated Sizes of Onsite Control Measures (Charleston, WV)

Total Area (acres)	0.7	
Estimated Imperviousness (%)	73%	
95th Percentile Rainfall Event (inches)	1.23	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.82	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by Direct Determination method (acres)	0.03	0.06
Bioretention estimated by SWMM (acres)	0.03	0.05
Off-site storage necessary to control the 10-yr event of 3.9 inches (acre-ft)	0.10	0.12

Note: The two hydrologic methods used (direct determination and SWMM) estimated similar bioretention sizes.

Scenario #2 - Denver, CO

A 4.5-acre site with 55% impervious area was selected from Denver, Colorado (Figure 12). If the 95th percentile rainfall event (1.07 inches) occurred on the existing site (i.e., with no control measures), 0.53 inches of runoff from the site would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.16 acres if the hydrologic soil group B is present or 0.3 acres if hydrologic soil group C (Table 8) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 2 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 6 inches.



Figure 12. Actual Site and Onsite Control Measures (Denver, CO)

Table 8. Estimated Sizes of Onsite Control Measures (Denver, CO)

Total Area (acres)	4.5	
Estimated Imperviousness (%)	55%	
95th Percentile Rainfall Event (inches)	1.07	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.53	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination method (acres)	0.16	0.3
Bioretention estimated by Rational Method (acres)	0.16	0.28
Off-site storage necessary to control the 10-yr event of 3.2 inches (acre-ft)	0.35	0.52

Scenario #3 - Cincinnati, OH

A 19-acre site with 51% impervious area was selected in Cincinnati, Ohio (Figure 13). If the 95th percentile rainfall event (1.45 inches) occurred on the existing site (i.e., no control measures were in place), 0.68 inches of runoff from the site would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.8 acres if the hydrologic soil group B is present or 1.3 acres if hydrologic soil group C (Table 9) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 9.4 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 8 inches.

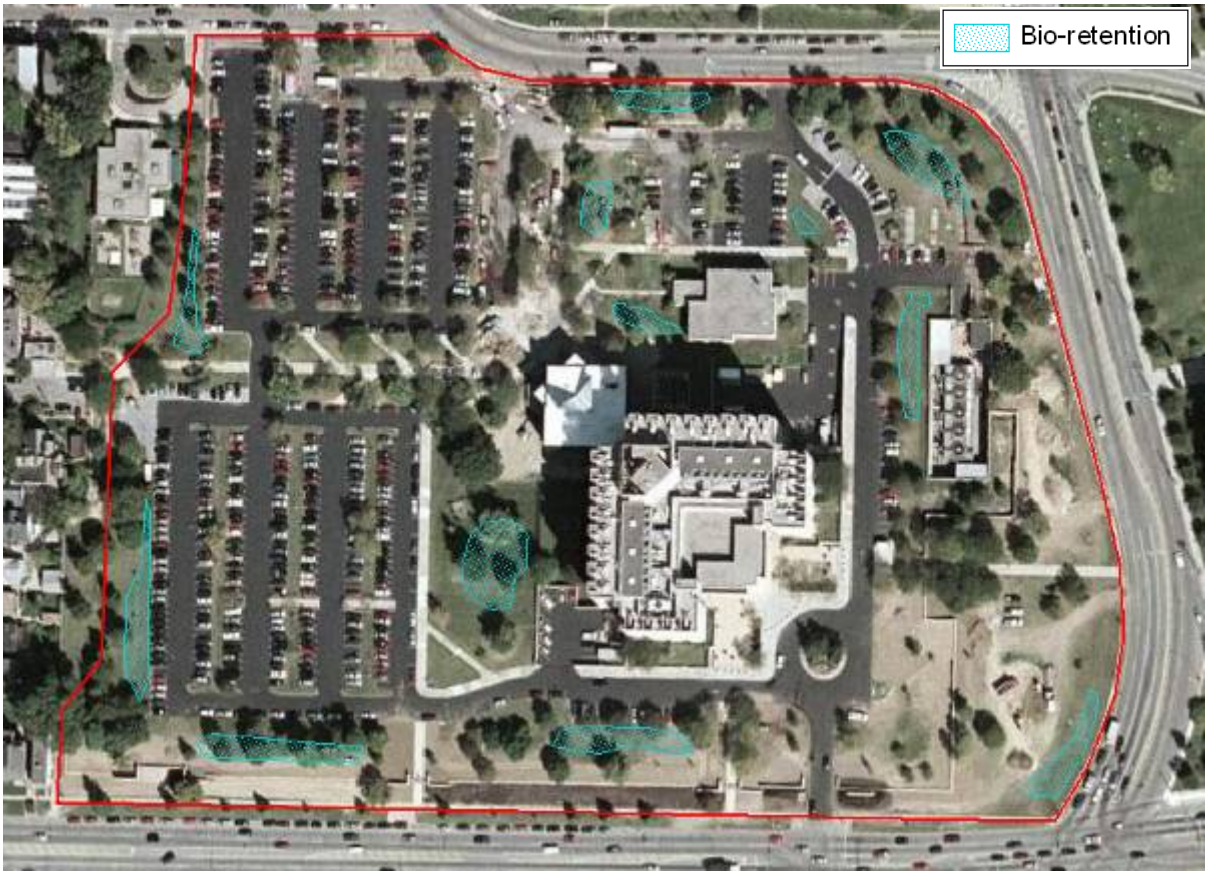


Figure 13. Actual Site and Onsite Control Measures (Cincinnati, OH)

Table 9. Estimated Sizes of Onsite Control Measures (Cincinnati, OH)

Total Area (acres)	19	
Estimated Imperviousness (%)	51%	
95th Percentile Rainfall Event (inches)	1.45	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.68	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.8	1.3
Off-site storage necessary to control the 10-yr event of 4.2 inches (acre-ft)	2.42	3.24

Scenario #4 - Portland, OR

A 27-acre site with 95% impervious area was selected in Portland, Oregon (Figure 14). If the 95th percentile rainfall event (1.0 inches) occurred on the existing site (i.e., no control measures), 0.86 inches of runoff would be generated and require management. This site has the greatest imperviousness among the 7 sites.

Given these site conditions, there is not enough pervious area to manage the entire runoff volume discharged by the 95th percentile rainfall event. As a result, other practices were evaluated and selected. The practices integrated into the design included a green roof, cisterns, and porous pavement. Based on the technical considerations of constructing and maintaining control measures at the site, it was assumed that approximately 30% of the available pervious area could be converted into bioretention cells; 20% of total rooftop area could be converted into green roofs; 40% of paved area could be converted into paver blocks; and 50,000 gallons of total volume could be captured in cisterns for use on this urbanized site. Using this system of four different practices, all runoff for the 95th percentile rainfall event would be controlled (Table 10).



Figure 14. Actual Site and Onsite Control Measures (Portland, OR)

Table 10. Estimated Sizes of Onsite Control Measures (Portland, OR)

Total Area (acres)	27	
Estimated Imperviousness (%)	95%	
95th percentile Rainfall Event (inches)	1.00	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.86	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Paver block area estimated by Direct Determination (acres)	1.4	3.5*
Bioretention estimated by Direct Determination (acres)	0.4	
Green Roof estimated by Direct Determination (acres)	1.7	
Cistern volume estimated by Direct Determination (gallons)	50,000	
Off-site storage necessary to control the 10-yr event of 3.7 inches (acre-ft)	5.37	5.62

*The size of porous pavement area was increased because the other control options were maximized based on the site-specific design assumptions.

A total of 1.3 acres of the site is pervious area or landscaped of which, 0.4 acres (30% of the pervious area) could be converted to bioretention cells that have a storage depth of 10 inches. Of the 8.8 acres of current rooftop area, 1.7 acres (20% of the rooftop area) could be retrofitted into green roof areas. Of the 16.9 acres of paved area, 1.4 acres (8% of the paved area) for hydrologic soil group B, or 3.5 acres (20% of the paved area) for hydrologic soil group C, of paver block systems could be implemented. One or more cisterns (as indicated in Figure 14) could be used to capture up to 50,000 gallons of runoff from rooftop areas. Note: The high percentage of imperviousness of the site (95%) requires that all infiltration designs be based on resident soil type and design volumes, or with adequate sub-bases or amended soils.

Scenario #5 – Near Phoenix, AZ

A 2-acre site with 47% impervious area was selected near Phoenix, Arizona (Figure 15). If the 95th percentile rainfall event (1.0 inches) occurred on the existing site (i.e., with no control measures), 0.42 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by installing bioretention systems totaling 0.06 acres if the hydrologic soil group B is present or 0.1 acres if hydrologic soil group C (Table 11) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 1.1 acres of pervious area is available for the placement of these practices. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 6 inches. Note: If the design storage depth were increased to 10 inches, the off-site storage necessary for the 10-year event could be reduced to 0.03 acre-ft for type B soils and 0.08 acre-ft for type C soils.



Figure 15. Actual Site and Onsite Control Measures (Phoenix, AZ)

Table 11. Estimated Sizes of Onsite Control Measures (Phoenix, AZ)

Total Area (acres)	2	
Estimated Imperviousness (%)	47%	
95th Percentile Rainfall Event (inches)	1.00	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.42	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.06	0.1
Off-site storage necessary to control the 10-yr event of 2.4 inches (acre-ft)	0.05	0.12

SARB_012028

Scenario #6 - Boston, MA

A 3.5-acre site with 69% impervious area was selected in Boston, Massachusetts (Figure 16). If the 95th percentile rainfall event (1.52 inches) occurred on the existing site (i.e., with no control measures), 0.98 inches of runoff would be generated and require management. Given these site characteristics, there is adequate area to place appropriately sized bioretention cells to capture the 95th percentile storm event. However, for the purposes of this analysis, unspecified conditions preclude the use of bioretention. As a result, a paver block system was selected as the best onsite control measure and the system was designed such that the necessary design parameters could be achieved by storing some of the volume in the paver media and by infiltrating the remainder of the volume. The runoff from the 95th percentile rainfall event could be controlled by installing a paver block area totaling 0.4 and 0.8 acres assuming soil types B and C, respectively (Table 12). For the purposes of this case study, a total of 1.5 acres of parking lot was made available to accommodate the paver block system. The area retrofitted with paver blocks would primarily be dedicated for use as parking stalls.



Figure 16. Actual Site and Onsite Control Measures (Boston, MA)

Table 12. Estimated Sizes of Onsite Control Measures (Boston, MA)

Total Area (acres)	3.5	
Estimated Imperviousness (%)	69%	
95th Percentile Rainfall Event (inches)	1.52	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.98	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Paver block area estimated by Direct Determination (acres)	0.4	0.8
Off-site storage necessary to control 10-yr event of 4.5 inches (acre-ft)	0.59	0.71

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Scenario #7 - Atlanta, GA

A 21-acre site with 70% impervious area was selected in Atlanta, Georgia (Figure 17). If the 95th percentile rainfall event (1.77 inches) occurred on the existing site (i.e., with no control measures), 1.17 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could not be adequately controlled solely with bioretention systems. Based on the technical considerations of constructing and maintaining control measures at the site, it was assumed that up to 15% of the pervious area could be converted into bioretention cells and up to 40% of paved area could be converted into a paver block system. If the stormwater management techniques used on the site include both bioretention and paver blocks as presented in Table 13, then all runoff for the 95th percentile rainfall event would be controlled.



Figure 17. Actual Site and Onsite Control Measures (Atlanta, GA)

Table 13. Estimated Sizes of Onsite Control Measures (Atlanta, GA)

Total Area (acres)	21	
Estimated Imperviousness (%)	70%	
95th Percentile Rainfall Event (inches)	1.77	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	1.17	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.9	
Paver block area estimated by the Direct Determination (acres)	0.9	3.2*
Bioretention estimated by TR-55	0.8**	0.9
Paver block area estimated by TR-55	0**	1.84
Off-site storage necessary to control 10-yr event of 6.0 inches (acre-ft)	5.85	6.62

*The size of porous pavement was increased because the bioretention was already reached its maximum size based on the site-specific design assumptions.

**Because TR-55 estimated smaller runoff in this scenario, bioretention can control all of the 95th percentile runoff if the site has soil group B.

For the example site in Atlanta, GA, areas of 1.8 acres for hydrologic soil group B, and 4.1 acres for hydrologic soil group C, would be required to manage the runoff discharged from a 95th percentile rainfall event. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 6.2 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 10 inches. Permeable pavement systems could be used to treat the remaining volume on the 10.8 acres of existing paved area.

In applying the TR-55 model, the overall curve numbers for the site were 87 and 91 for Group B and C soils, respectively. TR-55 was used to estimate 0.73 inches of runoff for soil group B and 0.97 inches for soil group C, which are smaller numbers than the 1.17 inches of runoff estimated by the Direct Determination method. As a result, the sizes of the onsite control measures designed using the TR-55 model were smaller than those designed using the Direct Determination method. Note: It is recommended that caution be exercised when using TR-55 to model storms less than 0.5 inches per event. See application of TR-55 in Table 6.

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Scenario #8 - Cincinnati, OH

A 19-acre site with 51% impervious area was selected in Cincinnati, Ohio (Figure 18). If the 95th percentile rainfall event (1.45 inches) occurred on the existing site (i.e., with no control measures), 0.68 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.8 acres if the hydrologic soil group B is present or 1.3 acres if hydrologic soil group C (Table 9) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 9.4 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 8 inches.

Scenario #8 represents an alternative to the Cincinnati, scenario in #3 (Figure 13). In this case, hydrologic soil group D was selected to represent the soil characteristics present for the entire site. Alternatively, simulations could have been run under the assumption that the use of infiltration practices were precluded by contaminated soils or high groundwater tables. Under these site conditions, bioretention options are severely limited and cannot be used to adequately capture the entire 95th percentile storm event. As a result, options such as cisterns and green roofs were considered. In the absence of management practices, the 95th percentile rainfall event discharges 1.45 inches of stormwater and 0.53 inches of this runoff is captured by onsite depression storage. The difference, 0.92 inches of runoff, would then require capture and management. Based on the technical considerations of constructing and maintaining controls at the site, it was assumed that up to 20% of pervious area can be converted into bioretention areas; up to 30% of paved area can be converted into porous pavement; and up to 30% of the rooftop area can be converted into green roofs. Cisterns can be added to the system if additional storage volume is required. It should be noted that green roofs were selected lowest in the hierarchy of practices evaluated because of cost and potential structural issues associated with design and placement on existing buildings. By using the four onsite control options as presented in Table 14, all runoff for the 95th percentile rainfall event would be controlled. From a management perspective, it was assumed that the design storage depth within the designated bioretention area was 6 inches because of the low infiltration rates adopted for this scenario.



Figure 18. Actual Site and Onsite Control Measures (Cincinnati, OH)

Table 14. Estimated Sizes of Onsite Control Measures (Cincinnati, OH)

Total Area (acres)	19
Estimated Imperviousness (%)	51%
95th Percentile Rainfall Event (inches)	1.45
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.92
Stormwater Management Applied	Hydrologic Soil Group D
Bioretention estimated by Direct Determination (acres)	1.9
Paver block area estimated by Direct Determination (acres)	2.4
Green Roof estimated by Direct Determination (acres)	0.5
Cisterns estimated by Direct Determination (gallons)	13,000

This site contains a total of 9.4 acres of pervious area, 8.0 acres of paved area, and 1.6 acres of rooftop area. If 1.9 acres (20%) of the pervious area were converted to bioretention cells; 2.4 acres (30%) of parking lot converted to paver blocks; and 0.5 acres (30%) of rooftop area were retrofitted to green roof areas for this site, then 97% of stormwater runoff from the 95th percentile storm would be captured on site. By also adding one or more cisterns (as indicated in Figure 18), an additional 3,000 gallons could be captured, thus illustrating that 100% of the rainfall from the 95th percentile event can be managed onsite with green infrastructure practices.

Comparison of the Runoff Estimation Methods

As illustrated above, runoff of the 95th percentile storm was estimated in order to size onsite control measures. These estimates were produced by applying four different methods: the Direct Determination method, the Rational Method, the NRCS TR-55, and the EPA SWMM. The results comparing each of these methods are presented in Table 15.

Table 15. Comparison of the estimated runoff (unit: inches)

Method		Direct Determination		Rational Method		TR-55		SWMM	
Soil Groups		B	C	B	C	B	C	B	C
1	Charleston, WV	0.82	0.82	0.83	0.84	0.36	0.53	0.82	0.83
2	Denver, CO	0.53	0.53	0.57	0.59	0.12	0.26	0.53	0.53
3	Cincinnati, OH	0.68	0.68	0.73	0.76	0.26	0.46		
4	Portland, OR	0.86	0.86	0.86	0.86	0.63	0.71		
5	Phoenix, AZ	0.42	0.42	0.46	0.48	0.06	0.17		
6	Boston, MA	0.98	0.98	0.99	1.00	0.51	0.70		
7	Atlanta, GA	1.17	1.17	1.17	1.19	0.73	0.97	1.19	1.23

As shown in the above table, the estimated runoff results from direct determination, the Rational Method, and SWMM are relatively similar. Runoff volumes using TR-55 are lower than the other estimates. SWMM modeling results using NRCS 24-hour rainfall distributions were nearly identical to the results based on uniform distribution.

Table 16. Applicability of the methods for analyzing onsite control measures

Purpose	Direct Determination	Rational Method	TR-55*	SWMM
Planning Tool	Applicable	Applicable	Applicable	Applicable
Preliminary Design	Applicable	Applicable	Applicable	Applicable
Detailed Design	Not applicable	Not applicable	Not applicable	Applicable
Actual Assessment (Long-term)	Not applicable	Not applicable	Not applicable	Applicable
Water Quality	Not applicable	Not applicable	Not applicable	Applicable

*Use with caution when applying this method for small storms

CONCLUSIONS

Although sites varied in terms of climate and soil conditions, in all of the scenarios selected, the 95th percentile storm event could be managed onsite with green infrastructure systems. There are many more infiltration, evapotranspiration and capture and use stormwater management options available than used in these analyses giving site operators additional flexibility in managing wet weather.

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APPENDIX A: Modeling Parameter Assumptions

Runoff from each land cover was estimated by the following equation:

$$Runoff = Rainfall - Depression\ Storage - Infiltration\ Loss \quad (1)$$

Depression Storage

Reference depression storage (inches)

Reference	Impervious	Pervious
1	0.05 - 0.1	0.1 - 0.3
2	0.01 - 0.11	0.02 - 0.6
3	0.1	0.2

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3. Walesh, S. G. (1989).*Urban Surface Water Management*. John Wiley & Sons, Inc.

Based on the above reference data, depression storage (or initial abstraction) to the direct determination method was assumed as follows:

- Rooftop: 0.1 inches
- Pavement: 0.1 inches
- Pervious area: 0.2 inches

Infiltration

Infiltration loss occurs only in pervious areas. In this analysis, infiltration was estimated by Horton's equation:

$$f = f_{min} + (f_{max} - f_{min})\, e^{-k\,t} \quad (2)$$

where, f = infiltration rate at time t (in/hr),
f_{min} = minimum or saturated infiltration rate (in/hr),
f_{max} = maximum or initial infiltration rate (in/hr),
k = infiltration rate decay factor (/hr), and
t = time (hr).

Reference infiltration parameters

Maximum infiltration rate (in.hr), f_{max}

Infiltration (in/hr)	Partially dried out with		Dry soils with	
	No vegetation	Dense vegetation	No vegetation	Dense vegetation
Sandy	2.5	5	5	10
Loam	1.5	3	3	6
Clay	0.5	1	1	2

Reference: Huber, W. C. and Dickinson, R. (1988). *Storm Water Management Model User's Manual, Version 4*. EPA/600/3-88/001a (NTIS PB88-236641/AS), U.S. Environmental Protection Agency, Athens, GA.

Minimum infiltration rate (in/hr), f_{min}

Hydrologic Soil Group	Infiltration (in/hr)
A	0.45 - 0.30
B	0.30 - 0.15
C	0.15 - 0.05
D	0.05 - 0

A: well drained sandy; D: poorly drained clay
Reference: Huber, W. C. and Dickinson, R. (1988). *Storm Water Management Model User's Manual, Version 4*. EPA/600/3-88/001a (NTIS PB88-236641/AS), U.S. Environmental Protection Agency, Athens, GA.

Decay coefficient, k

Soils	k (sec^{-1})	k (hr^{-1})
Sandy	0.00056	2
⇕	0.00083	3
	0.00115	4
Clay	0.00139	5

Reference: Huber, W. C. and Dickinson, R. (1988). *Storm Water Management Model User's Manual, Version 4*. EPA/600/3-88/001a (NTIS PB88-236641/AS), U.S. Environmental Protection Agency, Athens, GA.

Based on the above reference data, infiltration parameters to the direct determination method were assumed as follows:

- Hydrologic Soil Group B
  - Maximum infiltration rate: 5 in/hr
  - Minimum infiltration rate: 0.3 in/hr
  - Decay factor: 2 /hr
- Hydrologic Soil Group C
  - Maximum infiltration rate: 3 in/hr
  - Minimum infiltration rate: 0.1 in/hr
  - Decay factor: 3.5 /hr
- Hydrologic Soil Group D
  - Maximum infiltration rate: 1 in/hr
  - Minimum infiltration rate: 0.02 in/hr
  - Decay factor: 5 /hr

Infiltration loss for the 24-hr rainfall duration was estimated by the following equations with assumptions of a half hour Δt:

$$\textit{Infiltration Loss at the } n^{\text{th}} \textit{ time-step} = (f \cdot \Delta t) = \{(f_{n-1} + f_n)/2) \cdot \Delta t\} \quad (3)$$

$$\textit{Integrated Infiltration Loss for 24 hours} = \sum (f \cdot \Delta t) \quad (4)$$

Integrating infiltration loss during 24 hours with a half hour Δt

time-step	t (hr)	Infiltration rate (in/hr) [a]			Infiltration volume (inches) [b]		
		Soil B	Soil C	Soil D	Soil B	Soil C	Soil D
0	0	5	3	1	0	0	0
1	0.5	2.03	0.60	0.100	1.757	0.901	0.275
2	1	0.94	0.19	0.027	0.741	0.198	0.032
3	1.5	0.53	0.12	0.021	0.368	0.076	0.012
4	2	0.39	0.10	0.02	0.230	0.054	0.01
5	2.5	0.33	0.1	0.02	0.179	0.05	0.01
6	3	0.31	0.1	0.02	0.161	0.05	0.01
7	3.5	0.30	0.1	0.02	0.154	0.05	0.01
8	4	0.3	0.1	0.02	0.15	0.05	0.01
9	4.5	0.3	0.1	0.02	0.15	0.05	0.01
10	5	0.3	0.1	0.02	0.15	0.05	0.01
11	5.5	0.3	0.1	0.02	0.15	0.05	0.01
12	6	0.3	0.1	0.02	0.15	0.05	0.01
13	6.5	0.3	0.1	0.02	0.15	0.05	0.01
14	7	0.3	0.1	0.02	0.15	0.05	0.01
15	7.5	0.3	0.1	0.02	0.15	0.05	0.01
16	8	0.3	0.1	0.02	0.15	0.05	0.01
17	8.5	0.3	0.1	0.02	0.15	0.05	0.01
18	9	0.3	0.1	0.02	0.15	0.05	0.01
19	9.5	0.3	0.1	0.02	0.15	0.05	0.01
20	10	0.3	0.1	0.02	0.15	0.05	0.01
21	10.5	0.3	0.1	0.02	0.15	0.05	0.01
22	11	0.3	0.1	0.02	0.15	0.05	0.01
23	11.5	0.3	0.1	0.02	0.15	0.05	0.01
24	12	0.3	0.1	0.02	0.15	0.05	0.01
25	12.5	0.3	0.1	0.02	0.15	0.05	0.01
26	13	0.3	0.1	0.02	0.15	0.05	0.01
27	13.5	0.3	0.1	0.02	0.15	0.05	0.01
28	14	0.3	0.1	0.02	0.15	0.05	0.01
29	14.5	0.3	0.1	0.02	0.15	0.05	0.01
30	15	0.3	0.1	0.02	0.15	0.05	0.01
31	15.5	0.3	0.1	0.02	0.15	0.05	0.01
32	16	0.3	0.1	0.02	0.15	0.05	0.01
33	16.5	0.3	0.1	0.02	0.15	0.05	0.01
34	17	0.3	0.1	0.02	0.15	0.05	0.01
35	17.5	0.3	0.1	0.02	0.15	0.05	0.01
36	18	0.3	0.1	0.02	0.15	0.05	0.01
37	18.5	0.3	0.1	0.02	0.15	0.05	0.01
38	19	0.3	0.1	0.02	0.15	0.05	0.01
39	19.5	0.3	0.1	0.02	0.15	0.05	0.01
40	20	0.3	0.1	0.02	0.15	0.05	0.01
41	20.5	0.3	0.1	0.02	0.15	0.05	0.01
42	21	0.3	0.1	0.02	0.15	0.05	0.01
43	21.5	0.3	0.1	0.02	0.15	0.05	0.01
44	22	0.3	0.1	0.02	0.15	0.05	0.01

45	22.5	0.3	0.1	0.02	0.15	0.05	0.01
46	23	0.3	0.1	0.02	0.15	0.05	0.01
47	23.5	0.3	0.1	0.02	0.15	0.05	0.01
48	24	0.3	0.1	0.02	0.15	0.05	0.01
Sum: Infiltration loss during 24 hours [c]					9.743	3.430	0.769

[a] Calculated infiltration rate at each time by Equation (2)
[b] Calculated infiltration volume from the previous time to the current time by Equation (3)
[c] Integrated infiltration volume for 24 hours with a half hour Δt by Equation (4)

Based on the above calculation, 24-hr infiltration losses for pervious areas and bioretentions were modeled as follows:

- Soil Group B: 9.743 inches
- Soil Group C: 4.430 inches
- Soil Group D: 0.769 inches

Infiltrations of underlying soils at paver blocks were modeled conservatively by applying the minimum infiltration rate for each soil type (Infiltration loss = $f_{min} \cdot 24$) because the soils under the paver blocks may require or be subjected to some compaction for engineering stability. The estimated infiltration losses for each soil are presented below:

- Soil Group B: (0.3 in/hr) · (24 hrs) = 7.2 inches
- Soil Group C: (0.1 in/hr) · (24 hrs) = 2.4 inches
- Soil Group D: (0.02 in/hr) · (24 hrs) = 0.48 inches

Design Storage of Management Practices

Bioretention

Reference	Ponding (inches)	Mulch (inches)	Soil media (ft)	Soil Media Porosity	Underdrain
1	up to 12	2 - 4 (optional)	1 - 1.5	about 40%	bioretention systems utilize infiltration rather than an underdrain
2	6 - 12	2 - 3	2.5 - 4	about 40%	recommended, especially if initial testing infiltration rate < 0.52 in/hr
3	6 - 12		2 - 4		
4		2 - 3	1.5 - 4		if necessary
5	up to 6		1.5 - 2	30 - 40%	Optional
6	6 - 18	as needed	2 - 4		if necessary

1. State of New Jersey. (2004). *New Jersey Stormwater Best Management Practices Manual* http://www.nj.gov/dep/stormwater/tier_A/pdf/NJ_SWBMP_9.1 print.pdf
2. Maryland Department of the Environment (MDE), (2000). *2000 Maryland Stormwater Design Manual, Volumes I & II*, prepared by the Center for Watershed Protection and the Maryland Department of the Environment, Water Management Administration, Baltimore, MD. http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp
3. Clar, M. L. and R. Green, (1993). *Design Manual for Use of Bioretention in Storm Water Management*, prepared for the Department of Environmental Resources, Watershed Protection Branch, Prince George's County, MD, prepared by Engineering Technologies Associates, Inc. Ellicott City, MD, and Biohabitats, Inc., Towson, MD.

4. US Environmental Protection Agency. (1999). *Storm Water Technology Fact Sheet: Bioretention*. EPA 832-F-99-012. Office of Water. US Environmental Protection Agency. Washington, D.C. http://www.epa.gov/owm/mtb/biortn.pdf
5. Prince George's County. *Bioretention Design Specifications and Criteria*. Prince George's County, Maryland. http://www.co.pg.md.us/Government/AgencyIndex/DER/ESG/Bioretention/pdf/bioretention_design_manual.pdf
6. City of Indianapolis. (2008). *Indianapolis Stormwater Design Manual*. http://www.sustainindy.org/assets/uploads/4_05_Bioretention.pdf

Paver Blocks

Reference	Media (inches)	Void Space
1	12 or more	40%
2	9 or more	40%
3	12 - 36	40%

1. Univ. of California at Davis. (2008). Low Impact Development Techniques: Pervious Pavement. http://extension.ucdavis.edu/unit/center_for_water_and_land_use/pervious_pavement.asp
2. AMEC Earth and Environmental, Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, and Atlanta Regional Commission. (2001). Georgia Stormwater Management Manual Volume 2: Technical Handbook http://www.georgiastormwater.com/
3. Subsurface Infiltration Bed. http://www.tredyffrin.org/pdf/publicworks/CH2 - BMP4 Infiltration Bed.pdf

Green Roofs

Reference	Media (inches)
1	3 - 4
2	1 - 6
3	2 - 6

1. Charlie Miller. (2008). Extensive Green Roofs. Whole Building Design Guide (WBDG). http://www.wbdg.org/resources/greenroofs.php
2. Great Lakes WATER Institute. Green Roof Project: Green Roof Installation. http://www.glwi.uwm.edu/research/genomics/ecoli/greenroof/roofinstall.php
3. Paladino & Company. (2004). Green Roof Feasibility Review. King County Office Project. http://your.kingcounty.gov/solidwaste/greenbuilding/documents/KCGreenRoofStudy_Final.pdf

Based on the above reference data, design storages to the direct determination method were assumed as follows:

- Bioretention: up to 10 inches
- Green roof: 1 inch (2.5 inches deep media with 40% void space)
- Porous pavement: 4 inches (10 inches deep media with 40% void space)

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Memorandum

Date: 09 April 2009

To: Mark Grey, Director of Environmental Affairs Building Industry Association Of Southern California

From: Eric Strecker, Nichole Dunn, and Klaus Rathfelder, Geosyntec

Subject: NRDC comments on Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2008-0030

The Natural Resources Defense Council (NRDC) submitted comments on the Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2008-0030 (referred to herein as NRDC comments). As part of their comments, NRDC cites six numeric stormwater standards from jurisdictions nationwide as evidence that various jurisdictions have begun to implement numeric standards that require onsite retention, infiltration, and/or harvesting. Specific citations are included below in italics.

Geosyntec has reviewed the requirements of the stormwater standards cited by NRDC. Following each of the citations below, we provide of summary of the stormwater standards referenced. In particular, we focus on requirements for onsite retention and reuse and if and how these requirements consider site conditions. We have also attempted to characterize the current status of implementation of the requirements.

While the jurisdictions below may have begun implementing numeric standards with a focus on keeping and managing stormwater onsite, they generally recognize that this is not possible in all situations and allow for alternative measures in lieu of retaining all stormwater onsite.

Pennsylvania

Requirement: *"Capture at least the first two inches of rainfall from all impervious surfaces and retain onsite (through reuse, evaporation, transpiration, and/or infiltration) at least the first one inch of runoff" (NRDC comments/pg. 3)*

According to the Pennsylvania Stormwater Best Management Practices Manual, cited as the reference for the above information, "Pennsylvania laws and regulations do not directly manage

stormwater at the state level, although some state level management occurs through the Stormwater Management Act and the NPDES permitting program." However, the 3/2009 Draft NPDES Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) General Permit (PAG-13) requires applicants to comply with a Model Stormwater ordinance approved by the DEP in 2005 or later, or the 2008 Pennsylvania Model Stormwater Management Ordinance (SMO). Counties that discharge to special protection watersheds are not eligible for the General Permit and must apply for an individual permit. The volume control requirements stated in the Pennsylvania Stormwater Best Management Practices Manual are required by the Draft 2009 Pennsylvania SMO. Therefore, the standards in the Pennsylvania Stormwater BMP Manual are a requirement in the Draft Phase II General Permit under development by the Pennsylvania Department of Environmental Protection. In addition, the standard cited by NRDC is one of two guidelines in the SMO. The standard selected by NRDC is one that is specifically independent of site constraints and it was stated that it should not be used when regulated activities are greater than 1 acre or for any project that requires design of stormwater storage facilities. Also known as Control Guideline 2 or the Simplified Method, this guideline requires:

- The first 2" of runoff from NEW impervious surfaces be captured.
- At least the first 1" of runoff from NEW impervious surfaces be permanently removed from the runoff flow through reuse, evaporation, transpiration and/or infiltration.
- Where possible, all permanently removed runoff should infiltrated; however, it is suggested that in all cases at least 0.5" should be infiltrated.

The other guideline, which was not cited by NRDC, is Control Guideline 1 or the Design Storm Method. This guideline is applicable to any size of regulated activity and requires that the post-development total runoff volume for all storms equal to or less than the 2-year/24-hour event to not increase. This guideline also requires modeling and requires that for the existing condition all pervious areas must be modeled as in good condition and 20% of the existing impervious area must also be modeled as pervious area in good condition.

The Pennsylvania Stormwater BMP Manual also calls out several Special Management Areas (i.e., Brownfields, Highways and roads, karst areas, mined lands, near supply wells, urban areas, surface water supplies and Special Protection Waters) that may require the above standards to be modified on a case-by-case basis due to site conditions. Neither the General Permit, nor the model ordinance specifically addresses the limitations of Special Management Areas, though they do address Special Protection Waters.

Since the General Permit and SMO are still in draft form it is unknown how the authorities will address situations where Control Guideline 1 is used and the onsite management of the first 1" of runoff from new impervious surfaces is not feasible, or where the site is in a Special Management Area.

Pertinent findings from our review of the Pennsylvania stormwater ordinance are:

- The requirements cited by NRDC are general requirements (SMO) of a Draft Phase II general permit via reference to the manual. The requirements are not specific conditions in the Permit.
- The requirements cited are applicable to sites of 1 acre or less or that do not require design of stormwater storage facilities. For larger sites, the Draft SMO requires no increase in runoff volume up to the 2-year/24-hour event, which implicitly considers the pre-development site conditions.
- The Draft SMO provides allowances for special site constraints.
- The application of the above is still proposed in a draft permit, so there are no cases studies or information about the practical implications of the requirements.

Anacostia, Washington, D.C.

Requirement: *"Retain onsite the first one inch of rainfall and provide water quality treatment for rainfall up to the two-year storm volume" (NRDC comments/pg. 3)*

The original requirement was published in Final Environmental Standards June 2007, by the Anacostia Waterfront Corporation acting on behalf of the District of Columbia. The Anacostia Waterfront Initiative was a Memorandum of Understanding (MOU) entered into by 20 District and Federal agencies that owned or controlled land along the Anacostia Riverfront. The partnership formed by the MOU was formed to help attain a vision for the waterfront areas, known as the Waterfront Revitalization Endeavor. The Anacostia Waterfront Corporation was created to oversee and implement the Anacostia Waterfront Initiative for the cleanup and redevelopment along the Anacostia River. Before being dissolved by the NCRC and AWC Reorganization Act of 2008, the Anacostia Waterfront Corporation published, "Final Environmental Standards" in June of 2007 that required retention of the first 1" of runoff for beneficial reuse. However, the standards allow for exceptions where infiltration or collection and reuse are not feasible for public safety or environmental protection. If an exception is required, physical and/or financial offsets may be applied. Physical offsets require 1.5 times the amount of the stormwater that is not retained on site to be reduced through the off-site use of greenroofs, potable water conservation, and LID measures. However, if potable water conservation is used as a physical offset only 25% of the annual volume saved is credited. Financial offsets consist of payments to the Anacostia River Trust Corporation, a subsidiary of AWC, for twice the cost of obtaining an equivalent reduction of the stormwater flow being offset. Since the AWC was rolled back into the Washington D.C. Office of Planning, the District Department of the Environment is responsible for the implementation of these requirements.

While these standards have gone into law, they will not go into effect until the regulations have been promulgated, which has not happened to date[1].

Pertinent findings from our review of Anacostia stormwater requirements are:

- The requirements do not apply to the entire geographic area of the city, but are limited to small special district of 3,070 acres in area along the waterfront.
- The requirements specify retention and infiltration as the preferred stormwater management control, followed by capture and reuse.
- The requirements provide for offsets in cases when site conditions limit feasibility of infiltration and reuse.
- Since the regulations have not been issued, there are no cases studies or information about the practical implications of the requirements.

West Virginia

Requirement: *"Retain onsite the first one inch of rainfall from a 24-hour storm preceded by 48 hours of no measurable precipitation" (NRDC comments/pg. 3)*

While the draft permit currently under consideration in West Virginia states that the first 1" of rainfall must be kept and managed onsite, it also allows for credits if certain types of development are used. The five development types that earn credits are:

- Redevelopment
- Brownfield redevelopment
- High Density (>7 units per acre)
- Vertical Density (Floor to Area Ratio of 2 or >18 units per acre)
- Mixed Use and Transit Oriented Development (within 1/2 mile of transit)

Each of the development types above earns a credit of 0.1" against the first 1" of rainfall. Therefore, it is possible that a site would need to mitigate only 0.5". Similar to the Anacostia standard, West Virginia allows for physical and/or financial offsets where on-site treatment of the entire amount of runoff is not possible or practical. However, the draft West Virginia permit allows offsets for a maximum of 0.4" of the original amount (i.e., if the entire first 1" of rainfall needed to be kept and managed then offsets would only be allowed for 0.4" and 0.6" would need to be managed onsite).

[1] Personal communication with Shane Farthing of District Department of the Environment. Phone. Apr. 06, 2009.

The West Virginia standard has not been implemented yet since the permit is still in draft form. Therefore, it is unknown how the regulators would address a situation where a developer was not able to keep and manage the entire amount of rainfall because of site constraints or feasibility.

Pertinent findings from our review of West Virginia stormwater requirements are:

- The requirements specify an array of options for meeting on-site retention requirements.
- Stormwater credit options provide incentives for high density development in Brownfield areas and transportation corridors.
- The requirements provide for offsets in cases when site conditions limit feasibility of infiltration and reuse, however, full offsets are not allowable, and some on-site retention will be required for all developments.
- It is a draft permit, so there are no cases studies or information about the practical implications of the requirements.

Georgia

Requirement: *"Treat the runoff from 85% of the storms that occur in an average year (i.e., provide treatment for the runoff that results from a rainfall depth of 1.2 inches)" (NRDC comments/pg. 3)*

Similar to PA, this standard is from the GA Stormwater Management Manual, which provides guidance on how jurisdictions in the state might address stormwater management. While the entire state has not adopted this standard, some local jurisdictions such as the Metropolitan North Georgia Water District have adopted model ordinances that direct their members to follow the guidelines in the Stormwater Management Manual. In either case, the standard merely requires treatment of the first 1.2" of rainfall; it does not require retention or infiltration of the stormwater.

Central Coast, California (RWQCB, Phase II)

Requirement: *"Limit effective impervious area ("EIA") at development projects to no more than 5% of total project area (interim criteria); establish an EIA limitation between 3% and 10% in local stormwater management plans (permanent criteria)" (NRDC comments/pg. 4)*

The above standard was set forth in a letter to small MS4s. Limiting the effective impervious area is an ambiguous task, as ineffective impervious area is not defined clearly. It is not clear if effective impervious area implies:

1. Total offsite runoff is limited to a volume that is equivalent to 5% impervious area. Essentially this requires that runoff generated by 95% of the project area, under most conditions be managed on site; or
2. Runoff that is not directly connected to the storm sewer. In other words, runoff from 95% of the site must be directed to pervious areas prior to collection in the storm sewer.

This is an interim criteria and it remains unclear as to what ineffective really means.

All Federal Buildings over 5,000 square feet (under EPA's draft guidance for implementation of the Energy Independence and Security Act of 2007)

Requirement*: "Manage onsite (i.e., prevent the offsite discharge of) the 95th percentile storm through infiltration, harvesting, and/or evapotranspiration." (NRDC comments/pg. 4)*

According to H.R.6 Energy Independence and Security Act (EISA) of 2007, Sec. 438. Storm Water Runoff Requirements for Federal Development Projects include:

> "The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

In a presentation by Jennifer Molloy and Robert Goo from the USEPA in February 2009 to the Interagency Sustainability Work Group, they presented two options for meeting the Section 438 requirement of the EISA. Option 1 is to control the 95th percentile rainfall event by managing it onsite by using infiltration, evapotranspiration, and/or re-use. Option 2 is to preserve the predevelopment hydrology (rate, volume, duration, and temperature) by conducting hydrologic and hydraulic analyses for the 1, 2, 10, and 100-year 24-hour storm events. If Options 1 and 2 are not technically feasible due to site conditions or other factors, the agency/department must follow a process to employ onsite practices to the maximum extent technically feasible and document the design. Again, this stormwater management requirement recognizes that onsite management is not always feasible. The EPA guidance manual is still in draft form. Geosyntec has developed technical comments on the guidance manual and its methods and results regarding effectiveness.

Key points from Geosyntec's technical comments in regards to the EPA's numeric standards requiring onsite retention, infiltration, and/or harvesting include:

- That retention of the 95th percentile storm event may not be cost-effective for achieving the intended level of protection. This is not supported in the Draft Guidance, nor is it generally supported by the body of scientific knowledge.

- The requirement to retain the 95th percentile storm event does not account for the drawdown time of the captured volume. Therefore, if the capture system draws down slowly the storage volume remaining when the next storm arrives may not be adequate to capture the volume generated by the next storm, which would cause the second storm to bypass or partially bypass the retention system.

See attached comments on the draft manual submitted to EPA.

Discussion/Implications

Out of the six standards cited, the only one that does not specifically recognize that onsite management will not be possible in all cases is the Central Coast standard that is required to be incorporated into small MS4s stormwater management plans for them to be approved. However, this standard is also not as clear as the rest of the standards cited because it does not provide a clear definition of effective impervious areas.

Most of the jurisdictions cited above, recognize that it may not be feasible to manage the entire volume onsite and offer methods for improving the quality of the stormwater runoff within other means. Pennsylvania requires the first 1" of rainfall from new impervious surfaces to be permanently removed from the runoff flow. However, this regulation only applies when regulated activities are less than 1 acre and do not require stormwater storage facilities. In addition, the Pennsylvania Stormwater BMP Manual recognizes that when either of the control guidelines are applied to project, if the project is located in a Special Management Area, (i.e., brownfields, highways and roads, karst areas, mined lands, near supply wells, urban areas, surface water supplies and Special Protection Waters) the guidelines may need to be modified on a case-by-case basis.

The draft permit proposed by West Virginia requires onsite stormwater retention between 0.1" and 1", depending on how many credits are issued for the type of development, but also allows offsets for up to 0.4" of that amount. However, they recognize that it may not be technically feasible to keep the entire amount of rainfall onsite and allow for deviations from that rule as long as there is a net improvement in the overall stormwater runoff for a particular sewershed/watershed.

Anacostia's standard is less stringent that West Virginia's standard only in that they do not limit the allowed offset (i.e., if needed the entire standard could be addressed by using offsets). However, Anacostia does not offer credit for different development types either. Similar to Pennsylvania, the EPA in their draft guidance for EISA Sec. 438 they offer two methods for preserving the predevelopment hydrology and if neither of those will fully address the problem, they have a process for implementing BMPs to the maximum extent technically feasible.

Georgia's stormwater management manual and associated ordinances merely require the treatment of the first 1.2" of rainfall. It recognizes that in critical or sensitive areas, additional requirements may be needed and the use of structural controls may need to be restricted to protect a special resource or address certain water quality or drainage problems.

Based on the information presented above, while various jurisdictions are moving towards implementing numeric stormwater performance standards that include retention, they recognize that numeric standards for retention are difficult to implement across all site conditions and allow alternative methods to improve the stormwater runoff quality. None of the jurisdictions cited above that clearly require implementation of retention and infiltration as the preferred method for addressing post-construction stormwater runoff have had their regulations go into effect. Therefore, there are no case studies or information about the practical implications of the requirements and how they are actually being applied.

References

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California Regional Water Quality Control Board – Central Coast Region. 2008. *Notification to Traditional, Small MS4s on Process for Enrolling under the State's General NPDES Permit for Storm Water Discharges*.

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Pennsylvania Department of Environmental Protection. 2009. *Draft Pennsylvania National Pollution Discharge Elimination System (NPDES) Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) General Permit (PAG-13).*

Samuelson, Ruth. 2008. *Kwame Brown And Mayor "Work Cooperatively" On Southwest Land Transfer Resolution*. Washington City Paper. [online] www.washingtoncitypaper.com accessed 04/04/09.

West Virginia Department of Environmental Protection. 2008. *Draft General National Pollution Discharge Elimination System Water Pollution Control Permit. Stormwater Discharges from small Municipal Separate Storm Sewer Systems*. WV0116025.

April 9, 2009

Michael Adackapara
Division Chief
Santa Ana Regional Water Quality Control Board

RE: TENTATIVE ORDER NO. R8-2009-0030

Dear Mr. Adackapara,

Thank you for the opportunity to comment on the current draft of the Orange County Area NPDES permit. Overall, this draft is a great improvement. In particular, the change in Section XII, covering New Development, requiring mitigation of the water quality design storm instead of the setting an effective impervious area threshold is substantially more protective and less prescriptive.

Please find a table attached summarizing comments and suggested changes for the tentative order. Please let me know if you have any questions.

Sincerely,



Vaikko P. Allen II, CPSWQ, LEED-AP

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CONTECH Stormwater Solutions, Inc.
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Suggested Changes
NPDES No. CAS618030
Orange County Areawide Urban Stormwater Runoff Permit - Santa Ana Region

Submitted by Vaikko Allen, CPSWQ, Regulatory Manager - Southwest
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Section	Proposed Change or Comment	Justification
Finding 66	Change first sentence to "Treatment control BMPs with a hydraulic connection to groundwater, including unlined detention basins, infiltration areas (including LID-based) and constructed wetlands, could be sources of groundwater pollution and could become a nuisance and/or cause the spreading of surface water pollution if not properly designed and maintained."	This section incorrectly lists vortex systems, stormwater filters and catch basin inserts as potentially contributing to groundwater contamination. These BMPs, and other catch basin or vault based BMPs have no communication with groundwater and therefore can not be a source of groundwater pollution. They can not cause the spreading of surface water pollution since no pollutants are generated by or added to these devices. This is in contrast to vegetated BMPs, which even with no groundwater connection, may cause or contribute to surface water pollution if pollutants such as fertilizers, pesticides, herbicides and excessive irrigation are applied.
Finding 67	Change first sentence to "If not properly designed and maintained, the BMPs identified in Finding 66, and vault based BMPs with no groundwater communication such as vortex separators, catch basin inserts and various types of stormwater filters could create a nuisance and/or habitat for vectors22 (e.g., mosquitoes and rodents).	This change is needed to include the BMPs removed from finding 66.
Section XII.B.5.f	Add a requirement for spill protection in these high risk areas.	Traffic accidents, spills and persistent leaks of automotive or equipment fluids can contaminate groundwater and can be very difficult and expensive to clean up. In the high risk areas identified in this section, preventative measures should be taken to avoid contamination of soil and groundwater. For example BMPs should be installed with a minimum of 75 gallons of spill retention capability should be installed upstream of infiltrating BMPs. This minimum volume corresponds to a single diesel tank or hydraulic fluid tank capacity of a large truck.
Section XII.C.2.b	Replace "consider construction of parking lots walkways, etc., with permeable concrete and porous asphalt" with construction of parking lots walkways, etc., with permeable materials"	There are a variety of permeable paving alternatives beyond permeable concrete or porous asphalt. For example concrete pavers, and various open cell plastic grids that can be filled with gravel or planted with grass.

Section	Proposed Change or Comment	Justification
Section XII.C.2.b	Replace "minimize pipes, culverts and engineered systems for stormwater conveyance" with "minimize changes to the time of concentration on site"	Pipes and other structural conveyance systems can be used to disconnect impervious areas. For example runoff from a parking lot could be collected in a catch basin, conveyed through a pipe and discharged to a permeable area that is not immediately adjacent to the parking lot. This approach is particularly useful on retrofit sites where impervious area grading and landscape area is location is established. Oversized pipes with downstream flow controls can also be designed to provide detention on site.
Section XII.C.4	Remove this section	This section requires LID BMPs to capture the 85th percentile event. This should be the goal, as is captured in Section XII.C.5, but it will not be feasible to mitigate the entire 85th percentile event with LID BMPs on every site, and it may not be feasible for every LID BMP to be large enough to mitigate that design storm. In such cases, the use of LID BMPs should be maximized and the balance of the 85th percentile volume that is not treated by the LID BMPs on site, close to the source must be addressed following sections XII.C.6-7.
Section XII.C.5	Add a requirement that treatment control BMPs must be designed to have medium or high effectiveness for pollutants of concern on site based on full-scale, in-field performance monitoring conducted following a peer reviewed testing protocol.	Section XII.B.4 contains water quality design storm requirements. It does not specify any level of treatment that is required by BMPs treating this design storm. This addition is needed to ensure that BMPs are effective in controlling the pollutants that are expected on site.
Section XII.C.7.a-b	Remove these sections	These sections reiterate the requirement to mitigate the water quality volume on site using LID BMPs which is already given in section XII.C.5. The only distinguishable difference between these sections and previous requirements in section XII.C, is the location on the site at which the LID BMPs are implemented. It is overly prescriptive to dictate where on a site LID BMPs should be implemented. From the perspective of the water quality and quantity leaving a private site and entering the MS4, it is irrelevant where the LID IMPs are implemented. There are economic benefits that can be realized by using centralized vegetated, infiltrating BMPs. For example construction costs may be lower, inspection and maintenance burden may be reduced and fewer easements for service may be required. There is also an economy of scale for some BMPs, where larger BMPs can mitigate runoff at a lower cost per volume than smaller BMPs. These kinds of economic decisions should be left to the site owner as long as the overall water quality and quantity reduction requirements are met on site.

Golden State
Water Company
A Subsidiary of American States Water Company

April 9, 2009

Michael J. Adackapara
Division Chief
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Sent via email

RE: Comments on Second Draft of Tentative Order R8-2009-0030 NPDES No. CAS618030 Renewal of **Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region, Areawide Urban Storm Water Runoff Management Program, Orange County.**

As a drinking water utility, Golden State Water Company (GSWC) has a vested interest in preserving the quality of our streams and underground aquifers. GSWC supports the Santa Ana Regional Board's efforts as a partner in protecting our drinking water resources and appreciates the opportunity to comment on the above referenced Waste Discharge Requirements.

GSWC is dedicated to providing our customers with water that meets strict State and Federal drinking water standards. In order to meet drinking water standards, we have a variety of discharges from our drinking water system to the storm drain system for routine operations and maintenance. The flushing of the drinking water system is an approved and necessary activity to protect public health and safety. Routine potable water line flushing is encouraged by the California Department of Public Health (DPH) and the American Water Works Association, and at times is required by the DPH. GSWC has previously had coverage of these types of discharges under several permits, including CAG998001.

After review of the second draft of CAS618030, GSWC is looking for some clarification on the board's intent to cover discharges from drinking water providers.

The second draft of CAS618030, paragraph III.3.ii states:

"The permittees shall prohibit the following categories of non-storm water discharges unless the stated conditions are met:

a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES NO. CAG

Orange County District, 1920 West Corporate Way, Anaheim, CA 95670
Tel: (714) 535-8010 Fax: (714) 535-8664

998001, except that the separate coverage under the General De Minimus Permit is not required.

b) *Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1ppm or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters."*

On March 27th, CAG998001 Order No. R8-2009-0003 was renewed with the following language in paragraph VII.C.6.f:

*"As appropriate, the regulation of the following types of discharges by **MS4 permittees** (emphasis added) shall be transferred to the MS4 permits issued to the cities, municipalities and Counties within the Santa Ana Region, when updated MS4permits with applicable terms and conditions necessary to address the regulation of these discharges are adopted and effective.*

(1) Dewatering wastes from subterranean seepage, except for discharges from utility vaults;
(2) Discharges resulting from hydrostatic testing of vessels, pipelines, tanks, etc.;
(3) Discharges resulting from the maintenance of potable water supply pipelines, tanks, reservoirs, etc.;
(4) Discharges resulting from the disinfection of potable water supply pipelines, tanks, reservoirs, etc.;
(5) Discharges from potable water supply systems resulting from initial system startup, routine startup, sampling of influent flow, system failures, pressure releases, etc.;
(6) Discharges from fire hydrant testing or flushing;
(7) Air conditioning condensate;
(8) Swimming pool discharge;
(9) Discharges resulting from diverted stream flows; and
(10) Construction dewatering wastes.

GSWC is seeking clarification if the board's intent is to 1) regulate discharges from all potable water suppliers under the CAS618030 or 2) regulate only those potable water suppliers who are also MS4 permittees under CAS618030 while regulating the remaining special districts and private water companies that supply potable water to the public under CAG998001.

Thank you again for the opportunity to comment and seek clarification on proposed waste discharge requirements. If you have any questions or need more information, please contact Brandyn O'Gorman at (916) 853-3639.

Sincerely,

Brandyn O'Gorman

Manager of Environmental Compliance
Golden State Water Company

cc: Mr. Marc Brown, RWQCB
Mr. David Chang, GSWC

City of Huntington Beach

2000 Main Street ♦ PO Box 190 ♦ CA 92648

Travis K. Hopkins, PE
Director

Department of Public Works
(714) 536-5431

April 9, 2009

Via e-mail (M. Brown) and U.S. Mail

Mr. Gerald J. Thibeault
Executive Director
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comments Regarding Second Draft of Order No. R8-2009-0030 (NPDES No. CAS618030), Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Storm Water Runoff

Dear Mr. Thibeault:

Thank you for the opportunity to comment on the second draft of the *Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County* (permit). The City of Huntington Beach has reviewed the comment letter provided by the County of Orange (County) dated April 9, 2009 and concurs with their comments. Additionally, the City has the following additional comments to the Permit:

- **Sections N.71, X.2 and X.3** require inspection of commercial facilities to be ranked by priority, with a minimum criterion of 10% of the sites ranked "high"; 40% of the sites ranked "medium"; and the remainder of sites ranked "low" with regard to potential for pollutant discharge. As stated in our previous letter dated February 13, 2009, the number of high priority inspections within the City would increase from 36 to 357, which is an increase of 992%. The number of commercial inspections for high, medium, and low combined will increase from approximately 72 to 608 on an annual basis.

In addition, the City's environmental inspectors have received complaints from business owners regarding the inspection fees the City imposes in conjunction with the state of the economy. Currently, businesses pay $231 per inspection for the term of the permit. With this new permit, they will be paying $231 annually, not including any fee adjustments on an annual basis. Additionally, the inspectors have found that some "high" priority commercial facilities do not require an annual inspection and that a self-certification for those businesses would be acceptable. The City would like to allow these businesses to submit a self-certification four out of the five years of the permit term, with inspectors conducting a thorough inspection at least once during the term of the permit. If a high priority commercial facility is found to be non-compliant during the term of the permit, that facility would then be inspected on an annual basis to attain compliance with the permit. This self-certification would be in addition to the data gathering by the Permittees would be submitted in the City's annual report/Program Effectiveness Assessment.

- **Sections X.3 and X.5** require photographic documentation for all commercial facilities. The City recommends that the requirement be consistent with Section IX.3 Municipal Inspections of Industrial Facilities which requires photographic documentation when there is a water quality violation.

- The City agrees with the County's suggestion to refine existing enforcement reporting mechanisms, rather than creating additional reporting obligations which would require the submission of a copy of our entire enforcement database annually. Refining would enable more consistency, reduce administrative burden, and perhaps allow for the creation of a database similar to the California Integrated Water Quality System (CIWQS) that could provide consistency amongst Permittees. This database could be used for reporting of enforcement/water quality violations, would be accessible by the Regional Board, and would also allow similar public access for transparency as CIWQS.

If you have any questions related to the above comments, please do not hesitate to contact Terri Elliott at 714-375-8494.

Sincerely,

Tony Olmos, PE
City Engineer

TO/te/jk:cs

Public Works Department www.cityofirvine.ca.us

City of Irvine, One Civic Center Plaza, P.O. Box 19575, Irvine, California 92623-9575 (949) 724-6000

April 9, 2009

Gerard J. Thibeault, Executive Officer
California Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Dear Mr. Thibeault:

The City of Irvine would like to express our appreciation for the opportunity to comment on the Second Draft of Order No. R8-2008-0030 (NPDES No. CAS618030). We have especially appreciated the opportunity to meet with you, your staff, and other stakeholders to discuss the low impact development (LID) and hydromodification portions of the draft order.

We have reviewed the County of Orange comment letter of April 9, 2009 and fully support the comments submitted by the County. Since the City and County needed to prepare comments concurrently, our comments may overlap, to some extent, with those submitted by the County. As we have indicated, it will be difficult for co-permittees to continue to grow the stormwater program considering the economic environment. It is essential that a permit is adopted resulting in continuing water quality improvements while recognizing economic constraints.

We generally support the Second Draft including efforts to reduce runoff to the maximum extent practicable. We have concerns and requests for clarification outlined on the attachment. Our most significant concern is the proposed burdensome inspection and reporting requirements which will not result in tangible improvements to water quality.

We appreciate the Regional Board's consideration of our comments and their interest in developing a permit that will continue to improve water quality while meeting the needs of the co-permittees, residents, and other stakeholders in Orange County.

If you have any questions or need additional information, please contact Mike Loving, Water Quality Administrator, at (949) 724-6315.

Sincerely,

Manuel Gomez
Director of Public Works

Attachment

cc: Sean Joyce, City Manager
Sharon Landers, Assistant City Manager
Doug Williford, Community Development Director
Mike Loving, Water Quality Administrator

SARB_012059

PRINTED ON RECYCLED PAPER

1) Sections X.2 and X.3 require inspections for all commercial facilities. Based on the Second Draft, 10% of commercial sites must be prioritized as 'high' and inspected once a year; 40% must be prioritized as 'medium' and inspected once every two years; and the remaining 50% must be prioritized as 'low' and inspected once every permit cycle. This would put a tremendous burden on larger cities at a time of dwindling resources. For example, this requirement would result in 985 additional inspections per year for the City of Irvine at an increased annual cost of $279,700, and result in no discernable improvement to water quality. The required time for inspection is 3,545 hours per year, which is equivalent to 2.3 full time positions.

   We would like to propose the permittees use the prioritization scheme as outlined in the Second Draft but only carry make inspections on 'high' priority sites as is the case with the current MS4 permit. This should address the Regional Board's concern about some permittees not performing commercial inspections.

   Additionally, Sections X.3 and X.5 require photographic documentation for all aspects of each commercial facility inspection whether or not a violation exists. This is different than the requirement for industrial facility inspection found in section IX.3 which only requires photographic documentation when there is a water quality violation for industrial facility.

   The City of Irvine proposes to only require photographic documentation when there is a violation. This would minimize issues relating to trade-secrets and other legal issues resulting from taking pictures without offering any valid reason to the facility representative. It will also reduce the burden of having to file and cross reference a huge amount of data.

2) Section XII.A.7: Clarify that timing for update of project approval process is the same as for update of CEQA documents set forth in Section XII.A.6 (at time of DAMP finalization and no more than 24 months from permit adoption).

3) Section XII.B.1 and XII.C.1: We request the reference to "WQMP" to expressly refer to the adoption of a revised "model" WQMP so it is, in turn, clear that:

   a. under Section XII.C., LID requirements do not apply to development of conceptual or project WQMPs approved prior to 12 months after permit adoption, which is when the approval of the revised model WQMP is proposed to occur;
   b. under Section XII.D., hydromodification control requirements do not apply to the development of conceptual or project WQMPs approved prior to 12 months after permit adoption, which is when the approval of the revised model WQMP is proposed to occur;
   c. under Section XII.J, grandfathered projects are those receiving WQMP approval before approval 90 days after the approval of a revised model WQMP and within the period no more than 15 months after permit adoption.
   d. as a practical matter, permittees and stakeholders have at least 12 months when the revised WQMP must be adopted (and maybe 15 months if an approved conceptual or project WQMP is in place), to put a Watershed Master Plan into place under Section XII.D.5 that provides for hydromodification control on a regional basis and maps sensitive waters, in order to avoid a requirement to implement site-by-site hydromodification controls that meet one of the conditions in Section XII.D.2 (time of concentration control, infiltration of full runoff volume of 2 year storm event). Since conditions in Section XII.D.2 may be infeasible to meet onsite for certain projects (*e.g.*, those with high density/small parcel development plans (infill and transit oriented development), high groundwater,

pollutant plumes, clay soils, etc.), development of the regional hydromodification control plan will be critical to feasibility of individual development project compliance with hydromodification control plans.

4) Section XII.B.5.(a): Clarify that structural infiltration BMPs need to meet a minimum requirement that they should not increase seepage or exfiltration of contaminated groundwater that causes or contributes to an exceedance of surface water quality objectives.

5) Section X.II.D.2.(b): We request that this section be revised so that it does not prevent waters of the U.S. that are stabilized, hardened and improved from being conveyance channels that are *stabilized* and therefore *not* subject to hydrologic conditions of concern. Due to the implementation of ecologically friendly stabilization techniques in recent years, many conveyance channels deploy stabilization improvements that incorporate earthern channel improvements and vegetated stabilization techniques, resulting in the potential to characterize many conveyance channels as waters of the United States. Nevertheless, the conveyance channels are stabilized, and do not present hydrologic conditions of concern, so should not be characterized as sensitive waters simply due to their jurisdictional nature.

6) Section XII.I.5 requires 50% of sites with treatment control BMPs to be inspected prior to the rainy season with all treatment control BMPs to be inspected within a two year period. This means 50% of the sites with treatment control BMPs must be inspected on an annual basis during the dry season between May 1 and September 30. Since the inventory will grow every year, this inspection burden will grow as well.

   The City of Irvine would like to propose the permittees inspect 25% of the sites with treatment control BMPs with all the treatment control BMPs per year to be inspected within a four year period. In addition, we request the entire reporting period, from July 1 to June 30, to conduct inspections instead of limiting inspections during the dry period, from May 1 to September 30. This would allow additional time for permittees to update inventory information for all existing sites with treatment control BMPs and conduct inspections.

7) Item H. of Section XII requires the permittees to establish a mechanism, not only to track treatment control BMPs, but also to ensure appropriate easements and ownerships are properly recorded in public records at the County and/or the City and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

   The City of Irvine proposes to leave recordation requirements to the discretion of the permittees for the following reasons: 1) the County Recorder is already recording easements and ownerships information. Recordation at the City will duplicate this effort; 2) the City routinely accesses easement and ownership information from the County Recorder's office for water quality and code enforcement purposes; 3) the City maintains all approved project WQMPs on file for reference purposes including enforcement and periodic inspections; and 4) the Owner's certification page in the project WQMP clearly states that "Once the undersigned transfers its interest in the property, its successors-in-interest shall bear the aforementioned responsibility to implement and amend the WQMP." With these, the City has the means to obtain current owner information and legal authority to enforce requirements in the project WQMP.

8) The Second Draft requires the permittees to perform certain tasks within a certain time after adoption of this permit. For example, *"in the first annual report following adoption of this permit,"* or *"within six months of adoption of this order."* We are concerned that: 1) there will not be sufficient time to meet some of these requirements within six months or less following adoption of the permit; and 2) most of the permittees complete their budgets for the upcoming fiscal year many months prior to the beginning of the fiscal year on July 1. If there are permit requirements, for example, for completing a task within six months of the proposed April 24 adoption of the fourth term permit, the permittees will not have had an opportunity to include funding in their budgets to comply with the requirement until July of 2010. Therefore, we request the minimum time for completing the various tasks/deliverables outlined in the fourth term permit should be in sync with the permittees' ability to budget for them.

CITY OF LAGUNA HILLS

Public Services

April 9, 2009

By Email and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: COMMENTS FOR TENTATIVE ORDER NO. R8-2009-0030; NPDES NO. CAS618030.

Dear Mr. Thibeault:

The City of Laguna Hills has reviewed the subject order dated March 25, 2009, Waste Discharge Requirements for Discharges of Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District within the San Diego Region (Tentative Order No. R8-2009-0030) (NPDES No. CAS618030). The City of Laguna Hills as Co-Permittee, welcomes the opportunity to provide comments on the second draft of this Tentative Order.

The City of Laguna Hills submitted written comments on the first draft of the Tentative Order on January 30, 2009. Although some comments were addressed in some form or another, others were not responded to at all. City Staff believes that some of the specific regulations in the Tentative Order may adversely affect our ability to effectively deliver the water quality improvements that the Board and the City are seeking to obtain. Consequently, the City of Laguna Hills, working through the Principal Permittee, would like to work closely with the Regional Water Board staff to revise the Tentative Order to ensure that the most effective strategies are implemented to ensure improved water quality. The directives and provisions of concern to the City are as follows:

- Section VI.6, page 34 requires the permittees to provide notification to the Regional Board regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits on a quarterly basis. The Cities do not administer or enforce these permits and should not be forced to perform the work of others. Trying to add this responsibility will create a burden that is not warranted. Cities inspect industrial and construction sites according to their local codes and ordinances. Reporting to the Regional Board is currently done on an annual basis through the

Program Effectiveness Assessment (PEA). The City requests that this new reporting requirement be removed from the draft Tentative Order.

- Section X.1, page 40 requires the permittees to maintain and quarterly update an inventory of commercial facilities within its jurisdiction. This requirement does not seem necessary, as the permittees are regularly tracking their facilities through certificates of use and occupancy. As it is already being updated, the requirement to quarterly update does not seem necessary. The City currently submits its database annually to the Regional Board through the Program Effectiveness Assessment (PEA). This section should be modified to allow the permittees to constantly track their facilities and submit an annual inventory.

- Section X.2, page 41 allocates arbitrary percentages for high, medium, and low priority commercial sites. The draft Tentative Order proposes a minimum of 10% shall be high priority and 40% shall be medium priority sites. The permittees should be given the flexibility as to designating its facilities without being restricted by the Regional Board. It should be noted that this requirement can also be counter productive in the case of an Agency with 100% high priority sites. Per this new requirement, the Agency will need to reduce its inspections because they will be required to have at least 40% medium priority sites. This is why this requirement should be deleted and the permittees should be given the flexibility to rank their own sites.

- Section XII.H.1, page 57 requires the permittees to ensure that all public records including treatment control information is conveyed to the appropriate parties when there is a change in site ownership. This condition should be removed as it unnecessarily places a responsibility on the permittees. Recorded information is automatically transferred to the new owners in the case of an owner change and the City should not be responsible in keeping track of this. Furthermore, state law governs access to Public Records requests and this requirement should be deleted.

- Section XIII.4, page 59 requires the permittees to conduct individual or regional workshops for various commercial businesses on an annual basis. The City believes it is very difficult to have the business community attend these sorts of workshops during their business hours. The City suggests that it is more beneficial to educate while inspecting and with mailers per current requirements which the City is fulfilling. Educational material and other notices have a direct impact on the businesses, and these activities have yielded positive results. This requirement should be deleted.

The City believes the foregoing issues in the Tentative Order will place undue financial burden and prescriptive technical requirements on the City's Stormwater Program without necessarily achieving the desired water quality improvements. The City's limited resources will be diverted

by these regulations. The City believes that a revised Order addressing the City and County comments would assist the City in carrying out a more effective and successful Stormwater Program.

Sincerely,

Kenneth H. Rosenfield, P.E.
Director of Public Services

CITY OF LAKE FOREST

April 9, 2009

Mayor
Mark Tettemer

Mayor Pro Tem
Peter Herzog

Council Members
Richard Dixon
Kathryn McCullough
Marcia Rudolph

City Manager
Robert C. Dunek

Via US Mail and E-mail

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comments on Second Draft Order No. R8-2008-0030, Waste Discharge Requirements for the County of Orange, Orange County Orange County Flood Control District and The Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County

Dear Mr. Thibeault:

The City of Lake Forest ("City") respectfully submits this letter to the Santa Ana Regional Water Quality Control Board ("SARWQCB") to convey the City's formal written comments for the Second Draft of Tentative Order No. R8-2008-0030/NPDES Permit No. CAS618030 ("Draft Permit"). Again, the City sincerely commends the SARWQCB staff for their prudent revisions to the Draft Permit. SARWQCB staff made significant revisions in response to comments from the Copermittees, and other interested parties, to deliver a permit that appears to meet goals to protect the environment while meeting the needs of the regulated community. That being said, the City submitted comments on the first draft of the Permit that were not addressed in the most recent revision. The City's comments on these aspects of the Draft Permit follow.

The City is additionally aware that the County of Orange ("County") is submitting a similar comment letter regarding specific conditions contained in the Permit. The City would like to express its full support for the County's comments and intends the comments contained in this letter to supplement those submitted by the County and the other Permittees. Accordingly, please consider the County's comments to be incorporated in the City's letter by this reference.

COMMENTS

Operation and Maintenance of Post-Construction BMPs

Draft Permit Section XII.I.3 requires the Permittees to "develop a database with information regarding each structural treatment control BMP." This provision is not

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clearly defined and appears to require the Permittees to develop a listing of each structural treatment control BMP in the City, no matter when it was constructed. If this is the case, it would impose an unreasonable administrative burden on the City to require it to locate and document each and every structural BMP that has been installed to date. For that reason, the Draft Permit should be revised to require any such database to be prospective, and require only newly constructed BMPs to be included in the database.

Additionally, Draft Permit Section XII.I.5 requires the annual inspection of all public agency structural treatment control BMPs and 50% of priority development project structural treatment control BMPs. While this may be initially feasible with a relatively small number of structural BMPs to inspect, the inventory of structural BMPs and the number of required inspections will increase annually until it becomes infeasible due to staff and resource constraints. For that reason, the City requests that SARWQCB revise the Draft Permit to allow for self inspection and self certification by both the City and by HOAs and other structural BMP owners. The City further requests that SARWQCB revise the Draft Permit to allow the City to use the self certifications and/or inspections as a representative sampling of all structural BMPs in the City.

Deliverables and Submittal Dates are Unnecessarily Aggressive

The Draft Permit includes several deadlines that the City feels are too aggressive and need to be rolled back. These include the six month deadline for the hydrologic condition of concern mapping requirement; and the recently revised twelve month deadline for the Draft Permit's preliminary WQMP requirements. It is the City's position that these deadlines are unreasonably aggressive and are not feasible with the City's current staff and resources. For that reason, the City requests that the Regional Board revisit the deadlines and consider adjustments to the existing reporting process.

WQMP Priority Development Projects

The City has reviewed the revisions to the Permit's Water Quality Management Plan, and Low Impact Development (LID) requirements, and appreciates the flexibility provided by the Permit's Alternatives and In Lieu provisions. Implementing all of the Permit's LID and hydromodification requirements will not be feasible in all situations. The City is especially concerned with Permit section XII.B.2.i. That section requires the Permittees to incorporate the United States Environmental Protection Agency (USEPA) guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable on any streets, roads, highways and freeways having 5,000 square feet or more of paved surface. Under this low threshold, almost any road construction within the City's boundaries would be required to incorporate the Green Street designs in the USEPA guidance. These design principles include using brick, permeable asphalt, and permeable pavers as preferred construction materials. They also include incorporation of swales and other infiltration BMPs into the road design. While this is a laudable goal, the

design principles advocated in the USEPA guidance are not appropriate in all locations. For example, while permeable pavers, or infiltration friendly brick-work may be appropriate in a "town-center" setting, the limited durability and ongoing maintenance requirements associated with both makes them inappropriate for use in the construction of a new turning lane on a high traffic road.

Coyote Creek TMDL

While the City is not directly impacted by the section of the Draft Permit incorporating Total Maximum Daily Load (TMDL) requirements for Coyote Creek, the City is greatly concerned about the unprecedented application of TMDL requirements of the Los Angeles Regional Water Quality Control Board to portions of the watershed under the jurisdiction of the SARWQCB. If a TMDL is promulgated for watersheds or areas within the jurisdiction of one of the regional boards, it should not be applied to another jurisdiction unless a corresponding TMDL is legally adopted within the jurisdiction, thus affording regulated entities the opportunity to participate in (and if necessary dispute) the adoption of the TMDL.

The Draft Permit Includes Requirements that Exceed Federal Law

The Draft Permit includes numerous requirements that exceed the mandatory requirements imposed by federal law. The SARWQCB clearly has the authority to include such requirements in the Draft Permit, however, when so doing, it must comply with the statutory requirements set forth in the California Porter-Cologne Water Quality Control Act. (*City of Burbank v. State Water Resources Control Bd.* (2005) 35 Cal. 4th 613.) Additionally, as such requirements represent state, rather than federal, mandates, if they are included in the final permit, the Permittees are entitled to reimbursement from the State for the costs associated with implementing them. (California Constitution, Article XIII B, § 6.)

Distribution List

It appears that the Saddleback Valley School District was left off of the distribution list. Several other school districts are included on the distribution list, and Saddleback Valley School District should probably be included as well. This will ensure that it is aware of the Draft Permit, and its potential

CONCLUSION

We appreciate your attention to our comments. The City is committed to the goal of water quality improvement and wants to work with the SARWQCB in developing the most prudent and cost effective way to reach that goal. We look forward to receiving your response to the above comments and concerns. If you should have any questions, please contact Devin Slaven, Water Quality Specialist, at (949) 461-3436.

Sincerely,
CITY OF LAKE FOREST

Robert L. Woodings, P.E.
Director of Public Works/City Engineer

cc: Robert C. Dunek, City Manager
Theodore G. Simon, P.E., Engineering Services Manager
Devin E. Slaven, REA, Water Quality Specialist
Chris Crompton, County of Orange, RDMD

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CITY OF LAKE FOREST

April 9, 2009

Mayor
Mark Tettemer

Mayor Pro Tem
Peter Herzog

Council Members
Richard Dixon
Kathryn McCullough
Marcia Rudolph

City Manager
Robert C. Dunek

Via US Mail and E-mail

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comments on Second Draft Order No. R8-2008-0030, Waste Discharge Requirements for the County of Orange, Orange County Orange County Flood Control District and The Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County

Dear Mr. Thibeault:

The City of Lake Forest ("City") respectfully submits this letter to the Santa Ana Regional Water Quality Control Board ("SARWQCB") to convey the City's formal written comments for the Second Draft of Tentative Order No. R8-2008-0030/NPDES Permit No. CAS618030 ("Draft Permit"). Again, the City sincerely commends the SARWQCB staff for their prudent revisions to the Draft Permit. SARWQCB staff made significant revisions in response to comments from the Copermittees, and other interested parties, to deliver a permit that appears to meet goals to protect the environment while meeting the needs of the regulated community. That being said, the City submitted comments on the first draft of the Permit that were not addressed in the most recent revision. The City's comments on these aspects of the Draft Permit follow.

The City is additionally aware that the County of Orange ("County") is submitting a similar comment letter regarding specific conditions contained in the Permit. The City would like to express its full support for the County's comments and intends the comments contained in this letter to supplement those submitted by the County and the other Permittees. Accordingly, please consider the County's comments to be incorporated in the City's letter by this reference.

COMMENTS

Operation and Maintenance of Post-Construction BMPs

Draft Permit Section XII.I.3 requires the Permittees to "develop a database with information regarding each structural treatment control BMP." This provision is not

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clearly defined and appears to require the Permittees to develop a listing of each structural treatment control BMP in the City, no matter when it was constructed. If this is the case, it would impose an unreasonable administrative burden on the City to require it to locate and document each and every structural BMP that has been installed to date. For that reason, the Draft Permit should be revised to require any such database to be prospective, and require only newly constructed BMPs to be included in the database.

Additionally, Draft Permit Section XII.I.5 requires the annual inspection of all public agency structural treatment control BMPs and 50% of priority development project structural treatment control BMPs. While this may be initially feasible with a relatively small number of structural BMPs to inspect, the inventory of structural BMPs and the number of required inspections will increase annually until it becomes infeasible due to staff and resource constraints. For that reason, the City requests that SARWQCB revise the Draft Permit to allow for self inspection and self certification by both the City and by HOAs and other structural BMP owners. The City further requests that SARWQCB revise the Draft Permit to allow the City to use the self certifications and/or inspections as a representative sampling of all structural BMPs in the City.

Deliverables and Submittal Dates are Unnecessarily Aggressive

The Draft Permit includes several deadlines that the City feels are too aggressive and need to be rolled back. These include the six month deadline for the hydrologic condition of concern mapping requirement; and the recently revised twelve month deadline for the Draft Permit's preliminary WQMP requirements. It is the City's position that these deadlines are unreasonably aggressive and are not feasible with the City's current staff and resources. For that reason, the City requests that the Regional Board revisit the deadlines and consider adjustments to the existing reporting process.

WQMP Priority Development Projects

The City has reviewed the revisions to the Permit's Water Quality Management Plan, and Low Impact Development (LID) requirements, and appreciates the flexibility provided by the Permit's Alternatives and In Lieu provisions. Implementing all of the Permit's LID and hydromodification requirements will not be feasible in all situations. The City is especially concerned with Permit section XII.B.2.i. That section requires the Permittees to incorporate the United States Environmental Protection Agency (USEPA) guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable on any streets, roads, highways and freeways having 5,000 square feet or more of paved surface. Under this low threshold, almost any road construction within the City's boundaries would be required to incorporate the Green Street designs in the USEPA guidance. These design principles include using brick, permeable asphalt, and permeable pavers as preferred construction materials. They also include incorporation of swales and other infiltration BMPs into the road design. While this is a laudable goal, the

design principles advocated in the USEPA guidance are not appropriate in all locations. For example, while permeable pavers, or infiltration friendly brick-work may be appropriate in a "town-center" setting, the limited durability and ongoing maintenance requirements associated with both makes them inappropriate for use in the construction of a new turning lane on a high traffic road.

Coyote Creek TMDL

While the City is not directly impacted by the section of the Draft Permit incorporating Total Maximum Daily Load (TMDL) requirements for Coyote Creek, the City is greatly concerned about the unprecedented application of TMDL requirements of the Los Angeles Regional Water Quality Control Board to portions of the watershed under the jurisdiction of the SARWQCB. If a TMDL is promulgated for watersheds or areas within the jurisdiction of one of the regional boards, it should not be applied to another jurisdiction unless a corresponding TMDL is legally adopted within the jurisdiction, thus affording regulated entities the opportunity to participate in (and if necessary dispute) the adoption of the TMDL.

The Draft Permit Includes Requirements that Exceed Federal Law

The Draft Permit includes numerous requirements that exceed the mandatory requirements imposed by federal law. The SARWQCB clearly has the authority to include such requirements in the Draft Permit, however, when so doing, it must comply with the statutory requirements set forth in the California Porter-Cologne Water Quality Control Act. (*City of Burbank v. State Water Resources Control Bd.* (2005) 35 Cal. 4th 613.) Additionally, as such requirements represent state, rather than federal, mandates, if they are included in the final permit, the Permittees are entitled to reimbursement from the State for the costs associated with implementing them. (California Constitution, Article XIII B, § 6.)

Distribution List

It appears that the Saddleback Valley School District was left off of the distribution list. Several other school districts are included on the distribution list, and Saddleback Valley School District should probably be included as well. This will ensure that it is aware of the Draft Permit, and its potential

CONCLUSION

We appreciate your attention to our comments. The City is committed to the goal of water quality improvement and wants to work with the SARWQCB in developing the most prudent and cost effective way to reach that goal. We look forward to receiving your response to the above comments and concerns. If you should have any questions, please contact Devin Slaven, Water Quality Specialist, at (949) 461-3436.

Sincerely,
CITY OF LAKE FOREST

Robert L. Woodings, P.E.
Director of Public Works/City Engineer

cc: Robert C. Dunek, City Manager
Theodore G. Simon, P.E., Engineering Services Manager
Devin E. Slaven, REA, Water Quality Specialist
Chris Crompton, County of Orange, RDMD

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ORANGE COUNTY
OC Public Works
Our Community. Our Commitment.

Bryan Speegle, Director

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April 9, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Second Draft of Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The County is in receipt of the second draft of *Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County* (Order No. R8-2009-0030) dated March 25, 2009 and welcomes the opportunity to provide comments on the revised Order. The Permittees were involved in the development of these comments and the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Garden Grove, Fullerton, Huntington Beach, Irvine, La Palma, Laguna Hills, Lake Forest, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Westminster have directed that they be recognized as concurring entities.

The County would like to commend your staff again on both their initial efforts to incorporate the recommendations made in the Report of Waste Discharge into the Order and subsequent willingness to address the comments and key concerns presented in our letter of February 13, 2009. In particular, the series of stakeholder meetings to discuss the Tentative Order's land development provisions have been particularly helpful. Many of the specific comments, which centered on increased administrative burdens, over-extension of local regulatory reach, and TMDL integration, have been resolved. In addition, from the stakeholder meetings has emerged an initial series of consensus points that has provided the foundation for provisions that now prescribe a technically robust framework for implementing low impact development approaches to benefit water quality in the context of integrated watershed master planning.

The County's remaining areas of principal concern relate to reporting, inspection of commercial facilities, revisions to the land development requirements and the Coyote Creek TMDL, specifically:

<u>Reporting</u>

a. Reporting Requirements

The revised Order continues to require additional reporting to Regional Board staff and submittal of entire enforcement databases. The County continues to believe that the refining of existing reporting mechanisms, rather than the creation of additional reporting obligations, is the most effective approach to increasing transparency and accountability for our respective agencies. In addition, the opportunity for a collaborative and strategic review of current reporting would also likely provide a means of moving toward greater regional consistency and reduce the reporting burden of the Program for both the Regional Board and for the Permittees. The format of San Bernardino's municipal stormwater program has already been mentioned as one alternative model that should be considered in this context.

b. Compliance Submittals

The revised Order includes several requirements to be fulfilled and reported to the Regional Board within the first 6 months, or concurrent with the first annual report submittal, following adoption of the Order. The County is concerned that this timeline does not provide the Permittees with sufficient time to comply with the associated requirements. Furthermore, many of the Permittees have already completed their budgets for the upcoming fiscal year. Therefore, the County requests that these requirements, with the exception of the interim requirement previously discussed with Regional Board staff concerning hydrologic condition of concern (HCOC) mapping, be revised to include submittal dates of at least 12 months from adoption to allow the Permittees an adequate time period for compliance.

Inspections

a. Commercial Inspections

The revised Order continues to include new requirements that increase the universe of commercial facilities subject to inspection. The principal concerns here are the significant resource implications for cities, at a time of extraordinary fiscal and resource constraint. For example, three of the larger Permittees have calculated that the revised commercial inspection obligation will necessitate them conducting 5,551 additional inspections over a five year permit term. There also remains an underpinning question regarding the technical justification for this expanded program.

There is a substantial body of environmental quality and programmatic performance data available to inform development of a more appropriately constructed risk-based scheme for directing inspection resources. The Permittees would again advocate that the permit should provide an opportunity to develop this scheme as an alternative to the entirely arbitrary designation of risk in the current version of the permit and that alternate forms of inspections, such as self certifications, be available for consideration. It is therefore recommended that Section X.2 and 3 be revised as follows:

"2. Each permittee shall conduct, or require to be completed, commercial facility inspections as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, materials used and wastes generated at the site. Within 12 months of adoption of

this Order, the permittees shall develop a prioritization and inspection schedule for the commercial facilites in Section X.1 for approval of the Executive Officer. At least 10% of commercial sites (not including restaurant/food markets) must be ranked "high" and these represent the greatest threat to water quality." (Note – footnote 44 should also be deleted)

"3. Each permittee shall conduct, or require to be completed, commercial facility inspections for compliance with its ordinances, permits and this Order at frequencies determined by the approved prioritization and inspection schedule. Commercial sites ranked "high" shall be inspected at least one time per year. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; review of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; an assessment of management/employees awareness of storm water pollution measures; and appropriate documentation of conditions."

b. Post Construction Inspections

With land development projects, the installation and subsequent maintenance of treatment controls certainly needs to be verified. However, self certification is already a verification mechanism being used by Permittees and it and other third party verification mechanisms should not be precluded by the Order in exclusive favor of Permittee inspection over the life of a project. Given the current state of the economy, the Permittees, like all municipalities, would again reiterate that they are facing shrinking budgets and the Regional Board needs to give great weight to the best use of limited resources in achieving water quality objectives.

c. Coordination of Inspections with the Regional Board

Findings 26 to 30 in the Order clearly identify that there is a shared role for the Regional Board and the Permittees in conducting inspections of many facilities. The current limited resources available to both the Regional Board and the Permittees make it especially important that coordination on inspections be enhanced. It is recommended that a formal framework for inspection responsibilities be established in the many areas of overlapping jurisdiction. This could be recognized in the Order as an item that both parties should develop.

<u>Land Development Requirements</u>

a. Low Impact Development

The following clarifying text changes are recommended to Section XII.C 1 and 2:

1. "Within 12 months of adoption of this Order, the permittees shall update the model WQMP to incorporate LID principles (as per this Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated model WQMP shall be submitted for approval to the Executive Officer. Priority development projects that meet the feasibility criteria established pursuant to Section XII.E. shall implement the LID principles described in this Section XII.C."

2. "LID site design principles shall be designed to reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the predevelopment hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration and treatment systems as close as possible to the source of runoff. Site design considerations shall include, but not be limited to:"
(Bullets a-h remain the same)

The following text changes are recommended to Section XII.E.1:

1. "Within 12 months of adoption of this order, the Principal Permittee, in collaboration with the co-permittees, shall develop feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs." (Remaining paragraph remains the same)

b. Hydromodification

The provisions of the revised Order relating to water quality protection and the implementation of low impact development schemes have been substantially revised. They now provide a technically robust framework for implementing low impact development approaches to benefit water quality in the necessary context of integrated watershed master planning. However the Permittees are deeply concerned regarding a revision to the hydromodification provision, not considered by the stakeholder group, which appears to require that hydromodification be addressed in all development projects irrespective of the condition of the downstream conveyance channels that will receive runoff from the project. This revision appears to make irrelevant all of the careful crafting of the preceding language regarding low impact development and project design for water quality protection. We recommend that Section D.2.b be revised to read:

"b) As long as all downstream conveyance channels that receive runoff from the project remain engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat area will be affected."

c. Comments on Report Entitled "Low Impact Development Metrics in Stormwater Permitting"

The subject report, dated January 2009, was prepared jointly by the Orange County and Ventura County Stormwater Programs and was provided to Regional Board staff and to others during the above described stakeholder meetings. Dr. Richard Horner provided a formal critique of this report in comments submitted to the Regional Board on the first draft of this Order and this critique was also referenced in the comments of the Natural Resources Defense Council. Please find attached a written response to a number of Dr. Horner's issues.

<u>Coyote Creek TMDL</u>

Extensive comments were provided in our letter of February 13, 2009 regarding the inappropriate implementation of TMDLs developed by U.S. EPA for impaired waters in the Los

Angeles Region. The Regional Board's response to comments did not adequately address these comments.

We appreciate the effort that you and your staff have devoted to the development of the fourth term permit for the Orange County Stormwater Program. We look forward to meeting with you and your staff to quickly resolve the Permittees' remaining concerns regarding the Order to ensure that it meets our mutual goals.

Thank you for your attention to our comments. Please contact Richard Boon at (714) 955-0670 or Chris Crompton at (714) 834-6662 with any questions on this matter.

Sincerely,

Mary Anne Skorpanich
Director, OC Watersheds Program

cc: City Permittees

Attachment: Response to Dr. Horner's Comments on "Low Impact Development Metrics in Stormwater Permitting"

Geosyntec consultants

LARRY WALKER ASSOCIATES

Memorandum

Date:	9 April 2009
To:	Mary Anne Skorpanich, Director, OC Watersheds Program
cc:	Jeff Pratt, Public Works Director, County of Ventura
From:	Eric Strecker, P.E. and Aaron Poresky, E.I.T Geosyntec Consultants Malcolm Walker, P.E. Larry Walker and Associates
Subject:	Response to Critical Comments on "Low Impact Development Metrics in Stormwater Permitting"

This document contains Geosyntec response to elements of "Critique of Certain Elements of 'Low Impact Development Metrics in Stormwater Permitting'" (Dr. Richard Horner, February 2009 (paper not dated))

Dr. Horner's paper is referenced in a subsequent memorandum from the Natural Resources Defense Council (NRDC) to Ms. Carolyn Beswick and Members of the Santa Ana RWQCB titled: *Draft NPDES Stormwater Permit for the County of Orange, Tentative Order R8-2008-0030*. Comments on Dr. Horner's critique expressed herein apply to the NRDC memorandum by extension.

1 Overview

1.1 Dr. Horner's paper critiques elements of "Low Impact Development Metrics in Stormwater Permitting" prepared by Geosyntec Consultants and Larry Walker Associates (Geosyntec and LWA, 2009). The critique questions several assumptions and assertions made in the case studies contained therein, disagrees with the recommendations of the study, and selects elements from the study that support the assertion that a 5% effective impervious area (EIA) standard is both widely feasible and effective.

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2 General Responses

2.1 It appears that all parties are in agreement that an appropriate LID standard must be linked to a volumetric standard. One of the objectives of the Metric paper was to determine the practicality and environmental outcomes of the LID metrics proposed in the draft April 2008 Ventura Countywide permit and the November 2008 Orange Countywide permit. The Metrics paper addressed the lack of such a volumetric standard in the Draft Ventura County permit. Without a volumetric standard the EIA metric may be abused. It is acknowledged that a volumetric standard is included in the Draft Orange County permit.

2.2 Geosyntec and LWA do not agree with, nor does the Metrics paper support, the validity or effectiveness of a 5% EIA limit. While values in the range of 5% EIA have been found to correspond to a "threshold" for channel degradation in some studies, the use of these findings to support a 5% EIA standard for new development and redevlopment projects relies on two tenuous links. First, the definition of EIA contained in the two draft permits does not necessarily correspond to the definition employed by studies of the impacts of EIA. Second, the studies finding approximate thresholds of 5% EIA were based on watershed averages, not individual projects or parcels. The Metrics paper states that a volumetric criterion for LID implementation does not need to be linked to a specific spatial extent of disconnection and/or compliance on a lot-by-lot basis to be protective, and that establishing a lot-by-lot criterion could inadvertently cause adverse impacts to receiving water quality (e.g., could lead to sprawl or preclude infill/redevelopment projects from occurring).

2.3 From the arguments provided in the critique, it appears that Dr. Horner misinterpreted the context in which the LID provisions of the draft MS4 permits are proposed. The critique argues against a "delta volume" approach and for a "full volume approach" to LID sizing. We fully support the component of the draft permits that require treatment of the entire "water quality volume." The critique's apparent misunderstanding is to confuse the LID design standard with the water quality design standard. The bulk of the argument against a delta-volume as a LID sizing metric is based on this apparent misunderstanding and the resulting assumption that any volume above the delta volume would be allowed to discharge without treatment or hydrologic control. This is not the case for either the Ventura or Orange Countywide draft permits. Both the water quality treatment and hydromodification elements of the draft permits would prohibit this from occurring. This item is discussed further in Section 3.1 below.

2.4 Geosyntec and LWA do not agree with, nor does the Metrics paper support, the critique's assertion that infiltration and reuse are feasible in all densities and types of development. A variety of limitations can prevent infiltration on a project site which are typical in

southern California. Dr. Horner's study "Investigation of the Feasibility and Benefits for Low-Impact Site Design Practices ("LID") for Ventura County" (Horner, 2007) does not consider site specific infiltration rates and other limitations on infiltration; rather, it relies on a modeling study that assumed rather high infiltration rates based on San Fernando Valley soil types and applied those results in a rather simplified way to different case studies for example projects from San Diego County. Geosyntec has previously prepared a critique of this study (Geosyntec, 2008) that found various misrepresentations of findings and problematic assumptions that tended to result in uncertainty about claims of feasibility and effectiveness of an EIA standard at all project densities.

2.5 Horner (2007) relies on capture and reuse as a fall-back strategy where infiltration is not feasible. Stormwater reuse for the purpose of stormwater management requires a sufficient demand during the wet season to replenish the capacity of storage units to be effective as a stormwater management device. Horner (2007) does not attempt to demonstrate the effectiveness of capture and reuse. It is well understood that if sufficient water demand does not exist during the rainy season, the volume of storage that can be made available for subsequent storms is minimized. This would result in overall poor performance of capture and reuse to achieve stormwater management goals. Furthermore the Metric paper would be remised if it did not acknowledge the "practicality" challenges that are associated with the implementation of capture and reuse options, such as building and health code compliance.

2.6 We appreciate the detailed comments the critique offers on the case studies contained in the Metrics paper. Several were well-founded and could be used to make the case studies more robust. However, it is apparent that several others were made without consideration for the stated purposed of the case studies and thus unfairly misrepresent the findings of these studies. The findings of the Metrics paper do not support a lot-by-lot EIA criterion. In fact, the case studies demonstrate that lot-by-lot EIA limits are not the only, nor necessarily the best, way to realize the benefits of LID. The scope of the studies is not broad enough to dismiss the feasibility of this criterion nor did it attempt to do so. The critique takes this lack of dismissal as support for a lot-by-lot EIA limit and labels important constraints identified by the case studies as simply "negative". The critique's detailed comments on specific assumptions are tangential to the underlying discussion of whether a lot-by-lot EIA limit is superior to more appropriate watershed-scale metrics that may be better linked to the resources they are attempting to protect, as well as supported by the research on the impacts of impervious area on riparian ecology.

3 Specific Responses to the Critique

3.1 **Selection of an LID Design Storm.** On pages 1 through 3, the critique references a variety of studies that have found that the "full water quality volume" (calculated in a variety of ways across the country) represents the "point of diminishing returns" for water quality improvement. While we believe that this assumption should always be confirmed through analysis of site-specific rainfall patterns, we are in general agreement. The recommendations of the Metrics paper are not to replace the established water quality treatment criteria with the LID criteria. Rather, the Metrics paper recommends that the LID criteria should be less than the full water quality criteria and allow for natural condition runoff potential to be factored into calculations.

It appears that Dr. Horner erroneously treats the LID and water quality provisions of the draft permits interchangeably. Among the various regulatory standards that the critique cites (Georgia, Washington, Maine, Pennsylvania, North Carolina), only one standard appears to require retention of a specific design storm (Pennsylvania). This standard requires treatment of the first 2" of runoff from all impervious surfaces and permanent removal (i.e., infiltration, ET, or reuse) of 1" of runoff from new impervious surfaces. This does not seem to represent a "full volume" standard, nor does it seem to be consistent with the logic that the critique uses to support a full retention standard. Note that this "standard" is in a guidance document that is a draft form and has not been adopted to date. The other standards that were mentioned only require treatment of the design storm. It is not clear how these example regulations support a standard that would require capture and infiltration or reuse of the entire water quality volume. .

3.2 **Performance of LID vs. WQ Design Storm.** The critique relies on an event-based methodology to illustrate the difference between a "delta volume" and "full volume" approach, which inherently over-states the difference between these two standards. The critique claims that a "delta volume" design storm would result in significant impacts while a full volume design storm would result in none. (P 2)

> *"When managing water quality, in contrast, any untreated volume (in the delta volume scenario, this would be the amount that originally flowed from the undeveloped land) would deliver to the receiving water the many pollutants characteristic of urban runoff. There, these pollutants would create negative physical, chemical, and biological effects. On the other hand, if the appropriate water quality volume is used (i.e. no less than the 85th percentile event)* ***the LID-based stormwater management BMPs should deliver no pollutants to the receiving water****, since the retention and reuse or infiltration of that volume is practicable and achievable, as I have demonstrated separately by analyzing a range of development scenarios in southern California."* [Emphasis added]

This excerpt shows an apparent misunderstanding of BMP performance factors. BMPs are not designed to capture all of the runoff volume from every storm, but only that volume up to the design storm volume (e.g., 0.75 inches). Thus, the argument above applies only to a specific storm depth for which the difference in performance for "full volume" BMPs and for "delta volume" BMP would be greatest. Long term performance of a BMP depends on the patterns of rainfall and the drawdown rate of the BMP in addition to the storage volume provided. All other factors equal, the use of a "delta volume" approach (i.e., a smaller storage volume) would indeed infiltrate a lower portion of the overall runoff than a "full volume" approach, but the difference may be something on the order of capturing 70% versus 80% of the average annual runoff volume, not an "all or nothing" outcome. As the critique points out, the difference between the "delta volume" and the "full volume" is small for the cases considered. The runoff that is between the difference of the "delta volume" and the "full volume" would still require treatment to remove pollutants before discharge, which is not considered in the critique.

3.3 **Use of Horner, 2007 as a Basis for Assumption of Feasibility**. Dr. Horner's critique refers to his study entitled "Investigation of the Feasibility and Benefits for Low-Impact Site Design Practices ("LID") for Ventura County" as evidence of the benefits and feasibility of LID implementation at all densities. Geosyntec has already provided a critique of this study (Geosyntec, 2008) in which we found:

- Three of the six case studies assumed a lower imperviousness than typical of their land use category. For example, the restaurant case study assumed an imperviousness of 49%, although the Ventura County Hydrology Manual lists an average imperviousness of 85% for this land use. Lower imperviousness yields less runoff-generating surface and more area available for infiltration.

- The study assumed that all of the pervious area would be available for infiltration; no reduction was made to account for necessary building setbacks or to account for scenarios in which some pervious area is upgradient of impervious area or otherwise not suitable for infiltration.

- Dr. Horner's study made questionable use of a study of the benefit of infiltration basins in the San Fernando Valley. Geosyntec's critique identifies issues with this study as well as issues in the applicability of this study to Dr. Horner's findings for Ventura County. For example, the San Fernando Valley study assumed infiltration rates of 0.5 to 2 inches per hour and made use of daily rainfall totals from a San Fernando gage. The 2007 study did not attempt to validate or adjust these assumptions for the range of rainfall and soil conditions present in Ventura County.

- In higher density development and in areas of Ventura County that experience larger rainfall events, the conclusions of Dr. Horner's study were not supported by his calculations. The 2007 study relied on a fall-back strategy of capture and reuse where infiltration would not be sufficient to mitigate stormwater runoff; however, the study did not evaluate the effectiveness or feasibility of this concept.

Overall, the findings of the Horner (2007) study do not appear to fully support the stated conclusions related to volume reduction and feasibility of meeting an EIA standard. Considering the simplifications that the study relied upon, we believe that there should be more qualifications of, or limitations on, the findings.

3.4 **Benefits of LID in Case Studies**. Dr. Horner's critique asserts that the case studies contained in the Metrics paper do not address the benefits of LID. First, the stated intent of the studies was to evaluate the feasibility of implementation of a variety of interpretations of an EIA standard for LID implementation. It was not to perform a cost-benefit analysis. The primary benefits of LID lie in the volume reduction it can achieve on suitable sites. In fact, each scenario was linked to the volume retained on-site, thereby implicitly describing the benefits of implementation. The studies identified different ways in which equivalent benefit could be achieved.

3.5 **Walnut Village assumption of infiltration rate**. The critique contends that an assumption of 0.2 inches per hour for B soils is too low, and that the study ignores a basic tenant of LID: that soils should not be compacted during development. This case study was of an actual redevelopment project in Anaheim that included underground parking under the majority of the site and landscaped areas typically measuring 4-8 feet in width between the adjacent roadways and building foundations. We would like to make several comments related to this contention:

- In redevelopment projects, the condition of underlying soils may be out of the control of the site design engineer. While it is considered a "best practice" to recondition soil through soil amendments, this practice can only be feasibly implemented to a certain depth. If a low permeability soil layer lies below this depth, whether due to prior site compaction or natural site conditions, then reconditioning the surface, while increasing moisture storage capacity, would not necessarily increase the rate at which moisture storage capacity can be regenerated by infiltration.

- Both roadways and building foundations require compaction of underlying soils for structural stability. In an ideal scenario, the soil underlying the thin strips of landscaping would not be compacted, however it may very well be within the practical influence area of adjacent compacted areas.

- In cases where the landscaped area is proximate to the foundation of the underlying garage, compaction may be required for structural purposes, and in fact, infiltration may be prohibited for structural reasons.

- Typical guidance in the design of infiltrative BMPs suggests a factor of safety to account for long-term degradation of infiltration rates. For example, the Stormwater Management Manual of Western Washington (WADOE, 2005) recommends a factor of safety of 4 for BMPs relying primarily on infiltration in soils with unadjusted infiltration rates from 0.5 to 8.0 inches per hour. Such guidance seems prudent where the result of failure is the discharge of greater volumes of runoff to receiving waters and/or long durations of standing water potentially leading to public health concerns. The critique cites a range from 0.57 in/hr to 1.4 in/hr for B soils from the NRCS soil survey, a source which generally considers soils in their natural state (NRCS, 2007). Quoting from this source (Section 630.0702):

  "As a result of construction or other disturbances, the soil profile can be altered from its natural state and the listed group assignments generally no longer apply, nor can any supposition based on natural soils be made that will accurately describe the hydrologic properties of the disturbed soil. In these circumstances, an onsite investigation should be made to determine the hydrologic soil group."

Factoring the effects of incidental compaction in the urban environment and a prudent factor of safety, the assumption of 0.2 inches per hour as a design infiltration rate for B soils is consistent with the critique's citations. While the critique accurately points out that a slightly higher assumption would indeed reduce the drawdown time to less than 72 hours, this does not negate the fact that with relatively deep BMPs over soils with low infiltration rates, limited storage capacity would be regenerated for sequential storms. Such sequential storm sets are responsible for a large fraction of total precipitation in Southern California.

3.6 **Walnut Village – "non-essential hardscape".** Geosyntec and LWA agree that in some cases more hardscape is used in development than necessary. However, it should not be taken as a given that landscaping is less expensive. The statement in the case study should have been "apparently non-essential hardscape". The case studies explicitly state that not all site-specific constraints could be evaluated. It is likely that some of the hardscape that was removed for the 0% EIA case could have been needed for ADA access or to meet parking standards, if the case study were to be evaluated more closely.

3.7 **60 California – appropriateness of greenroofs and cisterns.** We appreciate the critiques's perspective on the trend of BMPs towards greenroofs and reuse. We fully

embrace these technologies in places where they can be demonstrated to have a good chance of success. However, the critique does not demonstrate that the use of greenroofs and stormwater reuse are commonplace. Currently, greenroofs have been implemented primarily in a few large cities and primarily on public buildings.

The critique refers to an established program of rainwater harvesting and reuse in Texas. While eastern Texas receives greater rainfall than Southern California, the critique states that western Texas "has rainfall conditions very much like southern California's". A detailed review of the Texas Rainwater Harvesting Guidelines (TWDB, 2005) showed that this program is primarily targeted toward using harvesting to meet water demands, not to control stormwater. It should also be noted that large parts of Texas receive summer rainfall in the form of thunderstorms which rarely, if ever, occur during the summer in Southern California. Figure 1 provides a summary comparison between precipitation and evapotranspiration patterns in western Texas versus southern California.

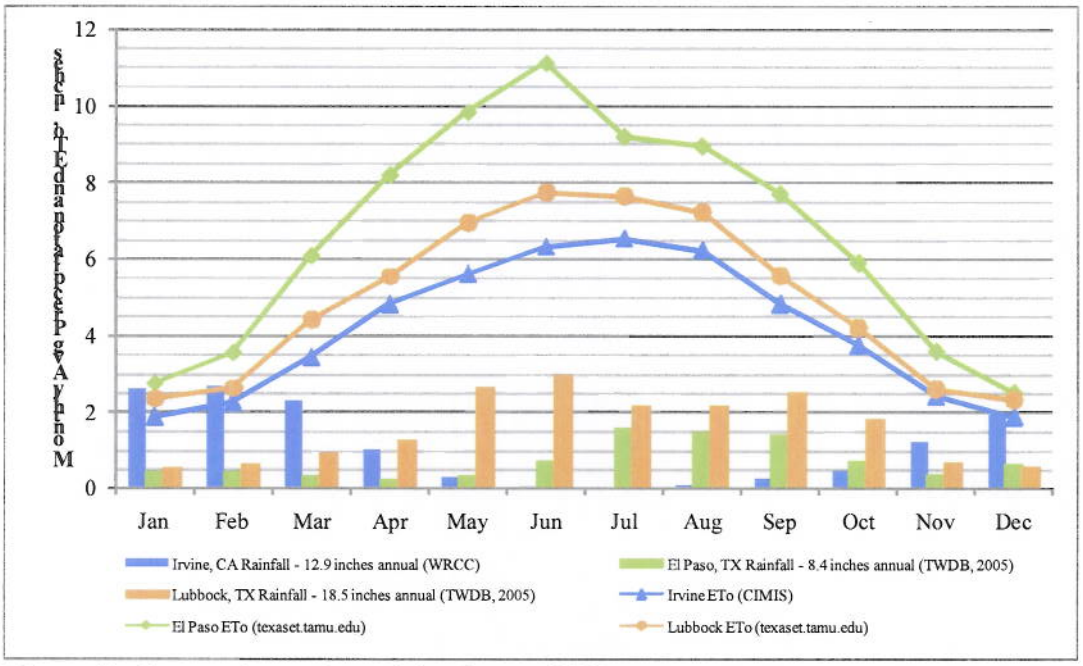

Figure 1: Comparison of precipitation and ET patterns between western Texas and southern California

Based on this preliminary comparison, western Texas appears to be a more favorable location than southern California for rainwater harvesting to manage stormwater impacts and meeting water demands. First, periods of higher rainfall are coincident with periods of higher ETo in west Texas, while the opposite is true in southern California. Second,

rainfall occurs more steadily throughout the year in west Texas compared to the normally dry spring, summer and fall months of southern California.

3.8 **60 California – anticipated performance of greenroofs and cisterns**. The critique provides a somewhat vague defense for the performance of greenroofs in Southern California. One cited study found that a greenroof in Pennsylvania could reduce average annual runoff volumes by 50 percent. This study was compared to Southern California by saying that pan evaporation rates are between 3.3 and 4.2 inches per month in Pennsylvania from June to September (presumably a wet season in that locale) while November – February pan evaporation ranges from 3.5 to 4.0 in Los Angeles. A review of local ET data in Los Angeles County showed that this comparison is not valid. Monthly ET rates in Southern California range from about 1.5 to 2.5 from November through February. Also, rainfall is more seasonally concentrated in Southern California than in the mid-Atlantic region. Figures 2 and 3 below provide a comparison between Irvine, CA and the Washington, DC vicinity, for example.

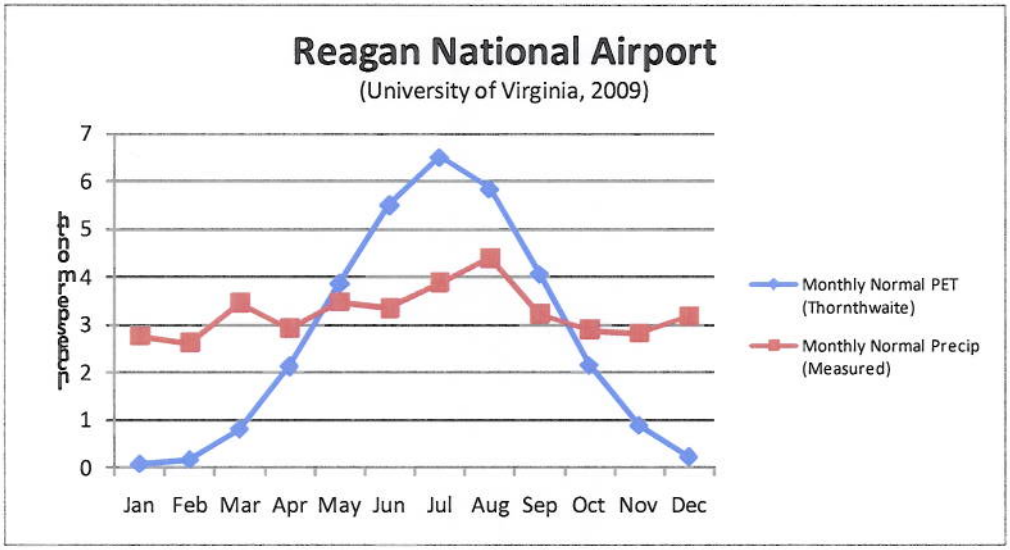

Figure 2: Monthly normal patterns of ET and precipitation at Reagan National Airport

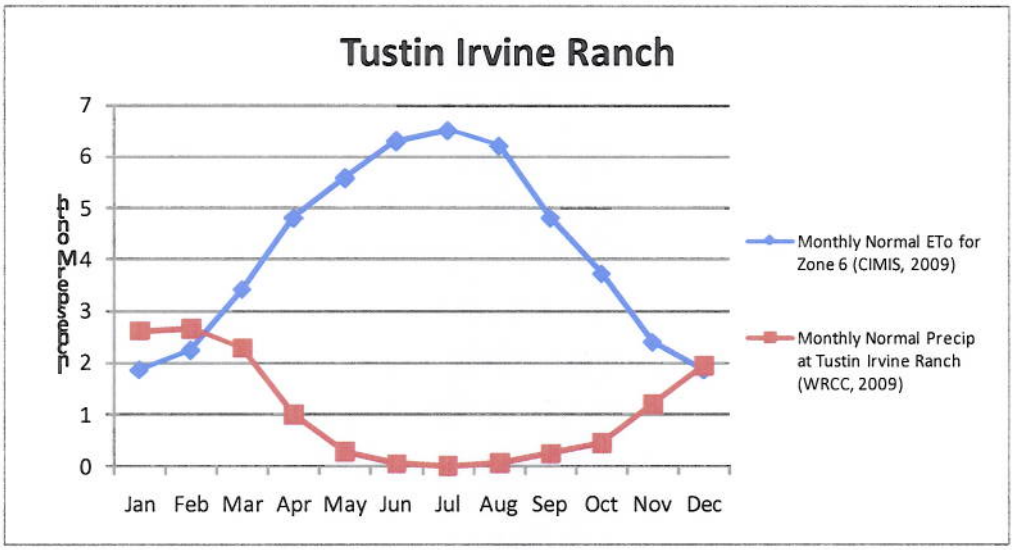

Figure 3: Monthly normal patterns of ET and precipitation in Irvine, CA

Dr. Horner states: "Therefore, Los Angeles has as much evaporation potential in the months when it most needs that potential as locations with successful green roofs elsewhere." Figure 2 shows that ET rates in December, January, and February are lower than the average precipitation. As precipitation is rarely average, on frequent occasions rainfall rates will significantly exceed ET rates. Thus Dr. Horner's conclusion does not seem to be supported by the examples provided.

Dr. Horner's critique does not address anticipated performance and feasibility of capture and reuse systems.

3.9 **60 California – regulatory barriers to indoor reuse**. We agree that codes should not be regarded as unbending. However, we feel it would not be responsible to discuss indoor reuse and its current feasibility without mentioning the current limitations and considering the time that may be needed to get code changes in place. We do not state that this should be basis for dismissing this approach.

3.10 **Ventura K-mart – scope of study**. We agree that the scope of this case study was too narrow to draw wide-ranging conclusions about cost. Likewise, the study did not "reject" tree boxes, bioretention, pervious pavement, green roofs, or water harvesting as the critique indicates. The study simply stated that two typical BMPs were chosen for evaluation. This is an issue of scope, not logic.

Dr. Horner himself took a simplified approach to costs by relying on the EPA report entitled: *Reducing Stormwater Costs through LID Strategies and Practices* (EPA 841-F-07-006, December 2007 - available for download at www.epa.gov/nps/lid). This

report generally found that LID could result in cost savings. It is well understood that design criteria play a large factor in the cost of BMPs, however only two of 17 case studies contained in the EPA 2007 reported design criteria. Likewise, only three of 17 estimated performance. It is not clear whether these sites were designed to similar standards. It is also unclear whether these sites represent opportunistic examples (i.e., sites that had a natural fit for LID-type BMPs) or whether they are a true cross-section of development sites with the various inherent constraints.

Some of the studies contained in EPA (2007) relied on BMPs, such as narrowing street width and downspout disconnection, which would not be widely applicable to many high-density redevelopment projects. Of the BMPs contained in the case studies that would likely be used for higher-density projects (bioretention, permeable pavement, green roofs, and cisterns), permeable pavement was considered in only two of 17 case studies, and green roofs were considered in only one of the 17 studies (cost-benefit analysis showed substantially greater costs than benefits for this study). Cisterns with reuse were not considered in any of the 17 studies. Considering these factors, this source should not be relied upon solely in evaluating the costs of implementing the proposed permit requirements.

3.11 **Ventura K-mart – method of runoff estimation**. We agree that the NRCS curve number is not the best method to use for small storms, however the critique of this method is tangential to overall results, and use of the NRCS curve number method would actually tend to under-predict infrastructure requirements (i.e., cost). We appreciate this comment. It is noted that in Dr. Horner's previous evaluation of feasibility and effectiveness (Horner, 2007), the curve number method was used to establish the volume that would need to be infiltrated on-site.

3.12 **Ventura K-mart – assumption of infiltration rate**. We appreciate this correction. It appears that an adjustment factor was not applied as described in Section 3.5 to account for long-term decline in infiltration rate. Correction of this error would result in substantially increased infrastructure requirements (i.e., cost).

4 References

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CITY OF ORANGE

PUBLIC WORKS DEPARTMENT www.cityoforange.org

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April 9, 2009

Mr. Marc Brown
California Regional Water Quality Control Board
Santa Ana Region
3737 Main St., Suite 500
Riverside, CA 92501- 3348

Subject: Second Draft Dated March 25, 2009 of Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and Incorporated Cities of Orange County, Tentative Draft Order R8–2008-0030, NPDES No. CAS618030, Area Wide Urban Storm Water Runoff

Dear Mr. Brown:

The second draft of the Orange County Municipal Storm Water Permit has made significant progress towards addressing the concerns of the permittees especially in the New Development requirements. We applaud your work and that of other regional board staff in listening to the concerns of the cities and County and addressing those concerns in the revised draft permit.

The issues addressed in this letter and attachment are those that were not specifically addressed in the response to comments matrix or issues that we believe continue to be a significant concern to the City. The City is particularly concerned with the implementation of LID on redevelopment projects and the mandatory 10/40/50% prioritization of commercial facilities. These issues and others are more fully discussed in the attachment to this letter.

Questions regarding these comments should be addressed to Gene Estrada at 714-744-5547.

Sincerely,

Joe DeFrancesco
Interim Public Works Director

Attachment: Comments on Second Draft Municipal Storm Water Permit

cc: John Sibley, City Manager
Alice Angus, Community Development Director
Chris Crompton, Manager, Environmental Resources, County of Orange

SARB_012091

ATTACHMENT

Comments on Draft Municipal Storm Water Permit

Following are comments on the revised March 25th second draft of the Orange County Municipal Storm Water permit. Comments are arranged in the order in which the provisions are found in the permit. An analysis of the provisions is provided along with the recommended actions and changes or clarifications required. Items requiring simple clarification are included at the end.

PERMIT PROVISIONS

Section X – Municipal Inspection of Commercial Facilities

This section contains the requirements for inspection of commercial facilities. Previous City comments to the provisions in this section indicated that the new requirement to inspect commercial businesses based on the 10/40/50 criteria was arbitrary with no technical justification that would result in additional City staffing requirements and costs. It was pointed out that this section would require the City to conduct over 900 new inspections during the new permit term (50 annually, 200 biennially and 250 once) without any assurance of improvement in water quality. Regional board staff's response to these comments stated that the mandatory 10/40/50 criteria was based on an analysis conducted of the Orange County permittees' annual reports that found some cities with few or zero commercial sites ranked as High, which was contrary to regional board staff expectations.

The City of Orange's commercial inspection program follows the prioritization and ranking procedure contained in the DAMP and believes its commercial facilities are appropriately prioritized based on the risk parameters identified in the DAMP. If regional board staff believes the DAMP prioritization procedure requires improvement, we welcome the opportunity to work cooperatively to develop a new facility prioritization procedure.

Recommendation:

Paragraph 2. Allow sites to be prioritized based on a revised DAMP ranking procedure. Alternatively, maintain the 10% mandatory ranking requirement of High facilities and allow inspection frequencies for Medium and Low ranked facilities consistent with the existing DAMP requirements (as needed).

Section XII - New Development

Section B – Water Quality Management Plan (WQMP) for Urban Runoff (For New Development/Significant Redevelopment)

The Subdivision category has been revised to include subdivisions with less than 10 units with combined impermeable surfaces of 10,000 sq. ft. This category would require a single family residence or two or more lots with a combined 10,000 sq. ft. of impervious surface to comply with all priority project requirements including LID and treatment BMPs. It may also require subdivisions with single lots sold individually to become priority projects at some point when the 2nd, 3rd, 4th or 5th lot sale triggers the priority designation. At this point it is not clear which lot owner would pay for any treatment BMP and if retrofitting to incorporate LID would be required of all previous lots sold as well as any future lots.

The basis for this requirement is included in Section IX paragraph 8 of the fact sheet, where it is stated that the threshold for commercial/industrial and residential projects has been lowered to 10,000 sq. ft. of impermeable surface for the sake of uniformity and consistency. However, the fact sheet goes on to mention only pollutant sources from industrial and commercial projects as a concern. Residential homes by their nature are significantly different from industrial and commercial facilities with regard to pollutant loads are not likely to be a major threat to water quality. Placing them in the same category with industrial and commercial sites simply because they contain the same square footage is inappropriate and lacks justification.

Recommendation:

Revise paragraph XII.B.2.b to maintain the current municipal permit's provision that includes a subdivision of 10 units or more as priority projects and delete the requirement that designates less than 10 units as priority projects.

Section C – Low Impact Development to Control Pollutants In Urban Runoff From New Development/Significant Redevelopment

We believe significant progress has been made on the implementation and application of Low Impact Development (LID) on new development projects in the second draft permit. However, we are still concerned with some of the requirements as they relate to redevelopment projects.

The permit correctly identifies in paragraph XII.C.6 that there are certain constraining factors such as space constraints that may limit the application of LID on redevelopment projects. This is a major limitation in implementing LID on redevelopment and in-fill projects and it is recommended that redevelopment and in-fill projects be exempt from the LID requirements.

Over 90% of the City's projects are redevelopment where a developer wishes to add to an existing structure or demolish the existing structure and build a new project. In these cases, the existing storm water conveyance systems are already in place and in most cases are not intended to be modified. Implementing LID on such sites would require new conveyance systems, changes in drainage pattern or the use of permeable BMPs (pavers, asphalt, concrete) to meet the permit requirements. The additional expenses to regrade, repave, add new pervious surfaces or modify the onsite storm drain system could make the project economically infeasible. These requirements would deter redevelopment in the City and in the end the City loses an opportunity to redevelop and improve older sections and the environment loses an opportunity for improvement of water quality.

The primary purpose of the implementation of LID as stated in Finding 61 of the fact sheet and paragraph 7 of Section XII.C is to mimic prevelopment conditions to compensate for land development impacts to hydrology and water quality. The City of Orange and other northern Orange County cities are highly urbanized and most drainage channels consist of rip rap, concrete or other materials, which have been engineered to convey storm water with maximum efficiency. The design of these systems has taken into account existing building conditions and employing LID design techniques on redevelopment projects will not have any cumulative hydrological impacts unless there is a significant increase in runoff from the existing condition, which is not likely or will be addressed on a project by project review. Therefore, it makes little sense to make LID a requirement in these cases. Impacts to water quality can be addressed by natural or mechanical BMPs.

Recommendation:
Exempt redevelopment and in-fill projects from the LID requirements where the sites drain to hardened or engineered channels.

Section XVI - Training

In its previous comments the City indicated that adding testing requirements and requiring Certificates of Compliance would create additional and unnecessary expenses and infringe on the City's right to set employee training and class specification

requirements. The response to comments matrix indicates that the permittees' concerns regarding the need for testing and Certificates of Compliance had been addressed. However, it appears that only paragraph 3 of Section XVI has been revised where "testing **or other procedures**" has been added. The requirement for Certificates of Compliance is still included at the end of the paragraph.

Recommendations:

Paragraph 3. Revise the last part of the last sentence as follows: "have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training. (delete Certificates of Compliance).

Alternatively, revise the sentence as follows: "completion of training **such as Certificates of Compliance, attendance sheets or other proof that training has been completed."**

Paragraph 4. Revise fourth as follows "a final test **or other procedure** to verify...."

Clarifications

Item 8 under Permit Requirements, Section IX of the Fact Sheet, states that the order contains a 5% limitation on effective impervious areas. This provision has been omitted from the second draft permit and should be deleted from the Fact Sheet.

Clarify in paragraph XII.B.2.c and XII.B.2.j whether land area or building area are used in determining the priority project designation.

Paragraph XII.C.3 includes dry wells in the category of allowable infiltration BMPs. In previous discussions with the Orange County Water District, dry wells were not recommended due to their potential to impact groundwater resources. Add that the use of dry wells shall be based on consultation with the water districts or omit dry wells from the paragraph.

Paragraph XII.D.2.b states that hydrologic conditions of concern do not exist if the downstream conveyance channels have been engineered or hardened and there is no impact to sensitive stream habitat. It further goes on to say that these conveyance channels cannot be waters of the U.S. In our experience, all conveyance channels are considered waters of the U.S and the Army Corps of Engineers has required 404 permits to conduct work in these channels as well as 401 certifications. Please clarify intent of paragraph.

ORANGE COUNTY
BUSINESS COUNCIL

2 Park Plaza, Suite 100 | Irvine, CA 92614-5904 | P 949.476.2242 | F 949.476.0443 | www.ocbc.org

April 9, 2009

Gerard J. Thibeault, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

BY U.S. POST AND ELECTRONIC MAIL TO MBROWN@WATERBOARDS.CA.GOV

Subject: Santa Ana Regional Water Quality Control Board Order No. R8-2008-0030, Waste Discharge Requirements for the County of Orange and The Incorporated Cities of Orange County Within the Santa Ana Region

Dear Mr. Thibeault:

The Orange County Business Council (OCBC), representing the largest, most innovative companies in America's fifth largest county, appreciates the opportunity to comment on the draft version of the above referenced MS4 Permit (Permit) for the County of Orange within the Santa Ana region.

As you know, this region and State are experiencing an unprecedented economic contraction affecting both the private and public sectors. Orange County, its cities, and this state are forced to make difficult cutbacks on public services. Men and women are losing their jobs. Unemployment is at record levels and hiring freezes are in place. While we believe the future of Orange County and California is bright, economic reality demands that we renew our long-term commitment to ensuring public resources are used as efficiently as possible. Protection of water quality is an important goal that we believe can be accomplished even in these challenging times as long as the required investments of the regulated community are warranted by the water quality progress to be achieved.

We believe the Permit, as written, is not acceptable as it mandates a low impact development strategy that is not based in sound public policy and imposes costly regulatory and administrative obstacles.

These obstacles, from our perspective, divert funds from other necessary objectives and do not substantially benefit water quality. With this in mind, we support the comments of Orange County Public Works which seek to:

1. Streamline streamlining reporting obligations;
2. Focus inspections on the most likely polluters based on a risk-based inspection regime; and
3. Clarify the intent of the Board in allowing for engineered flood control channels to serve their intended purpose.

We are concerned that certain requirements within section *XII New Development (Including Significant Redevelopment)* prevent cities from building roads and municipal buildings, and work against needed efforts to meet the region's housing needs. This is particularly important given the mandates of State law to increase housing and cluster development around transit facilities. Specifically our concerns are:

- The Permit should make clear that stormwater capture and infiltration is not required where infeasible or impractical. We are informed that much of the County area is not suitable for infiltration and would suggest that the Board work with the permittees and Orange County Water District to ensure the County is mapped to identify areas suitable for infiltration.

- Most if not all infill projects in the urban landscape are incapable of creating an environment that mimics the "pre-development hydrologic regime" and this should be specifically recognized within the Permit.

- The mandatory creation of a water quality management plan and adherence to USEPA's "Green Infrastructure" for public street projects larger than 5,000 square feet substantially increases the cost for roadway construction and eliminates funding for other municipal projects. Moreover, engineering low impact designs for roadways is not possible in many built-out environments. We do not believe cities should be required seek a special waiver from the executive director to avoid this requirement.

To be clear, OCBC is a strong champion of responsible infrastructure development and recognizes the need to incorporate low impact development objectives. However, engineering principles tell us that these concepts may be better addressed on a regional level than on a piecemeal, site by site basis.

The Orange County Business Council remains committed to investing in water quality as a top priority in the County of Orange and thanks you for your time to consider our comments.

Sincerely,

Lucy Dunn
President and CEO

LD:KM:bm

Orange County Water District Comments on draft Order No. R8-2009-0030 (NPDES No. CAS 618030)

The Orange County Water District (OCWD) was established by the State of California in 1933 to manage the Orange County Groundwater Basin. We are involved with projects and activities to manage the infiltration of water into the groundwater basin and protect and improve groundwater quality. Infiltration of water into the basin is very important, since infiltration or 'recharge' helps support pumping from the basin. The basin is the primary water supply for approximately 2.5 million people.

OCWD implements a proactive monitoring program for water recharged by the District. OCWD infiltrates water from the Santa Ana River, Santiago Creek, and water from other sources. We also recharge recycled water from the Groundwater Replenishment System. The District carefully monitors the quality of the water recharged and its impact on the groundwater basin.

We have reviewed the most recent draft of the MS4 Permit issued by the Santa Ana Regional Water Quality Control Board. OCWD recognizes and appreciates the environmental benefits of low-impact development and the goal of reducing pollution caused by urban runoff. However, infiltration of stormwater or urban runoff needs to be implemented carefully so that the water infiltrated into the ground does not negatively impact groundwater quality. The provisions in section XII(B)(5) of the draft permit need to be enhanced to protect groundwater quality.

Determining where infiltration is possible and appropriate within Orange County is a common goal shared by many parties. We believe it is prudent to evaluate the occurrence of hydrogeologic conditions such as shallow groundwater that may hinder infiltration and also evaluate potential impacts to groundwater quality. This analysis would help to evaluate whether infiltration is an effective and safe best management practice in Orange County. Accordingly, OCWD encourages the Regional Board, the permittees and stakeholders to coordinate on funding and creating a comprehensive map of Orange County identifying areas suitable for infiltration. This map (or maps) should identify hydrogeologic factors such as the elevation of the groundwater table, liquefaction potential, soil types, and related features such as where infiltration is not feasible due to topography, known plumes and other contamination concerns. OCWD would be pleased to share information which could be used for this mapping process.

Given the regional significance of the Orange County Groundwater Basin, the management of subsurface contamination and pollution migration are paramount concerns for the District. The District strongly supports the water quality protection efforts aimed at reducing stormwater pollutants. From a management and monitoring standpoint, it would likely be easier to ensure that the systems are properly managed and monitored if infiltration systems are grouped or

clustered on a regional basis, compared to having individual systems at a larger number of locations.

In light of these issues, we provide the following additional comments:

- Paragraph 90 in the fact sheet states the permitted discharge is consistent with the anti-degradation provisions of 40 CFS 131.12 and the State Board Resolution 68-16. The draft Order focuses on the quality of surface water and there is information presented to support the statement that the permitted discharge is consistent with anti-degradation provisions with respect to surface water quality. However, there is very limited analysis or discussion in the draft Order regarding potential impacts to groundwater quality. The draft Order references the studies conducted by the Los Angeles and San Gabriel Watershed Council on storm water recharge. It is important to note that the location of this study is not within the Santa Ana River Watershed. We are concerned that there are minimal data in Orange County regarding the potential impacts to groundwater quality that may result from infiltration systems, particularly when the infiltration systems are poorly maintained or infiltrate runoff from industrial land use areas. Data need to be collected in Orange County to assess the potential impacts to groundwater quality from infiltration systems such as vadose zone wells (also called 'dry wells') and subsurface horizontal systems such as infiltration galleries or French drains.
- The draft Order does not have an adequate analysis of anti-degradation provisions in State Board Resolution 68-16 with respect to potential adverse impacts to groundwater quality; an anti-degradation analysis in terms of groundwater quality should be provided in the Order.
- We should not rely too heavily on the studies conducted by the Los Angeles and San Gabriel Watershed Council; the studies are important, but groundwater quality data from Orange County are needed.
- We encourage the grouping or clustering of infiltration systems to the extent practical.
- The draft Order should provide for the collection of groundwater quality data in Orange County to assess potential groundwater quality impacts from infiltration systems such as vadose zone wells and subsurface horizontal systems; data collection could be focused on a selected number of sites.
- The groundwater quality data that should be collected in relation to the Order should be utilized to demonstrate the treatment effectiveness of the infiltration systems and that there is no adverse impact on groundwater quality; if the data indicate there was an adverse impact to groundwater quality, the infiltration system should of course be modified or terminated, and a plan developed and implemented to mitigate the negative impact to groundwater quality;

- We are concerned about the implications of footnote 50; the first part of footnote 50 reads “This restriction applies only to sites that are known to have soil and groundwater contamination.”
    - The word ‘and’ should be changed to ‘or’. It would not be appropriate to allow the restriction to be applied only in cases where both soil and groundwater contamination exists. If only soil contamination exists, the restriction should apply.
    - We are concerned that the restriction would not apply to certain land uses that may pose an elevated risk of having contaminated runoff. For example, if a new gas station is constructed and there is no soil or groundwater contamination, which might be the case for a new gas station, could an infiltration system could be built? There are some land uses that should have the restriction applied regardless of the presence of soil or groundwater contamination. If additional treatment prior to infiltration and increased monitoring is required, this may obviate some of our concerns but we are concerned about any and all land uses infiltrating their runoff unless there is careful monitoring.

Thank you for your consideration of these comments.

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for
Environmental Protection

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Phone (951) 782-4130 • FAX (951) 781-6288
www.waterboards.ca.gov/santaana

Arnold Schwarzenegger
Governor

April 10, 2009

TO: The Attached Mailing list

RENEWAL OF WASTE DISCHARGE REQUIREMENTS FOR THE COUNTY OF ORANGE, ORANGE COUNTY FLOOD CONTROL DISTRICT AND THE INCORPORATED CITIES OF ORANGE COUNTY, TENTATIVE ORDER NO. R8-2009-0030, NPDES NO. CAS618030, AREAWIDE URBAN STORM WATER RUNOFF

Enclosed is a copy of the third draft of tentative Order No. R8-2009-0030, NPDES No. CAS 618030. This order renews waste discharge requirements for the discharge of urban storm water from areas of Orange County within the Santa Ana Region. This item is scheduled for consideration by the Regional Board at the regularly scheduled Board meeting on April 24, 2009, to be held at the Santa Ana City Council Chambers. An agenda announcement for this meeting is posted on our website at: http://www.waterboards.ca.gov/santaana/board_info/agendas/2009_agendas.shtml.

We have posted a marked-up version of the third draft that includes all changes from the second draft at:

http://www.waterboards.ca.gov/santaana/water_issues/programs/stormwater/oc_permit.shtml

All comments received and response to comments will be posted at the above website by April 17, 2009.

To be notified of future information regarding this permit, please sign on to our E-mail notification list (select "Storm Water – Orange County Municipal") at http://www.waterboards.ca.gov/resources/email_subscriptions/reg8_subscribe.shtml

If you have any questions, please call me at (951) 782-3238, Mark Smythe at (951) 782-4998, or Marc Brown at (951) 321-4584.

Sincerely,

Michael J. Adackapara
Division Chief

Enclosures: Tentative Order No. R8-2009-0030 (third draft)

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

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plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

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b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

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facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

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beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

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16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the

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jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

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Inland Surface Streams

Santa Ana River, Reaches 1 and 2

Aliso Creek (tributary to Santa Ana River)

Carbon Canyon Creek (tributary to Santa Ana River)

Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

Silverado Creek (tributary to Santiago Creek)

Black Star Creek (tributary to Santiago Creek)

Ladd Creek (tributary to Santiago Creek)

San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

San Joaquin Freshwater Marsh (tributary to San Diego Creek)

Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

Santa Ana Delhi Channel (tributary to Newport Bay)

Big Canyon Wash (tributary to Newport Bay)

Buck Gully

Los Trancos Creek

Coyote Creek (tributary to San Gabriel River)

Other tributaries to the above listed rivers, creeks and channels

Bays, Estuaries, and Tidal Prisms

Anaheim Bay and Seal Beach National Wildlife Refuge

Sunset Bay

Bolsa Bay and Bolsa Chica Ecological Reserve

Upper and Lower Newport Bay

Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

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H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new

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developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. Each watershed has unique receiving water issues, land uses, topography, soils and stream stability and habitat issues. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants (e.g., Orange County Flood Control Master Plan, Irvine Ranch Water District Natural Treatment System Master Plan, Orange County Watershed Plans, Nutrient and Selenium Management Program, etc.). As recommended in the 2008 National Academy of Sciences Report on Urban Stormwater Management, this order provides an option for the permittees to develop and impleemnt watershed master plans integrating water quality, hydromodification, water supply and habitat protection issues. The Regional Board recognizes that a watershed master plan ~~management program~~ should integrate all other related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may

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be necessary. The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis.

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

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These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB 411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12.] The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13.]

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, “Management Guidelines for Use of Fertilizers and Pesticides”. The Report of Waste Discharge indicates that through

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

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implementation of this program, the municipalities have reduced the use of fertilizers and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal

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waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

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Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

Seal Beach (listed for enteroccocus, PCBs);

Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

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44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

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48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

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weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.46(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This order requires the permittees to comply with the urban runoff/storm water wasteload allocations ~~for both~~ specified in (1) Regional Board-adopted and USEPA approved TMDLs (including TMDLs for nutrients, fecal coliform, diazinon and chlorpyrifos); (2) Regional Board-adopted TMDLs that are approved by the State Board and State Office of Administrative Law and that are thereby effective (approval of organochlorine compounds TMDLs by the State is pending); and, (3) USEPA-promulgated TMDLs (including toxics TMDLs for the Newport watershed)~~and Regional Board adopted/EPA approved TMDLs~~. Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States

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55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes

Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

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requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mititgative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. To the maximum extent practicable, these LID BMPs must be implemented at the project site. Where LID BMPs are not feasible at the project site, more traditional, but equally effective control measures should be implemented.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

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study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25] and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be an equally effective ~~better~~ metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued

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[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to 10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of ~~groundwater~~ pollutants ~~ion~~ and could become a nuisance and/or cause the spreading of surface water pollution, and those treatment systems with a hydraulic connection to groundwater (e.g., detention basins, infiltration systems, constructed wetlands, etc.) could be sources of groundwater pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this

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order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants. There are other site conditions that limit the applicability of infiltration, including site soils, contaminant plumes, potential mobilization of naturally occurring contaminants such as selenium, high groundwater levels, etc. Such factors should be considered in the design and implementation of storm water control measures.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

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70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

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inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.46(d)(vii)(B)) require that the permits be consistent~~tees to comply~~ with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection

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program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

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80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

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Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicitl discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in

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1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

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PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and

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implementation plans, including physical elimination of undocumented connections and illicit discharges.

7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.

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2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
    i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
        a) Discharges composed entirely of storm water;
        b) Air conditioning condensate;
        c) Irrigation water;
        d) Passive foundation drains;

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e) Passive footing drains;

f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Diverted stream flows;

i) Rising ground waters and natural springs;

j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

k) Flows from riparian habitats and wetlands;

l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5);

m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges from permittee owned and/or operated facilities and activities unless the stated conditions are met:

a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

c) Discharges from lawn, greenbelt and median watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

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minimized through a Model Municipal Activity Maintenance Program designed to control irrigation runoff. ~~public education and water conservation efforts, as prescribed under Section XI, Residential Program.~~

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.
5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).
6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.
8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

[33] See previous footnote.

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IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.

2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.

3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

   d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

   So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

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V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.
3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.
4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

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5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis[34] and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[35]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

   f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[36];

[34] The reporting schedule may be revised with the approval of the Executive Officer.
[35] State Board WQO No. 2006-0003.

[36] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

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g) Discharges of runoff from the washing of toxic materials[37] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.
2. The permittees shall control, to the maximum extent practicable, the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.
3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.
4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s)

[37] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

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and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.

6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.

7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.

2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude [in decimals] or NAD83/WGS84[38] compatible formatting), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area

[38] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

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of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.

4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:

   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;

   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

   c) Visual observation for non-storm water discharges and potential pollutant sources;

   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement

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action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.

7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.
3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions

[39] See Footnote 38.

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issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

4. ~~-~~All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.
5. ~~-~~Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period[40].

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction[41]. As

[40] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

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required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[42] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

Commercial facilities may include, but may not be limited to[43]:

a) Transport, storage or transfer of pre-production plastic pellets.
b) Automobile mechanical repair, maintenance, fueling or cleaning;
c) Airplane maintenance, fueling or cleaning;
d) Marinas and boat maintenance, fueling or cleaning;
e) Equipment repair, maintenance, fueling or cleaning;
f) Automobile impound and storage facilities;
g) Pest control service facilities;
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
j) Building materials retail and storage facilities;
k) Portable sanitary service facilities;
l) Painting and coating;
m) Animal facilities such as petting zoos and boarding and training facilities;
n) Nurseries and greenhouses;
o) Landscape and hardscape installation;
p) Pool, lake and fountain cleaning;
q) Golf courses;
r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct, or require to be completed, inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 12 months of adoption of this order,

[41] The inventory update schedule may be revised with the approval of the Executive Officer.

[42] See Footnote 38.

[43] Mobile cleaning services are addressed in X.8, below.

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the permittees shall develop a prioritization and inspection schedule for the commercial facilities in Section X.1 for review and approval by the Executive Officer. Until that plan is approved, t~~T~~he following minimum criteria must be met for prioritization of commercial sites for inspections: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[44]; 2~~4~~0% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct, or require to be completed, commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.
4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or steam cleaning. The pilot program shall include at least two notifications of the

[44] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

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individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:

   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;

   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period[45].

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s to the maximum

[45] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

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extent practicable so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[46] and USDA's Backyard Conservation Program[47].
3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[48] to encourage efficient water use and to minimize runoff[49].
5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[50].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

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[46] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[47] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[48] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[49] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[50] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.

2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.

3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.

4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24

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months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process in conjunction with preparation of the DAMP finalization, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance

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with the approved Model WQMP and shall incorporate LID principles in the WQMP.

a. All significant redevelopment projects, where significant redevelopment is defined as ~~priority development~~ projects that ~~, which~~ include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in the addition or replacement ~~an increase~~ of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in the addition or replacement ~~an increase~~ of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

~~a.~~

b. ~~Subdivisions creating 10 lots or units and more, and subdivisions creating less than 10 lots or units, where the combined impervious surface area of the lots or units is equal to or greater than 10,000 square feet. This includes single family residences, multi-family residences, condominiums, apartments, etc.~~New development projects that create 10,000 square feet or more of impervious surface (collectively over the entire project site) including commercial, industrial, residential housing subdivisions (i.e., detached single family home subdivisions, multi-family attached subdivisions (town homes), condominiums, apartments, etc.), mixed-use, and public projects. This category includes development projects on public or private land, which fall under the planning and building authority of the permittees.

~~b.~~

~~c. Commercial and industrial developments, which are not subdivisions, of 10,000 square feet or more. This includes non-residential developments.~~

~~d.~~c. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

~~e.~~d. Restaurants where the land area of development is 5,000 square feet or more.

~~f.~~e. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

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~~g.~~f. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[51] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

~~h.~~g. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

~~i.~~h. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

~~j.~~i. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

~~k.~~j. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[52] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

   a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

   b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

   c) Minimize storm water contact with pollutant sources;

[51] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

[52] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

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d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

A. Volume

Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[53]; or,

2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

[53] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

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2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

   b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

   c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

   d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 5~~10~~ feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

   e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

   f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[54].

   g) Within 18 months of adoption of this order, the principal permittee shall develop a pilot program to monitor the impact of groundwater infiltration systems on the quality of groundwater. This monitoring program may be conducted by: (1) analyzing the quality of the runoff prior to infiltration; (2) by monitoring the quality of the infiltrate through the vadose zone; or (3) by monitoring groundwater quality upstream and downstream of the infiltration systems. The results of the pilot study shall be submitted with the next annual report.

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of

[54] This restriction applies only to sites that are known to have soil and/or groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

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regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for review and approval by ~~approval to~~ the Executive Officer[55]. Priority development projects that meet the feasibility criteria established pursuant to Section XII.E shall implement LID principles described in this section, Section XII.C.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire or capture the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. Any portion of this volume that is not infiltrated, harvested and re-used, evapotranspired or captured onsite by LID BMPs shall be treated and discharged using LID or conventional treatment control BMPs or mitigated as set forth in Section XII.C.7, below.

~~2.~~3. The permittees shall incorporate LID site design principles to reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration and treatment systems as close as feasible~~possible~~ to the source of runoff. Site design considerations shall include, but not be limited to:

[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

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a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials~~concrete and porous asphalt~~; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing ~~to replace~~ curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

~~3.~~4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to the maximum

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extent practicable; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

~~5.LID structural site design BMPs shall ensure capture of the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. The LID goal shall be to infiltrate, evapotranspire, harvest and beneficially reuse the design capture volume at the project site. Any volume that is not captured by the LID BMPs shall be treated using conventional treatment control BMPs in accordance with Section XII.B.4, above.~~

~~6.~~5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[56], New Urbanism[57] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.

7. If site conditions do not permit infiltration, ~~and/or~~ harvesting and re-use, and/or evapotranspiration of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:

[56] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[57] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

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~~6.~~

~~a)~~8. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

~~b)~~a) Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, ~~and/or~~ harvest and re-use, evapotranspire or treat at least the design capture volume.

~~c)~~b) Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, ~~and/or~~ harvest and re-use, evapotranspire or treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

~~d)~~c) Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, ~~and/or~~ harvest and re-use, evapotranspire or treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[58])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

[58] Hydromodification is the alteration of natural flow characteristics.

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c) Changes in time of concentration;

d) Potential for increases in post development downstream erosion; and,

e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected. ~~These conveyance channels should not include any waters of the U.S.~~

   c) The site infiltrates at least the runoff from a two-year storm event. The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees have the option to address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan that integrates water quality, hydromodification, water supply, and habitat. The Watershed

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Master Plan may be prepared for the whole watershed or for sub-watersheds. The Plan should include a map to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and specify hydromodification management standards for each sub-watershed. In the preparation of this Plan or plans, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; and (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board. The Watershed Master Plan or the sub-watershed plans shall be submitted to the Executive Officer for approval.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.

2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

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3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.

4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

   a) Redevelopment projects that reduce the overall impervious footprint
   b) Brownfield redevelopment
   c) High density developments (>7 units per acre)
   d) Mixed use and transit-oriented development (within ½ mile of transit)
   e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses
   f) Regional treatment systems with a capacity to treat flows from all upstream developments
   g) Contribution to an urban runoff fund (see 1, above)
   h) Offsite mitigation or dedications within the same watershed
   i) City Center area
   j) Historic Districts and Historic Preservation areas
   k) Live-work developments
   l) In-fill projects

F. APPROVAL OF WQMPs

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1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural

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treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.

3. The permittees shall develop a database with information regarding each structural treatment control BMP installed after adoption of this order. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.

4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.

5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 25~~0~~% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within every four year period~~a two year period~~. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record. The permittees may accept inspections conducted and certified by state licensed professional engineers in lieu of permittee inspections.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented to the maximum extent practicable for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.

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2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.

3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.

4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet

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cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.
2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.
3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:
   a) Parking facilities;
   b) Flood management and storm water conveyance systems (open channels);
   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and
   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.
4. All applicable public agency staff shall be trained as specified under Section XVI.
5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:
   a) Conduct annual integrated pest management self-audits;
   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

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c) Provide proper training to municipal and contract staff involved in the above activities;

d) Within ~~six~~one year ~~months~~ of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within one year~~six months~~ of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.

13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance

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contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.

14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.

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2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training, such as Certificate of Completion, attendance sheets or other proof that training has been completed. ~~(Certificate of Completion).~~
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

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XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections[59].
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

1. As required under a consent decree, in 2002, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay, including metals, organochlorine compounds, selenium and organophosphate pesticides. EPA and the Los Angeles Regional Water Quality Control Board established

[59] The reporting schedule may be revised with the approval of the Executive Officer.

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technical TMDLs for metals in Coyote Creek. Technical TMDLs do not include implementation plans or compliance schedules.

2. In collaboration with stakeholders, Regional Board staff are developing revised TMDLs that are expected to supplant the toxics TMDLs promulgated by EPA for the Newport watershed. The TMDLs will include implementation plans and compliance schedules. Implementation plans for the Coyote Creek TMDLs are also being developed.
3. In summary, work related to the following established TMDLs is ongoing:
   a) Metals (San Diego Creek and Newport Bay (including Rhine Channel))
   b) Metals (Mercury, Chromium) (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay; also see Paragraphs 5 and 6, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)
4. The permittees in the Newport Watershed shall comply with the wasteload allocations specified in the established TMDLs and shown in Tables 1 A/B/C, 2 A/B/C/D and 3. These wasteload allocations shall remain in effect unless and until alternative wasteload allocations are established in TMDLs approved by the Regional Board, State Board, Office of Administrative Law and EPA.

~~1.Implementation plans are being developed for the following TMDLs:~~

~~a)Metals (San Diego Creek and Newport Bay)~~

~~b)Metals (Rhine Channel)~~

~~c)Organochlorine compounds (San Diego Creek and Newport Bay, also see Paragraph 2, below)~~

~~d)Selenium (San Diego Creek and Newport Bay)~~

~~e)Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)~~

~~f)Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)~~

~~As required under a consent decree, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay that included TMDLs for metals, organochlorine compounds, selenium and organophosphate pesticides. As noted in the Findings, the Regional Board adopted TMDLs, including an implementation plan, for the organophosphate pesticides diazinon and chlorpyrifos. The diazinon and chlorpyrifos TMDLs have been fully approved and are now being implemented. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. The Regional Board adopted organochlorine TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. It has not~~

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~~been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. However, until Regional Board adopted TMDLs for the organochlorine compounds, metals and selenium are approved by the State Board, the Office of Administrative Law (OAL), and the EPA, the EPA promulgated TMDLs (see a-f, above) are the applicable TMDLs for these waterbodies. The permittees in the Newport Bay Watershed shall comply with the EPA promulgated wasteload allocations in Tables 1 A/B/C, 2 A/B/C/D and 3.~~

Tables 1 A/B/C/D – Urban Runoff Waste Load Allocations for Metals

(TMDLs promulgated by U.S. EPA)[60]

A- San Diego Creek and Tributaries – Concentration based TMDL

	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

D- Concentration-based Dissolved Metal TMDLs, WLAs and LAs for Newport Bay

[60] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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	Dissolved saltwater TMDLs and allocations which apply to direct discharges to the bay, including storm drains/channels and metals loading associated with boats	
	Acute	Chronic
Cd* (ug/L)	42	9.3
Cu (ug/L)	4.8	3.1
Pb (ug/L)	210	8.1
Zn (ug/L)	90	81

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[61]

A- San Diego Creek and Tributaries

Total DDT	Chlordane	Dieldrin	PCBs	Toxaphene
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	Chlordane	PCBs
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	Chlordane	Dieldrin	PCBs
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	Chlordane	Dieldrin	PCBs
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[62]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

[61] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[62] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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5. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. These TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. These TMDLs have not yet been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program (TRIP) that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. These TMDLs will become effective upon approval by the State Board and Office of Administrative Law but will not supplant the EPA organochlorine compounds TMDLs until they are approved by EPA. Accordingly, upon approval of the Regional Board-adopted organochlorine compounds TMDLs by the State Board and the Office of Administrative Law, the permittees shall comply with both the EPA and Regional Board wasteload allocations specified in Tables 2 A/B/C/D and Table 4, respectively. In accordance with the Regional Board TMDLs, compliance with the allocations specified in Table 4 shall be achieved as soon as possible but no later than December 31, 2015. Upon approval of the Regional Board-approved organochlorine compounds TMDLs by EPA, the applicable wasteload allocations shall be those specified in Table 4.

~~2.For the organochlorine compounds TMDLs, the Regional Board has adopted an implementation plan. That plan requires approvals from the State Board, OAL and the EPA. Once approved by the State Board, OAL, and EPA, the Regional Board TMDL will replace the TMDLs promulgated by EPA. The urban runoff wasteload allocations in those TMDLs are presented in Table 4. The permittees in the Newport Bay Watershed shall comply with the WLAs in Table 4 and the water column targets in Tables 5 A/B. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated a Toxicity Reduction and Investigation Program (TRIP) consistent with the implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations. Tables 6 A/B have EPA promulgated WLAs for toxic pollutants for San Diego Creek and Newport Bay. The permittees in the Newport Bay Watershed shall comply with the WLAs specified in Tables 6 A/B.~~

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Table 4 – Urban Runoff Waste Load Allocations for Organochlorine ~~Pesticides~~ Compounds (TMDLs approved by Santa Ana Regional Water Quality Control Board)[63]

	Total DDT	Chlordane	Total PCBs	Toxaphene
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.~~7~~ 8 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

6. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated the Toxicity Reduction and Investigation Program (TRIP) consistent with the Regional Board-approved implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations.

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[64]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l
Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

[63] From Resolution No. R8-2007-0024, Table NB-OCs-10

[64] From Resolution No. R8-2007-0024, Table NB-OCs-4

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	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

~~**Table 6 – Allocations for San Diego Creek and Newport Bay Watershed from the EPA Promulgated TMDLs for Toxic Pollutants**[65]~~

~~A. Sand Diego Creek~~

	~~DDT (including dicofol)~~	~~PCBs~~	~~Dieldrin~~	~~Toxaphene~~
~~Urban Runoff WLA~~	~~302.8 g/yr~~	~~177.7 g/yr~~	~~183.4 g/yr~~	~~6.2 g/yr~~

~~**B - Upper Newport Bay**~~

	~~Chlordane~~	~~DDT (including dicofol)~~	~~PCBs~~
~~Urban Runoff WLA~~	~~120.5 g/yr~~	~~207.4 g/yr~~	~~609.7 g/yr~~

7. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs and that are intended to replace the EPA TMDLs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. This Order will be reopened to incorporate revised allocations based upon TMDLs, including implementation plans, for metals and selenium approved by the Regional Board, State Board and Office of Administrative Law. As for the organochlorine compounds, the EPA promulgated allocations for these constituents will also remain in effect unless and until EPA approves the Regional Board's TMDLs for these constituents.

8. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries.

[65] U.S. EPA Region 9, Total Daily Loads for Toxic Pollutants, San Diego Creek and Newport Bay, California, June 14, 2002.

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Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive selenium (and nitrogen) management plans, which are expected to form the basis, at least in part, for the selenium implementation plan (and a revised nutrient TMDL implementation plan). A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the selenium TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one month after approval of the selenium TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements. ~~conjunction with watershed stakeholders, Regional Board staff is in the process of developing recommendations for revisions to the nutrient TMDLs and to the EPA promulgated TMDLs for selenium, and is formulating a selenium TMDL implementation plan. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive nitrogen and selenium management plans, which are expected to form the basis, at least in part, for a revised nutrient TMDL implementation plan and the selenium implementation plan. A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed~~

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~~Cooperative Watershed Program that will fulfill applicable requirements of the TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one month after approval of the TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.~~

9. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with the following wasteload allocations:

Table ~~7~~ 6 – Municipal Storm Water Wasteload Allocations - Coyote Creek

	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

10. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table ~~8~~ 7 – Numeric Targets - Coyote Creek
(total recoverable metals)

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	Copper	Lead	Zinc
Dry Weather[66]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

~~Dry Weather limit for copper is based on CTR saltwater criterion in San Gabriel River estuary~~

C. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table ~~9A~~ 8A – Fecal Coliform TMDL and Allocations for Newport Bay

To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2013	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table ~~9B~~ 8B – Fecal Coliform TMDL and Allocations for Newport Bay

Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.

[66] Based on saltwater CTR criterion in San Gabriel River estuary.

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Total Maximum Daily Load for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables ~~9a~~8A and ~~9b~~8B in accordance with the deadlines in Tables ~~9a~~8A and ~~9b~~8B. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.
3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables ~~10A~~ 9A and ~~10B~~ 9B are extracted from the

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Implementation Plan[67]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables ~~10~~ 9 A and B.

Table ~~10A~~9A

Diazinon and Chlorpyrifos Allocations for San Diego Creek*

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	~~Actue~~Acute	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6
~~Load Allocation~~	~~72~~	~~45~~	~~18~~	~~12.6~~
~~MOS~~	~~8~~	~~5~~	~~2~~	~~1.4~~
~~**TMDL**~~	~~**80**~~	~~**50**~~	~~**20**~~	~~**14**~~

~~MOS=Margin of safety;~ Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

Table ~~10B~~9B

Chlorpyrifos Allocations for Upper Newport Bay*

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1
~~Load Allocation~~	~~18~~	~~8.1~~
~~MOS~~	~~2~~	~~0.9~~
~~**TMDL**~~	~~**20**~~	~~**9**~~

~~MOS=Margin of safety;~ Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. ~~The permittees shall comply with the waste load allocations for urban runoff in Tables 9A and 9B.~~ The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

[67] Attachment to Resolution No. R8-2003-0039

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Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table ~~11~~ 10 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[68]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[69]	2007 Summer Allocation (Apr-Sept)[70]	2012 Winter Allocation (Oct-Mar)[71]
Newport Bay Watershed	lbs/year TN[72,73]	lbs/season TN	lbs/season TN	lbs/season TN
~~Wasteload Allocation~~				
Urban runoff	277,131[74]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table ~~12~~ 11 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[75]

	2012 Allocation lbs/day TN[76]

[68] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[69] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[70] See previous footnote.

[71] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[72] TIN = (NO3+NH3).

[73] TN = (TIN + Organic N).

[74] Estimated annual average (summer and winter loading).

[75] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

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TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table ~~13~~ 12 - Annual Total Phosphorous Load Allocations

For The Newport Bay Watershed[77]

	2002 Allocation lbs/year TP[78]	2007 Allocation lbs/year TP[79]
TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables ~~11~~10, ~~12~~ 11 and ~~13~~ 12 in accordance with the schedules in Tables ~~11~~10, ~~12~~ 11 and ~~13~~12. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

[76] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[77] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[78] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[79] See previous footnote

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b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determinations shall be ~~is~~ based on monitoring within the receiving waters. For sediment TMDLs, compliance determination shall be~~is~~ based on monitoring in the Creek.

2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:

   a) Review of the formal training needs of municipal employees

   b) Review of coordinating meeting/training for the designated NPDES inspectors.

2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.

3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.

4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each

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permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
   a) Each permittee's expenditures for the previous fiscal year,
   b) Each permittee's budget for the current fiscal year,
   c) A description of the source of funds, and
   d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring

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programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.

5. Within one year~~six months~~ of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.

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2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:
   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;
   b) Changes in land use and/or population including land use map updates;
   c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,
   d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.
2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).
3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.
4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on April 24, 2009.

_____
Gerard J. Thibeault
Executive Officer

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To be provided at a later date.

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To be provided at a later date.

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Order No. R8-20089-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

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Orange Unified School District
Placentia Unified School District
Saddleback Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

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State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2008~~9~~-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

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I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

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determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

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f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

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c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

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V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual Report

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Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

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Ordered by_____
Gerard J. Thibeault
Executive Officer

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

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plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

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b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

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facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

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beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

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16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the

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jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

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Inland Surface Streams

Santa Ana River, Reaches 1 and 2

Aliso Creek (tributary to Santa Ana River)

Carbon Canyon Creek (tributary to Santa Ana River)

Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

Silverado Creek (tributary to Santiago Creek)

Black Star Creek (tributary to Santiago Creek)

Ladd Creek (tributary to Santiago Creek)

San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

San Joaquin Freshwater Marsh (tributary to San Diego Creek)

Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

Santa Ana Delhi Channel (tributary to Newport Bay)

Big Canyon Wash (tributary to Newport Bay)

Buck Gully

Los Trancos Creek

Coyote Creek (tributary to San Gabriel River)

Other tributaries to the above listed rivers, creeks and channels

Bays, Estuaries, and Tidal Prisms

Anaheim Bay and Seal Beach National Wildlife Refuge

Sunset Bay

Bolsa Bay and Bolsa Chica Ecological Reserve

Upper and Lower Newport Bay

Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

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H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new

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developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. Each watershed has unique receiving water issues, land uses, topography, soils and stream stability and habitat issues. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants (e.g., Orange County Flood Control Master Plan, Irvine Ranch Water District Natural Treatment System Master Plan, Orange County Watershed Plans, Nutrient and Selenium Management Program, etc.). As recommended in the 2008 National Academy of Sciences Report on Urban Stormwater Management, this order provides an option for the permittees to develop and impleemnt watershed master plans integrating water quality, hydromodification, water supply and habitat protection issues. The Regional Board recognizes that a watershed master plan should integrate all other related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary.

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The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

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411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12]. The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13].

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, “Management Guidelines for Use of Fertilizers and Pesticides”. The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

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and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

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in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

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Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

Seal Beach (listed for enteroccocus, PCBs);

Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the

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Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban

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runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

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specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.46(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This order requires the permittees to comply with the urban runoff/storm water wasteload allocations specified in (1) Regional Board-adopted and USEPA approved TMDLs (including TMDLs for nutrients, fecal coliform, diazinon and chlorpyrifos); (2) Regional Board-adopted TMDLs that are approved by the State Board and State Office of Administrative Law and that are thereby effective (approval of organochlorine compounds TMDLs by the State is pending); and, (3) USEPA-promulgated TMDLs (including toxics TMDLs for the Newport watershed). Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

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control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

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61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mititgative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. To the maximum extent practicable, these LID BMPs must be implemented at the project site. Where LID BMPs are not feasible at the project site, more traditional, but equally effective control measures should be implemented.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

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study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25]and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be an equally effective metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to 10,000 square feet, making it consistent with the threshold for residential

[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

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subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of pollutants and could become a nuisance and/or cause the spreading of surface water pollution, and those treatment systems with a hydraulic connection to groundwater (e.g., detention basins, infiltration systems, constructed wetlands, etc.) could be sources of groundwater pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

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67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants. There are other site conditions that limit the applicability of infiltration, including site soils, contaminant plumes, potential mobilization of naturally occurring contaminants such as selenium, high groundwater levels, etc. Such factors should be considered in the design and implementation of storm water control measures.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

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discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

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guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.46(d)(vii)(B)) require that the Permits be consistent with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

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76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should

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include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

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83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicitl discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections

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and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

PERMIT REQUIREMENTS:

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IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.

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7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.

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2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
    i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
        a) Discharges composed entirely of storm water;
        b) Air conditioning condensate;
        c) Irrigation water;
        d) Passive foundation drains;

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e) Passive footing drains;

f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Diverted stream flows;

i) Rising ground waters and natural springs;

j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

k) Flows from riparian habitats and wetlands;

l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5);

m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges from permittee owned and/or operated facilities and activities unless the stated conditions are met:

a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

c) Discharges from lawn, greenbelt and median watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

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minimized through a Model Municipal Activity Maintenance Program designed to control irrigation runoff.

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.
5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).
6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.
8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

[33] See previous footnote.

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IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.

2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.

3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

   d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

   So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

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V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.
3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.
4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

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5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis[34] and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[35]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

   f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[36];

[34] The reporting schedule may be revised with the approval of the Executive Officer.
[35] State Board WQO No. 2006-0003.

[36] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

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g) Discharges of runoff from the washing of toxic materials[37] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.
2. The permittees shall control, to the maximum extent practicable, the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.
3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.
4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s)

[37] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

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and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.

6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.

7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.

2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude [in decimals] or NAD83/WGS84[38] compatible formatting), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area

[38] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

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of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.

4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:

   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;

   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

   c) Visual observation for non-storm water discharges and potential pollutant sources;

   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement

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action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.

7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.
3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions

[39] See Footnote 38.

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issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.
5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period[40].

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction[41]. As

[40] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

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required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[42] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

Commercial facilities may include, but may not be limited to[43]:

a) Transport, storage or transfer of pre-production plastic pellets.
b) Automobile mechanical repair, maintenance, fueling or cleaning;
c) Airplane maintenance, fueling or cleaning;
d) Marinas and boat maintenance, fueling or cleaning;
e) Equipment repair, maintenance, fueling or cleaning;
f) Automobile impound and storage facilities;
g) Pest control service facilities;
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
j) Building materials retail and storage facilities;
k) Portable sanitary service facilities;
l) Painting and coating;
m) Animal facilities such as petting zoos and boarding and training facilities;
n) Nurseries and greenhouses;
o) Landscape and hardscape installation;
p) Pool, lake and fountain cleaning;
q) Golf courses;
r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct, or require to be completed, inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 12 months of adoption of this order,

[41] The inventory update schedule may be revised with the approval of the Executive Officer.

[42] See Footnote 38.

[43] Mobile cleaning services are addressed in X.8, below.

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the permittees shall develop a prioritization and inspection schedule for the commercial facilities in Section X.1 for review and approval by the Executive Officer. Until that plan is approved, the following minimum criteria must be met for prioritization of commercial sites for inspections: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[44]; 20% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct, or require to be completed, commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.
4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or steam cleaning. The pilot program shall include at least two notifications of the

[44] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

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individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:

   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;

   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period[45].

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s to the maximum

[45] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

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extent practicable so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[46] and USDA's Backyard Conservation Program[47].
3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[48] to encourage efficient water use and to minimize runoff[49].
5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[50].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

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[46] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[47] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[48] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[49] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[50] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.
2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.
3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.
4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.
5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.
6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24

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months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process in conjunction with preparation of the DAMP finalization, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance

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with the approved Model WQMP and shall incorporate LID principles in the WQMP.

a. All significant redevelopment projects, where significant redevelopment is defined as projects that include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in the addition or replacement of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in the addition or replacement of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b. New development projects that create 10,000 square feet or more of impervious surface (collectively over the entire project site) including commercial, industrial, residential housing subdivisions (i.e., detached single family home subdivisions, multi-family attached subdivisions (town homes), condominiums, apartments, etc.), mixed-use, and public projects. This category includes development projects on public or private land, which fall under the planning and building authority of the permittees.

c. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

d. Restaurants where the land area of development is 5,000 square feet or more.

e. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

f. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[51] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

g. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

[51] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

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h. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

i. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

j. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[52] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

[52] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

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4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

   A. Volume

   Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[53]; or,

   2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

   3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

   4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

   OR

   B. Flow

   Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

   2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

   3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

[53] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

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b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 5 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[54].

g) Within 18 months of adoption of this order, the principal permittee shall develop a pilot program to monitor the impact of groundwater infiltration systems on the quality of groundwater. This monitoring program may be conducted by: (1) analyzing the quality of the runoff prior to infiltration; (2) by monitoring the quality of the infiltrate through the vadose zone; or (3) by monitoring groundwater quality upstream and downstream of the infiltration systems. The results of the pilot study shall be submitted with the next annual report.

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

[54] This restriction applies only to sites that are known to have soil and/or groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

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C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for review and approval by the Executive Officer[55]. Priority development projects that meet the feasibility criteria established pursuant to Section XII.E shall implement LID principles described in this section, Section XII.C.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire or capture the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. Any portion of this volume that is not infiltrated, harvested and re-used, evapotranspired or captured onsite by LID BMPs shall be treated and discharged using LID or conventional treatment control BMPs or mitigated as set forth in Section XII.C.7, below.

3. The permittees shall incorporate LID site design principles to reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

   a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

   b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped

[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

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areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to the maximum extent practicable; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction,

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saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[56], New Urbanism[57] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.

7. If site conditions do not permit infiltration, harvesting and re-use, and/or evapotranspiration of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:

8. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

    a) Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume.

    b) Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm

[56] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[57] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

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water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

c) Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[58])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

   e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected.

   c) The site infiltrates at least the runoff from a two-year storm event. The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies.

[58] Hydromodification is the alteration of natural flow characteristics.

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Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.
4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.
5. The permittees have the option to address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan that integrates water quality, hydromodification, water supply, and habitat. The Watershed Master Plan may be prepared for the whole watershed or for sub-watersheds. The Plan should include a map to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and specify hydromodification management standards for each sub-watershed. In the preparation of this Plan or plans, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; and (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board. The Watershed Master Plan or the sub-watershed plans shall be submitted to the Executive Officer for approval.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP

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is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.

2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.

4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish

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should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

a) Redevelopment projects that reduce the overall impervious footprint

b) Brownfield redevelopment

c) High density developments (>7 units per acre)

d) Mixed use and transit-oriented development (within ½ mile of transit)

e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses

f) Regional treatment systems with a capacity to treat flows from all upstream developments

g) Contribution to an urban runoff fund (see 1, above)

h) Offsite mitigation or dedications within the same watershed

i) City Center area

j) Historic Districts and Historic Preservation areas

k) Live-work developments

l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.

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4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.
3. The permittees shall develop a database with information regarding each structural treatment control BMP installed after adoption of this order. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.
4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.
5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 25% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within every four year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record. The permittees may accept

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inspections conducted and certified by state licensed professional engineers in lieu of permittee inspections.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented to the maximum extent practicable for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.
2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.
3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.
4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute

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developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.

2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public

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agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.

3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:

   a) Parking facilities;

   b) Flood management and storm water conveyance systems (open channels);

   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and

   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.

4. All applicable public agency staff shall be trained as specified under Section XVI.

5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:

   a) Conduct annual integrated pest management self-audits;

   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

   c) Provide proper training to municipal and contract staff involved in the above activities;

   d) Within one year of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within one year of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall

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submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.
12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.
13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.
14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.

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4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.
2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training, such as Certificate of Completion, attendance sheets or other proof that training has been completed. .
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood.

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The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.

5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections[59].
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

[59] The reporting schedule may be revised with the approval of the Executive Officer.

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XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

1. As required under a consent decree, in 2002, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay, including metals, organochlorine compounds, selenium and organophosphate pesticides. EPA and the Los Angeles Regional Water Quality Control Board established technical TMDLs for metals in Coyote Creek. Technical TMDLs do not include implementation plans or compliance schedules.
2. In collaboration with stakeholders, Regional Board staff are developing revised TMDLs that are expected to supplant the toxics TMDLs promulgated by EPA for the Newport watershed. The TMDLs will include implementation plans and compliance schedules. Implementation plans for the Coyote Creek TMDLs are also being developed.
3. In summary, work related to the following established TMDLs is ongoing:
   a) Metals (San Diego Creek and Newport Bay (including Rhine Channel))
   b) Metals (Mercury, Chromium) (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay; also see Paragraphs 5 and 6, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)
4. The permittees in the Newport Watershed shall comply with the wasteload allocations specified in the established TMDLs and shown in Tables 1 A/B/C, 2 A/B/C/D and 3. These wasteload allocations shall remain in effect unless and until alternative wasteload allocations are established in TMDLs approved by the Regional Board, State Board, Office of Administrative Law and EPA.

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Tables 1 A/B/C/D – Urban Runoff Waste Load Allocations for Metals (TMDLs promulgated by U.S. EPA)[60]

A- San Diego Creek and Tributaries – Concentration based TMDL

	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

D- Concentration-based Dissolved Metal TMDLs, WLAs and LAs for Newport Bay

	Dissolved saltwater TMDLs and allocations which apply to direct discharges to the bay, including storm drains/channels and metals loading associated with boats	
	Acute	Chronic
Cd* (ug/L)	42	9.3
Cu (ug/L)	4.8	3.1
Pb (ug/L)	210	8.1
Zn (ug/L)	90	81

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds

[60] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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(TMDLs promulgated by U.S. EPA)[61]

A- San Diego Creek and Tributaries

Total DDT	Chlordane	Dieldrin	PCBs	Toxaphene
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	Chlordane	PCBs
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	Chlordane	Dieldrin	PCBs
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	Chlordane	Dieldrin	PCBs
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[62]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

5. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. These TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. These TMDLs have not yet been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program (TRIP) that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. These TMDLs will become effective upon approval by the State Board and Office of Administrative Law but will not supplant the EPA organochlorine compounds TMDLs until they are approved by EPA. Accordingly, upon approval of the Regional Board-adopted organochlorine compounds TMDLs by the State Board and the Office of Administrative Law, the permittees shall comply with both the EPA and

[61] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[62] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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Regional Board wasteload allocations specified in Tables 2 A/B/C/D and Table 4, respectively. In accordance with the Regional Board TMDLs, compliance with the allocations specified in Table 4 shall be achieved as soon as possible but no later than December 31, 2015. Upon approval of the Regional Board-approved organochlorine compounds TMDLs by EPA, the applicable wasteload allocations shall be those specified in Table 4.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs approved by Santa Ana Regional Water Quality Control Board)[63]

	Total DDT	**Chlordane**	**Total PCBs**	**Toxaphene**
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.8 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

6. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated the Toxicity Reduction and Investigation Program (TRIP) consistent with the Regional Board-approved implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations.

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[64]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l

[63] From Resolution No. R8-2007-0024, Table NB-OCs-10

[64] From Resolution No. R8-2007-0024, Table NB-OCs-4

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Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

7. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs and that are intended to replace the EPA TMDLs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. This Order will be reopened to incorporate revised allocations based upon TMDLs, including implementation plans, for metals and selenium approved by the Regional Board, State Board and Office of Administrative Law. As for the organochlorine compounds, the EPA promulgated allocations for these constituents will also remain in effect unless and until EPA approves the Regional Board's TMDLs for these constituents.

8. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive selenium (and nitrogen) management plans, which are expected to form the basis, at least in part, for the selenium implementation plan (and a revised nutrient TMDL implementation plan). A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the selenium TMDL implementation plan must be submitted by the stakeholders covered

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by this order within 24 months of adoption of this order, or one month after approval of the selenium TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

9. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with the following wasteload allocations:

Table 6 – Municipal Storm Water Wasteload Allocations - Coyote Creek

	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

10. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 7 – Numeric Targets - Coyote Creek
(total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[65]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

[65] Based on saltwater CTR criterion in San Gabriel River estuary.

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C. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 8A – Fecal Coliform TMDL and Allocations for Newport Bay

To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2013	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 8B – Fecal Coliform TMDL and Allocations for Newport Bay

Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for		Monthly Median less than 14 MPN/100 mL, and not more than 10% of

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Fecal Coliform from Natural Sources in all Discharges		the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables 8A and 8B in accordance with the deadlines in Tables 8A and 8B. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.
3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 9A and 9B are extracted from the Implementation Plan[66]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 9 A and B.

Table 9A

Diazinon and Chlorpyrifos Allocations for San Diego Creek*

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Acute	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6

[66] Attachment to Resolution No. R8-2003-0039

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Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

Table 9B

Chlorpyrifos Allocations for Upper Newport Bay*

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 10 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[67]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[68]	2007 Summer Allocation (Apr-Sept)[69]	2012 Winter Allocation (Oct-Mar)[70]

[67] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[68] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[69] See previous footnote.

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Newport Bay Watershed	lbs/year TN[71,72]	lbs/season TN	lbs/season TN	lbs/season TN
Urban runoff	277,131[73]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 11 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[74]

	2012 Allocation lbs/day TN[75]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table 12 - Annual Total Phosphorous Load Allocations For The Newport Bay Watershed[76]

	2002 Allocation lbs/year TP[77]	2007 Allocation lbs/year TP[78]

[70] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[71] TIN = (NO3+NH3).

[72] TN = (TIN + Organic N).

[73] Estimated annual average (summer and winter loading).

[74] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[75] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[76] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[77] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[78] See previous footnote

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TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 10, 11 and 12 in accordance with the schedules in Tables 10, 11 and 12. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determinations shall be based on monitoring within the receiving waters. For sediment TMDLs, compliance determination shall be based on monitoring in the Creek.

2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

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XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
    a) Review of the formal training needs of municipal employees
    b) Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.
3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
    a) Each permittee's expenditures for the previous fiscal year,
    b) Each permittee's budget for the current fiscal year,
    c) A description of the source of funds, and
    d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.

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2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.

3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.

4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.

5. Within one year of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.

6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.

7. The permittees shall report to the Executive Officer of the Regional Board:

   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,

   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)

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8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:
   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;
   b) Changes in land use and/or population including land use map updates;
   c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,
   d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

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2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).
3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.
4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on April 24, 2009.

_____

Gerard J. Thibeault
Executive Officer

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To be provided at a later date.

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Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities
Area wide Urban Storm Water Runoff

Attachment "B"

To be provided at a later date.

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Order No. R8-2009-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

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Orange Unified School District
Placentia Unified School District
Saddleback Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

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State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2009-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

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I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

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determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

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f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

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c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

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V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual Report

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Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

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Ordered by_____
Gerard J. Thibeault
Executive Officer

Linda S. Adams
Secretary for Environmental Protection

California Regional Water Quality Control Board
Santa Ana Region

3737 Main Street, Suite 500, Riverside, California 92501-3348
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http://www.waterboards.ca.gov/santaana

Arnold Schwarzenegger
Governor

A G E N D A A N N O U N C E M E N T

REGIONAL BOARD MEETING
Friday, April 24, 2009
9:00 A.M.
City of Santa Ana
22 Civic Center Plaza
Santa Ana, CA

NOTICE

Changes and postponements that may occur to this agenda will be placed on our website and automatically forwarded to those who subscribe to our electronic mailing list. Anyone wishing to subscribe to our electronic agenda mailing list may do so, as follows: go to www.waterboards.ca.gov/santaana/ and choose "Email Subscriptions" from the homepage. Those who are not subscribers should visit our website prior to the board meeting date to view any changes to the agenda.

Supporting documents for agenda items are now posted on our website at least 7 days prior to the scheduled meeting. To view or download the documentation, go to www.waterboards.ca.gov/santaana/ and select the "*Public Notices*" page.

1. **Introductions**

2. **Public Forum** - Any person may address the Board at the commencement of the meeting on any matter within the Regional Board's jurisdiction and not related to an item that is to be considered separately. The Regional Board Chair requests that each person addressing the Regional Board observe a three–minute time limit.

3. **State Water Resources Control Board Liaison Report** - This item is for information only. No public testimony will be allowed, and the Regional Board will take no formal action.

4. **Approval of the Minutes of the Regular Board Meeting of March 27, 2009.**
{Felipa Carrillo 951/782-3285 fcarrillo@waterboards.ca.gov}

5. **Consideration of Consent Calendar Items** - Items marked with an asterisk (*) are expected to be routine and non-controversial. The Regional Board will be asked to consider these items at one time without discussion. If any interested party, Board Member or staff requests that an item be removed from the consent calendar, it will be taken up in the order shown.

*6. **Appeal of Staff's Denial of an Exemption from the Minimum Lot Size Requirement** - Gilberto Galvan, 1103 Stevenson Street, City of Colton, San Bernardino County - APN 0274-093-35.
{Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov}

*7. **Renewal of Waste Discharge Requirements for Eastern Municipal Water District, Riverside County (NPDES No. CA8000188)** - Discharge of approximately 52.5 million gallons per day of tertiary treated wastewater to Temescal Creek.
{Jun Martirez 951\782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2009-0014

*8. **Yucaipa Valley Water District Maximum Benefit Program** - The Board will consider approval of the plan and schedule for determining ambient water quality in the San Timoteo Management Zone as required pursuant to the Yucaipa Valley Water District Maximum Benefit Salt Management Program specified in the Basin Plan.
{Hope A. Smythe 951/782-4493 hsmythe@waterboards.ca.gov} Resolution No. R8-2009-0034

*9. **San Timoteo Watershed Management Agency and City of Beaumont Maximum Benefit Program** - The Board will consider approval of the plan and schedule for the removal of effluent discharge from the un-lined portions of the San Timoteo Creek and the plan and schedule for determining ambient water quality in the San Timoteo Management Zone. Both of these provisions are required pursuant to the San Timoteo Watershed Management Agency (STWMA) and City of Beaumont Maximum Benefit Salt Management Program specified in the Basin Plan.
{Hope A. Smythe 951/782-4493 hsmythe@waterboards.ca.gov} Resolution No. R8-2009-0035

*10. **Cooperative Agreement for the Newport Bay Watershed and the Central Watershed Management Area-Third Amendment and Full Restatement of Cooperative Agreement** - The Board will be asked to approve the Cooperative Agreement, which has been amended to provide a management framework for cooperation on water resource and water quality issues, including TMDLs, as well as implementation of the San Diego Creek-Newport Bay Watershed Comprehensive Stormwater Sediment Control Plan. The Cooperative Agreement was first entered into on September 30, 1983; on February 18, 2009, the Newport Bay Watershed Executive Committee approved the third amendment to the Cooperative Agreement. The amended Agreement must be approved by each member of the Executive Committee, including the Regional Board.
{Wanda M. Cross 951/782-4468 wcross@waterboards.ca.gov}

*11. **Resolution Regarding Funding from the State Water Resources Control Board (SWRCB) Emergency, Abandoned and Recalcitrant Site Account** - The Board will consider a resolution supporting the acceptance of funds for underground storage tank sites from the SWRCB Emergency, Abandoned and Recalcitrant Site Account.
{Kenneth Williams 951/782-4496 kwilliams@waterboards.ca.gov} Resolution No. R8-2009-0037

12. **Renewal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of Orange County, Urban Storm Water Runoff Management Program (NPDES No. CAS618030)** - The Board will conduct a public hearing on the proposed permit and will consider adoption of the permit.
{Mark E. Smythe 951/782-4998 msmythe@waterboards.ca.gov} Order No. R8-2009-0030

13. **Public Hearing on Clean Water Act Section 305(b) Integrated Report/Clean Water Act Section 303(d) List of Impaired Waterbodies** - The Regional Board will conduct a public hearing to consider approval of the Clean Water Act section 305(b) Integrated Water Quality Assessment Report including update of the Clean Water Act section 303(d) List of Impaired Water Bodies.
{Hope A. Smythe 909/782-4493 hsmythe@waterboards.ca.gov} Resolution No. R8-2009-0032

14. **Revised Request for Cleanup and Abatement Account Funding Related to Perchlorate Contamination** - The Board will consider adoption of a resolution revising its request for Cleanup and Abatement Account funds from the State Water Resources Control Board for work related to perchlorate contamination of groundwater in the Rialto area.
{Kurt V. Berchtold 951/782-3286 kberchtold@waterboards.ca.gov} Resolution No. R8-2009-0027
(This item was postponed from the March 27, 2009 meeting).

15. **Presentation to the Board of the Results of the Most Recent Wasteload Allocation Analysis for the Santa Ana River** - Task Force Consultants will brief the Board on the findings of the recently completed wasteload allocation work (information item).
{Hope A. Smythe 951/782-4493 hsmythe@waterboards.ca.gov}
(This item was postponed from the March 27, 2009 meeting).

16. **Regional Board Member and Executive Officer Communications —** Board Members and the Executive Officer may discuss meetings, communications, correspondence, or other items of general interest relating to matters within the Regional Board's jurisdiction. There will be no voting or formal action taken.

17. **Closed Session -** At any time during the regular session, the Regional Board may adjourn to a closed session to:
    a. consider evidence received in an adjudicatory hearing and deliberate on a decision to be reached based on that evidence (Gov. Code Section 11126(c)(3));
    b. consider the appointment, employment, evaluation of performance, or dismissal of a public employee or to hear complaints or charges brought against a public employee (Gov. Code Section 11126(a)(1));
    c. discuss significant exposure to litigation (Gov. Code Section 11126(e)(2)(B)(i));
    d. discuss whether to initiate litigation (Gov. Code Section 11126(e)(2)(C)(i)); and
    e. discuss pending litigation in the following matters (Gov. Code, § 11126, subd.(e)):
        (1) Stringfellow Hazardous Waste Site;
        (2) US EPA, Santa Ana Region v. Orange County Sanitation District (U.S. Dist. Ct., CD Cal.);
        (3) Goodrich Corporation v. California State Water Resources Control Board et al. (Los Angeles Sup. Ct. Case No. BS 110389,[consolidated with BS 110390 and BS 110391].);
        (4) In re Petitions of Kwikset Locks, Inc. (SWRCB/OCC File Nos. A-1732, 1732(a), 1732(b), 1732(c), and 1732(d));
        (5) In re Petition of Natural Resources Defense Council, Inc. (SWRCB/OCC File No. A-1883); and
        (6) In re Own Motion Review of Rialto-Area Perchlorate Contamination (SWRCB/OCC File No. A-1824).

18. **Adjournment** to the regular meeting of May 22, 2009, at 9:00 a.m., at the City of Santa Ana, Council Chambers, 22 Civic Center Plaza, Santa Ana, CA.

NOTICES

Any person who has a disability and requires reasonable accommodation to participate in this Regional Board Meeting should contact Felipa Carrillo at fcarrillo@waterboards.ca.gov, or at 951/782-3285, no later than ten (10) days prior to the meeting.

Any person interested in obtaining information and/or providing input regarding pending applications for Water Quality Standards Certification under Section 401 of the Federal Clean Water Act may do so by contacting Mark G. Adelson at 951/782-3234.

California Regional Water Quality Control Board
Santa Ana Region

April 24, 2009

UPDATE TO THE AGENDA

(Prepared 4-16-09)

The following item has been postponed:

*7. **Renewal of Waste Discharge Requirements for Eastern Municipal Water District, Riverside County (NPDES No. CA8000188)** - Discharge of approximately 52.5 million gallons per day of tertiary treated wastewater to Temescal Creek.
{Jun Martirez 951\782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2009-0014

California Regional Water Quality Control Board
Santa Ana Region

April 24, 2009

UPDATE TO THE AGENDA

(Prepared 4-20-09)

The following items have been postponed:

*7. **Renewal of Waste Discharge Requirements for Eastern Municipal Water District, Riverside County (NPDES No. CA8000188)** - Discharge of approximately 52.5 million gallons per day of tertiary treated wastewater to Temescal Creek.
{Jun Martirez 951\782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2009-0014

15. **Presentation to the Board of the Results of the Most Recent Wasteload Allocation Analysis for the Santa Ana River** - Task Force Consultants will brief the Board on the findings of the recently completed wasteload allocation work (information item).
{Hope A. Smythe 951/782-4493 hsmythe@waterboards.ca.gov}
(This item was postponed from the March 27, 2009 meeting).

Item No. 12
Errata

(Additions are underlined and deletions are strike-out)

1. Order No. R8-2009-0030, Findings 52 (Page 18) and 73 (Page 25):

Change the reference to 40 CFR 122.46(d)(vii)(B) to 40 CFR 122.44(d)(vii)(B)

2. Order No. R8-2009-0030, Finding 61, Page 20 (sentence before the last sentence in the paragraph):

61. ~~To the maximum extent practicable~~ These LID BMPs must be implemented at the project site in a manner that is consistent with the maximum extent practicable standard.

3. Order No. R8-2009-0030, Section III.3.l, Page 33 (last sentence):

III. DISCHARGE LIMITATIONS/PROHIBITIONS

l) However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section ~~XIX~~ XXI, Provision 5);

4. Order No. R8-2009-0030, Section VII.2, Page 38 (first sentence):

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

2. The permittees shall control ~~to the maximum extent practicable~~ the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s.

5. Order No. R8-2009-0030, Section XI.2, Page 46 (first sentence):

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s ~~to the~~ consistent with the maximum extent practicable standard so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

6. Order No. R8-2009-0030, Section XII.B.2.h, Page 50:

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

h. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" in a manner consistent with ~~to~~ the maximum extent practicable standard. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

7. Order No. R8-2009-0030, Section XII.C.3 and 4, Page 53 (first sentence):

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to a level that is consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.).

8. Order No. R8-2009-0030, Section XII.C.7 and 8, Page 55 (Paragraph 8 should be changed to subparagraph a) and the subsequent subparagraph numbers also should be changed):

7. If site conditions do not permit infiltration, harvesting and re-use, …

a. Implement LID principles at the project site. ….

b) Implement as many LID principles as possible at the project site close …

c) Implement LID on a sub-regional basis. For example, at a 100 unit …

d) Implement LID on a regional basis. For example, several developments …

9. Order No. R8-2009-0030, Section XII.D.5, Page 57(first sentence:)

5. The permittees ~~have the option to~~ shall address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan as described below:

The Watershed Master Plans shall integrate water quality, hydromodification, water supply, and habitat for the following watersheds: Coyote Creek-San Gabriel River; Anaheim Bay-Huntington Harbour; Santa Ana River; and Newport Bay-Newport Coast. Components of the Plan shall include: (1) maps to identify areas

susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and areas where storm water and urban runoff infiltration is possible and appropriate; and, (2) a hydromodification model to make available as a tool to enable proponents of land development projects to readily select storm water preventive and mitigative site BMP measures.

The maps shall be prepared within 12 months of the adoption of this order and a model Plan for one watershed shall be prepared within 24 months of adoption of this order. The model Plan should specify hydromodification management standards for each sub-watershed and provide assessment tools. In the preparation of the model Plan, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board, and (6) and water districts.

The model Watershed Master Plan shall be submitted to the Executive Officer for approval. Watershed Master Plans shall be completed for all watersheds 24 months after approval of the model Watershed Master Plan.

The Watershed Master Plans shall be designed to meet applicable water quality standards and the Federal Clean Water Act.

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10. Order No. R8-2009-0030, Section XII.J.1, Page 61 (second sentence):

J. PRE-APPROVED PROJECTS

1. The above provisions shall be implemented in a manner consistent with ~~to~~ the maximum extent practicable standard for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1).

11. Order No. R8-2009-0030, Section XVIII.E.2, Page 78 (sentence before the last sentence:)

2. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that an exceedance ~~violation~~ has occurred.

12. Order No. R8-2009-0030, Pages 83 and 84:

Add maps to Attachment "A" and Attachment "B"

State of California
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

FACT SHEET

April 24, 2009

ITEM: 12

SUBJECT: Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region, Areawide Urban Storm Water Runoff Management Program, Orange County, Order No. R8-2009-0030 (NPDES No. CAS 618030)

I. INTRODUCTION

The 1972 Clean Water Act (CWA) established the National Pollutant Discharge Elimination System (NPDES) permit program to regulate the discharge of pollutants from point sources to waters of the United States (US). Since then, considerable strides have been made in reducing conventional forms of pollution, such as from sewage treatment plants and industrial facilities, through the implementation of the NPDES program and other federal, state and local programs. The adverse effects of some of the persistent toxic pollutants (DDT, PCB, TBT) were addressed through manufacturing and use restrictions and through cleanup of contaminated sites. On the other hand, pollution from land runoff (including atmospheric deposition, urban, suburban and agricultural) was largely unabated until the 1987 CWA amendments. As a result, diffuse sources, including urban storm water runoff, now contribute a larger portion of many kinds of pollutants than the more thoroughly regulated sewage treatment plants and industrial facilities. The National Urban Runoff Program (NURP) final report to the Congress (US EPA, 1983) concluded that the goals of the CWA could not be achieved without addressing urban runoff discharges. The 1987 CWA amendments established a framework for regulating urban storm water runoff. Pursuant to these amendments, the Santa Ana Regional Water Quality Control Board (Regional Board) began regulating municipal storm water runoff in 1990.

The attached pages contain information concerning an application for renewal of Waste Discharge Requirements and a NPDES permit, which prescribes waste discharge requirements for urban storm water runoff from the cities and unincorporated areas in Orange County within the jurisdiction of the Santa Ana Regional Board. On July 21, 2006, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS 618030 (Report of Waste Discharge) for re-issuance of their areawide storm water NPDES permit. The permit application was submitted in accordance with the requirements of the previous NPDES permit (Order No. R8-2002-0010, NPDES No. CAS618030) which

expired on January 19, 2007. Additionally, the permit application follows guidance provided by staff of the State Water Resources Control Board (State Board), the Regional Water Quality Control Boards (Regional Boards), and the United States Environmental Protection Agency (US EPA).

On February 20, 2007, Order No. R8-2002-0010, NPDES No. CAS618030, was administratively extended in accordance with 40 CFR Part 122.6 and Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

Order No. R8-2009-0030 regulates discharges of urban storm water from the lower Santa Ana watershed to waters of the US, which ultimately drain into the Pacific Ocean.

II. REGULATORY BACKGROUND/CLEAN WATER ACT REQUIREMENTS

Urban runoff includes dry and wet weather flows and storm water runoff (collectively referred to as urban runoff) from urbanized areas through a storm water conveyance system. As water flows over streets, parking lots, construction sites, and industrial, commercial, residential and municipal areas, it can intercept pollutants from these areas and transport them to waters of the US. If appropriate pollution control measures are not implemented, urban runoff may contain pathogens (bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, mostly nitrogen and phosphorus compounds), oxygen-demanding substances (decaying matter), pesticides (DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (cadmium, chromium, copper, lead, zinc) and petroleum products (oil & grease, PAHs, petroleum hydrocarbons). If not properly managed and controlled, urbanization can change the stream hydrology and increase pollutant loading to receiving waters. As a watershed undergoes urbanization, pervious surface area decreases, runoff volume and velocity increase, riparian and wetland habitat decrease, the frequency and severity of flooding increase and pollutant loading increases. Most of these impacts are due to human activities that occur during and/or after urbanization. The pollutants and hydrologic changes can cause declines in aquatic resources, toxicity to marine organisms, and impact human health and the environment.

However, properly planned high-density development, with sufficient open space and low impact developments, can reduce urban sprawl and problems associated with sprawl. Urban in-fill development can be an element of smart growth, creating the opportunity to maintain relatively natural open space elsewhere in the area. The goal of low impact development is to produce post-construction runoff quality and quantity, to mimic that of pre-construction runoff quality and quantity.

The US EPA recognizes urban runoff as the number one source of estuarine pollution in coastal communities[1]. Studies[2] conducted in the Southern California area and other studies have reported a definite link between storm water runoff from urban areas and pollution in

[1] US EPA, 1999, 40CFR Parts 9, 122, 123, 124, National Pollutant Discharge Elimination System – Regulations for Revision of the Water Pollution Control Program Addressing Storm Water Discharges; Final Rule, 64FR 68727.

[2] Bay, S., Jones, B. H. and Schiff, K, 1999, Study of the Impact of Stormwater Discharge on Santa Monica Bay. Sea Grant Program, University of Southern California; and Haile, R.W., et. al., 1996, An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay.

nearshore zones. A number of Orange County beaches were closed during 1999 and 2000 due to microbial contamination. One of the studies conducted to determine the source of this microbial contamination indicated that urban runoff may be one of the sources of this contamination. If not properly controlled, urban runoff could be a significant source of pollutants in waters of the US. Table 1 includes a list of pollutants, their sources, and some of the adverse environmental consequences mostly resulting from urbanization.

Table 1[3]. Pollutants/Impacts of Urbanization on Waters of the US (Marine Pollution)

Pollutants	Sources	Effects and Trends
Toxins (e.g., biocides, PCBs, trace metals, heavy metals)	Industrial and municipal wastewaters; runoff from farms, forests, urban areas, and landfills; erosion of contaminated soils and sediments; vessels; atmospheric deposition	Poison and cause disease and reproductive failure; fat-soluble toxins may bioconcentrate, particularly in birds and mammals, and pose human health risks. Inputs into US waters have declined, but remaining inputs and contaminated sediments in urban and industrial areas pose threats to living resources.
Pesticides (e.g., DDT, diazinon, chlorpyrifos)	Urban runoff, agricultural runoff, commercial, industrial, residential, and farm use	Legacy pesticide (DDT, Chlordane, Dieldrin, etc.) use has been banned; still persists in the environment; some of the other pesticide uses are curtailed or restricted.
Biostimulants (organic wastes, plant nutrients)	Sewage and industrial wastes; runoff from farms and urban areas; nitrogen from combustion of fossil fuels	Organic wastes overload bottom habitats and deplete oxygen; nutrient inputs stimulate algal blooms (some harmful), which reduce water clarity, cause loss of seagrass and coral reef, and alter food chains supporting fisheries. While organic waste loadings have decreased, nutrient loadings have increased.
Petroleum products (oil, grease, petroleum hydrocarbons, PAHs)	Urban runoff and atmospheric deposition from land activities; shipping and tanker operations; accidental spills; coastal and offshore oil and gas production activities; natural seepage; PAHs from internal combustion engines	Petroleum hydrocarbons can affect bottom organisms and larvae; spills affect birds, mammals and nearshore marine life. While oil pollution from ships, accidental spills, and production activities has decreased, diffuse inputs from land-based activities have not.
Radioactive isotopes	Atmospheric fallout, industrial and military activities	Few known effects on marine life; bioaccumulation may pose human health risks where contamination is heavy.

[3]Adapted from "Marine Pollution in the United States" prepared for the Pew Oceans Commission, 2001.

Sediments	Erosion from farming, construction activities, forestry, mining, development; river diversions; coastal dredging and mining	Reduce water clarity and change bottom habitats; carry toxins and nutrients; clog fish gills and interfere with respiration in aquatic fauna. Sediment delivery by many rivers has decreased, but sedimentation poses problems in some areas; erosion from coastal development and sea-level rise is a future concern.

Plastics and other debris	Ships, fishing nets, containers, trash, urban runoff	Entangles marine life or is ingested; degrades beaches, wetlands and nearshore habitats. Floatables (from trash) are an aesthetic nuisance and can be a substrate for algae and insect vectors.
Thermal	Cooling water from power plants and industry, urban runoff from impervious	Kills some temperature-sensitive species; displaces others. Generally, less a risk to marine life than thought 20 years ago.
Noise	Vessel propulsion, sonar, seismic prospecting, low-frequency sound used in defense and research	May disturb marine mammals and other organisms that use sound for communication.
Pathogens (bacteria, protozoa, viruses)	Sewage, urban runoff, livestock, wildlife, discharges from boats and cruise ships	Pose health risks to swimmers and consumers of seafood. Sanitation has improved, but standards have been raised.
Alien species	Ships and ballast water, fishery stocking, aquarists	Displace native species, introduce new diseases; growing worldwide problem.

The Clean Water Act (CWA) prohibits the discharge of any pollutant to navigable waters from a point source unless an NPDES permit authorizes the discharge. Efforts to improve water quality under the NPDES program traditionally and primarily focused on reducing pollutants in discharges of industrial process wastewater and municipal sewage. The 1987 amendments to the CWA required municipal separate storm sewer systems (MS4s) and industrial facilities, including construction sites, to obtain NPDES permits for storm water runoff from their facilities. On November 16, 1990, the United States Environmental Protection Agency (EPA) promulgated the final Phase I storm water regulations. The storm water regulations are contained in 40 CFR Parts 122, 123 and 124.

The areawide NPDES permit for Orange County areas within the Santa Ana Regional Board's jurisdiction is being considered for renewal in accordance with Section 402 (p) of the CWA and all requirements applicable to an NPDES permit issued under the issuing authority's discretionary authority. The requirements included in this order are consistent with the CWA, the federal regulations governing urban storm water discharges, the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan), the California Water Code, and the State Board's Plans and Policies, including the Ocean Plan.

The Basin Plan is the basis for the Regional Board's regulatory programs. The Plan was developed and is periodically reviewed and updated in accordance with relevant federal and state law and regulations, including the Clean Water Act and the California Water Code. As required, the Basin Plan designates the beneficial uses of the waters of the region and specifies water quality objectives intended to protect those uses. (Beneficial uses and water quality objectives, together with an antidegradation policy, comprise federal "water quality standards"). The Basin Plan also specifies an implementation plan, which includes certain discharge prohibitions. In general, the Basin Plan makes no distinctions between wet and dry weather conditions in designating beneficial uses and setting water quality objectives, i.e., the beneficial uses, and correspondingly, the water quality objectives are assumed to apply year-round. (Note: In some cases, beneficial uses for certain surface waters are

designated as "I", or intermittent, in recognition of the fact that surface flows (and beneficial uses) may be present only during wet weather.) Most beneficial uses and water quality objectives were established in the 1971, 1975 and 1983 Basin Plans.

Water Code Section 13241 requires that certain factors be considered, at a minimum, when water quality objectives are established. These include economics and the need for developing housing in the Region. (The latter factor was added to the Water Code in 1987).

During the previous permit (R8-2002-0010) development process, the permittees raised an issue regarding compliance with Section 13241 of the California Water Code with respect to water quality objectives for wet weather conditions, specifically the cost of achieving compliance during wet weather conditions and the need for developing housing within the Region and its impact on urban storm water runoff. In response to this request, Regional Board staff in collaboration with the permittees in the region has organized a Storm Water Quality Standards Task Force. In the meantime, the provisions of this order will result in reasonable further progress towards the attainment of the existing water quality objectives, in accordance with the discretion in the permitting authority recognized by the United States Court of Appeals for the Ninth Circuit in Defenders of Wildlife v Browner, 191 F.3d 1159, 1164 (9th Cir. 1999).

III. BENEFICIAL USES

Storm water flows that are discharged to municipal storm drain systems in Orange County are tributary to various water bodies (inland surface streams, bays and tidal prisms, ocean waters, lakes and reservoirs) of the state. The beneficial uses of these water bodies include municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sportfishing, warm freshwater habitat, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats and estuarine habitat. The ultimate goal of this storm water management program is to protect the water quality standards of the receiving waters.

IV. PERMITTED AREA

The permitted area is delineated by the Los Angeles County-Orange County boundary line on the northwest, the San Bernardino-Orange County boundary line on the north and northeast, the Riverside County-Orange County boundary line on the east, the Santa Ana Regional Board-San Diego Regional Board boundary line on the southeast, and the Pacific Ocean on the southwest (see Attachment A of the order). The permittees serve a population of approximately 3.006[4] million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the Santa Ana Regional Board's jurisdiction). The permittees have jurisdiction over, and/or maintenance responsibility for, storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drain

[4] SCAG County Population Forecasts for 2005 (this is for the entire County) ((http://www.eltoroairport.org/issues/population.html)

systems. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. Storm water discharges from urbanized areas consist mainly of surface runoff from residential, commercial, and industrial developments. In addition, there are storm water discharges from agricultural land uses, including farming and animal operations. However, the CWA specifically excludes agricultural discharges from regulation under this program. Other areas of the County not addressed or which are excluded by the storm water regulations and areas not under the jurisdiction of the permittees are excluded from the area requested for coverage under this permit. These excluded areas and activities include:

1. Federal lands and state properties, including, but not limited to, military bases, national forests, hospitals, schools, colleges, universities, and highways;
2. Native American tribal lands; and
3. Utilities and special district properties.

Discharges from the permitted area drain into the Pacific Ocean. The watersheds regulated under this order generally referred to as the San Diego Creek/Newport Bay watershed and the Lower Santa Ana River Basin.

V. WATERSHED MANAGEMENT/LOWER SANTA ANA RIVER BASIN

To manage the water resources of the Region efficiently, it is critical to have a holistic approach. The entire storm drain system in Orange County is not controlled by a single entity; the County of Orange, the OCFCD, several cities, Caltrans, US Army Corps of Engineers and a number of other entities own, operate and/or manage the storm drain systems. In addition to the cities, the County and the OCFCD, there are a number of other significant contributors of storm water runoff to these storm drain systems. These include: large institutions such as the State University facilities, schools, hospitals, etc.; federal facilities such as Department of Defense facilities; State agencies such as Caltrans; water and wastewater management agencies such as Orange County Water District, Metropolitan Water District etc.; the National Forest Service; state parks; and entertainment centers such as Disneyland. The quality and quantity of storm water runoff into and out of Orange County also depends upon runoff from San Bernardino and Riverside County areas that are tributary to Orange County. Some of the runoff from Orange County enters the San Gabriel River or systems controlled by other entities, such as the Los Angeles County Flood Control District, which are under the Los Angeles Regional Board's jurisdiction.

Some of these facilities, such as Disneyland and Caltrans, are already under individual permits for storm water runoff. The Los Angeles and San Diego Regional Boards have also issued areawide storm water permits for areas within their jurisdiction.

Cooperation and coordination among all the stakeholders is essential for efficient and economical management of the watershed. It is also critical to manage nonpoint sources at a level consistent with the management of urban storm water runoff in a watershed, in order to prevent or remedy water quality impairment. Regional Board staff will facilitate coordination of monitoring and management programs among the various stakeholders, where necessary.

An integrated watershed management approach is consistent with the Strategic Plan (2008-2012) for the State and Regional Boards. A watershed wide approach is also necessary for implementation of the load and waste load allocations developed under the TMDL process (see Section B, below). The MS4 permittees and all the affected entities should be encouraged to participate in regional or watershed solutions instead of project-specific and fragmented solutions.

The pollutants in urban runoff originate from a multitude of sources and effective control of these pollutants requires a cooperative effort of all the stakeholders and many regulatory agencies. Every stage of urbanization should be considered in developing appropriate urban runoff pollution control methodologies. The program's success depends upon consideration of pollution control techniques during planning, construction and post-construction operations. At each stage, appropriate pollution prevention measures, proper site design considerations, source control measures and, if necessary, treatment techniques should be considered.

1. SUB-WATERSHEDS AND MAJOR CHALLENGES

   The Lower Santa Ana River Watershed can be subdivided into five tributary watersheds:

   a. *The San Gabriel River Drainage Area:* Carbon Canyon Creek and Coyote Creek drain into the San Gabriel River. Only a portion of the San Gabriel River is within the Santa Ana Regional Board's jurisdiction. The River empties into the Pacific Ocean at the boundary between two Regional Boards (Regions 4 and 8). Region 4 regulates most of the discharges to the San Gabriel River.

      The Los Angeles Regional Board (Region 4) listed the San Gabriel River as an impaired waterbody on the CWA Section 303(d) list of impaired waters. It is listed for ammonia, toxicity, algae, eutrophication, pH, odors, low dissolved oxygen, trash, lead, arsenic, copper, silver, mercury (tissue), coliform, DDT, PCBs, chlordane, and abnormal fish histology. A trash TMDL for the East Fork of the River was adopted by the Regional Board (Region 4) and approved by the US EPA. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River

watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

b. The Huntington Harbour and Bolsa Bay Drainage Area: This includes Anaheim Bay, Huntington Habour, Bolsa Bay, and Bolsa Chica Ecological Reserve. A number of flood control channels discharge into this area, including Anaheim-Barber, East Garden Grove-Wintersberg, and Bolsa Chica Channel. The area historically had a number of oil production facilities and an oil-well drilling mud disposal area. There are still some production wells in the area. Certain areas of the Bolsa Chica wetlands have been impacted by the oil production and related activities in the area. The drilling mud disposal area has been cleaned up, and through a collaborative effort of a number of state, federal, and local agencies and other entities the Bolsa Chica wetlands have been restored.

Anaheim Bay and Huntington Harbour are listed as impaired waterbodies (see Table 2), and TMDLs will be developed to address the pollutants causing the impairment.

c. The Santa Ana River Drainage Area: This includes Santa Ana River Reaches 1 and 2, Santiago Creek Reaches 1, 2, 3 and 4, Silverado Creek, Black Star Creek, Talbert Channel, Talbert Marsh and Greenville-Banning Channel. The major problem for the area is microbial contamination of the coastal zone. The initial studies conducted by the Orange County Sanitation District determined that their facilities were probably not the cause of the microbial problems in the nearshore zone. Subsequently, the Executive Officer issued a directive to the County of Orange and the cities of Santa Ana, Costa Mesa, Fountain Valley and Huntington Beach (urban storm water dischargers to this tributary area) under Section 13267 of the Water Code. This directive required the dischargers to provide a plan to identify, characterize and control sources that contributed to the microbial problems in the Huntington Beach area. Several studies were conducted to trace the source(s) of the microbial contamination. These studies could not conclusively determine the sources of microbial contamination in the Huntington Beach area. However, urban runoff was identified as one of the sources. The permittees have diverted most of the dry-weather flows to the sanitary sewer system and significant improvements have been noted in the beach water quality.

d. The Newport Bay Drainage Area: Tributaries include Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash, San Diego Creek Reaches 1 and 2, and San Joaquin Freshwater Marsh.

The Newport Bay watershed has a number of impaired waterbodies listed under Section 303(d) of the CWA (see Section 2, below for

details). The impairments are mostly due to nutrients, sediment, pesticides, pathogens and metals. To date, TMDLs have been developed for nutrients, sediment, and fecal coliform bacteria and some of the pesticides (diazinon and chlorpyrifos). These TMDLs are being implemented. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay. The Regional Board is in the process of developing TMDL implementation plans for these TMDLs.

The Irvine Ranch Water District (IRWD), which provides sewage collection and treatment services for most areas in this watershed, has been also accepting dry weather flows from some of the storm sewer systems. The IRWD constructed a number of water quality treatment wetlands for treating urban storm water runoff. These treatment wetlands are strategically located to capture and treat flows from different portions of the watershed. The IRWD also sponsored legislation that authorizes the District to collect storm water fees for maintenance of these treatment wetlands. These treatment wetlands are designed to remove sediment and nutrients from urban runoff but may be less efficient in removing pathogens and toxics (metals, pesticides, etc.). It is anticipated that a combination of site design, source control and other best management practices and these treatment wetlands will help to control the discharge of pollutants in urban runoff.

e *Irvine Coast and Newport Coast Areas of Special Biological Significance (ASBSs)* The Ocean Plan has 35 designated areas of special biological significance throughout the State; two of these ASBSs are within the Santa Ana Region, Irvine Coast Areas of Special Biological Significance, Newport Coast Areas of Special Biological Significance. The ASBSs require protection of species or biological communities to the extent that alteration of natural water quality is undesirable. The Crystal Cove area, which is within the Irvine Coast ASBS, is currently experiencing increased urban runoff from new developments in the area. The Ocean Plan contains a prohibition on discharges of wastes to ASBS. The State Board has developed conditions for special protection of ASBSs. All waste discharges to the ASBS are governed by the prohibition in the Ocean Plan are subject to the special protections prescribed by the State Board.

2. CWA SECTION 303(d) LIST AND TMDLs:

The 2006 water quality assessment conducted by the Regional Board identified a number of waterbodies within the Region as impaired waterbodies, under Section 303(d) of the CWA. These are waterbodies where the designated beneficial uses are not met and/or the water quality objectives are being violated. These waterbodies were placed on the CWA Section 303(d) list of impaired waters. The impaired waterbodies in Orange County within the Santa Ana Regional Board's jurisdiction are listed in Table 2.

Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the problem pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. It is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, with a margin of safety. The TMDLs are the basis for limitations established in waste discharge requirements. TMDLs have been developed for sediment and nutrients for San Diego Creek and Newport Bay and for fecal coliform bacteria in Newport Bay. The stakeholders in this watershed are collaborating in the development and implementation of the TMDLs. The Regional Board's Executive Officer has issued requirements for the submittal and implementation by the responsible parties of plans and schedules to address the TMDL requirements.

Table 2. Clean Water Act Section 303(d) Listed Waterbodies

Water Body	**Hydro Unit**	**Pollutant Stressor**	**Source**	**Priority**	**Size Affected**	**Unit**	**TMDL End Date**
Anaheim Bay	80111000	Nickel[5]	Source Unknown	Medium	402	Acres	2019
		Dieldrin[6]	Source Unknown	Medium	402	Acres	2019
		PCBs[7]	Source Unknown	Medium	402	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	402	Acres	2019
Balboa Beach	80114000	Pesticides[8]	Source Unknown	Medium	1.8	Miles	2019
		PCBs	Source Unknown	Medium	1.8	Miles	2019
Bolsa Chica State Beach	80111000	Metals (copper and nickel)	Source Unknown	Medium	2.6	Miles	2019
Buck Gully Creek	80111000	Pathogens	Source Unknown	Medium	0.3	Miles	2019

[5] EPA listing
[6] EPA listing
[7] EPA listing
[8] DDT and Dieldrin

Huntington Beach State Park	80111000	Pathogens (Entrococcus and indicator bacteria)	Source Unknown	Medium	5.8	Miles	2019
		PCBs	Source Unknown	Medium	5.8	Miles	2019
Huntington Harbour	80111000	Metals (copper, lead, nickel)	Source Unknown	Medium	221	Acres	2019
		Pathogens	Urban Runoff/Storm Sewers	Medium	221	Acres	2019
		Chlordane	Source Unknown	Medium	221	Acres	2019
		PCBs	Source Unknown	Medium	221	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	221	Acres	2019
Los Trancos Creek (Crystal Cove Creek)	80111000	Pathogens (fecal coliform, total coliform)	Source Unknown	Medium	0.19	Miles	2019
Newport Bay, Lower	80111000	Nutrients	Source Unknown	High	767	Acres	1999
		Chlordane	Source Unknown	Medium	767	Acres	2019
		DDT	Source Unknown	Medium	767	Acres	2019
		Copper	Source Unknown	High	767	Acres	2007
		PCBs	Source Unknown	Medium	767	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	767	Acres	2019

Newport Bay, Upper Ecological Reserve	80111000	Nutrients	Source Unknown	High	653	Acres	1999
		Copper	Source Unknown	High	653	Acres	2007
		Chlordane	Source Unknown	Medium	653	Acres	2019
		Metals	Urban Runoff Storm Sewers	Medium	653	Acres	2019
		DDT	Source Unknown	Medium	653	Acres	2019
		PCBs	Source Unknown	Medium	653	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	653	Acres	2019
Peters Canyon Channel	80111000	Pesticides (DDT, Toxaphene)	Source Unknown	Medium	3	Miles	2019
Rhine Channel	80114000	Metals (copper, lead, mercury, zinc)	Source Unknown	Medium	20	Acres	2019
		PCBs	Source Unknown	Medium	20	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	20	Acres	2019

San Diego Creek, Reach 1	80111000	Nutrients	Source Unknown	High	7.8	Miles	1999
		Selenium	Source Unknown	High	7.8	Miles	2007
		Fecal Coliform	Urban Runoff/Storm Sewers Other Urban Runoff	Medium	7.8	Miles	2019
		Toxaphene	Source Unknown	Medium	7.8	Miles	2019
San Diego Creek Reach 2	80111000	Nutrients	Agriculture, Urban Runoff/Storm Sewer, Groundwater Loadings	High	6.3	Miles	1999
		Metals	Urban Runoff/Storm Sewers	High	6.3	Miles	2007
Santiago Creek R4	80112000	Salinity/ TDS/ Chlorides	Source Unknown	Low	9.8	Miles	2019
Seal Beach	80111000	Enterococcus	Source Unknown	Low	0.53	Miles	2019
		PCBs	Source Unknown	Low	0.53	Miles	2019
Silverado Creek	80112000	Pathogens	Unknown Nonpoint Source	Low	11	Miles	2019
		Salinity/ TDS/ Chlorides	Unknown Nonpoint Source	Low	11	Miles	2019

The proposed order includes numeric effluent limits based on the wasteload/load allocations developed and approved by the Regional Board, State Board, Office of Administrative Law and the EPA.

VI. FIRST, SECOND AND THIRD TERM PERMITS: STORM WATER POLLUTION CONTROL PROGRAMS/POLICIES

Prior to EPA's promulgation of the final storm water regulations, the counties of Orange, Riverside and San Bernardino applied for areawide NPDES permits for storm water runoff. On July 13, 1990, the Regional Board issued Order No. 90-71 to the permittees (first term permit). On March 8, 1996, the Board adopted Order No. 96-31 (second term permit). On January 18, 2002, the Board adopted Order No. R8-2002-0010 (third term permit). These permits included the following requirements as outlined in the storm water regulations:

a. Prohibited non-storm water discharges to the MS4s, with certain exceptions.

b. Required the municipalities to develop and implement a drainage area management plan (DAMP) to reduce pollutants in urban storm water runoff to the maximum extent practicable (MEP[9]).

c. Required the discharges from the MS4s to meet water quality standards in receiving waters.

d. Required the municipalities to identify and eliminate illicit connections and illicit discharges to the MS4s.

e. Required the municipalities to establish and maintain legal authority to enforce storm water regulations.

f. Required monitoring of dry weather flows, storm flows, and receiving water quality, and required program assessment.

g. Required the permittees to identify and inspect construction sites and industrial and commercial facilities.

h. Required the permittees to develop and implement a Water Quality Management Plan to address post-development runoff.

The following programs and policies have been implemented or are being implemented by the permittees. During the first term permit, the permittees developed a Drainage Area Management Plan (1993 DAMP) which was approved by the Executive Officer of the Regional Board on April 29, 1994. The 1993 DAMP included a number of best management practices (BMPs) and a very extensive public education program. The 1993 DAMP was updated a number of times and a draft 2007 version of the DAMP was submitted with the permit renewal application. The monitoring program for the first term permit included 89 monitoring stations within streams and flood control channels and 21 stations within the bays, estuaries and the ocean. The findings and conclusions from these monitoring stations and monitoring programs of other municipal permittees (Riverside and San Bernardino Counties and others) were used to identify problem areas and to re-evaluate the monitoring program and the effectiveness of the BMPs. The direction of these program elements were depended upon the results of the ongoing studies and a holistic approach to watershed management.

Other elements of the storm water management program included identification and elimination of illicit discharges and illicit connections and establishment of adequate legal authority to control pollutants in storm water discharges. The permittees have completed a survey of their storm drain systems to identify illicit discharges/illicit connections and have adopted appropriate ordinances to establish legal authority. Some of the more specific achievements during the previous term permits are as follows:

1. *Interagency Agreements and Coordination*: Established a program management structure through an Interagency Implementation Agreement. Participated in regional monitoring programs and focused special studies/research programs.

[9] Maximum Extent Practicable (MEP) means to the maximum extent feasible, taking into account equitable considerations of synergistic, additive, and competing factors, including but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

Worked with the County Sanitation Districts, Health Care Agency, Integrated Waste Management Agency, and the Water Districts to provide a consistent urban storm water pollution control message to the public. Worked with Caltrans, other transportation agencies, the Storm Water Quality Task-Force, and others to further study and understand urban runoff problems and control measures. Supported regional studies to improve storm water management programs and monitoring programs through the Southern California Water Research Project.

i. *Ordinances, Plans and Policies:* Adopted a Model Water Quality Ordinance and Enforcement Consistency Guide; prepared a Water Pollution Enforcement Implementation Plan, Public Agency Activity BMP guideline, a Public Pesticide and Fertilizer Use Guideline, Criteria for MS4 Inspections, and a Water Quality Monitoring Plan, Model Water Quality Management Plan; and established a Technical Advisory Committee for overall program development and implementation.

j. *Program Review*: A number of existing programs were reviewed to determine their effectiveness in combating urban pollution and to recommend alternatives and or improvements, including litter control measures, street sweeping frequencies and methods, public agency activities and facilities, illicit discharges and illicit connections to the MS4 systems, and existing monitoring programs.

k. *Public Education:* A number of steps were taken to educate the public, businesses, industries, and commercial establishments regarding their role in urban runoff pollution controls. The appropriate industrial dischargers were notified of the storm water regulatory requirements. For a number of unregulated activities, BMP guidance (Fact Sheet) was developed (mobile detailing, automotive service centers, restaurants, pool maintenance). Finally, a countywide hotline was established for reporting any suspected water quality problems. The addition of the Residential Program to the fourth term permit includes requirements for permittees to identify residential areas and activities therein that are potential sources of pollutants and to develop Fact Sheets/BMPs for each and encourage residents to implement the pollution prevention measures.

l. *Public Agency Training:* Training was provided to public agency employees on how to implement New Development Guidelines and Public Works BMPs, how to conduct investigations of reported water quality problems and how to conduct inspections of industrial facilities, construction sites and public work projects. The municipal planners were trained to recognize water quality related problems in proposed developments. The fourth term permit includes additional training program requirements for storm water program managers and inspection staff. This was added following information collected during Regional Board staff audits of permittee's storm water management programs, which found that many of the permittee's storm water staff were inadequately trained to properly implement the required program elements contained within the third term permit.

m. *Related Activities:* Flood control channels were stabilized, sediment basins were constructed, and debris booms were installed; illicit connections were eliminated and illicit connections to the MS4s were documented , eradicated or permitted. During the third term permit, litter/trash control ordinances were reviewed and revised, and trash characterization programs were encouraged. Within the fourth term permit, a trash control element has been added as a requirement.

VII. PRIOR TERM PERMITS - WATER QUALITY IMPROVEMENTS

An accurate and quantifiable measurement of the impact of the above stated storm water management programs is difficult for a variety of reasons, such as the variability in chemical water quality data, the incremental nature of BMP implementation, lack of baseline monitoring data, and the existence of some of the programs and policies prior to initiation of formal storm water management programs. There are generally two accepted methodologies for assessing water quality improvements: (1) conventional monitoring such as chemical-specific water quality monitoring; and (2) non-conventional monitoring such as monitoring of the amount of household hazardous waste collected and disposed off at appropriate disposal sites, amount of used oil collected, debris removed by the debris boom, etc.

The water quality monitoring data collected during prior permit terms did not indicate any discernible trends or significant changes. However, the most recent monitoring data indicate that there are reductions in the mass loading rates for some of the metals like copper and zinc and improvements in beach water quality after diversion of dry weather flows to the sanitary sewers. The non-conventional monitoring data also indicate that other programs and policies have been very effective in keeping a significant quantity of wastes from being discharged into waters of the US.

During the second and third term permits, there was an increased focus on watershed management initiatives and coordination among the municipal permittees in Orange, Riverside and San Bernardino Counties. These efforts resulted in a number of regional monitoring programs and other coordinated program and policy developments.

It is anticipated that with continued implementation of the revised DAMP and other requirements specified in this order, including low impact developments, the goals and objectives of the storm water regulations will be met, including protection of water quality standards for all receiving waters.

VIII. FUTURE DIRECTION/2007 DRAFT DAMP

The NPDES permit renewal application included a revised draft of the DAMP (2007 DAMP) that includes programs and policies the permittees are proposing to implement during the fourth term permit. The 2007 draft DAMP is the principal guidance document for urban storm water management programs in Orange County and includes the following major components:

1. Continues to provide a framework for the program management activities and plan development.

    n. Continues to provide the legal authority to control discharges to the MS4s.

    o. Improves current BMPs to achieve further reduction in pollutant loading to the MS4s.

    p. Continues to include programs and policies for public education processes and to seek public support for urban storm water pollution prevention BMPs.

    q. Increases requirements for controls on new developments and significant redevelopments.

    r. Continues to ensure that construction sites implement appropriate pollution control measures during construction and effective post-construction water quality management plan (WQMP) implementation.

    s. Continues to ensure that industrial sites are adequately identified, categorized and inspected for compliance with storm water regulations.

    t. Continues to include programs and policies to eliminate illicit discharges and illicit connections to the MS4s.

    u. Continues to include monitoring of urban runoff.

    v. Includes provisions for any special focus studies and/or control measures.

A combination of these programs and policies and the requirements specified in this order should ensure control of pollutants in storm water runoff from facilities owned and/or controlled by the permittees.

IX. PERMIT REQUIREMENTS

The legislative history of storm water statutes (1987 CWA Amendments), US EPA regulations (40CFR Parts 122, 123, and 124), and clarifications issued by the State Water Resources Control Board (State Board Orders No. WQ 91-03 and WQ 92-04) indicate that a non-traditional NPDES permitting strategy was anticipated for regulating urban storm water runoff. Due to the economic and technical infeasibility of full-scale end-of-pipe treatments and the complexity of urban storm water runoff quality and quantity, MS4 permits generally include narrative requirements for the implementation of BMPs in place of numeric effluent limits.

The requirements included in this order are meant to specify those management practices, control techniques and system design and engineering methods that will result in maximum extent practicable protection of the beneficial uses of the receiving waters. The State Board (Orders No. WQ 98-01 and WQ 99-05) concluded that MS4s must meet the technology-based maximum extent practicable (MEP) standard and water quality standards (water quality objectives and beneficial uses). The US Court of Appeals for the Ninth Circuit

subsequently held that strict compliance with water quality standards in MS4 permits is at the discretion of the local permitting authority. Any requirements included in the order that are more stringent than the federal storm water regulations are in accordance with the CWA Section 402(p)(3)(iii), and the California Water Code Section 13377 and are consistent with the Regional Board's interpretation of the requisite MEP standard.

The Report of Waste Discharge (ROWD) included a discussion of the current status of Orange County's urban storm water management program and the proposed programs and policies for the next five years (fourth term permit). The proposed order incorporates these documents and the performance commitments made in the ROWD.

This order recognizes the significant progress made by the permittees during the first, second and third term permits in implementing the storm water regulations. The permit also recognizes regional and innovative solutions to such a complex problem. For these reasons, the order is somewhat less prescriptive when compared to some of the MS4 NPDES permits for urban runoff issued by other Regional Boards. However, in many other respects, it incorporates an integrated watershed approach in solving urban runoff related water quality and quantity issues. The proposed permit also includes numeric effluent limits based on wasteload/load allocations. With these requirements, it should achieve the same or better water quality benefits because of the programs and policies already being implemented or proposed for implementation, including regional and watershed wide solutions.

The major requirements include: (1) Discharge prohibitions; (2) Receiving water limitations; (3) Prohibition on illicit connections and illicit discharges; (4) Public and business education; (5) Adequate legal authority; (6) Programs and policies for municipal facilities and activities; (7) Inspection Activities by the municipalities; (8) New development/re-development requirements including a requirement to fully implement low impact development principles and to minimize any hydrologic conditions of concern; (9) Waste load allocations for nutrients, sediment, and fecal coliform bacteria; metals, and pesticides, including numeric effluent limits; and (10) Monitoring and reporting requirements.

These programs and policies are intended to improve urban storm water quality and protect the beneficial uses of receiving waters of the region.

1. DISCHARGE PROHIBITIONS

   In accordance with CWA Section 402(p)(3)(B)(ii), this order prohibits the discharge of non-storm water to the MS4s, with a few exceptions. The specified exceptions are consistent with 40 CFR 122.26(d)(2)(iv)(B)(1). If the permittees or the Executive Officer determines that any of the exempted non-storm water discharges contain pollutants, a separate NPDES permit or coverage under the Regional Board's De Minimis permit will be required.

2. RECEIVING WATER LIMITATIONS

   Receiving water limitations are included to ensure that discharges from MS4 systems do not cause or contribute to violations of applicable water quality standards in receiving waters. The compliance strategy for receiving water limitations is consistent with the US EPA and State Board guidance and recognizes the complexity of storm water management.

This order requires the permittees to meet water quality standards in receiving waters in accordance with US EPA requirements as specified in State Board Order No. WQ 99-05. If water quality standards are not met by implementation of current BMPs, the permittees are required to re-evaluate the programs and policies and to propose additional BMPs. Compliance determination will be based on this iterative BMP implementation/compliance evaluation process.

3. ILLICIT DISCHARGES AND ILLICIT CONNECTIONS TO MS4s

The permittees have completed their survey of the MS4 systems and eliminated or permitted all identified illicit connections. The permittees have also established a program to address illicit discharges and a mechanism to respond to spills and leaks and other incidents of discharges to the MS4s. The permittees are required to continue these programs to ensure that the discharges from MS4s do not become a source of pollutants in receiving waters.

4. PUBLIC AND BUSINESS EDUCATION OUTREACH PROGRAM

Public outreach is an important element of the overall urban pollution prevention program. The permittees have committed to implement a strategic and comprehensive public education program to maintain the integrity of the receiving waters and their ability to sustain beneficial uses. The principal permittee has taken the lead role in the outreach program and has targeted various groups including businesses, industry, development, utilities, environmental groups, institutions, homeowners, school children, and the general public. The proposed order includes additional requirements to address runoff from residential developments. The permittees have developed a number of educational materials, established a storm water pollution prevention hotline, started an advertising and educational campaign and distribute public education materials at a number of public events. The permittees are required to continue these efforts and to expand public participation and education programs.

5. LEGAL AUTHORITY

During the first two permit cycles, each permittee adopted a number of ordinances, municipal codes, and other regulations to establish legal authority to control discharges to the MS4s and to enforce these regulations as specified in 40 CFR 122.26(d)(2)(I)(B, C, E, and F). The permittees are required to enforce these ordinances and to take enforcement actions against violators (40 CFR 122.26(d)(2)(iv)(A-D)). The enforcement activities undertaken by a majority of the permittees have consisted primarily of Notices of Violation, which act to educate the public on the environmental consequences of illicit discharges. Several coastline municipalities have regularly issue Citations. In the case of the County, additional action has sometimes included recovery of investigation and clean-up costs from a responsible party. In the event of egregious or repeated violations, the option exists for a referral to the County District Attorney for possible prosecution. In order to eliminate unauthorized, non-storm water discharges, reduce the amount of pollutants commingling with storm water runoff and thereby protect water quality, an additional level of enforcement is required between Notices of Violation and District Attorney referrals. The third term permit required the permittees to establish the authority and resources to administer either civil or criminal fines and/or penalties for violations of their local water quality ordinances (and the Federal Clean Water

Act). The permittees now have this authority for civil or criminal penalties. Within the fourth term permit, permittees are required to exercise this authority by developing an enforcement program to be administered within the industrial, commercial and construction elements of their storm water management programs. The enforcement program has been required to be included as an update to each permittee's respective Local Implementation Plan.

6. PUBLIC FACILITIES AND ACTIVITIES

Education of municipal planning, inspection, and maintenance staff is critical to ensure that municipal facilities and activities do not cause or contribute to an exceedance of receiving water quality standards. The second and third term permits required the permittees to prepare an Environmental Performance Report to address public agency facilities and activities that are not regulated under the State's General Industrial Activities Storm Water Permit. It also required the permittees to report on an annual basis the actions taken to eliminate the discharge of pollutants from public agency activities and facilities. The permittees are required to inspect and maintain drainage facilities free of waste materials to control pollutants in storm water runoff flowing through these systems. The proposed order requires the permittees to continue to re-evaluate their facilities and activities on an annual basis to see if additional BMPs are needed to ensure water quality protection.

7. MUNICIPAL INSPECTION PROGRAM

The third term permit included requirements for inspection of construction, industrial, and commercial facilities within the permittees' jurisdiction in order to control the loading of pollutants entering the MS4 system. The permittees were required to inventory construction, industrial and commercial facilities; prioritize those facilities with respect to their potential for discharge of pollutants in runoff and their proximity to sensitive receiving waters; and perform regular inspections to insure compliance with local ordinances. Within the fourth term permit, permittees are also to develop a pilot program targeted at mobile businesses (mobile detailers, pool & carpet cleaning, etc.) that have been identified as potential pollutant sources. While initial observations of non-compliance may result in 'educational' type enforcement, repeated non-compliance will result in more severe forms of enforcement, such as monetary penalties, stop work orders or permit revocation. Regional Board staff audits of permittees' storm water programs during the third term permit found that a large percentage of the permittees had characterized inventories of construction, industrial and commercial facilities within each permittee's respective jurisdiction. However, upon review of each permittees inventory and inspection data, Regional Board staff noted that criteria outlined within the third term permit regarding program element criteria yielded a wide range of interpretation between permittees. Therefore, more prescriptive requirements within this element of the permit are included in the fourth term permit. The fourth term permit has also added a residential program element to be implemented by the permittees. This element improves upon the existing requirements within the third term permit, by adding specific criteria associated with developing a more successful means of reducing the discharge of pollutants from residential areas into the MS4 to the maximum extent practicable.

8. NEW DEVELOPMENT

During the third term permit, the permittees developed and revised existing new development guidelines. The permittees were required to implement these guidelines, with program implementation of post construction Water Quality Management Plan (WQMP) criteria standards. Additionally, this order requires the permittees to work towards the goal of restoring and preserving the natural hydrologic cycles in approving urban developments. To accomplish this goal, the permittees are required to implement low impact development principles through appropriate site design and source control BMPs. Recent studies have indicated that low impact development[10] (LID) is one of the most effective ways to minimize any adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member, Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), is developing a Low Impact Development Manual for Southern California with funding from the State Water Resources Control Board. This manual will be

[10] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the manual as a resource for proper LID design and implementation techniques. In order to avoid becoming a source of nuisance, a source of mobilization for existing subterranean contaminants and/or a source of habitat for vectors, LID infiltration BMPs must be properly designed and subsequently maintained.

The proposed order also includes a requirement to infiltrate, harvest and re-use, evapotranpirate or capture the volume of runoff produced from a 24-hour, 85th percentile storm event (design capture volume) for new and re-development projects. It also recognizes that certain soil and groundwater conditions, as well as other site conditions might preclude a particular site from achieving onsite retention and/or treatment of the design capture volume and includes alternatives and in-lieu programs.

Post construction activities conducted at properties that have been developed for commercial or industrial use may substantially increase the risk of post construction pollutants being generated from the developed site. Therefore, the WQMP threshold criteria priority development projects in the proposed order have been redefined from those of third term permit. Third term permit thresholds currently require the development and implementation of post construction WQMP for non-residential commercial/industrial construction projects, where the combined impervious surface area of the project is equal to or greater than 100,000 square feet. WQMP requirement thresholds for residential projects require a WQMP to be prepared when subdivision projects include 10 lots and units or more. Proposed fourth term permit threshold requirements for WQMP development and implementation have become standardized for commercial/industrial, as well as residential construction projects, where the combined impervious surface area of the project is equal to or greater than 10,000 square feet. The aforementioned criteria were redefined in order to adequately address potential pollutant sources, which may exist at properties which undergo development for commercial and industrial uses. Other criteria, which constitute a priority development project have carried over from third term permit to the proposed order.

9. SANITARY SEWER OVERFLOWS, SEPTIC SYSTEM FAILURES AND PORTABLE TOILET DISCHARGES

   The third term permit required the permittees to investigate adverse impacts on urban runoff quality from leaking septic systems and portable toilets. The information provided by the permittees indicates that leaking or failing septic systems are not significant problems in Orange County as most areas of the County are sewered. A number of beach closures in Orange County have been due to spills, overflows, and leaks from the sanitary sewer lines. To address these concerns, waste discharge requirements (SSO order) for local sanitary sewer agencies were adopted by the Regional Board. Subsequently, the State Board adopted an SSO order, Water Quality Order No. 2006-0003, to address this problem on a statewide basis. The Regional Board SSO order has since been rescinded. The permittees are required to comply with the statewide SSO order.

10. MONITORING REQUIREMENTS

During the first term permit and part of the second term permit, the permittees conducted extensive monitoring of the storm water flows, receiving water quality and sediment quality. These early programs focused on identifying pollutants, estimating pollutant loads, tracking compliance with water quality objectives, and identifying sources of pollutants. The Orange County monitoring program, like other monitoring programs nationwide, has established that there is a high degree of uncertainty in the quality of storm water runoff and that there are significant variations in the quality of urban runoff spatially and temporally. However, most of the monitoring programs to date have indicated that there a number of pollutants in urban storm water runoff. Only in a few cases has a definite link between pollutants in urban runoff and beneficial use impairment been established.

In 1999, the permittees re-evaluated their monitoring program and proposed a revised monitoring program. The goals of the 1999 Water Quality Monitoring Program were:

a. To determine the role of urban runoff in beneficial use impairment;

b. To collect technical information to develop an effective urban storm water management plan; and

c. To determine the effectiveness of a number of BMPs, also as an aid to the overall urban storm water management plan.

To accomplish these goals, the monitoring program focused on three areas:

a. Areas where constituent concentrations are substantially above system-wide averages. These areas were referred to as "warm spots" and the designation is based on monitoring data from prior years.

b. Areas of Critical Aquatic Resources (sites with important aquatic resources).

c. Sub-watersheds where certain BMPs have been installed to study their effectiveness.

Based on the results of this monitoring program and the requirements specified in the third term permit and based on guidance provided in "The Model Monitoring Program for Southern California"[11] , a revised monitoring program was submitted (2003 Monitoring Program).

The permittees also participate in a number of other regional monitoring programs such as those conducted by the Southern California Coastal Water Research Project and the California Regional Marine Monitoring Program.

The permittees are encouraged to continue their participation in regional and watershed-wide monitoring programs. By July 1, 2003, the permittees were required to re-evaluate their Water Quality Monitoring Program and submit a revised plan for approval. In February 2003, a revised plan was developed and final approval was given by the Executive Officer in July 2005. The revised plan includes the following monitoring elements: Mass Emissions, Estuary/Wetlands, Water Column Toxicity, Bacteriological/Pathogen, Bioassessment, Reconnaissance, Land Use Correlation, and TMDL/303(d) Listed Waterbodies.

[11] The Model Monitoring Program for Municipal

X. WATER QUALITY BENEFITS/COST ANALYSIS/FISCAL ANALYSIS

There are direct and indirect benefits from clean beaches, clean water, and a clean environment. It is difficult to assign a dollar value to the benefits the public derives from fishable and swimmable waters. In 1972, at the start of the NPDES program, only 1/3 of the US waters were swimmable and fishable. In 2001, 2/3 of the US waters meets these criteria. In the 2008, *Money* magazine survey of the "Best Places to Live", clean water and air ranked as the most important factors in choosing a place to live. Thus, environmental quality has a definite link to property values. Clean beaches and other water recreational facilities also attract tourists. According to the Orange County 2006 Community Indicators Project, it is estimated that on average, an out-of –county visitor spent an average of $107.00 per day in 2004. Huntington Beach's 8.5-mile shoreline attracts 10 million visitors a year[12]. During the summer of 1999 and 2000 when the beaches were closed to water contact recreation, the beach communities reported multi-million-dollar losses in tourist revenues.

The true magnitude of the urban runoff problem is still elusive and any reliable cost estimate for cleaning up urban runoff would be premature. For urban storm water runoff, end-of-pipe treatments are cost prohibitive and are not generally considered as a technologically feasible option. Over the last decade, the permittees have attempted to define the problem and implemented best management practices by implementing regional BMPs to combat the problem. The costs incurred by the permittees in implementing these programs and policies can be divided into three broad categories (the costs indicated below are for the entire Orange County storm water program):

[12] Los Angeles Times, May 9, 2001

1. Shared costs: These are costs that fund activities performed mostly by the principal permittee under the Implementation Agreement. These activities include overall storm water program coordination; intergovernmental agreements; representation at the Storm Water Quality Task Force, Regional Board/State Board meetings and other public forums; preparation and submittal of compliance reports and other reports required under the NPDES permits and Water Code Section 13267, budget and other program documentation; coordination of consultant studies, co-permittee meetings; and training seminars, water quality monitoring, and Countywide pubic education and outreach. Shared costs have increased from $0.81M at the inception of the Orange County Stormwater Program to $4.8M in 2006-7.

2. Individual Costs for DAMP Implementation: These are costs incurred by each permittee for implementing the BMPs (drainage facility inspections for illicit connections, drain inlet/catchbasin stenciling, public education, etc.) included in the DAMP. A number of programs and policies for non-point and storm water pollution controls existed prior to the urban storm water runoff NPDES program. However, the DAMP that was developed and implemented in response to the urban storm water runoff NPDES program required additional programs and policies for pollution control. These costs are attributable to DAMP implementation. In 2006/07, the Permittees determined their total Individual Costs to be $82.2M.

In addition to these expenditures, volunteer efforts (such as the annual "Beach and Innercoastal Watershed Cleanup Day", etc.) also contributed to the urban runoff pollution control efforts.

The permittees identified the following funding sources (2006/07):

FUNDING SOURCE	*PERCENTAGE*
General Funds	11.8%
Gas Taxes	1.3%
Grants	30%
Sanitation Fees	31.3%
Time & Materials Ordinance & Permit Fees	0.6%
Special District Funds	24.3%
Other Sources	0.2%

XI. ANTIDEGRADATION ANALYSIS

The Regional Board has considered whether a complete antidegradation analysis, pursuant to 40 CFR 131.12 and State Board Resolution No. 68-16, is required for these storm water discharges. The Regional Board finds that the pollutant loading rates to the receiving waters will be reduced with the implementation of the requirements in this order. As a result, the quality of storm water discharges and receiving waters will be improved. Since this order will not result in a lowering of water quality, a complete antidegradation analysis is not necessary, consistent with the federal and state antidegradation requirements.

XII. PUBLIC WORKSHOP

The Regional Board recognizes the significance of Orange County's Storm Water/Urban Runoff Management Program and will conduct, participate, and/or assist with any workshop

during the term of this order to promote and discuss the progress of the storm water management program. The details of the workshop will be posted on the Regional Board's website, published in local newspapers and mailed to interested parties. Persons wishing to be included in the mailing list for any of the items related to this order may register their e-mail address and/or mailing address with the Regional Board office at the address given below.

XIII. PUBLIC HEARING

The Regional Board opened a public hearing regarding the proposed waste discharge requirements on Friday, November 21, 2008 at 9:30 a.m. at the City Council Chambers, City of Yorba Linda. The public hearing was continued on Friday, January 18, 2002 at 9:00 a.m. at the City Council Chambers, City of Santa Ana, at which time Order No. R8-2002-0010 was adopted.

XIV. INFORMATION AND COPYING

Persons wishing further information may write to the above address or call Marc Brown at (951) 321-4584. Copies of the application, proposed waste discharge requirements, and other documents (other than those which the Executive Officer maintains as confidential) are available at the Regional Board office for inspection and copying by appointment scheduled between the hours of 8:30 a.m. and 4:00 p.m., Monday through Friday (excluding holidays).

XV. REGISTER OF INTERESTED PERSONS

Any person interested in a particular application or group of applications may leave his/her e-mail and/or mailing address and phone number as part of the file for an application. Copies of tentative waste discharge requirements will be mailed to all interested parties.

In addition to the permittees, comments were solicited from the following agencies and/or persons:

U. S. Environmental Protection Agency – Eugene Bromley (W-5-1)
US Army District, Los Angeles, Corps of Engineers - Permits Section
NOAA, National Marine Fisheries Service
US Fish and Wildlife Service - Carlsbad
State Water Resources Control Board – David Rice, Office of the Chief Counsel
State Water Resources Control Board – Bruce Fujimoto, Division of Water Quality
State Department of Water Resources - Glendale
California Regional Water Quality Control Board, North Coast Region (1) – Executive Officer
California Regional Water Quality Control Board, San Francisco Bay Region (2) – Executive Officer
California Regional Water Quality Control Board, Central Coast Region (3) –Executive Officer
California Regional Water Quality Control Board, Los Angeles Region (4) – Tracy Egoscue
California Regional Water Quality Control Board, Central Valley Region (5S) – Executive Officer
California Regional Water Quality Control Board, Central Valley Region (5R), Redding - AEO
California Regional Water Quality Control Board, Central Valley Region (5F), Fresno – AEO
California Regional Water Quality Control Board, Lahontan Region (6SLT), South Lake Tahoe – Executive Officer
California Regional Water Quality Control Board, Lahontan Region (6V), Victorville – AEO
California Regional Water Quality Control Board, Colorado River Basin Region (7) – Robert Purdue
California Regional Water Quality Control Board, San Diego Region (9) – John Robertus
State Department of Fish and Game - Long Beach
State Department of Health Services - Santa Ana
State Department of Parks and Recreation –
Orange County Health Care Agency – Larry Honeybourne
South Coast Air Quality Management District, Diamond Bar -
Caltrans, District 12, Santa Ana – Grace Pina-Garrett
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
U. S. Marine Corps Air Station, El Toro -
National Forest Service
URS/Greiner - Bob Collacott
The Irvine Company - Sat Tamaribuchi
Building Industry Association – Mark Grey
Latham & Watkins – Paul Singarella
Best, Best, and Krieger –

Southern California Association of Governments, Los Angeles - General Manager

Universities and Colleges (Chancellor)
University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts (Superintendent)
Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Elementary School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District
Ocean View Union High School District
Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals (Administrator)
Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital, Orange
Children's Hospital of Orange County. Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital

FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Environmental Organizations
Lawyers for Clean Water – Daniel Cooper
Orange County Coastkeeper – Garry Brown
Defend the Bay – Bob Caustin
Sierra Club, Orange County Chapter
Sierra Club, Los Angeles Chapter - General Manager
Natural Resources Defense Council (NRDC) – David Beckman
Cousteau Society
Amigos De Bolsa Chica
Audobon Sea & Sage Chapter
Huntington Beach Wetlands Conservancy
Surfrider Foundation- Nancy Gardner

Newspapers
Orange County Register – Pat Brennan
Los Angeles Times –
Press Enterprise –
Daily Pilot – Paul Clinton

Major Water/Wastewater Agencies
Santa Ana Watershed Project Authority – Celeste Cantu
Irvine Ranch Water District – General Manager
Los Alisos Water District - General Manager
El Toro Water District - General Manager
San Bernardino County Flood Control District - Naresh Varma
Riverside County Flood Control & Water Conservation District – Steve Stump/Mark Wills
L.A. County Department of Public Works - Gary Hildebrand
Orange County Sanitation Districts - Robert Ghirelli
Orange County Water District – General Manager
Metropolitan Water District - Ed Mean

Orange County MS4 Permit Urban Storm Water Runoff Management Program

Order No. R8-2009-0030 (NPDES No. CAS618030)

Public Hearing
April 24, 2009

Mark Smythe
Senior Environmental Scientist
Coastal Storm Water Unit
Santa Ana RWQCB

History of Storm Water Regulations

- National Pollutant Discharge Elimination System (NPDES) was established in 1972 through the Federal Clean Water Act to control point source pollution.
- In 1987, Federal regulations required industries and large municipalities to obtain NPDES permits for their storm water runoff.
- The three Region 8 MS4 permits were adopted in 1990.

Storm Water Permits

- Statewide General Construction
- Statewide General Industrial
- CalTrans

<u>Other SW discharges regulated through:</u>

- MS4 - Municipal Separate Storm Sewer System
  - Municipal activities
  - Industrial and construction activities
  - Commercial and service activities
  - Residential activities

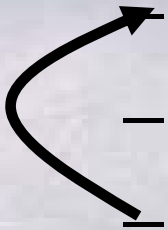
Municipal Permit Overview

- MS4 permits have not historically had numeric effluent limits, but TMDLs change that.
- For the most part, permittees must reduce pollutant loads in discharges from their MS4 to the **“Maximum Extent Practicable (MEP).”**
- Where MEP takes into account such issues as: the gravity of the problem, technical & economic feasibility, public health risks and societal benefits and concerns.

Maximum Extent Practicable

The permittees meet that MEP standard through an iterative process.

- If water quality standards (wqs) aren't being met,
- Implement Best Management Practices (BMPs)
- Monitor
- If there are still wqs exceedences,
- Implement improved BMPs
- Monitor



1990 MS4 Permit

- Develop a Drainage Area Management Plan (DAMP)
  - Catchbasin Stenciling and Cleaning
  - Steet Sweeping
  - Pesticide/Fertilizer Management
  - Post-construction Water Quality Management Plans
- Eliminate Illicit Connections and Discharges
  - Establish Legal Authority
  - Address Illicit Discharges
- Public Education
- Water Quality Monitoring

1996 MS4 Permit

- DAMP
- Eliminating Illicit Discharges and Connections
- Public Education
- Water Quality Monitoring

- Water Quality Ordinance and Enforcement Consistency Guide (developed at end of previous permit)
- Required Statewide General Construction Permit Coverage prior to grading permit issuance

2002 MS4 Permit

- DAMP
- Eliminating Illicit Discharges and Connections
- Public Education – Number of Impressions
- Water Quality Monitoring

- Municipal Inspections of Construction sites, Industrial facilities and Commercial businesses.
- New Development Structural Treatment BMPs.
- TMDLs incorporated for Newport Bay and San Diego Creek (nutrients and sediment).

Audits

- From 2003 to 2007 each co-permittee was audited by RB staff
- The 2-day audits included record review, program analysis and field observations.
- 5 of the 26 audits resulted in ACLs being issued ranging from $48,280 - $126,480.
- All 5 ACLs were paid without needing hearings.

Timeline

- Jun 21, 2006 ……. ROWD submitted
- Jan 18, 2007 ……. 2002 Permit expired & extended
- Oct 02, 2008 ……. Tri-County Meeting
- Nov 10, 2008 ……. 1st Draft released
- Nov 21, 2008 ……. Public workshop
- Dec 7 – Mar 4 …….. 8+ Stakeholder meetings
- Dec 30, 2008 ……... Comment deadline (1)
- Jan 30, 2009 ……. Comment deadline (2)
- Feb 13, 2009 ……... Comment deadline (3)
- Mar 25, 2009 ……. 2nd Draft released
- Apr 09, 2009 ……. Written comment deadline
- Apr 13, 2009 ……. 3rd Draft released to the Public
- Apr 24, 2009 ……. Public Hearing

Comment Letters

- Staff received 24 comment letters on the 1st (Nov. 11, 2008) draft that generated 173 individual comments.
- Staff received 13 comment letter on the 2nd (March 25, 2009) draft that resulted in 71 individual comments.
- Responses to these 244 comments are provided in the Response to Comments.

November 10, 2008 Draft

Major changes from 2002 MS4 Permit:

- Added categories and High/Medium/Low benchmarks to Commercial Program.
- Incorporation of Low Impact Development (LID) and Hydrologic Conditions of Concern (HCOC) requirements for new development and significant re-development.
- Addition of new TMDLs to the Permit.

November 10, 2008 Draft

Major changes from 2002 MS4 Permit:

- Added categories and High/Medium/Low benchmarks to Commercial Program.
- Incorporation of Low Impact Development (LID) and Hydrologic Conditions of Concern (HCOC) requirements for new development and significant re-development.
- Addition of new TMDLs to the Permit.

2002 Permit
Commercial Entities

- Automobile mechanical repair, maintenance, fueling or cleaning
- Automobile and other vehicle body repair or painting
- Mobile automobile or other vehicle washing
- Mobile carpet, drape or furniture cleaning
- Mobile high pressure or steam cleaning
- Painting and coating
- Nurseries and greenhouses
- Landscape and hardscape installation
- Pool, lake and fountain cleaning
- Other sites the Permittee determines may contribute significant pollutants
- Any commercial sites tributary to and within 500 feet of an ASBS

Commercial Inspections

2002 MS4 Permit

- Ranking was to be based on:
  - Overall threat to water quality
  - Type, magnitude and location of commercial activity
  - Potential for pollutant discharge
  - History of non-storm water discharges
- High priority sites were to be inspected by 7/1/03, Permittees were to establish inspection frequencies/priorities based on above criteria.

Commercial Rankings (2007-8)

	HIGH	MEDIUM	LOW
City 1	1	0	1585
City 2	0	44	974
City 3	0	514	1382
City 4	0	147	289
City 5	1	192	107
City 6	2	61	201
City 7	0	0	135
City 8	0	40	83

1st Draft Permit - Commercial

- Moved mobile cleaners to its own program
- Added plastic pellet storage/transport, pest control, building materials retail, vehicle maintenance/fueling/cleaning/storage.

	High	Med.	Low
% of total	10%	40%	50%
Inspection frequency	annually	biennially	Once per permit term

2nd Draft Permit - Commercial

- Acknowledged possible limitations when refused access.
- Dropped some of the business categories.
- Changed mobile business requirements to a pilot program.
- Confirmed that restaurant inspection program would continue on an annual inspection frequency.

3rd Draft Permit - Commercial

	High	Med.	Low
% of total	10%	20%	70%
Inspection frequency	annually	biennially	Once per permit term

- Provided the opportunity for permittees to develop an alternative inspection selection criteria and reporting framework.

November 10, 2008 Draft

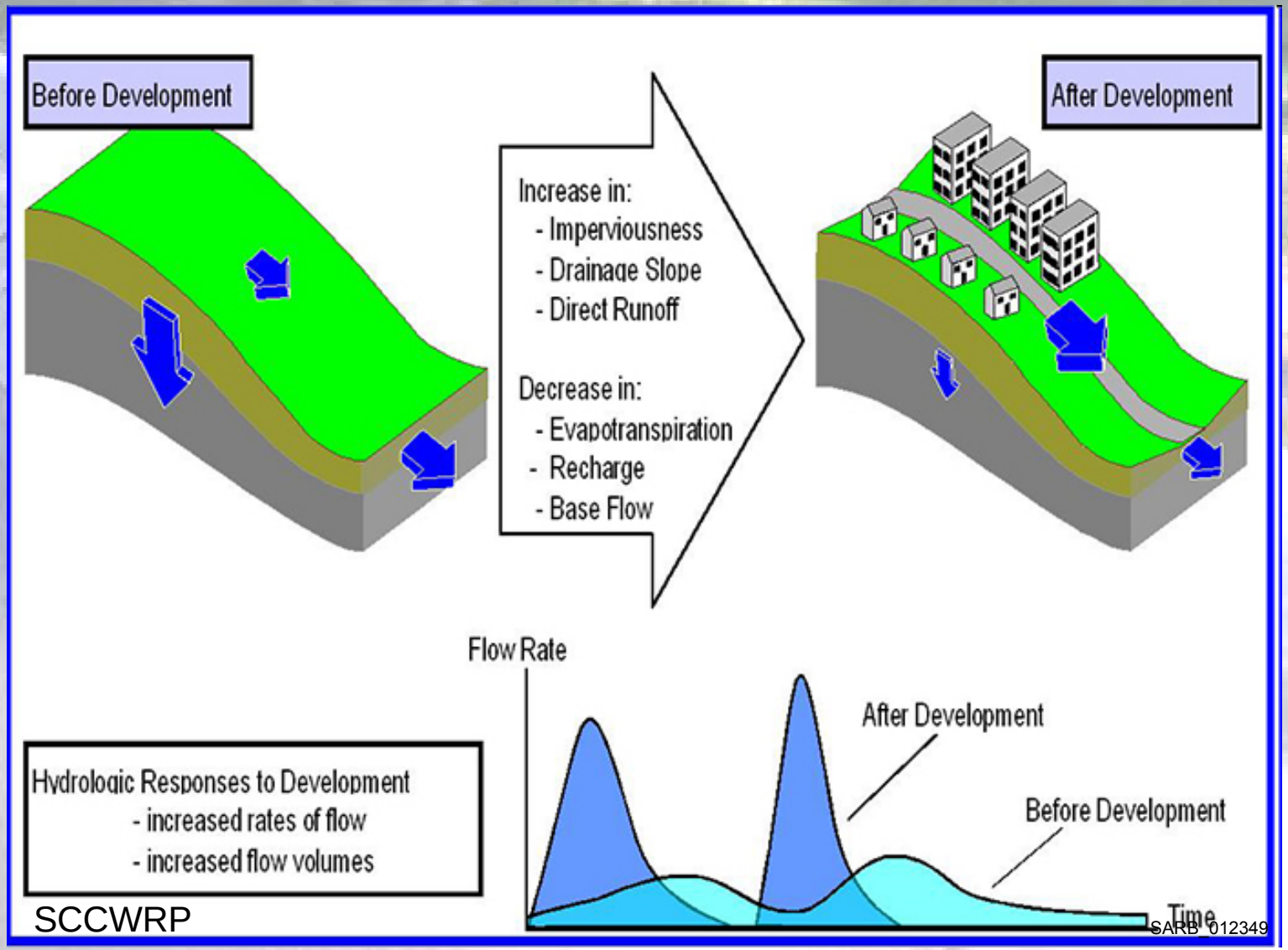
Major changes from 2002 MS4 Permit:

- Added categories and High/Medium/Low benchmarks to Commercial Program.
- Incorporation of Low Impact Development (LID) and Hydrologic Conditions of Concern (HCOC) requirements for new development and significant re-development.
- Addition of new TMDLs to the Permit.

2002 Permit
Post-construction BMPs

- Required structural BMPs to address post-construction runoff from new and significant re-development.
- BMPs included: catchbasin inserts, biofilters, porous pavement, infiltration basins, etc.
- With regards to increased runoff from build-out, there were requirements to consider the potential for hydromodification (downstream erosion) in CEQA and conditions of approval, but no specific control requirements.

Development and Runoff



SARB_012349

Low Impact Development

- The goal of Low Impact Development (LID) is to mimic pre-development site hydrology through source control and site design.
- By implementing BMPs that increase infiltration, evapotranspiration, harvesting/reuse and to a limited extent, biofiltration, one can reduce the Effective Impervious Area (EIA) of a site and reduce runoff.
- The ‘Effective’ part of EIA is where the hydraulic “connectedness” of the surface water drainage system is taken into account.

1st Draft Permit Post-construction BMPs (1 of 2)

- Use of LID BMPs, where feasible, to address pollutant loading and increased flow.
- 5% Effective Impervious Area (EIA) standard
- Groundwater protection measures included:
  - 10-foot vertical separation to seasonal high groundwater
  - 100 foot horizontal separation from supply wells
  - Infiltration not used in high pollutant areas
- Provided alternative requirements when LID is infeasible.
- All public agency and 50% private structural treatment BMPs must be inspected annually.

1st Draft Permit Post-construction BMPs (2 of 2)

More detailed requirements regarding Hydrologic Conditions of Concern (HCOC) or downstream erosion potential.

- If less than 5% EIA, no HCOC.
- If 5% EIA or greater:
  - Evaluate changes in: runoff volume, infiltration, concentration time and erosion.
  - If HCOC, prepare pre/post development hydrographs, if adverse erosion likely, additional controls are required.

2nd Draft Permit Post-construction BMPs (1 of 2)

- Low Impact Development
  - Changed LID BMP design criteria from 5% EIA to a capture volume based on 85th percentile, 24-hr storm event.
  - Added a requirement to prioritize LID BMPs: Highest priority for (a) Preventive techniques (e.g, preserving natural features); then (b) Mitigative measures (e.g., infiltration). Then the mitigation measures are to be prioritized (from highest to lowest) (a) Infiltration; (b) Harvest/re-use; and (c) bio-filtration.

2nd Draft Permit Post-construction BMPs (2 of 2)

- Hydromodification - HCOC
  - Changed the 5% EIA to a capture volume based on a 2-yr storm event.
  - Downstream Waters of the U.S. required HCOC analysis even if hardened/engineered.
  - Added an option for the permittees to develop a Watershed Master Plan to address HCOC on a regional basis.
- In-Lieu or Alternative Programs
  - The "infeasibility of LID BMPs" must meet a technically-based feasibility criteria before allowing alternatives and/or in-lieu programs.

3rd Draft Permit
Post-construction BMPs

- A pilot groundwater monitoring program be started by the permittees to address infiltration concerns.
- All infiltration activities are to be coordinated with the local groundwater management agency.
- Minimum 5-foot vertical separation to seasonal high groundwater for infiltration, instead of 10 feet.
- The model WQMP will be available for a 30-day public comment period prior to approval by the EO.
- If all downstream waters are hardened and engineered to accept the proposed flow, then it assumed that there are no hydrologic conditions of concern.
- Post-construction BMPs will be inspected every 4 years.

November 10, 2008 Draft

Major changes from 2002 MS4 Permit:

- Added categories and High/Medium/Low benchmarks to Commercial Program.
- Incorporation of Low Impact Development (LID) and Hydrologic Conditions of Concern (HCOC) requirements for new development and significant re-development.
- Addition of new TMDLs to the Permit.

2002 Permit
TMDLs

- TMDLs that had been approved at the time of the MS4 permit approval included:
  - Nitrogen and phosphorus (nutrients) for San Diego Creek and Newport Bay
  - Sediment for San Diego Creek and Newport Bay

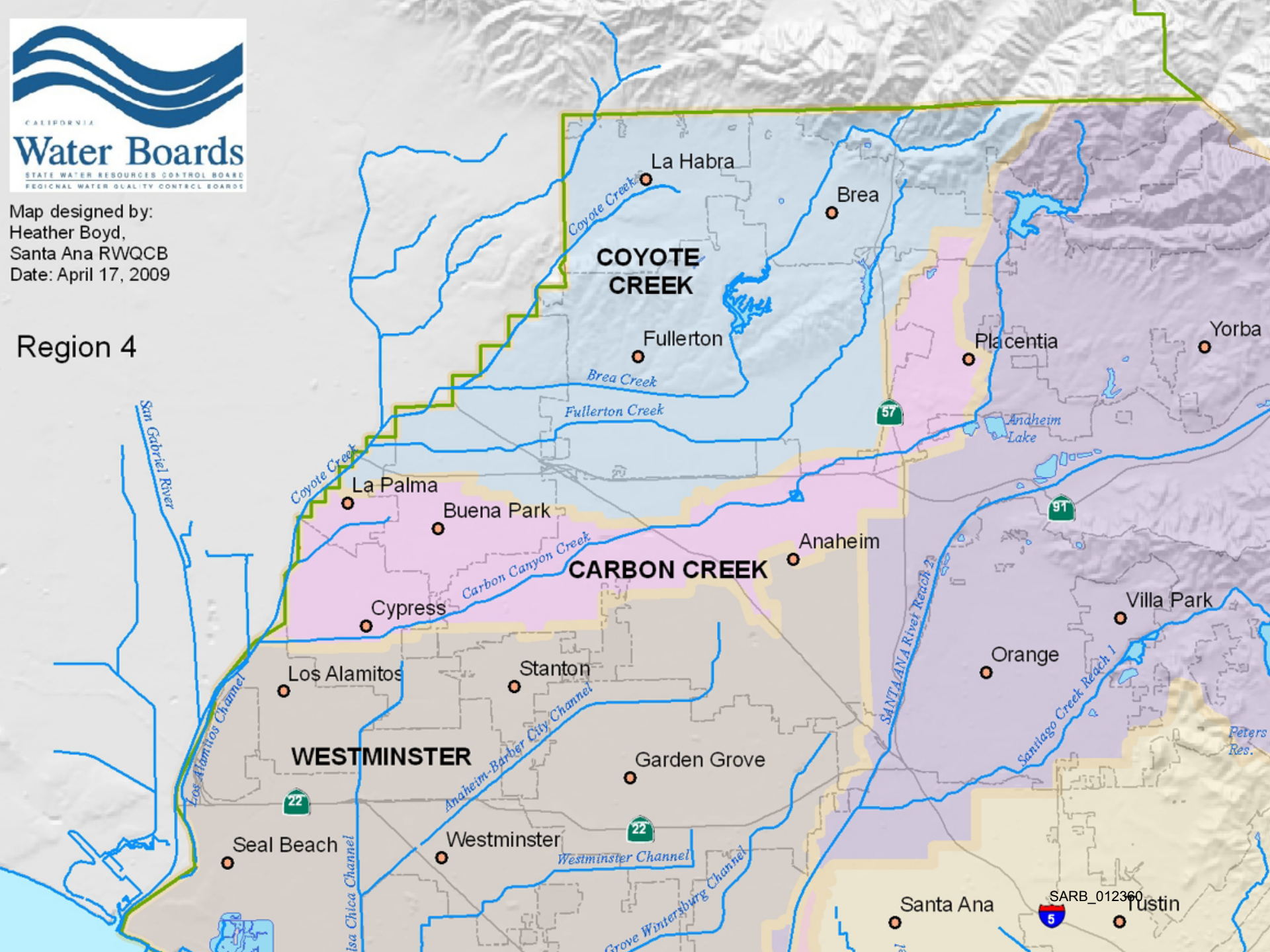
Total Maximum Daily Loads (TMDLs)

- Water quality objectives are set to protect beneficial uses (BUs).
- If WQ standards are not being met, a water is placed on the impaired waters list or 303(d) list.
- The TMDL is the amount of a pollutant that be discharged to a water and still support BUs.
- That load is split up among the point source and non-point source dischargers in the watershed.
- TMDLs for urban runoff are implemented through the MS4 permits.

1st Draft Permit – TMDLs (1 of 2)

- Nitrogen, phosphorus and sediment TMDLs for San Diego Creek and Newport Bay.

- Urban runoff waste load allocations (WLAs) and water column targets for metals in Coyote Creek that were adopted by the Los Angeles Region(R4):
  - Copper
  - Lead
  - Zinc


CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS
Map designed by:
Heather Boyd,
Santa Ana RWQCB
Date: April 17, 2009
Region 4
La Habra
Brea
COYOTE CREEK
Coyote Creek
Fullerton
Placentia
Yorba
Brea Creek
Fullerton Creek
Anaheim Lake
La Palma
Buena Park
Anaheim
CARBON CREEK
Carbon Canyon Creek
Cypress
Villa Park
Orange
Los Alamitos
Stanton
WESTMINSTER
Garden Grove
Seal Beach
Westminster
Westminster Channel
Santa Ana
Tustin
San Gabriel River
Los Alamitos Channel
Anaheim-Barber City Channel
SANTA ANA River Reach 2
Santiago Creek Reach 1
Peters Res.
57
91
22
5
SARB_012360

1st Draft Permit – TMDLs (2 of 2)

- Fecal Coliform in Newport Bay (compliance by 2013 - 2019).
- Water column targets for the organophosphorus pesticides - diazinon and chlorpyrifos in San Diego Creek and chlorpyrifos in Newport Bay.
- Water column targets for the organochlorine compound TMDLs adopted by the Regional Board
  - San Diego Creek (total DDT, toxaphene, total PCBs,chlordane)
  - Newport Bay (total DDT, total PCBs, chlordane).

2nd Draft Permit - TMDLs (1 of 2)

- Until Regional Board TMDLs have been approved by the State Board, Office of Administrative Law and U.S. EPA, any U.S. EPA promulgated TMDLs apply.
- It is clearly stated that the permittees must comply with TMDL WLAs and water column targets.

2nd Draft Permit – TMDLs (2 of 2)

- Added the U.S. EPA promulgated, water column targets for metals:

  San Diego Creek – selenium, copper, cadmium, lead, zinc
  Newport Bay – copper, cadmium, lead, zinc
  Rhine Channel – mercury, chromium

- Added the U.S. EPA promulgated WLA for organochlorine compounds:

  San Diego Creek – total DDT, chlordane, dieldrin, PCBs, toxaphene
  Upper Newport Bay – total DDT, chlordane, PCBs
  Lower Newport Bay – total DDT, chlordane, dieldrin, PCBs
  Rhine Channel – total DDT, chlordane, dieldrin, PCBs

3rd Draft Permit - TMDLs

- No major changes.

Comments on 3rd Draft Permit

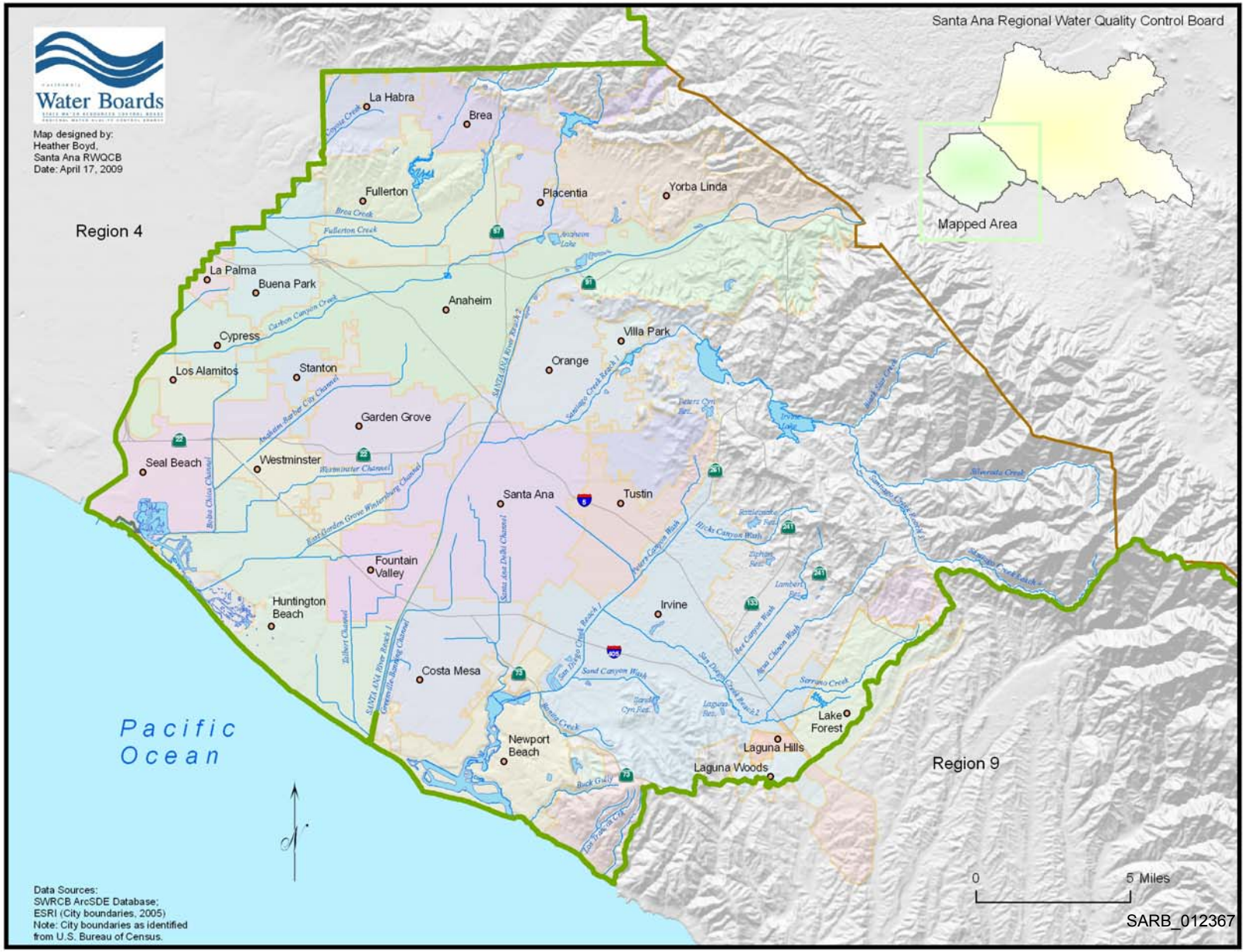
- Geosyntec
- County of Orange
- U.S. EPA
- NRDC
- Latham & Watkins
- CICWQ
- Prontowash
- OCWD
- County of Orange/OC CoastKeeper
- County of Riverside

Errata

- On advice of counsel, we've changed many of the "to the maximum extent practicable's" to "to a level consistent with the maximum extent practicable standard".
- XII.C.7.a-d were incorrectly formatted.
- Included the maps (Attachment A and B).
- III.I reference corrected.
- XII.D.5 substitute language

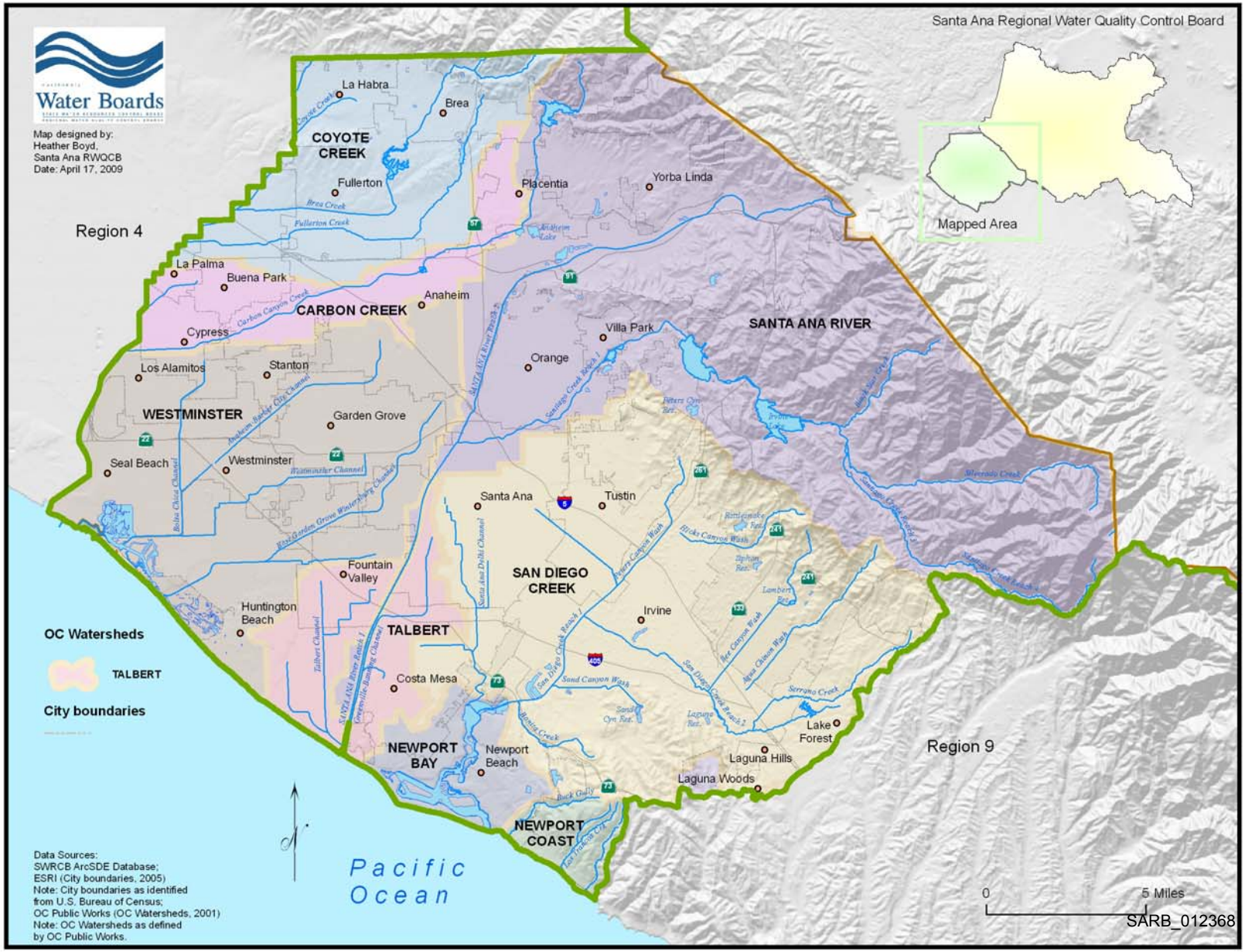
The County of Orange, OCFCD, and Incorporated Cities **Attachment "A"**

Area wide Urban Storm Water Runoff



The County of Orange, OCFCD, and Incorporated Cities **Attachment "B"**

Area wide Urban Storm Water Runoff



Conclusion

Staff recommends adoption of R8-2009-0030 with the changes proposed in the errata sheet.



SARB_012370

LID Techniques

- Bioretention cells, commonly known as rain gardens
- Cisterns and rain barrels
- Green roofs
- Permeable and porous pavements
- Grass swales are broad, open channels sown with erosion resistant and flood tolerant grasses. Used alongside roadways for years primarily as stormwater conveyances, swales can slow stormwater runoff, filter it, and allow it to soak into the ground. Swales and other biofiltration devices like grass filter-strips improve water quality and reduce in-stream erosion by slowing the velocity of stormwater runoff before it enters the stream.

U.S. Environmental Protection Agency. Washington, DC. "Fact Sheet: Low Impact Development and Other Green Design Strategies" June 1, 2006.

Orange County MS4 Permit Urban Storm Water Runoff Management Program

Order No. R8-2009-0030 (NPDES No. CAS618030)

Public Hearing
April 24, 2009

Mark Smythe
Senior Environmental Scientist
Coastal Storm Water Unit
Santa Ana RWQCB

History of Storm Water Regulations

- National Pollutant Discharge Elimination System (NPDES) was established in 1972 through the Federal Clean Water Act to control point source pollution.
- In 1987, Federal regulations required industries and large municipalities to obtain NPDES permits for their storm water runoff.
- The three Region 8 MS4 permits were adopted in 1990.

Storm Water Permits

- Statewide General Construction
- Statewide General Industrial
- CalTrans

<u>Other SW discharges regulated through:</u>

- MS4 - Municipal Separate Storm Sewer System
  - Municipal activities
  - Industrial and construction activities
  - Commercial and service activities
  - Residential activities

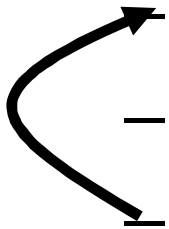
Municipal Permit Overview

- MS4 permits have not historically had numeric effluent limits, but TMDLs change that.
- For the most part, permittees must reduce pollutant loads in discharges from their MS4 to the **“Maximum Extent Practicable (MEP).”**
- Where MEP takes into account such issues as: the gravity of the problem, technical & economic feasibility, public health risks and societal benefits and concerns.

Maximum Extent Practicable

The permittees meet that MEP standard through an iterative process.

- If water quality standards (wqs) aren't being met,
- Implement Best Management Practices (BMPs)
- Monitor
- If there are still wqs exceedences,
- Implement improved BMPs
- Monitor



1990 MS4 Permit

- Develop a Drainage Area Management Plan (DAMP)
  - Catchbasin Stenciling and Cleaning
  - Steet Sweeping
  - Pesticide/Fertilizer Management
  - Post-construction Water Quality Management Plans
- Eliminate Illicit Connections and Discharges
  - Establish Legal Authority
  - Address Illicit Discharges
- Public Education
- Water Quality Monitoring

1996 MS4 Permit

- DAMP
- Eliminating Illicit Discharges and Connections
- Public Education
- Water Quality Monitoring

- Water Quality Ordinance and Enforcement Consistency Guide (developed at end of previous permit)
- Required Statewide General Construction Permit Coverage prior to grading permit issuance

2002 MS4 Permit

- DAMP
- Eliminating Illicit Discharges and Connections
- Public Education – Number of Impressions
- Water Quality Monitoring

- Municipal Inspections of Construction sites, Industrial facilities and Commercial businesses.
- New Development Structural Treatment BMPs.
- TMDLs incorporated for Newport Bay and San Diego Creek (nutrients and sediment).

Audits

- From 2003 to 2007 each co-permittee was audited by RB staff
- The 2-day audits included record review, program analysis and field observations.
- 5 of the 26 audits resulted in ACLs being issued ranging from $48,280 - $126,480.
- All 5 ACLs were paid without needing hearings.

Timeline



Comment Letters

- Staff received 24 comment letters on the 1st (Nov. 11, 2008) draft that generated 173 individual comments.
- Staff received 13 comment letter on the 2nd (March 25, 2009) draft that resulted in 71 individual comments.
- Responses to these 244 comments are provided in the Response to Comments.

November 10, 2008 Draft

Major changes from 2002 MS4 Permit:

- Added categories and High/Medium/Low benchmarks to Commercial Program.
- Incorporation of Low Impact Development (LID) and Hydrologic Conditions of Concern (HCOC) requirements for new development and significant re-development.
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November 10, 2008 Draft

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2002 Permit
Commercial Entities

- Automobile mechanical repair, maintenance, fueling or cleaning
- Automobile and other vehicle body repair or painting
- Mobile automobile or other vehicle washing
- Mobile carpet, drape or furniture cleaning
- Mobile high pressure or steam cleaning
- Painting and coating
- Nurseries and greenhouses
- Landscape and hardscape installation
- Pool, lake and fountain cleaning
- Other sites the Permittee determines may contribute significant pollutants
- Any commercial sites tributary to and within 500 feet of an ASBS

Commercial Inspections

2002 MS4 Permit

- Ranking was to be based on:
  - Overall threat to water quality
  - Type, magnitude and location of commercial activity
  - Potential for pollutant discharge
  - History of non-storm water discharges
- High priority sites were to be inspected by 7/1/03, Permittees were to establish inspection frequencies/priorities based on above criteria.

Commercial Rankings (2007-8)

	HIGH	MEDIUM	LOW
City 1	1	0	1585
City 2	0	44	974
City 3	0	514	1382
City 4	0	147	289
City 5	1	192	107
City 6	2	61	201
City 7	0	0	135
City 8	0	40	83

1st Draft Permit - Commercial

- Moved mobile cleaners to its own program
- Added plastic pellet storage/transport, pest control, building materials retail, vehicle maintenance/fueling/cleaning/storage.

	High	Med.	Low
% of total	10%	40%	50%
Inspection frequency	annually	biennially	Once per permit term

2nd Draft Permit - Commercial

- Acknowledged possible limitations when refused access.
- Dropped some of the business categories.
- Changed mobile business requirements to a pilot program.
- Confirmed that restaurant inspection program would continue on an annual inspection frequency.

3rd Draft Permit - Commercial

	High	Med.	Low
% of total	10%	20%	70%
Inspection frequency	annually	biennially	Once per permit term

- Provided the opportunity for permittees to develop an alternative inspection selection criteria and reporting framework.

November 10, 2008 Draft

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- Added categories and High/Medium/Low benchmarks to Commercial Program.
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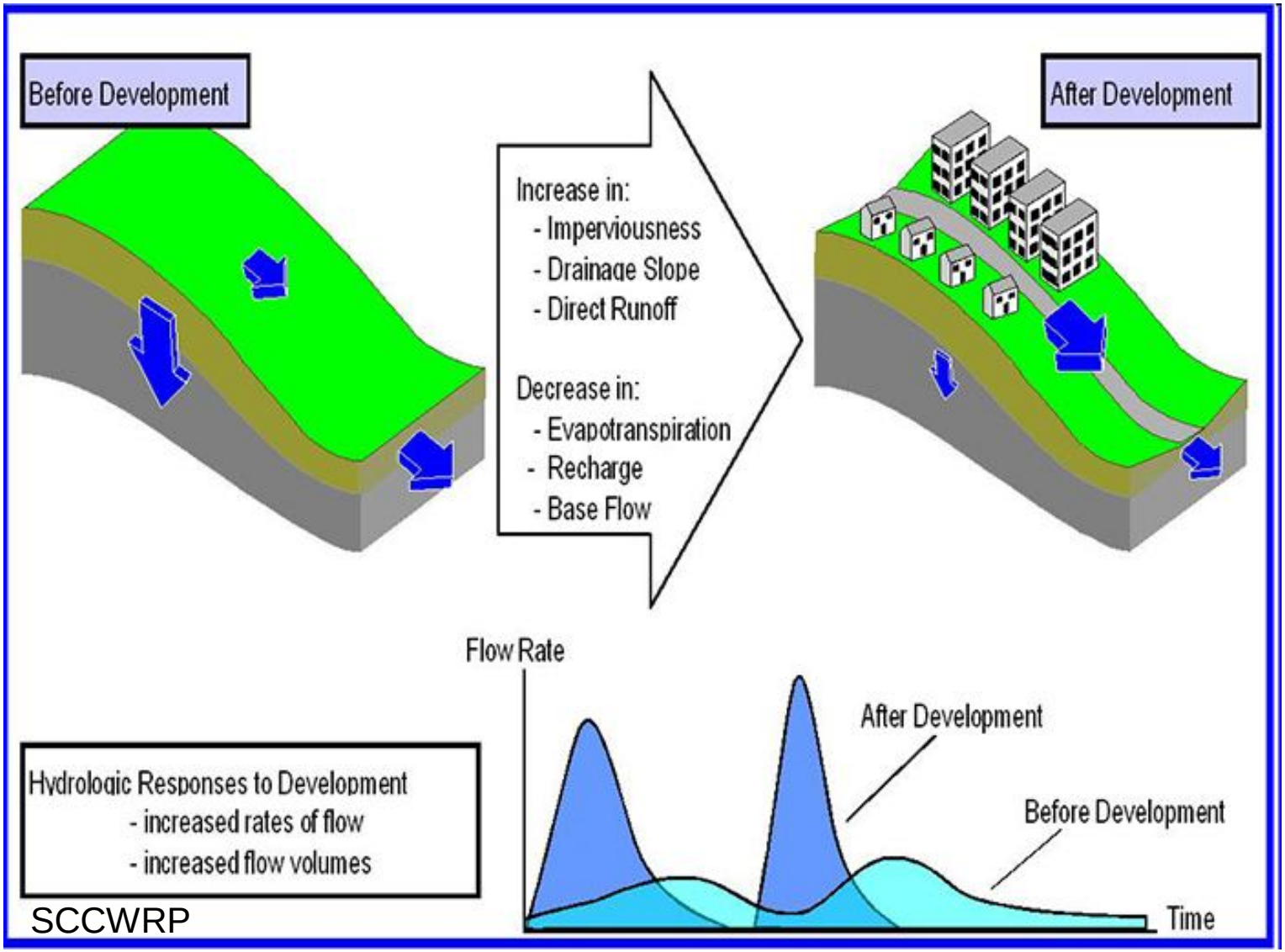
Development and Runoff



Low Impact Development

- The goal of Low Impact Development (LID) is to mimic pre-development site hydrology through source control and site design.
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1st Draft Permit
Post-construction BMPs (1 of 2)

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Post-construction BMPs (2 of 2)

More detailed requirements regarding Hydrologic Conditions of Concern (HCOC) or downstream erosion potential.

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2nd Draft Permit
Post-construction BMPs (2 of 2)

- Hydromodification - HCOC
  - Changed the 5% EIA to a capture volume based on a 2-yr storm event.
  - Downstream Waters of the U.S. required HCOC analysis even if hardened/engineered.
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3rd Draft Permit
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- All infiltration activities are to be coordinated with the local groundwater management agency.
- Minimum 5-foot vertical separation to seasonal high groundwater for infiltration, instead of 10 feet.
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  - Nitrogen and phosphorus (nutrients) for San Diego Creek and Newport Bay
  - Sediment for San Diego Creek and Newport Bay

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- TMDLs for urban runoff are implemented through the MS4 permits.

1st Draft Permit – TMDLs (1 of 2)

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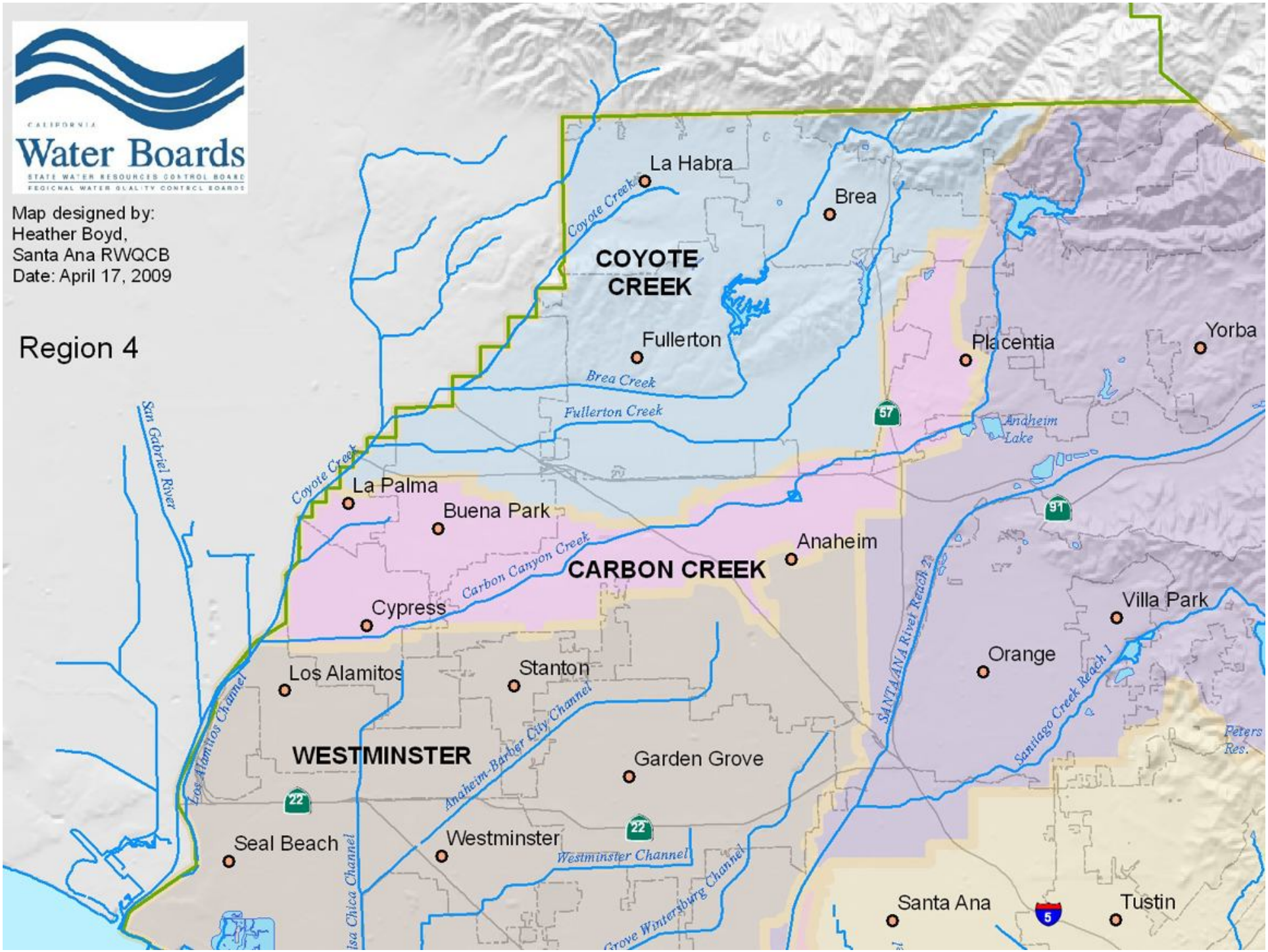
  - Lead
  - Zinc


Water Boards
Map designed by:
Heather Boyd,
Santa Ana RWQCB
Date: April 17, 2009
Region 4
La Habra
Brea
Coyote Creek
COYOTE CREEK
Fullerton
Placentia
Yorba
Brea Creek
Fullerton Creek
Anaheim Lake
San Gabriel River
Coyote Creek
La Palma
Buena Park
Carbon Canyon Creek
CARBON CREEK
Anaheim
Cypress
Villa Park
SANTA ANA River Reach 2
Orange
Los Alamitos
Stanton
Los Alamitos Channel
Anaheim-Barker City Channel
Santiago Creek Reach 1
Peters Res.
WESTMINSTER
Garden Grove
Seal Beach
Westminster
Westminster Channel
Grove Wintersburg Channel
Santa Ana
Tustin
57
91
22
5

SARB_012404

1st Draft Permit – TMDLs (2 of 2)

- Fecal Coliform in Newport Bay (compliance by 2013 - 2019).
- Water column targets for the organophosphorus pesticides - diazinon and chlorpyrifos in San Diego Creek and chlorpyrifos in Newport Bay.
- Water column targets for the organochlorine compound TMDLs adopted by the Regional Board
  - San Diego Creek (total DDT, toxaphene, total PCBs,chlordane)
  - Newport Bay (total DDT, total PCBs, chlordane).

2nd Draft Permit - TMDLs (1 of 2)

- Until Regional Board TMDLs have been approved by the State Board, Office of Administrative Law and U.S. EPA, any U.S. EPA promulgated TMDLs apply.
- It is clearly stated that the permittees must comply with TMDL WLAs and water column targets.

2nd Draft Permit – TMDLs (2 of 2)

- Added the U.S. EPA promulgated, water column targets for metals:

  San Diego Creek – selenium, copper, cadmium, lead, zinc
  Newport Bay – copper, cadmium, lead, zinc
  Rhine Channel – mercury, chromium

- Added the U.S. EPA promulgated WLA for organochlorine compounds:

  San Diego Creek – total DDT, chlordane, dieldrin, PCBs, toxaphene
  Upper Newport Bay – total DDT, chlordane, PCBs
  Lower Newport Bay – total DDT, chlordane, dieldrin, PCBs
  Rhine Channel – total DDT, chlordane, dieldrin, PCBs

3rd Draft Permit - TMDLs

- No major changes.

Comments on 3rd Draft Permit

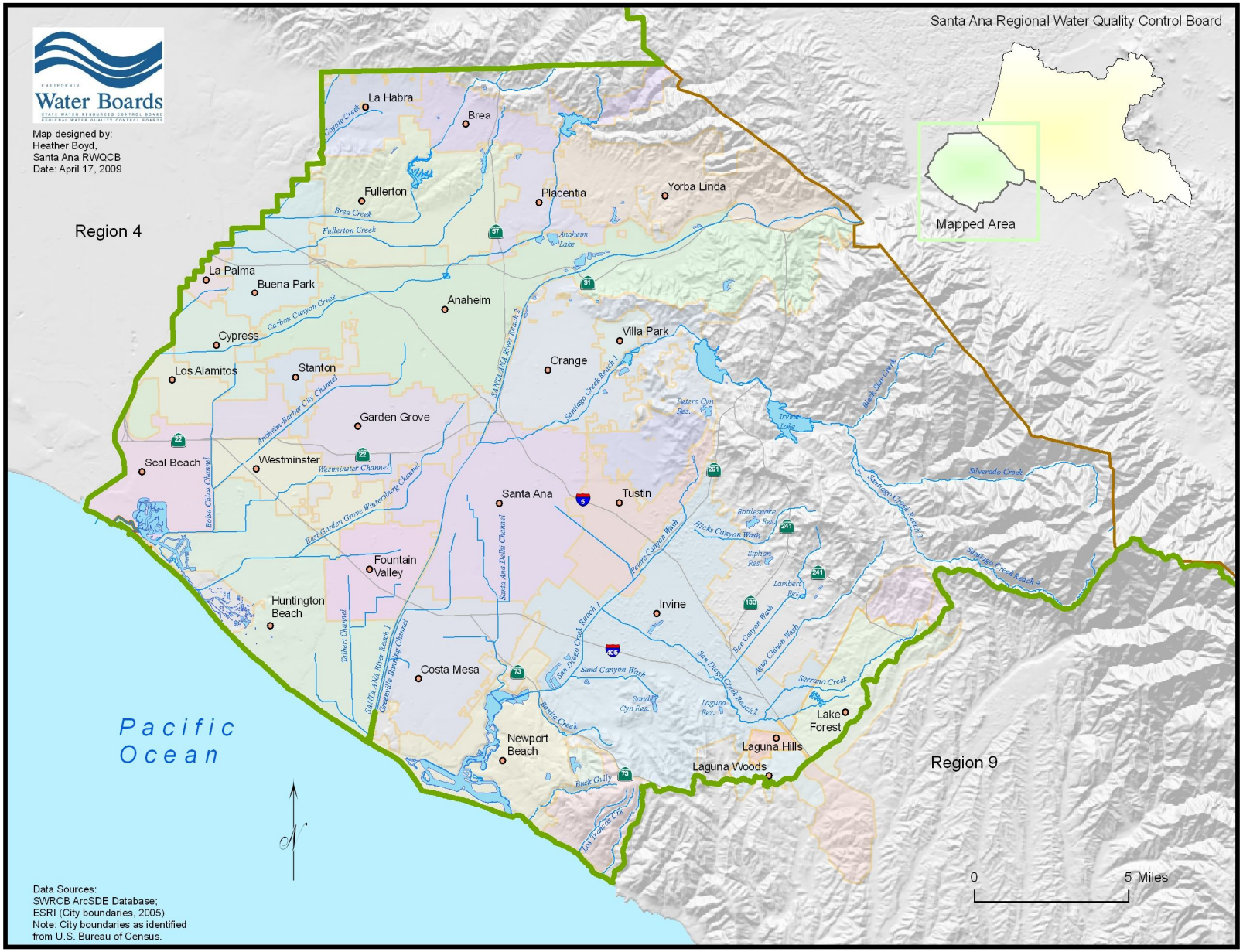
- County of Riverside
- Prontowash
- OCWD
- NRDC
- U.S. EPA
- County of Orange/OC CoastKeeper

Errata

- On advice of counsel, we've changed many of the "to the maximum extent practicable's" to "to a level consistent with the maximum extent practicable standard".
- XII.C.7.a-d were incorrectly formatted.
- Included the maps (Attachment A and B).

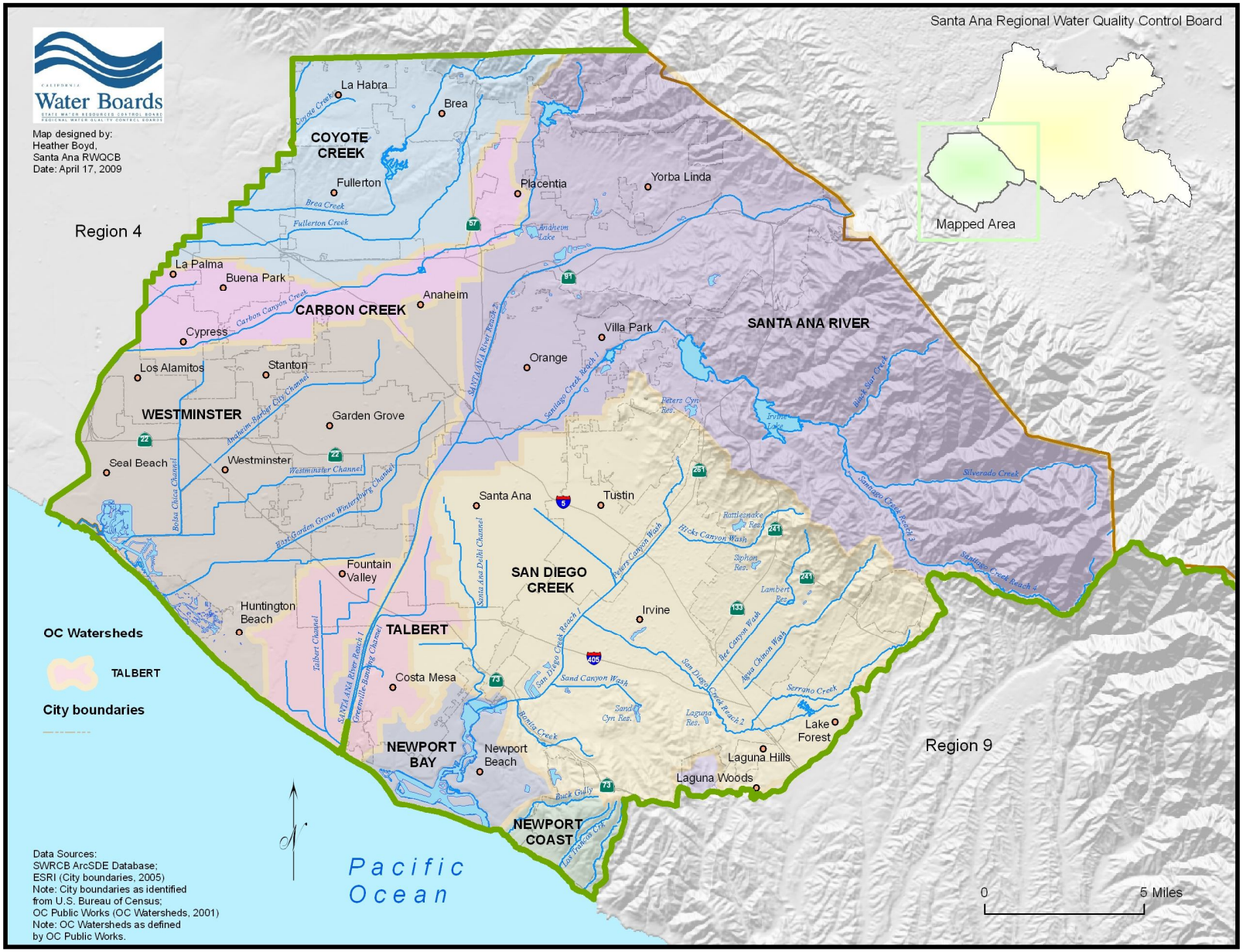
The County of Orange, OCFCD, and Incorporated Cities **Attachment "A"**

Area wide Urban Storm Water Runoff



The County of Orange, OCFCD, and Incorporated Cities **Attachment "B"**

Area wide Urban Storm Water Runoff



Conclusion

Staff recommends adoption of R8-2009-0030 with the changes proposed in the errata sheet.

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SANTA ANA REGION

CAROLE H. BESWICK, CHAIRPERSON

In the Matter of:	)
Public Hearing re: All items on the Agenda, including but not limited to, Renewal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of Orange County, Urban Storm Water Runoff Management Program (NPDES No. CAS618030); Public Hearing on Clean Water Act Section 305(b) Integrated Report/Clean Water Section 303(d) List of Impaired Waterbodies; Other Business	)

TRANSCRIPT OF PROCEEDINGS

Santa Ana, California

Friday, April 24, 2009

Reported by:

ALLISON SWANSON
CSR No. 13377

Job No.:
B1632WQWB

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SANTA ANA REGION

CAROLE H. BESWICK, CHAIRPERSON

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TRANSCRIPT OF PROCEEDINGS, taken at 220 Civic Center Plaza, Santa Ana, California, commencing at 9:00 a.m. on Friday, April 24, 2009, heard before the CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, SANTA ANA REGION, reported by ALLISON SWANSON, CSR No. 13377, a Certified Shorthand Reporter in and for the State of California, pursuant to Notice.

APPEARANCES:

CHAIRPERSON:	Carole H. Beswick
BOARD MEMBERS:	William Ruh Fred Ameri Steven PonTell Richard A. Freschi
EXECUTIVE OFFICER:	Gerard J. Thibeault
ASSISTANT EXECUTIVE OFFICER:	Kurt V. Berchtold
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Santa Ana, California, Friday, April 24, 2009

9:00 a.m.

MS. BESWICK: We can begin.

I would like to welcome board member PonTell.

Steve, if you wouldn't mind introducing yourself to the audience.

MR. PON TELL: Hi. I'm Steve PonTell, Recreation. I live in Ontario, but have a keen interest in Big Bear Lake.

MS. BESWICK: Thank you.

All right. We're now going to move to item 12, the Removal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of the County, Urban Storm Water Runoff Management Program (NPDES No. 618030).

This will be a public hearing with the potential of action to adopt the permit.

Mark Smythe, good morning.

MR. SMYTHE: Good morning, Madam Chair, members of the Board. I'm Mark Smythe. I'm a Senior Environmental Specialist. And I'm chief of the Coastal Stormwater Unit.

As the Chair said, we're here for a public hearing for the Orange County MF4 permit. What I plan to

do today is give a brief history on the 19 years of stormwater permits in this region and describe the process that led to the tentative permit before you today.

Stormwater permits are part of the natural solution to discharge elimination, or MPDS system. It was established in 1972 with the Clean Water Act. For the first 15 years, the regulations primarily dealt with major point sources such as sewage treatment plants and factories. But as those came under better control and water quality was still an issue, it was expanding to include other point sources including stormwater.

The three regional board MS4 permits, one for each county, were adopted in 1990.

Stormwater run off is regulated under four different permits. The first is a statewide general construction permit which deals with runoff from construction sites over one acre within our region and within the state.

The second is a general industrial stormwater permit. This permit deals with runoff of industrial sites as identified within the permit.

The third is the Cal Trans permit. That deals with runoff from Cal Trans construction sites and runoff from highways.

Most of the rest of the stormwater discharges

are regulated through the MS4 or Municipal Separate Storm Sewer Permit. This includes runoff from municipal activities, from industrial construction activities taking place within the city's and county's jurisdiction, runoff from commercial and service activities within their jurisdiction, and runoff from residential activities within their jurisdiction.

Stormwater permits and the MS4 permits, in particular, are different than most MPDS permits.

A normal MPS permit is based on a numeric ethical limit. That is, they're allowed to discharge a certain amount of copper, a certain amount of trico chloroform. And that's how you determine whether the facility is within compliance with the permit.

But for MS4 permits and stormwater permits, in general, because of the complexity of these flows, historically, they have not had numeric ethical limits. Although, MPL, and I'm going to be discussing that later, are beginning to change that.

But for the most part, these permits are based on implementing best management practices, or BMPs, to the maximum extent practicable. Where MEP, maximum extent practicable, takes into account such issues as the gravity, the severity of the problem, the societal benefit from addressing the problem, and technical and economic

feasibility of addressing the problem.

The MEP standard is addressed through an iterative process. That's if water quality standards are not being met, the permittee is expected to implement best management practice. These can be anything from public education-type best management practices to actual structural best management practices such as trash booms.

Those PMBs are implemented and monitoring is done to see if they're addressing the problem. If there are still water quality exceedances (sic), then they are to improved BMP, monitor, and continuing in that process.

So back in 1990, the first MS4 permits were adopted here in this region. Because it was a new program, it was -- the first permit was really a developmental program-type permit. They were to develop -- their plan for implementing this permit, this drainage area management plan, and identify the PBPs they would be implementing to meet the permit requirements. Such as catch basin stens line and cleaning, street sweeping, fertilizer, pesticide management within their own operations, and runoff from post-construction -- well, runoff from post construction.

They also were to eliminate illicit connections and illegal discharges, set up a public education program, and start up a water quality monitoring program.

Six years later, the permit was reissued. And

pretty much stayed the same because it was first issued in 1990. In general, it didn't change. The emphasis was on getting the program right. What did change was that there were water quality ordinances and enforcement consistency guides that were developed at the end of the first permit. And those were adopted by the City and County as their means of enforcing on illegal -- or illicit discharges and connections.

And they required that statewide general construction permit coverage would be shown prior to issuing grading permits. This was kind of a hand-in-hand type operation to make sure that prior to them issuing grading permits, they had the proper permitting with the state.

As I said, not a lot changed between 1990 and '96. But six years later, the 2002 permit, there were some major program additions at that time.

Of course, the dam was still being implemented. They were still required to address illicit discharges and connections.

Public education added a standard in that they needed to provide a certain number of impressions. That is, if you put an ad on the radio, there's the estimate of how many people hear the ad. That's added up to if you put fliers in water bills, the number of people that receive those water bills. So that would add up to a minimum number

of impressions to try to educate the public attitude, the difference between sanitation drains and storm drains. And they continue the water quality monitoring.

One of the new sets of programs started in 2002 were municipal inspections of construction sites, industrial facilities, and commercial businesses.

There was also new development, structural BMPs required. At that time their water quality management plan, the plan they had used to address post-construction, not the runoff pollutant during construction, but after a site's been in -- is in use, the PBP that address the pollutant flows coming from, say, new residences, from commercial facilities, and from industrial facilities.

And for the first time, TMDLs were incorporated. In 2002, there were three TMDLs in place for Newport Bay and San Diego for nutrients, nitrogen and phosphorus, and for sediment.

Because of the new programs that were implemented in the 2002 permit, regional board staff implemented an audit program of the 26 cities within the region. And it took a month per city to do our initial workup and analysis of the program up to that date. A two-day audit, where we went over the program with the permittees, went out in the field to ensure that their inspectors were doing the job they were supposed to, and

then a period to write the report and to work with them on addressing the problems we found within the program.

What we found was that most of the cities were trying. No program was perfect, but most of the programs were well on their way to getting to the point they needed to be. However, there were five cities that had substantially deficient programs that set them apart from the rest. And those five cities received administrative civil liabilities with assessments ranging from $48,280 to $126,480. And all five ACLs were paid by the cities without needing hearings.

While the audits were going on, the end of this permit was coming up. And so the County filed their report of waste discharge, telling us what they had done during the last permit term and what they wanted to do during the next permit term.

The 2002 permit expired in January of '07 and was administratively extended. And then during '07 and '08, there were a series of meetings held between stakeholders and regional staff, trying to flush out what the next permit would look like.

The first draft was released November 10, 2008, shortly followed by a public workshop. From that public workshop it became apparent that the new development standards would need work to get buy-in from all the

interested parties.

So a series of stakeholder meetings were set up that ran for approximately three months. Meeting with -- I'll get to that later -- with the stakeholders. Because of those meetings, and the progress of those meetings, the comment deadline on that first draft was pushed out two times, and finally on February 13th, we received comments on the first draft.

The comments were addressed. A second draft was released. Comments were received until April 9th on that second draft. And finally, a third draft was released on April 13th.

MS. BESWICK: Mark, just so I'm clear. There was one deadline and it ended up being February 13?

THE WITNESS: It ended up being -- yes. We had initially asked, at that public workshop, that the deadline be December 30th because of the progress being made with the stakeholders in the meeting, and kick it out, and then, in fact, we kicked it one more time to February 13th.

All toll on comments, staff received 37 comment letters on the first two drafts from which 244 comments were extracted and are listed in the response comments you have before you.

Now, even though that may seem like a lot, by the time we hit the second and third drafts, the area of

concern was limited to two or three subsections of this permit. And the majority of the permit has gone unchanged through the last couple of draft permit cycles.

The three major areas that have seen change are the commercial inspection program, the new development program, and the addition of new TMDLs to the permit.

What I plan to do is to go over each of these three sections, tell you what is in the current permit, the 2002 permit, and how these sections have changed over the last three drafts.

For the commercial program, the 2002 permit, the one that they're under right now, listed a certain number of commercial entities that the cities and county needed to inventory, prioritize, and inspect. Those included automotive-related businesses, mobile cleaners, painting operations, nursery operations, landscape, and water feature cleaning enterprises.

And as I said, they were to be ranked on the overall threat to water quality. Ranked high, medium, and low. And that permit required that all high ranked commercial entities be inspected by July 2003. And then for the permittees to establish a program -- a framework for an inspection and priority based program.

Now, when staff started writing the first draft of the permit, and also during the audits, we saw some

problems with this program with some of the cities.

As I said, there are 26 cities. And by the time we looked at the 2007/2008 annual report, we found approximately a third of them had very few high prioritized commercial facilities. This showed us there needed to be changes to the program. And, therefore, within the first draft of the permit, these were the changes that were made.

First, we moved mobile cleaners to their own category. Mobile cleaners are kind of a beast among themselves. They don't have headquarters in the city that they operate. And they are there for a limited amount of time. And so, really, it needed to be pulled into its own program and a framework established to address those mobile cleaners.

We also added some categories to that initial list that you saw, including plastic pellet storage and transport. And this works kind of hand-in-hand with the whole statewide plastics initiative. There was also pest control yards added to it, building materials retail. And whereas the last one had automotive-related commercial facilities, this one added other vehicles such as planes, boats, and heavy equipment to the list.

And there were standards added to the number of commercial facilities ranked high, medium, and low.

In this case, based on the city or county's

inventory, the top ten percent that represent the worst water quality threat, based on the first draft, were required to be ranked high and inspected annually. The next 40 percent with the highest water quality threat needed to be ranked medium and inspected every two years. And the remainder would be inspected every permit term.

As you imagine, we received comments on this portion of the draft. And for the second draft, made some changes. First of all, we acknowledged the possible limitations on refusal of access.

We dropped some of the business categories. We changed the mobile business program to a pilot program to give them an opportunity to get a program off the ground.

And in the past permit restaurants were being inspected on an annual basis. And while it was implied in the first draft of the permit, we put it specifically in the second draft of the permit so it would explicitly state that.

Based on comments received on the second draft, additional changes were made to the third draft. For one thing, we dropped the medium category to 20 percent and pushed the other 20 percent to low. But probably more importantly, we provided an opportunity for the permittees to develop an alternate inspection framework, a reporting framework that would be approved by the executive officer.

All right. The second major area of change deals with requirements for best management practices implemented at new development.

Our first permit required structural best management practices to address post-construction runoff from new and significant development. Those types of BMPs would include such things as catch basin inserts, bio-filters, porous pavement, infiltration galleries, that type of an actual structural BMP. Rather than site design BMPs like putting a plant a certain way or reducing foot prints.

Now, those BMPs really are only addressing one effect of new development. And that's the increase of the pollutant loading. What it is not affecting is the increase in runoff. While there were requirements within the current permit, the 2002 permit, that addressed the increased runoff, they were general in nature and dealt with things to be considered during the sequence process and when issuing conditions of approval.

The thing to note is as development takes place -- as you can see, on undeveloped land you have a lot of infiltration, less runoff. As you get impermeable surfaces, you decrease the amount of infiltration and increase the amount of runoff. And not only do you increase the amount of runoff because the structures are there to

speed stormwater to its ultimate receiving waters, you also get flashes of high flows that can cause downstream erosion, hydromodification, hydrological conditions of concerns, all kinds of terms regarding scouring and downstream erosion from this increased runoff.

One of the best ways to address that increase in runoff is through low impact development. The goal of low impact development is to mimic the hydrology that existed prior to the development. By implementing BMPs that increase infiltration to both evapotranspiration, harvesting and reuse, and bioinfiltration, one can reduce the effective impervious area of a site and reduce runoff.

Now, the effective part of EIA is where hydraulic connectivity comes into play. If a building is built, the pad and the roof form an impervious surface. The water that would have normally infiltrated now runs off the roof and does not have an opportunity to infiltrate. If that runoff is directed directly to the gutter and then goes into the MS4, that is part of the effective imperviousness of the area. It does not give it a chance to infiltrate. It's gone straight to the MS4.

However, if that downspout is connected to a rain garden, to a cistern, to rain barrels, it is then given the opportunity to infiltrate, and so does not add to the effective impervious area. So LID was incorporated into the

first draft of the permit.

It required the use of LID BMPs where feasible to address the pollutant loading and increase flow. And why might it not it be feasible? If you have areas of ground water contamination or subsurface soil contamination, you don't want to be infiltrating over that and spreading it. You have a situation where you have high ground water and increased infiltration may cause flooding. There may be clay soils that even with soil amendment may not be amenable to infiltration. And you may have issues of hillside slippage due to increases in infiltration. Those are the things that need to be taken under consideration when using LID.

There was a standard for that LID. And that was a 5 percent effective impervious area. That site needed to look -- it looked like there was only 5 percent of it with impervious surface. And the other 95 percent would allow infiltration, be it through natural infiltration or rerouting of other impervious areas to infiltrate other areas.

There was ground water protection components within this first draft, including a ten-foot vertical separation to seasonal ground water. A 100-foot horizontal separation of any supply wells. And that infiltration not be used in high pollutant areas. There were alternative

requirements when LID would be infeasible, something else would have to be done. It wouldn't be, "Well, we can't do LID, so we're not doing anything."

Finally, public agencies were required to inspect 50 percent of these structural treatments of BMPs going on that will be developed to make sure they're being properly maintained by the owners of those facilities.

Now, that was looking at pollutant load issues. How did we address --

MR. PON TELL: Quick question. Inspected by whom?

MR. SMYTHE: Inspected by -- it was, at the time, inspected by public agencies, by the city or by the county. That has changed through the drafts, but that was the initial requirement.

To address runoff issues, hydrological conditions of concern, to make sure we were not getting downstream erosion, if that 5 percent EIA was met, then it was assumed that site, after its development, was mimicking enough of the predevelopment conditions that there would not be downstream erosion.

But if it was higher than a 5 percent EIA, then there would be potential for downstream erosion, and so additional studies were required. And if that downstream erosion was to take place, then additional controls would be required on-site.

MR. AMERI: Maybe you said it, but I didn't understand. What if LID is not feasible, what would be the alternatives?

MR. SMYTHE: There would be the potential for doing it offsite. Michael, have you heard any other --

MR. AMERI: Regional --

MR. SMYTHE: Yes.

MR. AMERI: -- treatment. What else? What if not regional not --

MR. ADACKAPARA: You have a few options.

One of the options is they could actually establish an urban runoff fund and contribute to that fund.

The other option, you could go offsite and do some other mitigation measures.

So there were a few options included. And those are included in Section E of the permit. And I think Mark is briefly going to go over that.

MR. AMERI: Okay. You are. Good.

MR. SMYTHE: All right.

So based on this first draft, this is where the stakeholder groups got together and met the main group, met eight times, maybe three, four hours each time. And other sub groups got together and put together white papers. This was the topic that predominated those discussions.

And, in fact, one of the first things that came

out of those discussions was we had multiple definitions of what effective impervious area, EIA, really was. There were a lot of different permutations that were brought up. And kind of through the questions, used that as a standard.

One of the things that were incorporated into the second draft was a shift from the 5 percent EIA to a capture volume of the 85th percentile, 24-hour storm event.

There were also additional requirements for prioritizing the LID BMPs. With preventative techniques taking the highest priority, preserving natural drainage features, so you don't have to mitigate. Or where mitigating measures are needed, those were ranked too with infiltration and evapotranspiration being the highest, going down to harvest and reuse, and finally bioinfiltration.

And with regards to hydromodification, the standard was changed from the 5 percent EIA to a capture volume based on a two-year storm event.

A change was made -- in the first draft, if all downstream waters were engineered so they could take the flow, the first draft said it was assumed, then, there would not be a hydrological condition of concern, and studies weren't needed.

The second draft altered that so there was an exception. If downstreamed water to the US -- or if downstream waters included waters of the US, then a

hydrologic condition of concern study was needed, even if those waters were engineered because of potential for restoration.

And, finally, there was an option added to -- for the permittees to develop a watership master plan to deal with hydrological conditions of concern, hydromodification on a watershed-type basis rather than on a site-by-site basis.

And, finally, some criteria were added to the method for determining whether LID BMPs would be infeasible prior to allowing the alternatives or in lieu program.

Again, we received a number of comments. This has been the issue that has continued to have comments come in right up until last night.

And the third permit -- third draft, made the following changes. To address ground water concerns, regional board staff added that a pile monitor -- ground water monitoring program be started by the committees to address infiltration concerns. And all infiltration activities be coordinated through the local ground water agency.

The ten-foot vertical separation was changed to a five-foot, based on comments received saying that if it were at ten-foot, much of Orange County would be ineligible for infiltration because of seasonal high ground water. The

model WQMP was -- that will be created by the permittees, which was for EO approval, will be available for 30-day public comment period prior to EO approval.

And it would change if all downstream waters are hard to engineer to accept the proposed low, then, again, we're going to the fact that it is assumed that hydrological conditions of concern would not take place. And so no hydrological conditions of concern analysis are now needed. And the post-construction BMPs will need to be inspected every four years instead of every two years. And there's provision included for third party inspection of those facilities.

The third portion of this permit that saw changes were with the addition of new TMDLs. In 2002, the only three permit -- three team deals adopted were the nitrogen and phosphorent or nutrient TMDLs of San Diego Creek and Newport Bay and the sediment TMDLs for San Diego Creek and Newport Bay.

Real brief primer on TMDLs. It starts with beneficial uses. "Beneficial uses" are the -- Beneficial uses are the various waters in the region are established in the basis plan. Those beneficial uses include things like municipal drinking water supply, contact recreation, non-contact recreation, warm and cold water fisheries, wild life habitat, ground water recharge, and there's a number

more.

The basis plan lists water quality objectives that need to be met to protect those beneficial uses. You don't want too high tricho chloroform in waters that are swimmable.

If water quality standards, that is, those water quality objectives are exceeded or beneficial uses are not supported or because there's degradation within the waters, the water quality standards are not being met and the water's placed on the impaired water list or the 303D list. And that's something Pavlova Patally (phonetic) will be speaking about in the next item.

When water goes on the 303D list, the total maximum daily loads need to be calculated for those pollutants for those waters. What the total maximum daily load is is the amount of pollutant that can be discharged to the water and still support the beneficial use.

That load is then split up among point sources in the form of waste load allocation and non-point sources for load allegations to meet that TMDL. For those waste load allegations that address urban runoff, they're best implemented through the MS4 permit.

So for the first draft of TMDL -- the first draft permit, the TMDLs, we included the ones that had been in the previous permit, the nitrogen, phosphorus, sediment

TMDLs for San Diego Creek and Newport Bay and added the waste load allocations for the TMDL for Coyote Creek that was adopted by Los Angeles Regional Board. And those were for copper, lead, and zinc. This is a rather controversial one.

If you take a look, Coyote Creek runs within our region and then runs right along the LA and Orange County -- and hence the LA Regional Board and Santa Ana Regional Board boundary line. The majority of Coyote Creek and the San Gabriel River, which it's contributory to, are all under the jurisdiction of Los Angeles Regional Board.

Los Angeles Regional Board determined that there were impairments along the section of Coyote Creek, and hence, the cities that discharge, even though they're within our region, are part of that TMDL. Their discharge goes into the water that's impaired.

Consequently, our MS4 permit requires the cities within our region to comply with the LA Region's TMDL for Coyote Creek. And it is not a one-way street. North of this are the cities of Claremont and Pomona. Those are within the LA Region. They're Los Angeles County cities. They discharge, eventually, to Chino Creek, which is in our region. And there are TMDLs coming up for Chino Creek that we are going to expect the LA Regional Board to write into

their permit to address our TMDLs.

It is going both ways on this. It is a tricky one because it's a political boundary between the two regions rather than a watershed boundary between the two regions.

Also some of the other TMDLs that have been adopted since 2002 include fico coliform TMDL in Newport Bay, organophosphorous pesticides for San Diego Creek and Newport Bay, and an organochlorine compounds for San Diego Creek and Newport Bay.

After we released this first draft, we received comments from US CPA. Their comments stated that while the Regional Board TMDLs for organochlorine compounds and for selenium and for some other metals had been adopted by the Regional Board, they had not yet been adopted by State Board or approved by the Office of Administrative Law or EPA. So they had not gone all the way through yet. And EPA had promulgated TMDLs already for those waters. They had already established numbers for those waters.

What was required was that those technical TMDLs be listed within our MS4 permit as water quality standards, or water quality objectives.

The second thing is they wanted -- it clearly stated that permittees must comply with TMDL waste load allocations and water column targets as water quality

objectives.

So those EPA-promulgated water column targets for metals, that you see there, were included in our second draft tentative permit. And also for the organochlorine compounds.

After those changes were made, no further changes were made in the third draft of the permit.

Comments. Most of the comments that we received -- or all of the comments we received prior to April 9th were included in your response to comments that are part of your package. We received a number of comments after April 9th, and I will address those one by one.

The first one was on April 9th, memo from Geosyntec. It was a memo in response to a memo that had been put out by Dr. Horner, who represented NRDC and had -- let's just say it was in response to his memo. It argued with some of the points made in the memo and made additional points of their own, regarding these issues.

The second was an e-mail from the County of Orange, their counsel, asking that finding J52 be changed for TMDLs. That change is actually in your errata sheet. It is change --

MS. BESWICK: Is it the map one?

MR. SMYTHE: No, it is -- Michael, which is the J52, which on the errata sheet? The finding 52, what errata

number is it? It was a reference to 40 CFR.

MR. ADACKAPARA: Finding 52, that was provided, actually, by the county counsel.

MR. SMYTHE: Right. Is it on the errata sheet?

MR. ADACKAPARA: Yeah, it is on the errata sheet.

MR. SMYTHE: Which one is it?

MR. ADACKAPARA: It's number one on the errata sheet.

MR. SMYTHE: Thank you. Sorry.

That's number one on the errata sheet. So that one was addressed.

And they also commented that the technical TMDLs, the EPA-promulgated TMDLs, should not be included in our permit. However, it is Staff's -- Staff's found state and federal regulations require implementations of EPA promulgated TMDLs within that permit.

The next letter we received was from Geosyntec on behalf of Orange County. Oh, it was in response to another NRDC memo, where it -- NRDC had stated that the report of waste discharge issued by the County of Orange does not include assessment of controls implemented during the previous seven to five years. And Geosyntec's letter stated that it had and showed evidence of that.

The next comment we received was from John Kemmerer of US CPA and NRDCA, asking for changes to the LID timeframe as to the adoption of the

permit. And concern when LID doesn't capture the full 85 percent.

It's not shone on your errata sheet, but at this time Staff is recommending the following change to items 12C1 --

MR. AMERI: What page, can you tell us?

MS. BESWICK: It is on the errata sheet.

MR. SMYTHE: This is not on the errata sheet.

MR. ADACKAPARA: Page 53.

MR. SMYTHE: Page 53 of the permit.

MS. BESWICK: Page 53. Okay.

MR. SMYTHE: So it is 12C1 and 2. So those are the changes --

MR. AMERI: One more time, please. Page 53. C what?

MR. SMYTHE: C1 and 2.

MR. AMERI: Changing the time table?

MR. SMYTHE: Right. If you take a look at that last sentence deleting --

MR. AMERI: No change to one.

MR. SMYTHE: Yeah, there's a change to one.

If you look at the screen. It is deleting the phrase that "meets the feasibility criteria established pursuant to section 12E." That's the portion being deleted from C1, being proposed to be deleted.

And on C2 --

MR. THIBEAULT: Mark, why don't you read the sentence as it will read after the change?

MR. SMYTHE: All right.

MS. MC CHESNEY: Mark, can I interrupt for a second?

MR. SMYTHE: Yes.

MS. BESWICK: Do you have spare copies, because the the people in the audience do not have the errata sheet.

MS. BESWICK: It is not the errata sheet. It is actually in the permit.

MS. MC CHESNEY: All right. Do you have spare copies?

MR. ADACKAPARA: We don't have extra copies of this is correction. It is not in the current errata sheet. It is the only item not included in the errata sheet.

MS. MC CHESNEY: Do you have extra copies of the errata sheet? Do you have copies of the errata sheet?

MR. ADACKAPARA: Yes, we do.

MR. SMYTHE: For the public?

MR. ADACKAPARA: Yeah.

MR. AMERI: Can you please read what the original language was and how it compares.

MR. SMYTHE: Yes, I will.

The final sentence in C1 will read, or proposed to read, "Priority development projects shall implement LID

principles described in this section, Section 12C."

MR. AMERI: What does that mean? I'm confused. It said met the feasibility pursuant to section --

MR. SMYTHE: Michael?

Go ahead. Would you repeat that?

MR. AMERI: You said that the last sentence had changed. "Priority development projects" -- what? I can't read it on the screen.

MR. ADACKAPARA: Essentially, what it is saying --

MR. AMERI: What are we changing to what?

MS. BESWICK: You're taking out the "meet the feasibility criteria established pursuant to Section 12E." That phrase would potentially come out.

MR. AMERI: Okay.

MR. RUH: Just priority development projects shall employee LID principles in this section, Section 12C.

MR. AMERI: Okay. I got it now.

MR. SMYTHE: And for number two, the second sentence will read -- there will be -- okay. Maybe I should just read the whole thing.

"The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and reuse, or evapotranspire the 85th percentile storm event, capture design volume as specified in section 12B4A1 above."

We're inserting, "Projects that do not comply with this requirement shall meet the requirements established in section 12E for alternative or in lieu compliance. Any portion of these design capture volume, or this design capture volume, that's not infiltrated, harvest and reused, evapotranspirated, or captured on site by LID BMPs shall be treated and discharged using LID or conventional treatment BMPs or mitigated as set forth in 12C7 below."

MS. BESWICK: Let's keep that at hand. Let's keep that one so it's easy to pull back up.

MR. AMERI: I have questions on that.

MS. BESWICK: Absolutely.

MR. SMYTHE: Okay. Shall we go on to the rest?

MS. BESWICK: Yeah.

MR. SMYTHE: All right.

Now, that 12C1 and 12C2 were in consideration of comments made by NRDC and US EPA. All right.

So shifting, we received comments from Latham & Watkins that LID should include the word "filter." And the regional board staff has included the biofilter and believes that if properly designed and maintained biofilter will be appropriate. It may not be as effective as evapotranspiration or infiltration BMPs. And we'll address this through the model WQMB approval process in

12 -- identified in 12E.

And CIWQ -- the California, or the Construction Industry Coalition on Water Quality, I believe it is, also said LID should include filters. And, as I stated, it does include biofilter now.

Pronto Wash had provided previous comments and additional comments requesting additional controls on mobile washers. Regional board staff feel that the prohibition on unauthorized non-storm water discharges as well as the language in 67B that requires cities in the county to have authority to prohibit mobile wash discharges sufficiently address this concern.

Orange County Water District provided comments asking that the five-foot separation, vertical separation between seasonal high ground water and infiltration galleries be increased back up to the ten-foot. At this point, Staff is purposing the five-foot.

Orange County Coast Keeper and the County of Orange had requested that the watershed master planning process be changed from a conditional to a requirement. That staff has accepted. And it is item 9 in your errata sheet. And that shows the replacement language.

And the final comment we received was from the County of Riverside. And the thrust of their comments, there were some recommendations to findings which have

already been made. The primary portion of their comments were, there were several sections they did not want incorporated into their MS4 permit, which will be addressed when their MS4 permit comes up.

One of the erratas also was to include the maps, which I believe is included in here by reference -- yes. Item 12. And those are the maps, the city map and watershed map that will be included in the permit.

Conclusion. Staff recommends adoption of the R820090030 with the changes purposed in the errata sheet and presented in this presentation.

Staff's prepped to answer questions.

MS. BESWICK: And we may have some for you.

Gerry, did you want --

MR. THIBEAULT: Just to finally, hopefully, clarify that one issue in the errata sheet.

Are there any other changes other than the two items that were not included in the errata?

MR. ADACKAPARA: No. We don't have any other changes at this point.

MR. THIBEAULT: Okay. We can leave that one screen up there, and everyone can see very clearly what the change is, and can copy it down or -- so let's go ahead and let's leave that up there. This is the only change that was not included in the errata sheets.

MS. BESWICK: Got it.

Are there questions? Any board members have questions of Mark before we open the public hearing?

No?

Yes, Steve.

MR. PON TELL: I guess the question is one on the process. Should I -- if I do have questions throughout the permit, just wait until after the public hearing and ask all the questions at the same time? Will that be an easier process?

MS. BESWICK: It might be because we may find that some of these come up during the course of the discussion. And I think we should feel free to ask people who are making comments, questions -- if questions arise during their presentation.

All right. So with that in mind, we'll open the public hearing.

Thank you, Mark.

I have a great number of cards. And, also, I think that there's a potential for a group, if you will, presentation. So when we get to that, we'll see if we can comment.

What I'd like to do first -- I've had a request. Mayor pro tem of the city of Lake Forest, Peter Herzog. And Peter needs to be somewhere else. I'm going to ask him

if he would like to make comment first.

MR. HERZOG: Thank you very much. I wasn't expecting a comment that quick. Thank you very much.

My name is Peter Herzog. I'm the mayor pro tem in the City of Lake Forest. And I'm glad to be here before the members of the Board.

Obviously, we certainly appreciate all the efforts of your staff and yourselves in working with the permittees and the cities of Orange County and, quite frankly, everyone who's very heavily involved in the committee enforcement of the implementation aspect.

I submit that the proposed permit before you -- obviously, the discussion this morning has changed on the screen, but otherwise -- that this purposed permit does add a great deal of progress to what has already occurred previously. So it is a step forward. It is moving forward in looking at the overall perspective of the watersheds. That is what we're all interested in.

And quite frankly, from my standpoint, I think your staff and this board exceeded what is required. And that's an option you have. So that you're well within the bounds of the parameters.

And I'll be very frank, there are various portions that I don't like, and we would like to see deleted. You know, just be frank, that I do think, in light

of all the work that has been done, that today's the day. It is time to move forward and start getting back to moving forward with progressing with the quality of the basin.

Now, there are changes. You're aware of the economic goings on. And cities are not immune from that. And unfortunately, even in the current budget cycle, cities have cut 10 to 15 percent from the actual spending. And had that be -- now, in the current budget cycle. And, unfortunately, it doesn't look any better. It looks worse.

In this 09/10 budget cycle, you're going to see further decrease in budget. And, frankly, what we see over the life of the permit, that probably the financial recourses of the city's not going to improve that greatly.

We want to really focus on projects that will actually go toward the health of the watershed. And that requires maximum flexibility so all parties come together and move forward with that goal.

The reasons I point that out again, is I think that the need for flexibility -- I think it's important for this Board to actually expand the best management practices to provide the cities and the developers with as much flexibility to meet the overall check list. Again, the big picture is the health of the watershed. That's what we're trying to achieve, and the water quality involved in that.

So let's create as much flexibility as possible,

so we can get there. Restricting it and pulling back or adding additional problematic issues is not really looking at the ultimate goal. And I think it is important to keep that heavily in mind.

And that's important with regards to the soil retention of water and requiring homeowners and businesses to mechanically infiltrate.

As the staff pointed out, there are certain areas where nature has made that extremely difficult. At my neck of the woods, down at the south end of our district, we live with that every day. Our area is not really all that excited or compatible with that kind of infiltration. There may be other areas that are, but our area certainly is not.

And that, again, goes to the flexibility aspect that's extremely important so that we can continue to do the work that Lake Forest and other cities down in my area have done to try to improve the watershed.

I respectfully submit that there has been a great deal of work done. Today's the time to make a decision. Not tomorrow. Not next month. It is time to move forward. The cities look forward to working with your staff and the Board. And looking to the health of the watershed.

And, again, I think extremely important, particularly when the economy we're in and we're going to be

facing over the life of the permit that the maximum flexibility be provided not only to the developing community, but to the cities as well who are the ones -- particularly in Orange County, where we essentially cover all of the geography of Orange County, over 90 percent of that we're ultimately responsible.

So I appreciate your time, appreciate your efforts. And thank you for this opportunity.

MS. BESWICK: Thank you.

Richard Boon, you want to come up?

And, Richard, it is my understanding -- you can help me with this. You might have a presentation that is going to be comprehensive as to the counts.

MR. BOON: That's not correct. I had some written remarks to present verbally only.

For the benefit of the room, Richard Boon with the County of Orange. I'm responsible for the countywide elements of the Orange County stormwater program.

MS. BESWICK: You're speaking on behalf of yourself at this point?

MR. BOON: I think -- I believe -- I'm certainly speaking for the county.

MS. BESWICK: Let me tell you why I'm confused. I have a note, the permittees 20- or 30-minute time slot for the presentation. And my impression was it was in part for

the counties and cities, that this was part of your presentation.

MR. BOON: No, we didn't ask for that.

MS. BESWICK: Okay. And you asked for 15 minutes.

MR. BOON: I was anticipating ten minutes. I speak on behalf of the County of Orange. I also represent the cities in the Stormwater Project.

MS. BESWICK: Thank you.

MR. BOON: I'm not going to start on my prepared remarks. I think -- I respectfully ask for an opportunity for a recess to think very carefully about the language that has been put up here. There's one defining paragraph in this program. And it is section C2, the one before you.

The red line version you have there, regrettably, does not reflect the change that's been made to the full draft permit. There's a word that has been struck, that's not shown as struck on the overhead. And I think, for all the parties in the room, we need an opportunity to think very, very carefully about what is being proposed here, and what is not provided on the errata sheet to us.

MS. BESWICK: Right. What word are you telling us -- which word, so we're on the same --

MR. BOON: Yeah, the word "capture" has gone. And it is not shown as a deletion. And that's a key word.

MS. BESWICK: In paragraph two?

MR. BOON: In paragraph two.

MR. ADACKAPARA: I think "capture" -- it is a mistake, actually.

The version we put over there did not -- "capture" should not be there. That's in the paragraph of the permit.

MR. BOON: But this is the defining paragraph that the force and permit for Orange County. We need to be absolutely clear on what we're all considering.

MS. BESWICK: So let's just renew it.

If you had even -- you're talking about after evapotranspire; right? It should say, "Or capture," is not there. And Mike's saying it should be there?

MR. BOON: Yes.

MS. BESWICK: It should say, "Or capture," still.

MR. THIBEAULT: So Mark Smythe, is this correct as it's shown on the screen?

MR. SMYTHE: No. That's not what we're proposing.

MR. THIBEAULT: What is it you're proposing?

MR. SMYTHE: Right now, Michael's changing it. It should still be in there.

MS. BESWICK: It should still say, "Or capture the 85th percentile."

Thank you for catching that. That's a big difference.

MR. THIBEAULT: And this is now as staff proposed it?

MR. SMYTHE: I will look through it now, but, yes.

MR. BOON: I still think we would benefit from having an opportunity to think very carefully about what is being proposed here. This is truly the defining paragraph of the permit.

MS. BESWICK: I think we'll give you that opportunity. We'll take the subsequent speaker card. Some of them that are different aspects of the permit. So I'll keep your card. All right?

MR. BOON: Okay.

MS. BESWICK: All right. And then when we get to you, you can give me a sign that you're ready to talk about -- or come back to you as we get through the speakers. Is that going to work?

MR. BOON: Thank you very much.

MS. BESWICK: Thank you.

Dr. Walrod, are you still with us?

MR. RECUPERO: Just one moment.

MS. BESWICK: You had mentioned you needed to leave. I hope I'm not catching you as you're walking out the door.

MR. RECUPERO: Thank you, Madam Chair.

My name is Michael Recupero. I'm not Dr. Walrod. He did have to leave. I don't know if you're going to take a recess now.

MS. BESWICK: I don't intend to take a recess, unless there's a reason that people can't converse with each other while we are doing this.

MR. RECUPERO: No.

My name is Michael Recupero. I'm representing the Orange County Business Council this morning. We appreciate the opportunity of presenting this. And appreciate all the work you've done with the stakeholders.

I think that the primary concern of the Business Council relates to -- if we could get pushed to the end that would be appreciated.

MS. BESWICK: Okay. Let me try it this way. Is there anyone in the room that would like to speak to us now? I'm going to invite you up and let you come back later.

MR. RECUPERO: Madam Chair, I think the 11th hour language has changed a lot of dynamics. I think the big concern -- I agree with the County of Orange, if I could have a few minutes to look at it, that would be appreciated.

MS. BESWICK: Go right ahead.

John, did you want to speak?

MR. KEMMERER: Yeah.

MS. BESWICK: Great.

MR. KEMMERER: Good morning, Madam Chair and board members. I'm John Kemmerer with the Environmental Protection Agency. I was out here in November

at the workshop on this. Nice to see you again. And introduce myself. I'm an Associate Director of the Water Division in EPA Region 9. I'm part of a small group working out of Southern California.

I'm glad to be here today. In November I provided brief remarks in support of this permit. And, again, today, to express EPA strong support for the work Staff has done on this program.

To reiterate some of the things I mentioned back in November. We recognize that controlling stormwater is one of the more challenging aspects of the Clean Water Act. As a nation, we need to improve the management of stormwater and better control the impacts towards that end.

We believe the revised permits, like the one you're considering today, need to take advantage of the previous permit. You're considering the fourth round here today. It is important to take advantage of what we learned over the last 20 years.

There was mention of the audits your staff has done here in Orange County. In addition, EPA Region 9 has done 59 audits in our region. And we've concluded -- one of our main conclusion from the audits is these permits need to include more quantifiable requirements to ensure that we're following these respected from stormwater discharges.

Really, across the country, the permits often have fairly vague, frankly, requirements in them, and we really think that the work your staff has done here really has addressed the historic problems with stormwater permits and are including more focused and measurable requirements so everybody knows what is required and we can ensure that the water quality is protected.

When I spoke in November, I highlighted two specific aspect of the permit. And those were the LID provisions and the incorporation of maximum daily loads. And I would like to get into that today.

Back in November I expressed support for what was then in the permit, which was the 5 percent effective impervious area requirement for LID. The version you have before you today has been revised.

And I want to make sure you realize we are fully supportive of the revision that's been done here in the design capture volume approach for the measurable implementation of LID. We think that your staff and stakeholders here really made some admirable efforts to get together and come up with this approach. And we think its a very good one and meets our objectives to have measurable LID requirements in permits.

We also made some suggestions back in February about the in lieu programs. Everybody recognizes that

implementation of LID is not going to be something that's practical in every single project. But if a development cannot implement LID, there still needs to be some efforts taken to protect water quality.

We believe what you've come up with and what staff came up with as an alternative approach is really important and very meaningful and realistic approach for addressing those situations where that's impracticable.

I do want to say, since this is staring me in the face, this language up here, that this is really critical to our support of the LID provisions of the permit.

Frankly, we were supportive of the March 25th version of the permit. And felt it had LID provisions. We saw that there were ways of improving it. And I think the best intensions were made in trying to improve the last version of the permit. But when the April 10th version came out, there were these two sections in particular that became very problematic for us.

And we feel like these changes up there -- and I apologize for missing the word "capture," that was totally my fault. I believe these changes need to be made.

I'll mention -- this probably has taken a little bit more time than I claim --

MS. BESWICK: That's all right. This is very important. I think this is the most -- discussion we're having.

MS. MC CHESNEY: Maybe -- because the people out there want to hear.

MS. BESWICK: I was thinking the same thing.

MS. MC CHESNEY: They may want to come in and you can explain your --

MS. BESWICK: Why don't you do that. Let's just take a breath.

MR. THIBEAULT: Larry's going out there.

MS. BESWICK: And asking them to come back in. I think this is awful important to them.

You may want to back up and start over about the part where it was you that didn't get the word in there.

We've asked everyone to come back into the room because I think there's some enlightenment to be offered here. Mr. Kemmerer's comment from the EPA. So I'm going to ask him to revisit what he was just telling us.

MR. KEMMERER: I was -- as I was mentioning, I'm really impressed with what's been done on the permit with the LID. EPA's fully supportive of this 85 percentile capture volume rather than the 5 percent EIA. We believe --

MS. MC CHESNEY: Can you speak into the mic?

MR. KEMMERER: But we do -- and actually, the way the LID provisions were incorporated into the March 25th version of the permit was acceptable to us. But we had major concerns with how -- the last minute changes that were made

in the April 10th version which led us to suggest the changes here.

And I take full responsibility for missing the word "capture" in item number 2. I'm sorry about that.

But let me tell you what our rationale is for this. In Section Number 1 of this -- on the screen here, basically, what was added to the permit for the April 10th version was some language that basically said if -- those projects that meet the feasibility criteria in that alternative section would need to comply with the LID provision of this program.

Like I mentioned earlier, that we really are supportive of that alternative section. I believe that's a critical part of the permit. We don't believe -- we believe that this language that was inserted on the April 10th version puts the cart before the horse in how the feasibility analysis is done.

Right now, with that language in the April 10th version, the LID -- the numeric LID provision, which we applaud in the permit, would not apply until the feasibility criteria were approved by the EO. And although all of us here today, I'm sure, hope that the feasibility criteria can be developed in a timely manner and approved, we see the down side of this being that there's a possibility that if the development of these feasibility criteria drag out and

aren't prepared in a timely manner, or are not approved in a timely manner, the numeric requirements, the numeric LID requirements of this program will not apply.

So our view, if you delete that line there that's on the screen, all of the provisions in section 12E still apply. You still have that alternative available and, ideally, again, it will be done in a timely manner and we will move forward.

We've seen, in these permits, things don't always go the way you like and take longer than you expect. And we don't feel it's worth the risk of including that language in there and having the possibility that the feasibility criteria could be a disputed item and drag out over time. And then those revisions in Section 2 would not apply.

MS. BESWICK: The concern is primarily the timeframe for the feasibility criteria. That is going to be developed by the executive officer.

MR. KEMMERER: It's going to be developed by the permittees and approved by the executive officer.

MS. BESWICK: Do you want to comment on it?

MR. THIBEAULT: If I could. It is relevant to the context here.

The permittees are required to provide this feasibility study within 12 months. Failure to do that --

and I know things drag on, although we never had it happen here, things can. If they don't submit that within the 12 months, they are in violation of the permit and subject to enforcement, including monetary penalty.

It is not like if people don't feel like getting it within 12 months it is okay. It is an enforceable permit requirement.

And also, with all due respect, the alternative, without these language changes, still required LID principles to be considered for all development elsewhere in the permit. It is not like there was a free ride. Although EPA -- and I suspect others -- wanted it specifically identified with this language change. Even without this language change, there's still a requirement for new development to be -- to have LID principles considered, even without the feasible study.

MR. KEMMERER: I guess I have two quick responses to that.

I agree with you, Gerry, that the feasibility study needs to be submitted. It would be a violation of the permit if they don't submit it within 12 months. It is not in place until it is approved. You could get an inadequate set of criteria for the feasibility determinations and want to make sure it is scientifically sound and that you are comfortable with those criteria.

And I could see you providing some comments on the feasibility study criteria. I could see this going back and forth for a while. It doesn't seem to me, or us at EPA, that there's any reason to include this in here because you are going to have these requirements in the permit. And, again, you're unnecessarily leaving a door open if there's a delay if you go back and forth on that.

On the second point, I agree there's other LID provisions in here. Our support of this permit is really predicated on having the numeric and measurable requirements. As I mentioned up front, we supported the 5 percent EIA approach. We support the approach that all the stakeholders on this 85th percentile, controlling the 85 percentile.

It is my understanding -- you can correct me if I'm wrong -- that that 85th percentile requirement will not kick in until you approved the feasibility criteria under the permit. That's why we feel that language in Section 1 should be removed.

So why don't I go on and explain the second one. The second one, actually, I thought was really a great example to me. I've kind of -- good intentions sometimes don't work out the way you like.

I think the intent here was to clarify the language. I think this was actually overall by moving --

this language was further down in section 12C before. It was moved up and made prominent. And I think it was a good idea. The problem is with the language that's in there now. It leaves -- basically, equates the use of LID tools and the alternative section, 12E requirements, and the use of conventional BMPs, conventional treatment control BMPs.

You could read the language before that change was made and say you meet the requirements of this LID section of the permit by using treatment control BMPs only. And I know that's not the intent of the permit. And I know -- in one of the stakeholder meetings, it is my belief it is not the intent of anyone here.

I think the language as is is, frankly, a little messy. And it needs to be clarified to make it clear that you need -- that the permit requires compliance with either the controlling the design capture volume or complying with that alternative section, 12E. If you don't do those two things, you're not complying with the permit.

The way the permit was worded in April, the implication was there that you could also comply with the permit by using conventional treatment BMPs.

That's the logic for the input on these two sections of the permit. And it is -- my belief is, and I was trying to talk, working with Mike on this -- I believe this language change makes it clear, you know, if you're

going to comply with the permit, these are the two ways of doing it, using controlling the design storm volume or meeting the alternatives in section 12E.

So I'm sure there's other ways of dealing with this and other languages to be made. This is what I came up with as I thought was the cleanest way of not having to change a bunch of different sections in the permit.

So why don't I finish -- so, again, on the LID, I think you have an opportunity to improve a rarely effective permit here on requiring LID. And I think it is going to result in some major improvements in water quality in this area.

The other aspect of the permit that was mentioned in the opening remarks here that we commented on was the TMDL section of the permit. We provided a lot of comments on that. And we -- we're very encouraged by the way the comments were addressed by the permit. We made suggestions that the permit language -- make it clear how the waste load allocation's assigned to the admissible stormwater was addressed by the permit.

And going back to my first point about the need for clear measurable requirements, we believe TMDLs are a perfect example of how we really need clear requirements in these permits. We've been implementing stormwater permits across the region. And lots of permits that have vague

language about incorporation of TMDLs that are not working.

And this language that your staff put into the permit is very clear. It makes -- gives everyone the understanding what needs to be gone to meet the TMDL waste load allocation.

And in our view this will enable the Board to ensure that the pollutant discharges from municipal stormwater to impaired waters in this region are being appropriately controlled with the ultimate objective of obtaining the water quality standards.

We don't agree with some of the comments made about -- the legal comment about not being able to incorporate a technical TMDL. That's not at all our legal view. We disagree with some of the comments that have been made about relying on more of an iterative BMP approach. We feel like that's the way things have been done in the past and have not worked.

I really encourage you to adopt the permit.

I want to end by just saying, your staff has done just incredible work bringing this to you today. We've seen across the region how long it takes. The time frames they worked under are just incredible.

I want to commend Mike Adackapara on his patience and tireless efforts.

And I'm glad to answer any other questions.

MS. BESWICK: If there are no questions, I think it will be appropriate after this input for us to take a break.

So we're going to break until 10:45.

(Pause in the proceedings)

MS. BESWICK: Now, you know what I'd really like to do is I'd like to go back and ask if either of the earlier speakers that came up and wanted time out, is at this point interested in coming back up or proceed with other speakers.

Richard, what would you like to do?

MR. BOON: I think if -- I just need five more minutes. So to proceed with other speakers.

MS. BESWICK: That works for me.

I asked earlier if there were other speakers who wanted to be taken at this time. I'm willing to do that now.

Anyone else want to -- do you need another minute, too?

And while he's coming forward, did you want to make any comments?

MR. THIBEAULT: Is John still here?

MS. BESWICK: Is John Kemmerer still here? He's sitting in the corner.

MR. THIBEAULT: Excuse me, Jason, before you get started. It seems to me that -- and I should point out that

this is why we don't like to argue these things in front of the Board. This is why we look to do it in stakeholder sessions. Because they are complicated things that are just not best done in this kind of setting.

But in this case, it seems like a huge gulf between two opposing sides here. When really what it is is a 12-month plus approval process for LID consideration.

And it is not as though the LID process would not come in to play if John's language is not adopted. It is that it would be implemented 12 months, plus whatever time it takes for approval after adoption of the permit.

Now, in that interim time, the conventional process is still proceed. There are susump language in the permit that requires the 85th percentile treatment through structural BMPs, in the interim, anyway, it is not like the existing process has stopped. The difference is LID would be considered for new projects, but it would not be a required captured volume.

The same capture volume would still be required under structural BMPs. 12 months, plus approval. That's the difference in the language.

Now, also with the language that's proposed here, in all fairness, this requires LID principles to be kicked off now. But it doesn't mean that anybody goes into non-compliance this afternoon if this permit's adopted. The

process requires that LID principles be considered for new developments, be considered in the new process.

So it is a 12-month, plus approval time, difference in approach.

A lot of energy is going into this difference here this morning. It is really not that big of a difference.

MS. BESWICK: Okay. Jason, good morning.

MR. UHLEY: Thank you very much.

My name is Jason Uhley. I'm with the Riverside County Flood Control and Water Conservation District. I'm providing my comments today on behalf of the Riverside County MS4 program.

We would like to start by thanking the staff and the Board for continuing to work directly with the permittees, the Orange County permittees and the stakeholders to develop a permit that's objective and really considers the issues that all the different stakeholders and committees raised.

I think the statement I'm about to make is preaching to the choir. But this was an issue that was important to the city manager, management steering committee. They asked me to come here today and ask that, similar to the process that Orange County went through, that our permit be based on our 2002 permit. That to be

specific to our water quality issues. That we would be afforded the same opportunity for input and comment on our permit that Orange County has been provided.

The main concern is it's very typical for the permits to be written in stone and cut and paste to different areas. We want to ask that the Board consider that and work with us off the 2002 permit.

Thank you.

MS. BESWICK: Thank you. All right.

MR. BOON: Okay. We'll hit the reset button.

MS. BESWICK: Okay. Great. I hear the printer at work, if that helps any.

MR. BOON: Good morning. My name is Richard Boon. I'm with the County of Orange. And I manage the county-wide elements of the stormwater program.

As an initial matter, I want to emphasize our overall support for the adoption of this permit. We do have two areas of concern that I will get to.

My comments today will focus on the permit re-issuance process today. Highlight the technical changes presented by this transformative fourth term provision. Bring to your attention, as I said, was one, but now two areas of concern. And include with the statement with what the permittees think is the next and final step in the permit process.

For the permittees, this process, as Mark already laid down in his presentation, started in early 2006 with preparation of our report of waste discharge, more commonly known as the ROWD. This document presented a comprehensive assessment of the Orange County Stormwater Program which was compiled using a multiple lines of evidence approach.

We included your own audit findings, facilitated permittee workshops, the cast work effectiveness assessment guidance, and a comprehensive analysis of all available environmental quality and program performance data.

Now, ROWD identified many positive program outcomes, proposed a few changes, and included commitments to further develop the programing key areas, including a number of significant source control initiatives and development and commitment to a watershed based approach to water quality planning to complement the countywide program.

The ROWD and its recommendations were the subject of public workshops as well as stakeholder consultation meetings through the second half of 2006 and early part 2007. The staff acknowledges their receipt of this document. And it is clearly informed on the development of the tentative order.

In November 2008, we received the first draft

of the order before us. In response to this document, we readily acknowledged that your staff accepted, and indeed, incorporate many of your specific recommendations. However, the response also pointed out the permit additionally presented many new requirements.

I think were intended to ensure greater permittee accountability, extend local regulatory oversight of our community, established a new performance standard for land development, and also incorporate additional total maximum daily loads.

So the significant technical challenges. While the opportunity to engage with staff and discuss the draft order has resolved many of our concerns, and we appreciate the many stakeholder meetings. I think there were five or six of those as well as stakeholder sub working group meetings, there were another five or six of those.

There will certainly be significant challenges ahead for the permittees in developing and implementing programs to fulfill the requirements of the transformative fourth term permit.

At a time of unprecedented fiscal constraint, a number of these changes need to be explicitly recognized. The order before you significantly increases the administrative burden of the Orange County Stormwater Program by establishing additional reporting requirements

and extending our local regulatory reached.

The universe of commercial facilities, as Mark has noted, subject to inspection, is broadened by a significant number of new categories.

Mobile businesses are specifically targeted. And development and redevelopment become subject of verification of site practices for water quality protection over the lifetime of each project.

For example, we currently inspect an inventory of over 30,000 commercial and industrial facilities. For three of our largest cities alone, a broadened universe of commercial sites would entail an additional 1100 site inspections each year.

We welcome the inclusion in the draft order for alternative verification mechanisms, that Mark pointed out, to continue to work with the staff to examine how we may better prioritize or target our scarce inspection resources and also to refine the reporting processes. Nonetheless, these new provisions will require the allocations of additional resources to maintain compliance.

The land development provision certainly represents the greatest area of challenge to the permittees. The 85th percentile storm event in Orange County deposits 17.3 million gallons of rain water on every square mile of landscape. Historically, we sought to convey most of the

rain water directly to the ocean.

The order seeks to have us fundamentally rethink the urban storm management. Such that in 12 months we will have to deliver to you a model planning approval process for implementation across North Orange County that's intended to deliver landscapes capable of substantially absorbing this volume of rain water in every square mile in every storm event. It is, indeed, a transformative fourth term permit.

Certainly, we see on embracing the regulatory momentum behind low impact development approaches for stormwater management. We also recognize that the overarching water act goal and the need for more sustainable patterns of urban development require us to address the hydrologic as well as water chemistry impacts of stormwater runoff.

However, at the same time we see concerns being communicated about ground water protection from the Orange County Water District and redevelopment challenges. Also, we need to look very carefully at this desire to see the infiltration of large volumes of surface waters at rates far in excess of a natural landscape. Where up to 95 percent of rain volume would be expected to be lost back to the atmosphere through evapotranspiration. And also infiltration in the landscape underlined in much of the

Central Orange County area by shallow perched aquifers and areas of subsurface contamination.

We also have concerns about the long term viability of a disaggregated lot-by-lot approach for stormwater management.

While we believe that the land development section of the permit poses very significant challenges for the permittees, we believe the draft order sets an appropriate approach for beginning the shift from treat-and-release to low impact development approaches and for introducing new requirements for hydromodification.

It also appropriately obligates the permittees to development the detail of this program. It will be a hugely challenging undertaking, and the permittees may very well be back before you within the period of development this program element to report progress in this direction.

So that takes me to the two areas of concern. On the TMDL issue, we entirely agree that available waste load allocations should be implemented through an iterative BMP process. We do, however, need to indicate for the record a disagreement with the inclusion of technical TMDLs.

Only TMDLs with implementation plans adopted into the Santa Ana Basin Plan are enforceable and thus appropriately implemented through an MDS permit.

So the issue that has arisen this morning, I

think we have a lot of concern about the due process aspect of seeing language presented to us that was not part of the errata sheet in the first cut. And this is no reflection on the staff. We're all human. It wasn't actually correctly written.

With regard to the first change that's being suggested by US CPA, I think if there's a concern that these criteria ultimately are not forthcoming and there are projects that continue to be approved under the existing regime in the interim. I think we can better get to the concern by establishing a date, 18 months from now, whereby these default conditions would kick in, if we haven't gone to an approval of the model program. Rather than saying they apply immediately in the interim.

That said, I think the preference would be for that language to be struck in the first paragraph. But we offer an alternative for that particular instance.

And then with regard to the change in C2. There's some key words in there that have tremendous significance to everyone in the room. And with your permission, I would like to ask County's environmental legal counsel to make some clarifying remarks on that.

UNIDENTIFIED SPEAKER: Good morning, Ms. Beswick, members of the Board.

So this shows you you shouldn't come with

prepared remarks because everything is on the fly here.

So following up on Richard's comment on C2, and just generally these changes in section C. You know, I'm sure for members of the Board and, you know, for most of the general public, these -- what appear to be minor changes actually, potentially, have a fairly significant impact on everybody, all the stakeholders, everybody interested in this stuff.

It is very difficult, on the fly, to know exactly what those implications mean. And so that's why everyone's struggling with how to respond to the changes when it is not quite understood what the intent of the changes were -- and not withstanding the EPA's attempt for clarification -- what the effect is going to be.

I think -- I believe it is our understanding that EPA's proposed change to C2 would essentially require that LID principles, consistent with EPA's definition of LID, be required for this 85th percentile storm event, the design capture volume.

Again, it's EPA's proposed change. It is our understanding this provision, C2, would be interpreted consistent with EPA's definition of the principles of LID.

And that's the clarification and the comment that we wanted to make at this point.

Richard, did you want to continue or -- and

I'll just add one other point. On the striking the language in the first C1. You know, it does appear to be really a timing issue, as the executive officer was indicating.

I think it is a practical matter. I'm not sure if the feasibility criteria are meant to determine when the LID principles are feasible, it seem -- it is hard to understand how projects are going to start implementing LID principles before the feasibility analysis is done.

We understand the concern. We don't want that process to drag on too long. It seems to me, makes more sense to figure out a way -- if EPA's concern is that process, that back and forth process is going to take too long. Let's figure out a way to cap that rather than taking away the feasibility criteria.

How do projects know whether the LID principles are feasible or not if you don't have a feasibility criteria?

I think, again, as a practical matter, striking that language from C1 is not the way to do it. It would be better to -- again, as the executive officer was suggesting -- figure out a way how to make sure that process doesn't drag on forever.

And, again, these are fairly significant changes. You know, let's not get caught up in the fact that rather than them implementing in 12 months, they might be

16 months or 18 months or 6 months, you know. Let's work on the time rather than striking the criteria all together.

And I do have additional comments, but I believe -- well, following also on Richard's comment on the TMDL issue. It is -- there's a lot of tension, as you might be aware, between MS4 permits and TMDLs. And the tension arises from the standard that it is applicable to the MS4 permits. You're all familiar at this point with the maximum extent practical standards. That's the standard applicable to MS4 permits.

There's -- it is not a clear nexus between MS4 permits and TMDL implementation. But what is clear, under state law, under California, before TMDLs were enforceable, it must be incorporated into the appropriate basin plan. So in this case the Santa Ana Basin Plan.

You have to amended the basin plan in accordance with the state law. That includes getting state board approval, OAL approval, and ultimately EPA approval. If the TMDLs -- again, according to state law -- are not incorporated into the base plan, they have no legal standing, they are not enforceable by the regional board.

The tentative order in section 18 -- I think it is 18B. Yes. 18B has a whole section on the technical TMDLs.

Technical TMDLs are TMDLs that don't have an

implementation plan. Under state law, TMDLs are not enforceable until it has an implementation plan. And these technical TMDLs don't have an implementation plan, they're not enforceable.

It is not appropriate to try to implement them through an MS4 permit. They're not enforceable. Until they're enforceable, they shouldn't be implemented through a MS4 plan.

And, finally, I want to touch on the Coyote Creek TMDL. That's rather unique. The Los Angeles Regional Board came up with a waste load allocation for Coyote Creek.

There's a portion of Coyote Creek that's impaired. The portion of Coyote Creek that runs through Region 8 is not listed as impaired. TMDLs are applicable to water quality segments, water segments.

So the segment of Coyote Creek that runs through the Santa Ana Region has not been listed as impaired. So it is fine for the Los Angeles Regional Board to say, "Sources upstream are contributing to the downstream segment."

That's fine. That's happened in other places. San Francisco Regional Bay area is dealing with similar issues.

What would be appropriate for them to do is

come up with a waste load allocation that they think would help with their segment for the Santa Ana segment.

But then the next step that has to happen, rather than adopting that into an MS4 permit, the Santa Ana Board has to go through the process of listing their segment as impaired and developing their own TMDL for that segment.

That's the final step that has to happen. You can't short circuit it by relying on the waste load allocation developed from a sister region. This region has to do it itself. Implement it into its basin plan. And ideally, that's going to be consistent with the Los Angeles Board's basing plan. And everyone's happy.

You can't short circuit the process. You need to go through the process of listing the Coyote Creek segment in Santa Ana Region as impaired, develop TMDLs, and waste load allocations, and implementing those through your own basin plan.

I think that basically touches on the issues that have arisen so far. But maybe we'll have additional issues coming up throughout the day. I ask for time for clarification later on, unless there are any questions.

MR. THIBEAULT: May we respond?

MS. BESWICK: If you want to make a comment, you may.

MR. THIBEAULT: There are a couple of things.

One, with respect to paragraph C1 and C2, and, you know, and the difference that we've talked about, 18 months or whatever.

The fact that there are no feasibility criteria yet and take time period to develop them, doesn't mean that LID approach still can't be taken. What it means is that for individual projects there would have to be engineering evaluation and analysis.

And then if it turns out, as a result of that analysis, that the engineering professional feels that LID principles are inappropriate, then there's a section in the permit that we've all read, Section 7: "If site conditions do not permit infiltration, harvesting and reuse, and/or evapotranspiration of the design capture volume at the project's site as close to the source as possible, the alternative discussed below should be considered and credits in lieu programs may be implemented," so -- "may be considered." And then it goes on to Section 9.

So there's an off-ramp. If LID is feasible, as a result of the individual project evaluation, then you implement it. If it is not feasible, then the permit provides the alternative that can be taken to address the fact that certain areas are -- certain projects might be infeasible for implementation for LID principles.

MS. BESWICK: Thank you.

Any other questions or comments for the speaker?

If not, I'd like to move along, if we could.

Richard, you have more?

MR. BOON: No, I'm finished.

MS. BESWICK: Thank you.

I'm going to ask Paul Singarela to come forward now. And Paul will be followed by Mark Grey.

If people want to, again, get ready to speak.

And followed by Eric Strecker.

MR. SINGARELA: Good morning, Madam Chair, members of the Board, Executive Officer Thibeault.

Paul Singarela here this morning on behalf of the Construction Industry, Coalition for Water Quality.

I want to say I was a participant in the process that the executive officer described, went on for about four months, a number of those meetings. It was very good faith, earnest process. Everybody really participated productively. And we all learned a lot about the terms. What LID means. What EIA may or may not mean.

And here we are today. I think the process has run its course, and there was fruits of it.

We're adjusting to a permit that's in flux. And that's always very difficult.

I came here to talk about one permit. And I'm

going to have to address a different kind of permit here this morning. So bear with me. I'm going to have to make two presentations. I'm going to go as quickly as I can through this.

I think on this page, here, it is a very important page with C1 and C2. I understand that US CPA's overarching concern is simply to make sure that conventional BMPs, you know, putting in trash interceptors in an existing catch basin or something like that, are not elevated to the same level as the low impact PMBs, what we've all been calling LID BMPs.

We understand that. We have no intent of trying to use a trash interceptor struck into an existing catch basin as a way to comply with these new LID requirements. We agree with EPA on that.

I also understand that EPA would not stand in the way if this Board wanted to recognize the broader conception of LID that we're asking you to take under serious consideration. And that broader conception LID simply introduces, in addition to the onsite, keep it onsite, retention BMPs, simply introduces what we call "biotreatment." Which, in essence, many of you are familiar with the IRWD.

Biotreatment is natural treatment. Running stormwater through some vegetative system that allows some

runoff to flow offsite.

Our understanding is EPA is fine if this agency and this staff get behind biotreatment and elevate it to the bask of LID BMPs that are available. I think there's a question over whether you're doing that. It is a significant question.

One way to get at that issue would be in C2, the first sentence, in addition or in replacement of "capture" to substitute the word "biotreatment."

And understand why we're focusing on the first sentence of C2 that's perhaps the -- or one of the few penultimate sentences in this permit. And we very much need to know what it means. And right now the BMP options, you can read them, are infiltrate, that's keep it onsite; harvest and reuse, that's keep it onsite -- that's rain barrels and cisterns; evapotranspire, that's keep it onsite and make it disappear -- I'm not quite sure how that happens -- or capture.

Capture, kind of ironically, seems to be the only vehicle through which a new development is going to be allowed to have runoff. But it is an ambiguous term that calls for some articulation.

You can think of capture of perhaps, you know, trout fishing, catch-and-release trout fishing. You catch the fish. You lovingly release it back into the stream

after proper treatment. That's our view of what "capture" means. Catch and release. You catch it onsite and then you treat it with biotreatment and then you actually can still have some runoff leaving your site.

We don't think that EPA objects to that. We think some work can be done on that first sentence. Perhaps just a word change or perhaps some delineation on the part of the Board to make it clear.

Going to the first paragraph, I think what the County meant to say is that it is in favor of seeing that language restored. They were speaking of the stricken language. I know that my client very much would like to see the language restored. I didn't see -- I didn't hear US EPA making a substantive objection to this language.

This language is huge for us. We're talking about feasibility criteria. And how do you judge all the BMPs in this new world of LID BMPs. If it is a timing issue, there are many ways to address a timing issue. But just eviscerating the issue doesn't seem to be the logical outcome of Mr. Kemmerer's comment on that provision.

And then thirdly, this new sentence in paragraph two, C2 -- by the way, you should know that this paragraph, without all these changes, pretty much came from NRDC and their recent comments. There were a few changes.

For example, the word "capture" was not NRDC's

word. That word was recommended by the County. But we're talking about, basically, an NRDC paragraph here. And now we've got the new NRDC sentence added to it.

And going back to EPA's concern, EPA's concern is to make sure you're not elevating, you know, the catch basin trash interceptor to a LID BMP. I don't think you need to do this, this new sentence, to accomplish that.

By the way, what this does accomplish, I think -- and we're, you know, interpreting on the fly -- it means that Gery Thibeault is going to be a very busy man. Because when you get referred to 12E, that's a waiver upon a vigorous showing -- that's a permit term, vigorous. I've never seen that word in a permit -- a vigorous showing of technical feasibility, you can get a waiver from Mr. Thibeault.

Well, Gery's a busy guy. I'm not putting a lot of stock in the waiver provision. If you went to 12E, you may forget about it, especially given how long it takes to process things like that. So for a real project in the real world, 12E is not where you want to be.

I asked the staff and Board to consider, can we actually accomplish what Mr. Kemmerer wants without that sentence?

And I think what he may be trying to do is avoiding several off-ramps to having to do it onsite, having

to do LID onsite.

Those off-ramps are in paragraph 8 of what is in front of you. 8A, 8B, and 8C -- those are off-ramps. They're not meant to be off-ramps for LID. I think EPA is interpreting them to be off-ramps for LID. And they're not meant to be.

I think there's a word in there, perhaps distasteful to Mr. Kemmerer. It's the word "treat." I think he looked at 8A, 8B, and 8C and said, "Oh, boy, 'treat.' Well, that's the catch basin insert. We don't want that. EPA doesn't want that. We don't want that." So perhaps some work on those paragraphs -- 8A, 8B, and 8C.

By the way, with your errata, are 7A, 7B, 7C, and 7D. Whatever you're looking at, you need to work with some shifting paragraph numbers there.

But, perhaps, just change the word "treat" to "biotreat." And make it clear it is not the conventional BMP that Mr. Kemmerer was concerned about. And maybe we can save the off-ramps.

What are the off-ramps from? From having to do the LID stuff onsite all the time. Just ain't going to happen. There are going to be plenty of circumstances where we need to move a little bit offsite. We need to move subregional.

What does this Board care if the LID is

accomplished within the four corners of an acre or even ten acres if a developer can avail itself of something nearby to accomplish the same water quality benefit.

I'm responding to this now. I see three major issues there. Perhaps they can be worked out today. It is a little bit difficult to do this on the fly. We want to be constructive, as we've been all along. And we wanted to present some ideas to you that will clearly require some further discussion as this day proceeds. The day becomes much more complicated by this.

What I really wanted to talk about --

MS. BESWICK: This better be good.

MR. SINGARELA: What we'd like to do today is persuade you that there's a major fork in the road here. You know, the Robert Frost, The Path Less Travelled. There's a fork in the road here.

And that fork has to do with LID stuff. Are you -- and this is a matter of policy. Are you going to embrace a broader conception of the LID? Or are you going to embrace and adopt and require this narrow conception of LID that's not consistent with the EPA definition?

The narrow conception of LID is being promoted by NRDC. They want it onsite. They say, "Hey, if you keep it all onsite, there's no pollution. There's not a single molecule that gets off site."

That has a simplistic appeal to it. It just doesn't hold up to scrutiny. And, by the way, it is inconsistent with EPA's definition of LID. It's inconsistent with the State Water Board's definition of LID.

Those definitions of LID allow filtration. Filtration is understood to be, what we call, biotreatment. The State Board's definition of LID allows for detention. What NRDC is talking about is retain it, retain it, retain it onsite all the time. 100 percent detention.

The State Water Board's word is understood to mean slow it down, treat it perhaps with biological process and actually allow the runoff to continue off of the site.

This is a huge choice here. Let me just try to illustrate it for you. The 85th percentile storm. This is one of the products of the negotiation. We're happy that we agree what the design capture volume should be. It is a big deal.

Under the existing scenario that Mr. Smythe showed to you -- under the existing scenario, an undeveloped piece of land, that entire 85th percentile volume comes off the property. We're not in BMPs. We're just undeveloped land. That entire volume goes off the site.

Think about how dramatic NRDC's proposal is. Under NRDC's proposal, all of that water is going to stay on that property. And then think about our proposal.

Our proposal is much closer, actually, to their proposal than it is to the undeveloped state. In our proposal we say, "Yes, we'll try to keep it onsite." That makes sense. We don't have anything against infiltration BMPs where they make sense. We don't have any objection to harvesting, this new concept of harvesting and reuse, if it makes sense. We don't have any objection to evapotranspiration BMPs, if we can figure out what they mean.

We don't have any objection to those three types of BMPs, which is what they would limit us to. And they would make us do all that on site.

Our proposal is to do that when it is feasible. And then simply to add one more category of BMP. It is simply the biotreatment category of BMP.

A biotreatment category of BMP also requires the entire volume to be treated, but it is the catch and release version of LID. It requires good treatment through natural processes and then a discharge. It allows a discharge to come off the site.

Now, you can understand why that one word in C2, first sentence, is so important to us. Because we're actually relying on one word here, "capture," for our whole conception of LID. It is very scary to a certain extent. It's very tenuous. And I think you can appreciate some of

the angst we're suffering here today. I think you can appreciate why we're asking this Board to make this choice very clear.

This is a policy decision. This isn't technical.

MS. BESWICK: And I think we got that.

MR. SINGARELA: Okay.

MS. BESWICK: I don't mean -- but, I mean, that was what you started with. And we understand it's a policy decision. And, actually, it has been discussed at the Water Quality Coordinating Committee with other regional boards as well. So we get that.

MR. SINGARELA: Thank you.

MS. BESWICK: And I'd kind of like to move it along a little bit. I have an awful lot of speakers. Some that want ten, fifteen minutes.

MR. SINGARELA: I understand. I'll wrap it up.

So make no mistake about it. This narrow conception of LID that NRDC wants you to embrace as a policy for this region is zero runoff. It's zero runoff for new development, all the way up to the 85th percentile storm. Yeah, of course, if you have some Noah's Ark storm, they'll let you have something come off the property. But it is a zero runoff proposal.

So what are you saying? Well, what you would

be saying if you were adopting this permit is all new development can't actually use the public storm drain. You're cut off. You're stranded. You're an island from the public storm drain. Is that what you want to do? Does that make sense as a matter of policy? It doesn't make sense to us.

And contrast it to everybody else that's already using the public storm drain. Where is the existing water quality problem coming from today? From the rest of the basin.

We, the developers, who are using the best BMPs, are penalized and denied access to the public storm drain. That is what you're being asked to embrace.

I say to the agency, it ought to get all your questions answered today. You ought to deliberate on this. This is a huge issue for the future of this region. And we think when you really put it to scrutiny, you'll come to us and let us continue to use natural treatment systems like the IRWD approach. You'll let us use those in addition to the three narrow BMPs and let us use it onsite or offsite.

Thank you very much, Madam Chairman. I appreciate the patience.

MS. BESWICK: Thank you.

MR. PON TELL: Madam Chair?

MS. BESWICK: Yes.

MR. PON TELL: Could I ask a question? Because it is one of my questions, and now it is being introduced. Maybe the staff could just explain something to me.

MS. BESWICK: Sure.

MR. PON TELL: I am curious about the 85th percentile. Is that -- why not 84? Why not 86? Why not 70? And how does it correlate to what the natural flow from the natural property would have been with or without development? I'm curious. What's the logic behind that?

MR. THIBEAULT: The 85th percent --

MR. ADACKAPARA: The 85th percentile was something that was adopted by the Los Angeles Regional Water Quality Control Board, what is called the susump requirements. Those susump requirements were challenged and they stayed -- when the Water Quality Control Board finally upheld what the Los Angeles Regional Water Quality Control Board adopted.

And that approximates to about 95 percent of the storm event. So essentially what we're saying, if you treat the 85th percentile of the storm, you capture about 95 percent of the runoff. It was based on that.

And then that order that the state board adopted was considered as a precedent-setting order. And the chief counsel from the state board issued a memo saying all boards needed to adopt this.

So the 85th percentile comes from that.

MR. THIBEAULT: And, further, Mike, what I was going to say is the 85th percentile capture or treatment is already part of the WQMB for Orange County. It is something already being implemented under the existing program. So it is not a change in direction.

MR. PON TELL: So just as -- not as water hydrologist, explain to me the logic behind capturing and depending on the definition to the extent possible, retained onsite more water than would have normally been retained onsite. If the site was undeveloped, and assume 80 percent of the water was running off the site, as opposed to 85 percent of it being captured now, what's the rationale?

MR. ADACKAPARA: Under natural conditions, most of the water will be evapotranspired or percolated into the ground.

MR. PON TELL: Define "most."

You said most of the water will be -- because depending on soil conditions --

MR. ADACKAPARA: I don't remember the exact numbers. But it is pretty close to 90 percent of the water that falls on the soil. That's for undeveloped land. There's no structures on the land. There will be trees and bushes and other vegetation to take care of the water that falls on the

land. So most of the water will be percolated.

And the numbers -- if I'm not mistaken, it is pretty close to 90 percent of the water that falls on the ground.

MR. PON TELL: So the 85 percent would correlate to what would be naturally retained without any development?

MR. ADACKAPARA: That's right.

MR. PON TELL: That's the intent?

MR. ADACKAPARA: That's the intent.

MR. AMERI: Let me just explain something here.

The 85 percentile is not 85 percent of a pre-construction. It is 85th percentile of the average rain fall during the year which essentially comes out 95 percent of any kind of storm event that happens in Orange County.

In other words, the new development will not be able to drain any water to the storm drain system 95 percent of the time during the year.

MR. PON TELL: Is that correct or --

MR. ADACKAPARA: That's reasonably accurate, yeah.

MR. FRESCHI: That sounds very narrow to me. I agree with the gentleman. That's a narrow imposition on the building and the development -- building or development of the property.

MS. BESWICK: If we could. I'd like to finish hearing the speakers, and then let's talk about that. I

think we need to do that.

Mark Grey, followed by Eric Strecker.

MR. GREY: Chair Beswick, members of the Board, staff.

Mark Grey, representing the Construction Industry Coalition on Water Quality.

I'm going to -- Paul covered a number of the areas today. I'll endeavor to be as brief and snappy and entertaining as I can.

MS. BESWICK: You're off to a good start.

MR. GREY: Thank you.

First off, so you know who I'm representing. I'm the technical director for the Construction Industry Coalition on Water Quality. And I represent the management and the labor, the women and men who build most of the projects that we are providing conditions for in these permits in Southern California. And I represent the Associated General Contractors of California, the Building Industry Association of Southern California, the Engineering Contractors Association, and the Southern California Contractors Association.

Again, it is a coalition of management and labor, women and men who build the infrastructure and housing needs throughout Southern California.

MS. BESWICK: Can I add, then, is Paul in your

employ on this subject?

MR. GREY: Paul works with us, and also Eric, after me, works with us.

MS. BESWICK: Well, try and only cover things not already covered.

MR. GREY: Exactly. I've got a presentation.

There were some changes today. I'm going to cut to the chase on a couple topics that Paul -- I don't think he covered in detail.

First off, what I want to cover today -- next slide, please. I wanted to make remarks on the progress we made in the stakeholder group that was an excellent process. We did have a divide in that process. Paul talked about that divide.

Universal retention of the 85th percentile storm, which, for the audience and everyone else, that equates to three-quarters of an inch to, maybe, in the foothill areas up to an inch and a half of rain fall. Something we can all relate to.

We're talking about handling, in low impact development BMPs, three-quarters of an inch to an inch and a half, depending on your location. We reached this divide in the stakeholder group.

I'm going to present a couple slides on low impact development definition from US CPA and the

State Water Resources Control Board. Very important definitions that we're asking staff to help us clarify and make sure that's what you mean in the permit. That's my clarification point.

Next slide, please.

We have a great history of progress. Great history of collaboration, supporting stormwater management sound solutions in Orange County. We really -- I want to point out we support this master planning concept into the permit. Very important. Can guide us in infiltration, where infiltration suitability. Can guide us where harvesting and reuse makes sense. Relative to what agencies like Orange County Water District is doing. Where it is appropriate. Where is it is not. We are very supportive of master planning in this permit.

Next slide, please.

The divide -- Paul mentioned the divide. We don't believe that universal retention makes sense for low impact development. Filtration of water through engineering BMPs is an essential tool in using LID principles. This is widely recognized and is recognized in national programs.

And now if I could just jump to what would be slide five. Go back, please.

The US EPA LID definition, this appears in the green infrastructure glossary. We've provided the cite to

Gary, Mr. Thibeault and Mike Adackapara, part of the staff has the citation.

LID, a comprehensive stormwater management insight design technique. Within the LID framework, the goal of any construction project is to design a hydrologically functional site that mimics predevelopment conditions. This is achieved by using design techniques that infiltrate, filter, evaporate, restore, and runoff close to the source. I added the emphasis on hydrologically functional and filter. "Filter" is an important word. "Filter" means biofiltration. It means biotreatment. It means treat and release. That's what we're asking for in this permit. That the conception of LID includes not only infiltration, harvest and use, evapotranspiration, but biofiltration as well. Very important and critical.

Next slide, please.

State Board definition. This is our State Water Resources Control board. The goal of LID is to mimic the site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and retain runoff close to the source of rain fall.

I think you get our point. "Filter" is a very important word here.

I would like to jump to slide 7 and 8, please.

There's been quite a bit of talk, and what I'm

going to skip over that I'll provide in our comments. There's quite a bit of talk about national programs. How much water they handle, what LID BMPs are allowed in these national programs.

We've examined them very closely and provide on the record, really, what are in these national programs and what they require. I just offer that to staff and to the board members for your use.

Next slide, please.

Next slide after that.

Before I go here. I ask you for just a few clarifications. Number one, we are seeking clarification that the LID performance standard permit and anticipate the use of all LID BMPs, including LID treatment BMPs that release water.

I think I made that point over and over. I want to re-emphasize. That's very important to us. We hope you please confirm that the definition of low impact development BMPs that's used in this permit is constant with the EPA definition. We would appropriate that clarification. And I've got other comments on the slide that can you see.

Next slide.

Number two in section C2, this word "capture." That's very ambiguous and vague. We prefer it be

biotreatment. It could also be biofiltration or filtration. We feel strongly that the word "capture" provides a tremendous amount of ambiguity.

And I'm trying to be brief, Chair Beswick.

Number three, the last clarification that we seek. We request that the word "strategy" in section 12C3, which is obviously after two, replaced with the word "preference."

And there, somewhat, we think that this would support staff's intent, and we've talked to Staff in length and stakeholder groups and subgroups that we talked about LID BMP sizing about prioritizing various LID measures. And we think this change would support Staff's intent of prioritizing but not mandating the mimicking of predevelopment hydrology. This then would be a directional statement and not a mandate.

I conclude today in my remarks -- last slide, please. We support LID at the Construction Coalition on Water Quality. We support the full conception of it. Not allowing it to be zero discharge. That doesn't make sense. It doesn't mimic predevelopment hydrology. It doesn't necessarily match the water balance.

We feel there's a strong technical and legal foundation for that, allowing some runoff from the property.

And finally, as I pointed out, I asked you to

seek clarification on some points. Especially, the LID definition provided by US EPA and a couple word changes, that you can see from the deliberations today, that C -- 2 some of the language, especially the word "capture" caused confusion. We think by adding the word "biotreatment" or "filtration," that that would clear up that ambiguity.

Thank you very much. Welcome any comment or questions.

MS. BESWICK: Anyone have questions?

MR. AMERI: That's at least very important to me. Mike, could you provide us with an actual written definition of LID by EPA and by the State so we can actually -- not that we don't trust you.

MR. GREY: Thank you.

MR. ADACKAPARA: There are actually a lot of definitions for LID. Some of the definitions do include filter as an option. Some definitions do not include filter as an option. I don't know if there's one legally defensible definition.

There are so many definitions. Even if we look at EPA site. The EPA itself has several definitions for LID.

The State Board has come out with some definitions. Most of those definitions do include filter.

MR. AMERI: You're handing me to the website.

John, do you know if these definitions are the correct language?

Is John still here?

MR. KEMMERER: Yeah. I have provided -- Mary Lynn just said -- I want to make sure, in our submissions to the Board, we provided all the links of the sources. I would agree with Mike, most of the definitions include the word "filter."

MR. AMERI: I didn't know the word "filter" was included in the definition of EPA and State language for LID. I really didn't know that.

MR. FRESCHI: Is a copy of your presentation available to us? I don't have it here.

MR. KEMMERER: Yes, sir. No, I have not.

MS. BESWICK: No hard copy. I don't think we have a hard copy of your slide.

Mr. Kemmerer: I'll get one made.

MS. BESWICK: Thank you.

MR. FRESCHI: Just the definition page. That's all I'd like to see.

MR. KEMMERER: We have provided it in some attachments and letters to the Board.

MR. AMERI: On that big --

MR. KEMMERER: I'll be happy to find it and pull it out for you, Chair Beswick. May I?

MS. BESWICK: Okay. While he's doing a search, we'll have Eric come up and address us. After Eric, we'll have Greg Woodside.

MR. STRECKER: Madam Chair and the Board, I'm pleased to be here today. It has been very intellectually stimulating to be involved in the consensus building process up to this point. But I'm going to be the technical nerd here and get into the engineering side of things. I'll try to be as fun as an engineer can be.

If I can go to the next slide.

Just a brief introduction on myself. I've been a registered civil engineer in the State of California since 1987. I've got almost 25 years experience helping folks think about both the applied research side of urban stormwater as well as actually getting things into the ground. I was a member of the Blue Ribbon Panel to the State Board on whether numerical effluent limits are feasible in the stormwater permits. And I've managed a number of other projects. And I won't go through the rest of those.

Next slide.

I think we need to step back and see what makes stormwater BMP effective or not. It's really a function of a number of parameters.

First one, what does the runoff look like? How

does it arrive? How do storms arrive? Do they come together? Are they spread out? Those kinds of thing.

Next thing you need to think about, what kind of volume am I going to have to store that water, either temporarily -- I guess it's all temporary -- until I can infiltrate it, evapotranspire it, harvest and reuse, or draw it down. So -- and I just alluded to the next part, how we look at BMP function. It is not about the size of the facility. It is about how fast I can recover the storage, so I'm ready for the next event.

If the tank is full or the bioretention system is full, the next event comes and I'm bypassing. And I don't get the treatment or capture onsite or whatever the goal is.

And finally, what's important is the treatment processes included. What are the physical, biological, and chemical treatment processes that I include in the system to get after the pollutants and parameters of concern. And that, to me, is an issue even with infiltrate. I want to make sure before I infiltrate I'm doing the right processes along with if I discharge from the site.

Next slide.

So let's talk about weather patterns -- it's actually applicable to the West Coast. The West Coast, if the high pressure ridge is up, we're not getting a lot of rain. We might get a freak thunderstorm once in a while. The high

pressure ridge is down, we get a series of storms coming through, pretty much, back to back. That's very different than other parts of the country. Say, if you go to the East Coast where the storm patterns are much more regular throughout the course of the year.

In addition, much of our runoff falls in January and February. And next highest portion is in December and March, so those are really when the rainfall comes.

So the results of that is when we look at harvest and using for irrigation onsite, it is very different. We are getting all the water at the same time. It's very hard to use that in a way for irrigation. And then evaporation opportunities are limited. We're getting rainfall at the same time we want to be evaporating.

Next slide.

One of the things I haven't heard in a lot of this debate is thinking about what is really the natural water balance. One of the things I'll fault LID with today, they haven't thought about ground water. Everybody's focused on mimicking hydrology. And hydrology, to me, as a practicing engineer, does not include just surface runoff. It also includes what infiltrates and impacts ground water.

So in Southern California -- and I can -- the citations are in some of the submittals I have given to

you -- roughly on the order of 80 to 95 percent of precipitation on undeveloped lands is evapotranspirated. And then somewhere between 2 to 10 percent is either runoff on an average annual basis or deeper infiltration.

You know, and when we put in impervious areas, we reduce the area we can use for evapotranspiration. And if we have a goal as a society in having dense developments that, again, limits the ET areas that are available. And we can help mitigate that by putting in things like green roofs and porous pavements.

But, you know, I look at how applicable those are in all conditions and whether they're going to work everywhere.

Next slide.

So let's talk about infiltration. The first question, can you do it? And much of the soils in Orange County have very limitability to quickly infiltrate. I don't know how many of you have dug a hole in the ground to plant a tree. And you put water in it and see how long it sits there.

I would also argue that soil amendments -- you can put soil amendments in the hole, all you're doing is reducing the storage of the hole. The water's still going to sit there for a long time. You really have to think about what are the underlying soils. You're not going to

fix the problem by just amending the soils on the site. You might increase the storage, but, ultimately, it will not fix the problem of getting the water in the ground.

So when that storage that's provided in infiltration is full, bypass occurs.

Next slide.

The next question you have to ask. Should or how much should I infiltrate?

So I think about things like where I have natural plumes like selenium out in Peter's Canyon Wash area. There's manmade plumes. We have areas upgrading of dry streams, if I shove a bunch of more water in the ground over natural conditions I might convert to a willow Arundo thicket. And I'd like to say, Mr. Toad isn't happy in that circumstance.

That was a joke. Sorry.

If I don't match ET rates, then I'm going to have infiltration -- if I use infiltration to match runoff, I'm going to have increased infiltration over natural conditions. Is that a good thing? I would say, if I was in an aquifer that's being managed, great.

You know, Central Valley, California, where they're pumping the heck out of that thing, I'd be infiltrating in a safe manner as much as I could. But in watersheds where that's not the case, I would be thinking

about that.

Next slide.

The next question is, if I'm going to do it, I need to do it carefully. I need to do it in areas above the water supply aquifer or unnaturally low for some circumstance, but up to a certain point to get back to where it should be, and it must be done in a way to protect the water supply. We need to work with water agencies and say, "Let's do this in a way you can live with." So bottom line, infiltration should be carefully thought through on a watershed-by-watershed basis.

Next slide.

Let's talk about evapotranspiration. After development, there's going to be less area of evapotranspiration available. So even with vegetative roofs and especially in high density projects. It's not appropriate to compare monthly precip to monthly ET rates when one's looking for using ET as a way to get rid of stormwater. Again, the storms arrive back to back. And storage within the soils are not going to recover enough when the next storm arrives.

On the next slide, this is the -- the magenta color is the average monthly precip in Irvine. And the green color is the average monthly evapotranspiration. And a point has been made in some of the submittals that when

you look at December/January, they're roughly equivalent, "Why can't we do it?"

The next slide shows weekly values. And here the blue, again, is rainfall on any given week, or average for a week and the evapotranspiration levels. So you start to get an understanding that I'm getting a lot of water when my evaporation rates are low.

The next slide.

Here's a natural site, you know, predevelopment. I have the whole site to use as my ET. I like to call it the sponge. You know, after I develop and put in bioretention areas, shown in blue -- let's say, in this example, even if I put green roofs on all the houses, that's not the same level of sponge pre and post. And so we have the difference between ET levels and precip as it comes, and then compounded with the fact we don't have as much area to use for evapotranspiration.

So the next slide.

We also have an issue from a vertical standpoint. Again, I've got the system spread out. I can amend soils in the bioretention area. I can amend soils out in the rest of the site as well to try to act as more of a sponge. And I should do those kinds of things. But I'm only going to have that certain area of a small bioretention area, in this particular case, to do my, you know, storage

of the runoff from the site and get it into the ground.

So next slide.

What are the general water balance implications? I'm not the top chart -- this will be different for every site. On the top chart, in semiarid climate, I'm showing a 70 percent ET. I mentioned earlier it can be much higher than that.

Let's say, you know, on site it is 10 percent surface discharge and 20 percent percolation. If I put in LID to match pre and post runoff, I might have 70 percent percolation. In the water supply reservoir, great. In somewhere where that's not appropriate, that's a potential habitat change issue or other issue, ground water table, elevation levels, and the rest of it.

So my point in all of this is we really need to think carefully, you know, where it is smart to infiltrate and how much ET can I really get on a site.

Next slide.

So let's talk about capture and reuse.

One of the projects I had the pleasure to work on with the Irvine Company is the Pelican Hills Resort. And that was a unique condition. We actually have cisterns -- you're seeing a picture of a 650,000-gallon cistern that was put in. We drained a Crystal Cove in this project. A highly sensitive project.

The Irvine Company asked me to come up with a way to have no increase of runoff. And they wanted to increase infiltration. I say, "What do I have left to play with?"

What I had was the evapotranspiration sponge. And looking at irrigation on just the site, I couldn't get there. Fortunately, I was next door to a 36-hole golf course; I could get there with the greens because they do water those relatively soon.

So the key for capture and reuse is having a use for the water in the first place. Can I use it for irrigation or toilet flushing or some other process water?

The second one is being able to use it. There's lots of code issues that we haven't talked about today.

And the third one is being able to get rid of the water fast enough. And if I can't get that tank drained within a 2- to 3- to 4-day period, the next storm will come along and start bypassing the system. So it will not be as effective.

Next slide.

So this is a slide, actually, where I did a double damp size tank. And this is a series of storms. I picked an example from 1962.

So you can see in February of '62, there were

quite a number of storms that came back to back. What it is showing, there's, you know, bypass events going on every event during that sequence there and then releasing runoff. And this was a tank designed for 1.6 inches of capture from the site. Not the damp size.

So next slide.

And what happens when I look at pollutant loadings? Now, I'm back to a damp size tank. But I provided you guys an example of a hundred acre residential development where I use a cistern for capture, and used for both irrigation and toilet flushing. I've probably over assumed irrigation because I used the simplifier approach to that, and it's probably less available than I came up with.

And toilet flushing I also used some numbers that when people -- for those of you who can't go to the men's restroom, there's no flush urinals in there. If I was going to make this work, I'd want high flush urinals in the winter and no flush in the summer, I guess.

So the bottom line is when I looked at over average annual pollutant loading basis on the capture and reuse, assuming I didn't treat the bypass, I would only capture -- remove 55 percent of the load of TSS, that's total subpoenaed solids. Or with bioretention with under drains I would remove about 63 percent.

I would say, in this case, I would argue that

the bioretention with under drains was a better solution.

Next slide.

And then if we look at the average concentrations coming out of the systems. With the cistern bypass, again, provided you don't require an extra treatment beyond the cistern size, then we're releasing at the inflow concentration. So we've had no treatment for that bypass.

So the other point I'd make is the bioretention with the under drains is resulting in a lower concentration on an average annual basis as well.

So the point here, again, we got to drain the tank fast enough, similar to the drain range for ET and infiltration systems.

And we're talking about the 85th percentile storm earlier. And that, actually, in studies around the country has shown to treat about 80 percent of the runoff. And that was assuming about a 36-hour drawdown time. And that's how that number was first developed. It was a study by Better Bonus at Urban Drainage in Denver. And along with Larry Rozner (phonetic) who's now at Colorado State.

Again, as a key element, it is not just the size of what you require, but also the drawdown rate was included in that.

We have irrigation, you know, use is limited

with these systems, seasonal issues. You know, there's a big push to do zero scaping. So drought tolerant plants. I have some suggestions, "Why don't you overwater for a long time?" I'm thinking, what's a plant pallet that likes to be dry and then also be flooded for a long time. There's issues there.

Competition for reclaimed water. You know, if we require folks to do this for toilet flushing. About the same time that IRWD has the worst time to get rid of reclaimed water is the same time we would be trying to use it for irrigation. And all of a sudden, we have a conflict between those two things.

One of the things I have looked at -- I have come up with a new name for a ratio. I'm calling it TUTIA. And I do think if you do have enough toilet flushing -- toilet users to impervious areas, you can actually show -- it can work.

I did this in a building in downtown Los Angeles. And we were going to combine it with the Gray Water System. And I could show it could work cost wise, got to a reasonable standpoint. Unfortunately, I ran into the City of Los Angeles building code folks; it was "over my dead body" in terms of that -- being able to do that.

I think there's some points where some of these

systems start to become more viable when you have enough processed water use.

Finally, this next slide -- just so you guys are aware of some of the infrastructure you would need. You've got to think about the conveyance and pretreatment to get the runoff into some sort of a storage tank. There's treatment issues. If you're going to use it for irrigation, particularly, in a pressurized system, you're going to have backflow valves, UV treatment, and the rest of it, pumping and piping and all those kinds of infrastructure issues.

And, again, I think in certain applications it makes sense. And other ones we might ask the question.

So next slide.

That just gives you a summary of some of the codes that we're going to have to think about. So in summary on harvest and use, I think, we need to be -- carefully consider where it makes sense or not.

Next slide.

You have seen this definition, so I'm not going to go into that, the first one.

The second one, I think, is important, though. There was a National Research Council report put out. It was called Urban Stormwater Management in the United States. In that report they retitled LID -- they use their own term, Aquatic Resource Conservation Design.

Next slide.

In that document, they're quote, "ACRD offers an array of techniques to reduce the quantity through infiltration and evapotranspiration and improve the quality of any remaining runoff. These practices included" -- and I'll point you to things like swails and filter strips and other things that are not retained on site type BMPs.

On the next slide they actually recognize that in some situations the practices may not be feasible. And then they recommend using the best combination of some of the more traditional controls.

Next slide.

The last thing I'll end with before I summarize, is I do think we need to take a watershed approach to this. Every watershed has unique soils, contamination issues, ground water quality, land uses, ground water elevations, receiving water sensitivities, and the rest.

And I get concerned when we have a one size fits all solution that starts limiting what I think might be the best solution. I think we need to work through the watershed approaches that address all of the elements I have up there.

So in summary -- next slide.

We need to think about the precipitation

patterns and how they effect the performance of these systems. Infiltration is not broadly feasible, effective, and/or desirable in all cases. Harvest and use and runoff due to runoff patterns and ET potential has limited application. We should try to do as much as we can. And I've tried to do it on my projects, but it is limited. And then LID and the permit should include all of the elements of LID, including source control -- we haven't talked a lot about that today -- retention, detention, and filtration.

I thank you very much for your time.

MS. BESWICK: That was great, actually.

Thanks for being as brisk as you could be with that. There was a lot of the information.

I'm asking Gery, -- I think it would be important to have you comment on this issue we've heard thoroughly discussed now about asking that people retain only onsite.

MR. THIBEAULT: I would like to point out, first of all -- Eric, I hope you were listening. Eric gave, you know, an awfully good proposal for his company to do the feasibility studies that Orange County needs. And I want to make it clear that what was just described here is what we've asked for in the permit. Someone to do the evaluation, to look at the feasibility.

If you're getting the impression that we're

requiring everything be retained onsite, then someone is giving you the wrong impression.

What we're requiring is the county to do what Eric just described. Go through the feasibility and, you know, I know we'll say it 50 more times, but we want to make sure that where infiltration or capture or whatever the other options are, are not feasible, no one is suggesting that they be required.

And if you are made to feel like that's what the permit requires, I suggest we need to look at it again. It says, if not feasible, don't do it.

And so this type of evaluation -- and Eric's done a lot of these things. I mean, he's had a lot of experience. This is exactly the kind of feasibility study we are looking for from the permittees.

MS. BESWICK: And earlier when Mark was talking, he talked about technically-based feasibility criteria. Is that what we're looking for as a result of the feasibility study?

MR. THIBEAULT: Uh-huh.

MS. BESWICK: I guess it was important to make sure we all understood there's not one method being purposed here. It is just awfully focused on one thing. I want to make sure we're not losing sight of the broader picture.

Greg Woodside, followed by Garry Brown.

MR. WOODSIDE: Good day.

Greg Woodside. I'm here for the Orange County Water District. I'm the planning and watershed management director.

Just a couple points. We're concerned -- we've commented and we've talked with your staff. We're concerned that if infiltration systems are not operated correctly, they're not maintained correctly, there could be impacts on ground water quality.

There have been studies in other areas in LA County about infiltration systems like these. And there are no adverse impacts to ground water quality found if they're maintained and operated correctly. That's what the studies showed.

We don't have that kind of data in Orange County. We appreciate the fact that the permit now has a pilot ground water monitoring program. We think that's important. We appreciate that inclusion.

We certainly feel that infiltration is not feasible in all locations. That's been discussed already.

But there are conditions, such as shallow ground water, where infiltration might not work.

We do --

MS. BESWICK: Say that again.

MR. WOODSIDE: There are conditions where

infiltration just may not work because of shallow ground water.

We do encourage infiltration to the extent practical at a regional level. We feel if it's at a regional level, or a subregional level, you know, more of a clustered implementation, it will be easier to monitor if there's any potential impact. We think that's something beneficial.

We have one technical point. It was mentioned earlier, the separation. There's the separation distance between the bottom of the infiltration system and the seasonal high ground. We have a little diagram here that shows what we're talking about.

So simplified graphic here. We have the ground surface. We have what is call beta zone or dry well type infiltration. That's symbolized by the well. And it's above the saturation zone, it's above the seasonal height ground water level, in the what we call beta zone, or unsaturated zone.

And the current draft has a five-foot separation between the bottom of the infiltration system and the high ground water elevation.

The previous draft was ten feet. And we would request that they go back to the ten feet.

MS. BESWICK: By the way, we have a monitor down

here. We're able to see what you're showing us.

MR. WOODSIDE: The question marks were there because there's a degree of uncertainty about what the elevation is for the seasonal high ground water table.

The Water District, ourselves, we have a lot of data. The data is deeper. We don't have a lot of data to say where the seasonal high ground water table is in some locations. Now, in some locations it is pretty well defined. But there's other locations where the seasonal high ground water table is not well defined. There's uncertainty about what depth it is.

We would strongly request we go back to ten feet, so that there can be a margin of safety there.

The data that's out there shows, if these systems are built in the unsaturated zone, they will work. We need to make sure that they're in the unsaturated zone, above the water table.

So we feel if we go back to the ten-foot separation distance, we'll account for some of the uncertainty in where that seasonal high water table is. And it would be more protected.

That's our one request.

MS. BESWICK: Can somebody talk about why we went from 10 to 5.

MR. THIBEAULT: I'll take that, Mark.

With respect to the five feet. Technically, five feet should be perfectly adequate for soil treatment and of percolated runoff. And that's been shown, you know, in a number of studies in the past.

So I think we misunderstood what Greg was getting at earlier in the process when he asked us to go -- to go back to ten feet. And that was the fact that just the data that are available for the high ground water levels in most areas are just not very good. And so the extra five feet was to provide a margin of safety when the data aren't good for seasonal high ground water levels.

And this is one of those issues that Tim Moore talked you to about at the last board meeting. Where it is a policy decision -- it is a risk decision between 5 and 10 feet. This is not a technical decision.

And the ten feet does provide for more water quality protection. Five feet, if you have good data, provides good water quality protection with respect to percolated runoff. So it is a data issue. It is not a technical treatment issue.

MS. BESWICK: The question is, do we have good data?

MR. THIBEAULT: No.

MS. BESWICK: Thank you.

Garry, followed by Bart Lounsbury.

MR. BROWN: Actually, Madam Chair, we have a

presentation. And Dave Beckman is going to go first.

MS. BESWICK: Great.

MR. BECKMAN: Good morning. Good afternoon, Madam Chair and members of the Board.

During the first hour of my presentation, I'm going to have --

MS. BESWICK: During the first hour of your presentation we're going to have lunch.

MR. BECKMAN: We'll try to move it along.

I'm a senior --

MS. BESWICK: David, one minute.

Do you need a break?

I'm sorry to do that to you. The court reporter has been -- we won't go anywhere.

Do you mind if we give her a couple of minutes?

MR. AMERI: Can we combine her break with our break?

MS. BESWICK: No, we can't.

MR. AMERI: Okay.

MS. BESWICK: Were you thinking of a lunch break?

MR. AMERI: Yeah.

MS. BESWICK: We don't have lunch yet.

(Pause in the proceedings)

MS. BESWICK: David, thank you for your patience.

MR. BECKMAN: Thank you, again. I hope that doesn't count against our hour.

MS. BESWICK: No. Yeah, it is counted against your hour. You have 15 minutes.

MR. BECKMAN: I had no idea what the folks this morning were going to say.

Madam Chair, members of the Board, David Beckman with NRDC. I codirect the National Water Program at the NRDC. And we're pleased to be here today.

Bart Lounsbury, who works at NRDC, and Garry Brown, we're all doing this joint presentation for you so you get the NGO perspective in one bite-sized capsule.

Bart is going to walk you through some context. I really feel after this morning you need that context. Because if you just walked in here today, or dropped in from some other planet, you would think LID was exotic. That it was somehow being redefined in some narrow fashion. That it was onerous. It might have all sorts of negative impacts on the community.

I heard everything except more high school absenteeism or teen pregnancy, when Eric Strecker told you all the variables.

MS. BESWICK: The hearing's not over.

MR. BECKMAN: Right, there may be more problems.

And you wouldn't know at all what is going on in the United States and the rest of the world of LID. It is not difficult. It is well-proven. And, most important

for your regulatory responsibility, it is the only thing on the table today that gives this permit any chance of being successful. Gives it any chance of being lawful when adopted. And gives the permittees any chance of actually meeting water quality standards, as another part of the permit requires them to do.

In our perspective, in listening to the discussion this morning, that LID is a gift horse that these permittees are looking in the mouth. This is the solution. And more and more people, including the building industry, nationally -- and I think in California, to some extent too -- are recognizing this is something they should embrace. Not throw so many hurdles in front of.

And so the discussion on feasibility and infeasibility, all of the issues, are important. But the permit, as the executive officer indicated, said if it is infeasible, you don't have to do it. And NRDC says, if it's infeasible, you don't have to do it.

Now, where we differ is what is feasible and what's not. And as to that, you should look at the record. You have extensive amount of information -- we're going to summarize it for you today -- that talks about feasibility of LID. And it particularly talks about feasibility on retaining water onsite whenever practicable. Not every drop. That was, I think, either a misstatement or just in

the flow of an extemporaneous set of comments that was a suggestion we're requiring -- we want you to require every drop of water be retained on site. That's not true. We don't.

But we do want that maximized. And why do we want it maximized? Because it's a superior way to address the water quality problem in Orange County. That has, unfortunately, a huge number of impaired water bodies. Not withstanding your best efforts of those of the permittees.

This community has not been successful yet in addressing water quality problems. That directs you, or should direct you in terms of policy. And I assure you, it changes the legal framework. It changes the context of what a permit should look like.

So what we're here to say today is you should set a standard that does requires the maximum extent practicable. And then you should allow appropriate exception whenever it is not possible to accomplish that.

You should not set a minimum standard that might be the lowest common denominator that works everywhere because that's not consistent with good policy, and there will not be a successful approach in terms of the water quality.

I'm going to back-end some of the comments that Bart will make to try and give you the context why it is so

important.

So with that kind of, hopefully, a refraining to focus on MEP, to focus on your obligation to meet water quality standards, to recognize we do have to do things differently. Bart will come up and give you some of that context around the country. We'll show you an EPA definition of LID exactly like ours. And I will describe what we'd like to see done with the program.

Thank you.

MR. LOUNSBURY: Good morning, Madam Chair, members of the Board.

I'm Bart Lounsbury from the Natural Resources Defense Council, as David mentioned.

David hinted at this, but the reason we're so focused on LID today, and probably why a lot of the commenters here today are so focused on LID, is that the conversion of impervious surfaces and natural areas to impervious surfaces through development is the leading cause of water quality impairment in Orange County and, indeed, around the country in general.

And LID has been proven through many studies to be a superior technique for treating stormwater. The Ocean Protection Council of California, just last year, came out with a very strongly worded resolution, that I believe we sent to you in our packet, showing that LID is a practicable

and superior approach. And encouraging regional boards and various other entities to adopt LID as their approach to stormwater management.

US EPA has said the same thing. You heard that today from Mr. Kemmerer.

How do these practices function? Well, apparently there are many definitions out there. This is one from EPA which actually says that it is retention. It is infiltration, evapotranspiration, and reuse of stormwater.

Those are three different techniques. Mr. Strecker touched on this. They're all viable here in different scenarios. And where infeasible, we believe there are alternatives that can be taken. And that this permit does, to some extent, accommodate, but needs to accommodate better.

The State Water Resources Control Board has noted the extreme importance for having performance requirements for LID implementation.

So in this case what we've been arguing about, I think, a lot today is exactly that paragraph -- those couple paragraphs in the permit, where the performance requirement is established. That's why it is important.

US EPA also placed, as you heard from Mr. Kemmerer, very high degree of emphasis on assuring that

there are clear, measurable, and enforceable provisions for the implementation of LID. And where it is infeasible to implement LID onsite, there should be appropriate offsite mitigation options to achieve equivalent results.

Now, EPA also stated, that where onsite management is not feasible, conventional means should not be counted toward this type of numerical performance standard that should be established by the permit. And that's very important.

The types of techniques that we've been talking about fall into various categories. Maybe people who argue about what is LID and what is not. We agree some are much more effective than others. And those are ones we should privilege in this permit. And that's what we're trying to do through our comments on this permit today.

EPA, in fact, has also noted that in this region, typically, permits rely on deferring the creation of standards to plans that are drafted by the permittees and later submitted for approval by the EO or potentially not even for approved at all, necessarily. And those tend to rely on qualitative provisions rather than specific measurable criteria.

Which is particularly problematic because the permits themselves should have established those specific measurable criteria. Which would then defer plans that

don't even have the criteria in them. We want to make sure that this permit itself has the necessary criteria at the outset.

This has been so problematic, in fact, in the San Francisco Bay Region context, that EPA has threatened to consider objection to that permit. This is a letter -- from a letter they wrote to the San Francisco Regional Board this month.

So this is an extremely important issue for all of us. And EPA, appropriately, today is placing a very high degree of emphasis on ensuring that these kinds of standards are in the permit.

Why are we focused on LID? Because it is so vastly superior to conventional BMPs. We had Dr. Richard Horner, who is the preeminent expert on stormwater in this country. In fact, he was on the National Academy of Sciences Panel mentioned by Mr. Strecker.

We had him do a study for us in various areas around California, San Diego, Ventura County, the San Francisco Bay area, analyzing the feasibility of LID limitations and the benefits that would accrue from that implementation.

These are the results for Ventura County. They're very similar for San Francisco Bay, as well as

San Diego. And can you see here that LID BMPs are achieving significantly higher rates of pollution reduction, as compared to even the best performing BMPs.

He also -- Dr. Horner also studied specific case sites here -- this is a restaurant I think he did -- and how much runoff reduction would occur through the implementation of these BMPs in a feasible manner.

And you can see here that there would be approximately a 7 percent runoff loss on an undeveloped site. Which correlates with what Mr. Adackapara was saying. Then with no stormwater mitigation, 49 percent lost. Even with the best performing conventional BMPs, it's 26 percent loss. But under the designed storm conditions, with LID properly implemented, there would be no runoff loss on the site. This has vast benefits.

Also at another case study site, a large single-family home subdivision. In addition to removing pollution, obviously, from the system, it also saves water that results in cost saving for developers, for homeowners, and also reduction of even green house gas emission because of the extreme energy intensity of our water supplies here in Southern California.

I don't think there's any surprise everybody supports LID, including the National Association of Home Builders. No one here today said that LID is not a great

technique for managing stormwater.

So around the country new standards are being adopted. There's an emerging trend toward the types of retention standards that we think this permit needs to incorporate.

Anacostia in Washington DC, an urban area, has adopted this standard, which is to retain the first one inch of rainfall onsite. That's retention.

As someone mentioned earlier, the design storm, the 85th percentile storm in Orange County results in about .75 inches of stormwater in most locations. This is actually a more stringent standard.

And then wherever that's infeasible to meet, there should be offsight mitigation options. And they have multiplier ratios for those, in Anacostia.

The situation is very similar in the West Virginia draft phase 2 permit. Retain the first one inch onsite. If you can't do that, use offsite mitigation or in lieu payment at a 1.5 multiplier for the unretained portion.

That's something we think is very feasible, here. And we hope that that's what you'll ultimately do with this permit.

Philadelphia has the same standard. Retain and infiltrate the first one inch. They actually only allow

infiltration of the first one inch. We are supporting a standard that allows for infiltration of evapotranspiration and harvest and reuse.

We have various techniques to accommodate a wide range of sites. And even when that's infeasible there's always the option for offsite mitigation.

I think David will speak specifically to the concerns of this permit and the language it includes now.

MR. BECKMAN: Thank you, Bart.

Hopefully, that gives you some sense -- and what I want to emphasize, what is before you, even with the EPA changes, is less than what West Virginia -- a phase two, not even a phase one permit is considering -- less than highly urbanized area in Washington DC.

And you've had a chance to review the letter we sent. We have six or eight different standards that demonstrate to you that what you're asked to approve today, with the EPA changes, is significantly less stringent than many other places around country.

You wouldn't get that sense, I don't think, from this morning's presentation. But I think it's critical for your deliberation. Will Orange County adopt something less stringent than a phase two community in West Virginia? That's the question.

Now, we have a lot of concerns with the permit.

Even with the EPA changes, that we appreciate and we think strengthen the permit. You should understand that this is not the NRDC permit as Mr. Singarela suggested or an NRDC provision.

We have suggested something more stringent. We have concerns about the design storm. And more specifically, what happens if you can't retain the 85th percentile storm that you've selected onsite.

As Bart indicated, we think you should follow what every new communities that are considering what these requirements are doing. Which is very similar to a wetland situation, where you mitigate offsite.

Why do you do that? Because we are after a watershed level of performance. We don't want the exception for infeasibility to mean that folks don't do as much as they reasonably can, when you can go, maybe, on an adjacent parcel and accomplish what you couldn't accomplish given the circumstances of your development.

Why is that important? It's important because we won't maintain the water quality goals if we are constantly lowering the requirements based on a series of factors.

So we want that clear performance standard. I think the EPA suggestion goes a long way towards that goal. And just so you can see the difference between something

that's clear and something that's not.

This is West Virginia. And it is very clear. "You must implement and enforce site design standards and manage to keep the first one inch of rainfall from a 24-hour storm proceeded by 48 hours of no measured precipitation. Runoff volume can be achieved" -- and they give you the various ways to do it.

And then they clarify it. "The first one inch must be 100 percent managed with no discharge to service waters." Your permit is not that clear. And it should be.

That's the kind of language that results in good performance because that's the kind of language that we can all understand.

So that's one area of concern.

The EPA suggestion linking a lack of ability to comply with the standard onsite to these alternative programs is helpful. But those programs aren't developed.

One concern we have with this permit and, frankly, others is that the permits don't make the regional board make the decisions that the regional board should be making. You are the only folks in the room that are allowed to issue a permit. With all due respect to the executive officer, he is not.

By having the executive officer basically judge all the feasibility issues, all the alternatives, you're

basically giving up your responsibility, in my view, to decide decisions and be the deciders, so to speak.

Why is that a problem? For lots of legal reasons. But from a practical respect, how is the public supposed to engage in that process? How do you know if Mr. Thibeault makes the right decision, or doesn't make the right decision?

That is a significant issue. There's a lot of case law on it now that makes it clear the executive officer can't be in the position alone of judging the adequacy of provisions like this. Because they're, effectively, the management of the permit.

We want to see the programs spelled out in a public way. And you should make the decision on that. Not anybody else.

And I've basically covered this bullet as well.

Now, one of the things I'm going to try to do before turning it over to Garry is just to connect the dots.

Bart indicated why LID is so important. Why that retention standard is so critical. But there's a context even beyond LID that, I think, is important for the Board to consider in making its decision. And that's there are other issues in this watershed. There's the need to comply with TMDLs, for example.

How will you comply with the TMDLs if you don't

significantly reduce the amount of the pollution? If you don't require permittees and those they regulate to select the best BMPs, the likelihood of meeting the TMDL requirements is very low. And that creates other legal problems.

By selecting strong management provisions, you actually can assist the permittees in doing what we want them to do. Which is to improve water quality. All of the feasibility concerns that have been raised, as I said, can be dealt with with proper provisions. But they shouldn't ignore the vast amount of science and technical information out there that shows these provisions and ones much more stringent are feasible. That's the information before you.

That's why I would ask Mr. Kemmerer to respond. That the issue about the language in the first provision is not just about a delay. It's about the presumption that we need to prove in Orange County something that's -- prove the feasibility of LID in Orange County, but it's been proven to be feasible everywhere else. That this is some new thing. It is not.

In fact, it's being done here by builders in Orange County before the permit is being considered by you.

There's another issue. There's a new case that you probably haven't dealt with before because of -- the permit wasn't reissued in 2007. And that's the

Friends of Pinto Creek v. US EPA.

Long story short. In impaired watersheds like we have, unfortunately, in Orange County, there's a significant restriction on new development and new sources of pollution when there are no TMDLs in place. And there are restrictions when there are TMDLs.

Practically speaking, what's the best way to make sure the permit complies with these kinds of requirements? It is to require the techniques that maximally reduce water pollution. And that is retention of water in new development as opposed to its discharge.

Another problem we've highlighted, the permit doesn't comply with the basic requirement in the statute itself to effectively prohibit non-stormwater discharges.

And very briefly I'll touch on the issue here, or one example of the issue. And that is that you allow runoff during the dry season from lawns and irrigation. Irrigation water which studies demonstrate are highly polluted.

And that's inconsistent with what the act requires. And it's sort of ironic that your peer regional board that covers Southern Orange County, the San Diego Board, has just come out with its draft permit that has stacks of information about how highly polluted those discharges are.

And those are discharges that your permit allows with conditions that are, in our view, not acceptable. Those non-stormwater discharges need to be prohibited. The law requires them to be prohibited. And from a policy perspective, we're not going go get to the end result if we continue to ignore these pieces of the puzzle.

The final thing I would say is that we could understand, perhaps, a difference of opinion if there had been a compressive examination of the likely pollution reduction of this permit. In other words, if you tell us, "We're not going to do exactly what you want with LID, but we're going to retrofit. We're gonna do a bunch of other things. We are going to show you that we have a reasonable belief, based on science, that we'll be successful. We'll meet those water quality standards." That would be one thing.

And perhaps you as a board might think, "Why don't we be more flexible with development, if we know we're going do get there anyway. We're gonna meet our budget. We might spend a little more on a nicer dinner. But we're going to meet the budget, so we'll do it."

That's not in front of you. You can look anywhere you want, in the reams of information you've been given and in any comment by any party, and nowhere will you find an estimate of the effectiveness of this permit. And

that should trouble you from a policy perspective.

Because I would submit, not withstanding your best intention, you don't know what you're doing. How can you? How can you make a determination when you don't know what the effectiveness of the permit's likely to be?

The federal regulations require an estimate of what the purposed program will do in terms of pollution reduction. And we would submit that that's been too long ignored. Not just in this region, but in many other regions and, in deed, in many other places in the country.

And we would certainly submit to you that absent that kind of information, it's incumbent on you when you have information about superior approaches that are practicable with the National Association of Home Builders and NRDC, like, those should be in the permit.

So what that means is, we would like for you to implement the red line -- which we have copies of if you want, they were submitted with our last set of comments -- that shows you what we think should be done with the LID section. Certainly, at minimum, EPA's changes, the small ones -- the two small ones that they've made, should be part of your decision and should not be changed or watered down with the kind of suggestions that you've heard.

And we think, at the end of the day, you will have a permit you feel good about which is practicable and

much more likely to do the job as necessary than one you saw this morning or the one, with all due respect to my friends in the room, that some others would like you to adopt.

With that, I really appreciate the work. I'd also like to thank Mike. We're involved in this kind of process everywhere. I've been in the process and sometimes they start and three years later they're not over.

And while we certainly have some respectful disagreements on substance, we think you've done a terrific job in moving it along. Very professional. Very businesslike. I think it makes it a lot easier for everybody when you can actually get, hopefully, to a result as opposed to this constant process.

And you should be very appreciative of your staff. I think everyone in the room is.

Thank you very much.

Garry, you are going to close.

MR. BROWN: Hello. My name is Garry Brown, Orange County Coast Keeper.

First thing I want to do is kind of echo what David just said about the staff. Our organization for the last decade has worked closely with the Regional Board Staff and built a relationship with them. And it's a relationship we appreciate.

And when this came up, which every five years it does, we basically -- in Orange County, a group of us had been talking about this for some time. And in December we came, a small group of us, and asked if we could stop the comment period date of the end of December to, basically, take some time out and maybe change the paradigm.

We've had a long success of working with various developers in Orange County. I think at all times we have been somewhat reasonable. And we have a reputation for that. So we have, often, discussions on how we can make this better.

And in December, what I felt, personally, was that, you know, we can go through the process again and try to clamp it down some more. And we can probably -- we can guarantee it will be more expensive for developers, more expensive for the city. But can we guarantee the water quality is going to be better on the direction we're going? And the answer is no. I couldn't stand up and say the water quality will be better.

So, you know, to me, we need to change the paradigm. How the past permits have gone. And that's what this attempt has been -- to do. And that's why it hasn't got any discussion today.

But the section yesterday that was mailed and is on your errata sheet on the master watershed plans. And

I think that alleviates a lot of the discussion you have heard this morning and objection.

We look at -- how can we change the paradigm of the permit to, you know, make somewhat reasonable, but yet accomplish a higher standard of water quality. And our thought was let's develop a strong permit. Let's take susump, and let's have the 85th percentile. And let's retain that water. And I'm not going go repeat what you have heard a dozen times today. We have to have a strong permit.

And then the second -- like the second leg of a three-legged stool. Let's develop watershed master plans. And in the next two years -- and virtually everything Mr. Strecker said in all of the different nuances of Orange County. That if you're in Serrano Creek, we know there's erosion problems. If you're in San Diego Creek, we know where the plumes are. We know other issues. We know TMDLs. The whole point in the watershed master plans is to encapsulate everything that was basically discussed earlier as infeasibility or feasibility.

And so what we would like is to proceed with that, have a strong, almost default permit, have, basically, these watershed master plans so nobody can say one rule fits all. Because it will be one rule based on the circumstance and science of that particular watershed. That's the

direction we want to go.

The third leg of the stool, we want to go online hydromodification modeling with something like UCI. And have online historic rainfall data. The geologic data.

The ultimate would be if engineers, when they were designing a project, they go online and pull out all of the historic data, all of the rainfall data, and they would know how to size. And then when their plans go to plan check in the city, the plan checker would go on the same website and validate the information.

What we're looking at is a longer, wider vision than this permit. This permit is the first leg in, certainly, the watershed master plan.

Where it mandates is the second leg. And down the road, we want to develop the third leg. We think that, one, bottom line, we'll have a much more effective permit. We will have, actually, done significant in drastically improving water quality standards for Orange County.

You know, one of the concerns about using the word "infiltration" -- over the years we, as I said, we work with various developers. You have got very responsible developers. We started a relationship with Irvine Company, as you know, in an era of -- through litigation. And that turned into a partnership for developing water quality.

And we have touted their work at the

Newport Coast on water quality as being the best in the nation. My point is, if Irvine Company -- and what they have already proven they're efforts in water quality. Then you know, we won't have a problem. But not everyone's Irvine Company.

You now, MEP, for example. Our frustration with MEP is to the responsible developer, you know, that's fine. To the guy that's on a shoe string and trying to cut every corner he can, MEP translates into let's do the least for the cheapest.

My problem with this is that you add filtration, that's the way out. That's where the responsible developers and redevelopers will do what they need to do and do it right. The ones who are trying to skate by and do the least, you know, they're going to look at that and say, "Okay. We'll dig a ditch and throw some plant seeds in it." And that's a vegetative swell, and the runoff will come off. That's the way out. That's our concern.

We need to have a strong permit to begin with. And so we certainly would appreciate your deliberations in giving us that.

Thank you very much.

MS. BESWICK: Thank you.

MR. PON TELL: Madam Chair?

MS. BESWICK: Yes. Questions?

MR. PON TELL: Just two follow-up questions. On the one slide you showed -- I think it was Paul that showed the natural runoff being 7 percent, and LID runoff being zero percent. Is that desirable or is the goal 7 percent?

MR. LOUNSBURY: That's under the design storm condition.

So the goal there is not necessarily a hydromodification goal, which is more about matching peak flows and durations and what not, which is also in the permit. The goal with the LID provision should be mostly water quality.

So in that case, by reducing runoff to zero, you can be sure under the design storm condition, there's no pollution going to receiving water. That's not zero percent runoff overall because we're talking about a design storm scenario. Which, as people have noted, is not necessarily -- or does not take into account all the rainfall in the year. It is less than 95 percent of the rainfall that is captured.

MR. PON TELL: Can you say that again?

MR. LOUNSBURY: Sure. I think that -- and we've submitted many studies, so we can look through the records and find this exactly.

Not all of the rainfall in any given year is

captured within the 85th percentile design storm scenario. There will be runoff. Period, if you're just capturing the 85th percentile storm and retaining it onsite.

So that 7 percent discharge under natural conditions and zero percent discharge under the LID provision doesn't mean that every single site in Orange County will never discharge stormwater during the entire year.

Does that clarify?

MR. BECKMAN: That's perfect. I just wanted to add, one thing you have to keep in mind is, what is on a natural site and what is on a developed site.

The reason it is so important to limit water pollution or the flow of pollution is because once you've developed, it's no longer natural. There are pesticides and herbicides and potentially bacteria and other metals and all the other things you know from your work are in the water in Orange County.

The ability to limit the amount of pollution by limiting runoff is critical to the ultimate environmental goal. As Bart said, that's not -- because it is a design storm, it is not all water. You'll still get runoff from the site.

Most of the standards for hydromodification that US EPA adopted -- even the ones that are in the federal

energy bill that relate to federal sites, one of the newest -- they assume that if you retain, roughly, an inch of rainfall, that's a down payment on the hydromodification requirements.

In other words, in order to make that hydromodification graph look like it should, you have to do some runoff. That's generally the way the system, or the standards work. So what we're asking for here is something far less than what other communities are doing.

I think that's the point that's really, really important.

MR. PON TELL: Just a follow-up question. I guess what I'm confused by, you're comparing an arid community with non-arid community. So capturing an inch of water in a non-arid environment is a fraction of the total. Where capturing an inch of water in an arid environment is 100 percent of the total.

So I'm just kind of trying to grasp the net effect of making those kinds of comparison and adopting a policy then. If in any of those communities, you know, that one inch was 20 percent of the rainfall that was being captured, and then we were then to apply a 20 percent factor on the capture, it seems to me that might be an equally relevant way to evaluate.

MR. BECKMAN: I think there are a couple responses.

That's a good question. The way you can normalize the situation is through the design storm. And those communities, notwithstanding whatever -- maybe they have 30 inches of rain -- I think your point, right -- and maybe we have 10 inches here. So how do you deal with the question?

You deal with it, in part, with the design storm. The requirement in West Virginia, hypothetically, isn't to capture all of the rain they have during a certain month. It is an inch of rain. The standard here is less than that. In any case, it normalizes for the fact that there are different amounts of rainfall in different places.

It is, actually, more difficult to accomplish the standard in an area with more rain. Because as Mr. Strecker indicated, if you have a lot of rain, it can be, you know, the ability of soil to evaporate, the ability of systems to capture rain after repeated storms is more challenging than if you have only a few rain storms every year.

The other thing I would say, just to complete the answer, is we asked Dr. Horner to look at the questions of these standards that we're holding out to you as an example. And asked the question, is the evaporation rate in those places comparable to Southern California? Because that would be an important thing to consider.

If, for example, you couldn't evaporate water, or you couldn't somehow store it, then maybe the standards are not apples to apples. I think is part of what you're asking.

That's in our submittal most recently to you. We looked at all of the standards that we have put forward in our comments. And the conclusion, as you can see, is that Southern California is either on average the same as the other communities, or in some cases, is in a lot better situation to deal with the standards that we're advocating. Because of the fact that we get a lot of sun during -- between storms in Southern California.

We try to look at those apples to apples questions. And we are suggesting to you that this is an apple to apples situation. And, if anything, that supports a stronger standard than you're looking at today.

MR. PON TELL: I have two quick questions for staff.

One issue was raised about the non-stormwater discharges, to what extent I think it was implied that our requirement did not meet the standard that's required.

MR. ADACKAPARA: Our requirements actually are specified in section three of the -- roman numeral section three, that's page 32, and it actually prohibits non-stormwater discharges. And it is consistent with the federal regulations and the Clean Water Act.

MR. PON TELL: My second question.

There was a question about the, quote, unquote, "Ability to state with some level of certainty with regard to the overall effectiveness of the permit towards achieving the water quality standards."

MR. ADACKAPARA: Actually, in the report of waste discharge, that was submitted by the County. They have provided an effective analysis.

And in addition to that, Geosyntec, provided by somebody, of all the effectiveness analysis that has been included in the report of waste discharge. And also in other reports that the County has provided.

We did not provide a copy of the Geosyntec summary to you because it came in yesterday night. But they did provide that analysis.

MR. PON TELL: And based on that analysis --

MR. ADACKAPARA: Based on that analysis, the program seems to be effective. But some of the programs could not be -- they could not reach a conclusion about some of the programs that are being implemented. So they are proposing additional programs, additional best management practices.

And we are requiring in the permit additional controls so that the program becomes more effective.

MR. PON TELL: Thank you.

MS. BESWICK: Is that it, Steve?

What we're going to do now -- we have had food delivered to the conference room in the back. We're going to have a closed session while we have some nourishment as well. The closed session will be on the item on personnel.

So we'll be on a break until 1:30.

(Lunch recess)

MS. BESWICK: Back in session.

What we're going to do -- we have several more folks who would like to offer input. But I think at this point we're going to become a little more constant with our three-minute rule. Yes, Gery said I'm going to get a little heavy-handed.

I think the Board members are going to throw me off the floor.

And then -- I know there are a couple of people that wanted to add another comment. I'm going to give you a minute or two to do it. I'm going to force the three-minute rule now.

So let's see, is Mary Lynn Coffee in the room?

There she is. Followed by -- is Matt Yeager still here? I don't see him. I'll put his card underneath. And Jim Fitzpatrick.

Go ahead, Mary.

MS. COFFEE: Thank you.

Good afternoon.

I represent the city of Irvine and its division of the Great Park Corporation. And I understand the City of Orange also concurs with these comments.

I would like to encourage the Board, as heard before, to clarify this provision C2 of Section 12 because the clarification is really very critical for this permit.

We appreciate Mr. Thibeault's clarification that feasibility criteria will be developed to determine when it is feasible to retain runoff onsite versus when that needs to be done somewhere else. It is still important to revise this section or clarify it so biotreatment BMPs are available for use in meeting the standards of Section C.

You know, the EPA's language here clarifies that this section, C2, tells you when you have complied with the LID requirements of this permit, and when have you to go to Section E and look for additional mitigation under water quality mitigation credits or other kinds of fee programs to comply.

And the clarification that we're requesting would make it clear that biotreatment BMPs are available for use in complying with the standard. And that you don't have to go to section 12E to use those types of BMPs. And they are, in fact, available without a waiver and the offsite mitigation credit programs that are anticipated by Section E.

So we encourage you to go ahead with that clarification of the term "capture" to incorporate biotreatment.

And we'd also like to point out that that clarification is consistent with the generally accepted scientific and technical definition of LID. We're not asking for an exotic definition of LID.

An exotic definition might be one that excluded biotreatment of BMPs. But rather a clarification that the types of LID BMPs that are typically thought of to be LID technologies that are available. And I would note, in addition to the definitions we gave you, all of the guidance for LID BMP implementation that we looked at as part of the stakeholder process, including guidance developed by NRDC for recommendations on how to implement LID BMPs do provide recommendations for implementation of biotreatment BMPs. I don't think it is a radical departure to allow those types of BMPs to be used.

And the last point I'd like to make, clarifying that biotreatment is a tool available to meet the standard is also, I think, very important when we're thinking about how protective is the stormwater standard that you're creating -- stormwater control standard you're creating with this section, C2.

You've heard from Dr. Strecker that requiring

retention of that full water quality volume, the runoff from that 85th percentile storm event, which is roughly equivalent -- I think someone, Mr. Ameri, said that it's roughly equivalent to 95 percent of rainfall. Or I think we also saw in the stakeholder process roughly equivalent to somewhere around the first .9 inch of rain.

The required retention of that amount may not -- may be, actually, less protective of the water quality than allowing some of that to be treated via biotreatment. Because in this region, a semi-arid region, where we get back-to-back storm patterns, you may end up with discharge of untreated water much more frequently. And he also noted that it is critical to allow biotreatment because anything else would result in a change in the natural water balance when you take into account ground water and evapotranspiration.

With that clarification, we support this permit. It is a tough permit. It has 25 to 30 new requirements, programs, et cetera. But that water quality is critical in Orange County. We support the permit with that clarification.

Also, I want to indicate that we highly support the master plan process that was set forth in the errata sheet today. And look forward to participating in that along with Coast Keeper and the other permittees.

Thank you.

MS. BESWICK: Thank you.

For those of you who just walked into the room. Since we have reconvened, I'm enforcing the three-minute rule. And I'd really appreciate it if we would bring up new points at this point rather than reviewing things discussed in detail over the last few minutes.

Gene Estrada. Is Larry McKenney still here?

Larry, you will follow, then.

MR. ESTRADA: Good morning, Madam Chair, board members.

I will keep my comments brief.

I thought we were going to go ahead and fairly adopt the permit today. But one of the comments I did want to make was that on the errata sheet -- those were the changes for the implementation of an approval of water quality management plans.

In the errata sheet we seem to have made a change that, to me, is fairly significant and would affect some of the projects. And that is the implementation as to when we actually are required to implement LID.

It seems that there's no provision right now to allow projects that have been approved through the cities either through the planning process or discretionary permits. There was language there previously. And that

language has been deleted now.

I'm concerned about what we would do for projects that are already in place and have been approved by the City, but don't have approved water quality management plans.

For instance, they have approved parcel or tentative maps. And to go back and have to go back and now have to redo the plans for implementation of low impact or hydromodifications is going to be very difficult to do. And something we shouldn't have to do.

MS. BESWICK: Good point. Thank you.

Larry, followed by -- did Matt come back in? I didn't see him.

MR. MC KENNEY: Good afternoon.

I'm Larry McKenney. I work for RBF Consultanting. I was asked by Lennar to participate in the stakeholder group meetings with regard to this permit. And Lennar, of course, is doing the Heritage Field's Great Park Neighborhood's Development at the Old El Toro site. So it is a large development in this permit area.

I think the first thing I would say is that Lennar probably sees a lot of things in this permit that gives them a lot of concern and pause. There are a lot of things in this permit they don't like, even though they want to do the right thing.

However, we believed in the stakeholder group that we were reaching consensus on a lot of issues and reaching a mutually acceptable conclusion. And so we're really not happy with some of the proposed changes to the permit language today. And we hope that the permit does go through and get adopted.

MS. BESWICK: You're talking about today's language changes?

MR. MC KENNEY: And some things suggested in speaker comments today to go even beyond that.

MS. BESWICK: But none of that is on the table at the moment.

MR. MC KENNEY: I did mention two things. Not new things, but I wanted to add a twist.

MS. BESWICK: You're not playing along.

MR. MC KENNEY: One is just with regard to the inclusion of biofiltration as a part of, sort of the first tier of --

MS. BESWICK: We got that. We've got that. Next.

MR. MC KENNEY: I want to suggest, in lieu of Garry Brown's concern, that that be viewed as an out for developers. Certainly, there's no problem with subjecting that to design standards or something so that it's clear what that is. The County can develop that as part of its implementation plan.

And then the last thing I want to mention, there are provisions that are in the permit that Paul Singarela referred to as the off-ramps -- that are in Section 7 now -- that allow for the implementation of these same kinds of LID approaches on a regional scale if it's not appropriate or feasible to do them at a site scale.

And I think there's concern now, with some changes in the language that occurred, we may have lost the ability to go to that alternative without going through EO waiver process. I just wanted to note, I think that that's a very valuable and important part of the permit.

It actually was Richard Horner's suggestion to include that kind of an approach in the permit. And we develop it and implemented it as part of the stakeholder group. And I'm not sure what the effect of the language is now.

I wanted some clarification that we still can use that kind of larger regional approach once we've done what we can do onsite without going through a waiver process.

MS. BESWICK: Did you see something in the errata or -- that would indicate to you that the change --

MR. MC KENNEY: I'm just trying to understand the paragraph 2 that's up here as it's rewritten now. I just want to make sure -- I may be completely wrong. I just

want to make sure we don't have to do everything on site and then go to a waiver.

MS. BESWICK: Remember, this is not adopted. This still has to be discussed. I don't see where that would really change the EO's authority in this.

Good point.

MR. MC KENNEY: Something for you to consider in your discussions. I'd like to be able to preserve the Section 7 regional alternatives, once we've done what we can do onsite.

Thank you very much.

MS. BESWICK: Thank you.

Is Jim Fitzpatrick here? And Irwin Haydock?

MR. FITZPATRICK: Thank you.

My name in Jim Fitzpatrick.

Hello, again. Happy Earth Day.

I wanted to introduce a new concept called Low Impact Car Wash Standards.

First of all, thank you to the permit writers. I appreciate the dialing up to this state. I did pass out some information. Mike, has the Board received that?

MR. ADACKAPARA: Yeah.

MS. BESWICK: Yeah, we did get it.

MR. FITZPATRICK: Great.

There's an opportunity here to prevent

pollution and contaminants from the mobile car washing and detailing. And it's very simple. Require these businesses to operate to the same standards as a commercial car wash. Because that's what they are.

I operated in the City of Santa Ana. And I went through a rigorous one-year process. I had to demonstrate how I was going to be handling the waste water.

Pronto Wash is the planet leader in hand car wash and detailing. What makes us unique is we get a car clean with one pint of water and don't create any runoff.

Yet, when I say I'm mobile in the same city, unless I'm a massage parlor or something like that, with, often, $25 I can receive a permit to operate within the city. And I don't have to go through the same process.

Although, in this permit I do see there's a pilot program. I don't see any standards that materially change the BMPs from what exist right now. And right now -- let's take the two worst case scenarios: Cleaning rims and cleaning engines.

If you go up to any detailer and say, "I'm going to sell my car." As sure as the sun will rise tomorrow, you'll get up-sold to an engine detail, where they spray caustic degreasers -- spray all that to the ground, put a dressing on. Well, all that contaminate and pollution is now sitting on the ground.

The way the current permit reads -- the interpretation by the County of Orange, who is the permittee that directs the co-permittees to the cities. They look at that that says, if that water does not enter the public right of way, no harm, no foul.

And so as proof that runoff from car washes do create issues, the International Car Wash Association has published the Car Wash Runoff and Effluence Study in Puget Sound that offers the facts and data it does kill fish.

So what I would recommend, then, is looking at cities outside of Orange County. I'm so disappointed that I operate primarily here in Orange County and I don't have the engagement of the cities and the counties here.

If you look at the City of Calabasas -- a very small city that's going through the same financial distress that all these other cities are. They do have a process where you do have to come to City Hall. And it is a zero discharge standard. And that's what I'm advocating, is the standard be to a zero discharge. Not, if the water doesn't leave the property, no harm, no foul.

When you look at this, I believe it is reasonable. Because not only is Calabasas, but the City of Oxnard. And the State Water Board is getting much more active on this topic than I'm seeing here in

Orange County -- both North and South Orange County.

Also, the City of Vista, we went through -- they invited us in to test their standard and their process. But they also have a zero discharge. Then you look at the People's Republic of Santa Monica or Pasadena, and they've taken extraordinary measures on this subject. And I'm not seeing that here from the County of Orange.

So it's reasonable in a small city like Calabasas to have between eight and ten people from the industry who have been able to satisfy these standards of zero discharge. It is achievable.

And what I ask the Board to do is be a little more prescriptive to staff because there's nothing in this permit right now, other than to go through the pilot program, as to what you're intentions are for creating pollution through this industry.

So that would be my request, that the Board give direction to Staff to set the standard as a commercial car wash in a zero discharge environment.

Thank you for your time.

MS. BESWICK: Great. Thank you.

Is Irwin here?

MR. HAYDOCK: Yes, ma'am.

Thank you very much.

My name is Irwin Haydock. I'm a resident of

Fountain Valley. And I came here today to speak about item 10, which was on the consent council. So it got passed before I had a chance to speak about it.

I had been sitting here listening all morning to the wonderful conversations. And it reminds me of my successful career of 25 years with the LA County Sanitation Districts and Orange County Sanitation Districts, avoiding the rules and requirements for the 301H Program. And negotiating successfully until I left both agencies when they then had to go to full secondary treatment.

As I aged, I found that wasn't a bad thing to do. In fact, the Orange County Sanitation District, which's well on its way to secondary treatment, is now passing it's clean water over to the Orange County Water District, and we are reclaiming 70 million gallons a day of fresh water. That seems to fit with my background which is a PhD in ecology.

And I'm concerned about, now, in my role as a retired person, I'm an advisor to the Newport Bay Naturalist and Friends, and we're trying to develop the watershed management program. And I would second what Garry said about watershed management.

And the state seems to have that as a mantra now where we would use collaborative, adaptive management with eco-system based principles to develop full scale plans

for each watershed that makes sense; that are systematic, that are sustainable, and are the right thing to do.

I have to cut to the chase because you've limited me to three minutes.

And my point is we now have Marine Life Protection Act process going on on the coastal zone. We have ASBSs that you regulate, which they complain about, well, you can't have discharges in them and so on. And we have watersheds that have TMDLs.

What I want is a system that allows us to go from the pines to the palms, to do all the right things. And I think the way to do that -- I read last night in Isaac Newton -- James Glick wrote a biography about him. And he says this, "The Aristotelian cannon enshrines systemization and rigor, categories and rules. It formed an edifice of reason, knowledge about knowledge, supplemented by ancient poets and medieval evil divines. It was a complete education which scarcely changed from generation to generation.

Newton began by reading closely, but not finishing, the Organon and the Nicobanion ethics," in parentheses, "for the things we have to learn before we can do them, we learn by doing them."

And I really liked what the beginning speaker said today from Lake Forest. I don't like it all, but I

think I want you to move ahead with it. And we'll fix it as we go along. Remember, in making the policies, you revisit them over and over and over again.

Thank you very much.

MS. BESWICK: Thank you very much.

And did Matt Yeager come back? There he is. You came too far not to be able to speak.

MR. YEAGER: Thank you, Madam Chair and members of the Board for opportunity to address you today.

I'm here on behalf of the San Bernardino County Stormwater Program. And there are 16 cities in the valley in the Santa Ana watershed and county and the flood control district of the permittees.

Similar to what Jason Uhley told you, this isn't our permit. We understand that. We have been watching this permit along with the South Orange County permit and Ventura permit and Bay area permit that's going on up there because it will impact what happens to our permit. And for this reason I believe it is the next one in the queue for MS4 permits.

And, you know, we appreciate all the staff time, discussion that's taken place. A lot of -- we've learned a lot in this process. And we'll be in a better position to do our permit than Orange County was to start with.

What I ask is that we be afforded the same opportunity to start from our ROWD, that was submitted back in '06, to -- we spent a year developing our ROWD with input from members, from staff members. And we would like to not discard that effort. We'd like to be able to use that still and proceed from that as a starting point. Rather than taking a look at all the Orange County language and using that as our framework and a template. Which is what our permittees, the city managers, city engineers are a little afraid of. We're going to be given that language and have to live with it. Because it will now become MEP for us.

That's all I really wanted to say. Hopefully you can afford a little staff time for us, too.

MS. BESWICK: Thank you, Matt.

Our track record is pretty good. I think you can trust us on this.

I'm out of cards. I know at least one person wanted to recomment. And I said I would give him a minute to -- yes.

Oh, Mark hasn't had a chance to speak yet.

I'm sorry. I'm confusing you. If you don't mind waiting.

MR. RECUPERO: Madam Chair, members of the Board.

Mike Recupero. I apologize for our clumsy

dance. This is a regulated community that looks at words and meaning really careful. We have spent the last six months hashing out this permit down to the word. So when we showed up this morning and the word changes, it made us uncomfortable, the fact we didn't understand what it means. Made us essentially go to pieces.

So with that in mind, if the Board is going to consider this language, I just ask for maybe a clarification of a few things. The first of which is whether or not this language changes the feasibility analysis. The sentence is stricken up there. If that's true, or if this is going to be our permit language, what does that mean? And I think that's important for the regulated community to know.

Number two, what is the threshold of the showing of feasibility? And who is the trier of fact on that? If the City of Anaheim wants to put in a parking lot or redo -- redevelop a portion of a library, are we actually doing a feasibility analysis that shows that infiltration cannot be done? And once that's done, are we going to a waiver hearing at the Board? And is every public works project doing that? Is every homeowner doing that when they're required to do a WQMB? Is every commercial facility or an Applebee's expected to go to a waiver hearing?

I don't know what the answer is, but I know it's a large concern because simply for the volume of the

project that gets done.

The third point is if, indeed, "capture" is going to be defined to include bioinfiltration, or biotreatment, biofiltration, as we said time and time again, I think there's a greater level of comfort on the regulated community side.

And lastly, we support the Orange County Water District separation distance of ten feet between the bottom of the infiltration device and the water table.

Thank you for your time.

MS. BESWICK: Thank you. Good points. And you were very succinct. Thank you.

UNIDENTIFIED: Chair Beswick, members of the Board, one minute. And I promise Paul will be entertaining.

MR. SINGARELA: Paul Singarela for Pickwick.

As you go into these deliberations, the issue from our perspective on LID is biotreatment. Is biotreatment going to be part of the compliance, part of the standard, part of what you define as MEP? Or is biotreatment something we have to earn only by showing technical feasibility and getting some waiver?

We don't want to go over in waiver land or getting a variance. Biotreatment needs to be part of baseline compliance. I ask you to deliberate on that, and hopefully resolve that issue today.

Thank you.

MS. BESWICK: That was good. Very quick. I think that's -- unless I'm -- one minute.

MR. BOON: Richard Boon, County of Orange.

I need to have the last word.

At 9:00 o'clock this morning, the County of Orange, all of the permittee cities, I think were enthusiastic and supported adoption. And that included the errata sheet and all the additional provisions in the errata sheet, including, I think, what must be a rarity for a regulated entity, asking for something that was previously optional be made mandatory, the watershed action planning process.

With regard to the language that you have before you, I think we would be prepared -- and I think we could very quickly offer you some alternative language on the revision to C1. Perhaps that establishes a point in time, 18 months or 24 months, after this process of trying to come up with a revised model WQMB such that the program would preassume that all projects are feasible, unless we've come up with some criteria for determining there are cases of infeasibility.

With regard to C2, when Haydock quoted Newton, I would refer to the comic strip in Fraz in the LA Times.

MS. BESWICK: Ten seconds.

MR. BOON: Ten seconds.

There are simple answers to complex problems that are generally wrong. Mike, I think, put together a permit that is a swiss watch in its sophistication and interconnectedness. And we would ask the revision to C2 be struck.

MS. BESWICK: Thank you.

Okay. I think we're at the point where we can, at least, stop, if not close, the public hearing. And I'm going to turn to the Board members. But as I do that, I'm going to play on what Richard just said. And that is he tells us that people came here today, and we heard all day long, people came here enthused about this permit, ready to support it. It was like -- I like the swiss watch analogy. Way to go, Mike -- and then we ran up against something new to everyone in room. Not just to you, but to us.

And so something that we might consider -- I'm not suggesting -- just as we begin our debate, what we might consider is -- let's look at the good parts of this. See if we can come to terms on the pieces that everyone's in accordance with. But, perhaps, an option could be to leave the public hearing open on just the two items in question until our next meeting, which would be about 30 days, I think. May 22nd, close. Perhaps giving time for people to submit comments.

And we could keep the public hearing open just to those two points for our meeting in May. And if there were still issues about it, we could address them then. That's one suggestion as we begin discussion.

MR. RUH: Madam Chair, I think that's an excellent suggestion. We had concurrence on so much of this already. We could move forward on that and do what any prudent -- even a business would do -- the areas we have some question, let's revisit it. Keep it open. I think that's a very fair way to do this.

MR. AMERI: Ditto. I agree. I think we should limit the next hearing to specific items which essentially 90 percent, I think, is going to be items 12C1 and C2.

But I have a couple other points I'd like for consideration before now and next month.

One of them is Item E1 which essentially gives the EO too much power. If the feasibility -- if one of the LID procedures is not feasible, at the discretion of the EO to make the decision whether another alternative is feasible or not. And if the applicant doesn't agree with them, guess where the decision goes to? State. It never comes to us. And I totally disagree with that.

We are the body that makes the decision. We are the one that approved the permit. We are giving our EO the authority to make that decision. And if the applicant

disagrees with his decision, we should be the body that -- to consider that Applicant's, you know, appeal. Which is in agreement with what David Beckman said, basically, a hundred percent.

I do believe that we really need to have a very clear, concise definition of what LID really is. None of us really knows what it really includes. Is it the three items of infiltration, evapotranspiration, and unused harvesting? Does it also include a fourth element which is filtration and treatment and release?

And I see this thing from one of the speakers that very clearly indicates that the US EPA and the states criterias (sic) mention filters as one of the four elements of LID. Then what I hear are arguments that that's not true. EPA has other definitions.

I'm not comfortable with what it is. The staff needs to really convince me either that 100 percent filter is the fourth element in LID, or convince me that it is not. Or come and tell me it is in their research 75 percent of the time it is in there, 25 percent isn't. I need to be very, very, very clear whether there has been practice or not.

Third is something that Steve mentioned, the 85th percentile event. He brought up a real good point. What is the 85th percentile? In Seattle it is probably

5, 10 percent of the rain events that happen over the year. Where is it in Orange County? 80 percent of the time? 90 percent of the time? Some said 95 percent of the time. In other words, we build storm drains in development. We spend all of that money. 95 percent of the time it is dry when it rains. 5 percent of the time, when you have a little bit of rain over one and a half inch or whatever, goes into your storm drain. Why do you build storm drains then? Let's eliminate building storm drains in new development and say onsite retention. Period. These are issues I have.

I agreed with you that 90 percent of the discussion should be concentrated on items 12C1 and C2. But I would like to be clear on these other items before I'm ready to express an opinion.

MS. BESWICK: Richard?

MR. FRESCHI: I concur with your point. And I also agree with Fred, that's delineated in footnote number 55.

I think, not withstanding the fact if it is turned down by this Board it goes to the state, I would rather have it -- if it is turned down by our EO, it comes to our board, and we make the decision. Because if that's the case, and it is turned down by the EO, then the company or the organization has to spend a whole lot of time and lot of effort and lot of money going up and arguing it in

Sacramento. And I ask us to consider that provision.

That's it.

MS. BESWICK: Steve, anything you want to add?

MR. PON TELL: Sure.

MS. BESWICK: Any reactions to --

MR. PON TELL: Well, first of all, let me confirm -- so Gery is in section E1. Is that the case, if there's an EO decision that it would be appealed directly to the State?

MR. THIBEAULT: Yes.

MR. PON TELL: So we can modify that to say that if someone would appeal the EO decision, it can be appealed to our Board?

MR. THIBEAULT: Yeah. And you can also modify it to bring the whole decision back to the Board.

MR. AMERI: We don't want that.

MR. THIBEAULT: And I would recommend that you do that instead of having the EO review it.

MR. PON TELL: I think we should at least, maybe, use the standard by which we review septic tank appeals. So at least have Staff have that level of review, to the extent it is necessary to have a board have a step in that process.

I found a lot of the conversation very interesting. I'm sitting here, Madam Chair, do we really need to keep the public hearing open on these, essentially, two items? Maybe for form, it may not be a bad idea,

because there were suggestions of additional alternative language that might be injected into it.

I do also agree this is actually -- having the opportunity to review it -- I viewed it as a very well crafted and balanced approach to what can be incredibly complicated issues. Congratulations to the process and the working group that invested the time in this.

Just some conceptual thoughts and especially, maybe with regard to San Bernardino and Riverside, some things to think about. I think the 12-month process for, you know, developing some more specific plans with low impact development is helpful to everybody.

There's a concern in the back of my mind about jumping on to a solution du jour that says, today -- and I don't know if I captured it exactly right -- the concept of capturing and mitigating runoff on a lot-by-lot basis being the best solution that may or may not be the case. I think there can be arguments for logical, neighborhood, local, community based, regional, subregional solutions for different types of activity. And to the extent possible, I think that the planning process in -- as it articulates in this permit -- should allow that level of flexibility and creativity in thought with regard to what may happen in any particular incident and what may be the best solution.

I am always curious when standards are set with

regards to modifications of parcels up to 5,000 square feet or 10,000 square feet or 100,000 square feet, because my question always is, why not 98? Why not 105? Where is the rational and logical way of thinking about it?

As LID moves forward, I think good planning is going to require an increasing amount of thinking about the system solutions, about how development occurs not just on lot-by-lot or project-by-project bases, but within the context of the community.

The other question that always comes to mind is -- in using Orange County specifically as an example -- what percentage of activity are we actually talking about since a significant percentage of Orange County is already built out?

So to the extent -- I think I heard someone say, the only way we are going to solve the water quality challenges is through low impact development. Well, you're talking about one, two, three percent of the entire county, then, is going to save the entire future.

So I think there is a disproportionate weight given to some solutions when it may be that a subregional or neighborhood or community solution can actually capture and deal with the currently built environment, which is the primary generator of runoff and all of the various pollutants we're concerned about. As opposed to the small

fraction of new development that's going to be occurring in Orange County over the next decade or two, over the next year or five.

I seriously doubt that there will be a lot of new development anywhere for quite a while. I hesitate to put our entire future, essentially, on the bubble of LID. I hope there would be some other solutions articulated in the permit that would be able to achieve our goals.

With regard to some specific recommendations, I see no reason not to include the term "biofilter" with regard to the catch-and-release -- whatever the right characterization would be. I assume staff could come up with the appropriate term.

I would also see that, you know, the ten-foot standard with regard to the separation -- and I do appreciate the ground water purveyors having an interest. And it would seem to me they would have a significant input into assessing what they believe would be a safety factor with regard to water quality.

I also don't necessarily see anything wrong with changing in C Number 3, essentially, the sentence that talks about the design -- instead of "The design strategy shall be to maintain or replicate," "the design preference shall be to maintain or replicate."

And so, once again, all going back to the

intent of, we want to do the best job possible. We want to use the best science possible. We want to devote our recourses to the best, most cost effective solutions that then perpetuate, essentially, clean water.

And my final comment would be, I would hope -- it is kind of interesting, reading through the cost benefit analysis on the permit -- which, I believe, was about a page and a half -- with a primary emphasis on looking at the ocean water, the beaches, the use of the beaches, et cetera, as a primary benefit and tying that to tourism and tying that to tourism dollars. It would be my strong suggestion if we can, in any way, beef up cost benefit analysis -- if we're going to be putting more energy towards smaller and smaller solutions down to a lot-based solution, per se, then we may need to add additional elements in order to actually have a cost benefit analysis of the permit that's being proposed.

With that, Madam Chairman, I would be prepared to vote today. I'd be prepared to vote in a month. It is to your pleasure.

MS. BESWICK: I want to give Bill a chance to comment.

MR. AMERI: Excuse me. I have one more comment.

MS. BESWICK: Could Bill comment before? And then I said Gery had a comment. I will give everybody a shot. And

I might comment.

MR. RUH: Other than the two items we have presented before us, which seem to be the point of contention, I believe we've gone through in good faith, everybody with the stakeholder process.

I believe the stakeholder process was designed to reach a consensus as best we could with everyone at the table in agreement. Not everyone is going to get every single item they want. But we come together in reason.

I see no problem going forward with it. Other than these two items, keeping them for the next meeting, to move forward with it just as it has been presented. Because that's what the stakeholders agreed to.

And to put other things in and change it, means we have to go back to another -- open the whole thing up. We've had agreement on consensus. The stakeholders worked this out. Other than these two items before us, which we can continue and let the stakeholders work with that, I think we need to go forward in good faith with what they've already worked on.

Thank you.

MS. BESWICK: I asked Gery -- I'm sorry. Did you want --

MS. MC CHESNEY: I had a few comments to make on the process.

MS. BESWICK: Great. Thank you. Please.

MS. MC CHESNEY: Now?

MS. BESWICK: You want to do it?

MS. MC CHESNEY: Sure.

One thing is that because it is an MPDS permit, it is required that there be response to all comments. I want to check with Staff if any comments today are new comments that weren't responded to in the record. And to -- if you postpone -- if you continue the hearing, then they can be responded in writing and provided later. If you don't continue the hearing, then we need to make sure they're responded to today.

The other thing is on the issue -- if you want to continue the hearing, I would suggest that if you want to have a future opportunity to consider the two items, continue the hearing and not vote today.

The reason is you're going to have two dates by which if anyone wants to file a petition to the state board, there will be two dates to do that and create a cumbersome process. But what you could do is say that you closed the public hearing now. You're providing an opportunity only to submit additional written comments on those items. And set a date certain by which that happens. So you're not, at the last minute, getting the comments, and then it's only on that.

So when you come back, again, you can allow additional public comment if needed on those items, but not review the whole hearing. And then you can vote on that.

MS. BESWICK: Thank you. Those are important.

Mr. Ameri.

MR. AMERI: These are just comments we may not want to include to be discussed later on and with just those two items next hearing, I have no problem with that. Besides what I already said. There are three other technical issues.

I don't see the logic behind changing the 5 percent EIA from a metric that we had to a volume capture metric based on the design volume. I am a little bit of a technical guy, but it is above my head.

MS. BESWICK: I asked Gery to address some of the things.

MR. AMERI: Number two, I don't see any problem with really keeping the ten-foot for the water table instead of the five.

And since it hasn't been brought up, I'm assuming all the stakeholders are in agreement, and the county, especially, is in agreement on the timeline. Because we have a lot of timelines here -- with 18 months within this. I hope this is all agreeable to everybody. And if it is all agreeable to -- that item should not be

included in the next, you know, focused hearing.

But I just wanted to make sure the time tables are acceptable. I didn't hear anything objectionable to that. So I think that, kind of, concludes my comments.

MS. BESWICK: Okay. I thought I asked Gery to address some of these things. Just a little bit of clarity. And then I'll keep the remarks to the end.

Gery?

MR. THIBEAULT: Yes. Thank you, Madam Chair. There are a few things. And I guess I can go backwards from Fritz to Steve.

The ten percent separation, Staff agrees with that. I recommend that be changed from five-foot to 10-foot separation.

The logic of changing from the 5 percent EIA to the 85th percentile is something that was worked out with all the stakeholders. This isn't something -- this is not prescriptive. It is an agreement that was worked out during all the stakeholder meetings that we had. I can go into it again --

MR. AMERI: No. If it is agreed to, I don't care.

MR. THIBEAULT: One of the things that Mr. PonTell mentioned was about the design changing in C3, the fifth line, where we talked about a design strategy. And Steve was looking for preference.

It is more than a preference; it is a goal. It is something that's being sought after. And so it is -- I was hoping he would use a higher level of strength word than "preference" because it is something we would really like to see implemented. And so if "strategy" is not good, perhaps "goal" would be another option.

MR. PON TELL: Yeah, I would agree with "goal."

MR. THIBEAULT: Great.

With the lot-by-lot evaluation, we're not sure where this comes from. There's nothing in the permit that requires anything lot-by-lot. If somebody has an approach that is at regional or in -- neighborhood oriented or whatever, and doesn't violate the prohibition on discharging pollutants to waters in the US. Which is always, like, the number one factor that prohibits long-range regional treatment from being implemented. Then there's nothing that says that kind of approach couldn't work.

You could capture and percolate everything. That's sort of what, like, the Inland Empire Utility Agency and some of the others are doing with large scale stormwater capture programs that they're implementing. I don't think there's anything in this permit that would ever prohibit anyone from looking at a larger scale perspective.

MR. PON TELL: I was quoting, I believe, the gentleman from Orange County who talked about potential concern about

the disaggregation of runoff mitigation to lot-by-lot treatment. I think he said something like that.

My read of the permit is it allows for a neighborhood, subregional, whatever the case may be, solution. And if I was a local jurisdiction attempting to cause a certain amount of development, or economic development to occur, I would probably want to develop a multi-entity resolution that can help to create walkable water ways and path ways and whatever else the case may be and accomplish the mitigation.

MR. THIBEAULT: That's something that Staff tried to include in the flexibility in the permit.

With respect to biotreatment. Staff doesn't have any objection to including that, these words into the two places. Page 55, number 7: If site conditions do not permit infiltration, harvesting and reuse. And then we would add biotreatment, comma.

And then in C2, on the screen. The third line after evapotranspire, comma, biotreat, comma, or capture. There's no reason why that couldn't be included.

With respect to having the process come back to the Board on appeal as opposed to just to the EO and then to the State Board. You can do it any way you'd like with respect to that.

And, typically, when there would be a

disagreement, it would be at a technical level. It would be, you know, engineering versus policy kinds of argument. And we can certainly bring those back to the Board. And then the next appeal would be to the State Board. And then -- what we're trying to do is make the process be a little easier to be approved.

But there's no reason it can't come back to the Board. It is going to take a little longer. If you intended 18 months for this to be done, that may be not enough, if it is going to need Board approval. We may have to give a little longer. Maybe --

MR. AMERI: My reason for that was that, really, we want to have a test of the implementation of this permit through our staff. We want to hear if there are -- I mean, yeah, we are not all technical and all that. But we have had a lot of technical presentations here that we made decision on, as far as ACLs and stuff like that what you show very technical, complicated stuff. I'm not afraid of hearing someone come in and presenting a design issue and for us to hear and make policy decision.

MR. ADACKAPARA: I think the intent was, actually, you know, if they were a noncontroversial issue, it doesn't have to come back to the Board. That was the main intent.

But if there are controversial issues that come up during the public notification process -- if you

look at footnote 55 on page 53, it actually provides two options. Either the EO can approve it or the regional board can approve it.

MR. AMERI: No. I think it has to be specific. If there is no agreement between the Applicant and the EO on the feasibility of doing something beyond the LID, it should be appealed to the Board. Period. Like we do with ACLs; right?

MR. THIBEAULT: And then with respect to the threshold question that was raised earlier. Our response to that would be, the threshold should be identified as part of the feasibility study. The threshold should be proposed as part of the feasibility study. And then that proposal, the way it's looking now, would come back to the Board. And you would identify whether the proposed threshold feasibility is adequate. So good luck with that, by the way.

Madam Chair, if you do leave the public hearing open for C1 and C2, it should be left open for all of C -- if we have changes we need to do a consistency review of the permit.

MS. BESWICK: Make sure it all --

MR. THIBEAULT: We might need to make changes, just for continuity.

MR. RUH: Would May 22nd be enough?

MS. BESWICK: Yes, it will.

MR. RUH: Maybe I'll take a stab at a motion.

MS. BESWICK: Can I have comment?

MR. RUH: Sorry.

MS. BESWICK: The reason I want to comment -- I want to start by saying, I'm always amazed and proud and always enjoy touting our region when we go to other meetings. Our stakeholders are an amazing group. They are so willing to give tremendous amount time. And have such a sincere approach to the process. And I think that also speaks highly of our staff. Because it means they believe they'll be treated ethically and fairly by the staff as well.

I guess my comments are going to come from the standpoint, I respect the process around here. And I also -- some of my fellow board members heard me say, I'm loathe to rewrite things at the Board table because -- especially here, when I think I heard there were eight stakeholder meetings. I'm not sure I'm really willing to second guess the people that participated in at least eight meetings on a word.

But that's not to say I would not be willing to be persuaded. If you want to have biofiltering, I'm good with that. If you want to go to goal rather -- but it is just it is not my nature to do that. I agree with the going from 5-foot to the 10-foot.

But the fact is that personally I'm not

enthused about doing other than keeping open the dialing about the items under C. I actually think, Fred, you can end up costing an applicant more time and money if they come here for an appeal and then go to the State Board for appeal. They can actually end up spending even longer.

MR. AMERI: We got to keep the option open.

MS. BESWICK: I'll go either way on it. I think you need to think about who the ultimate authority is. If we deny, they can end up --

MR. AMERI: I don't want that issue of E1 being overlooked. Either it's got to be --

MS. BESWICK: I'm perfectly fine -- my inclination on that one, I don't have a problem with EO making the decision. But I think the appeal could come to us. I'm not objecting to that. I'm suggesting if the appeal comes to us, it could also have a second step. That's all. And so when talking about saving people time and money, that's something to consider.

But for me, I would just as soon keep this open. Whatever you want to do on a motion as far as the appeal of the EO piece is fine. I really, personally, have a pretty high regard for the work that has been done by the stakeholder group, and I thank them for their time and conscience effort. And Mike as well. Very good job. This is tough stuff.

Now, go right ahead. Have a motion, Mr. Ruh.

MR. RUH: My motion is to keep the two items open and to vote on the rest.

MR. PON TELL: I think Counsel advised not doing that.

MS. BESWICK: Not keeping it open?

MS. MC CHESNEY: To not vote today on the permit, but to allow additional comment.

MS. BESWICK: He's just making a motion to keep the public hearing open?

MR. PON TELL: He's making a motion to vote on the rest.

MS. BESWICK: Excuse me.

MR. RUH: No. Keep it open so that we can talk about these two items.

MS. BESWICK: Well, could I make a suggestion? I think that -- let's go back to what Frances suggested.

MS. MC CHESNEY: You don't need a motion at this point. You can, by consensus, continue the public hearing to May 22nd, leaving -- and provide an opportunity to comment on, specifically, section 12C. And then deliberate next time.

MS. BESWICK: I think Bill's probably trying to get some vehicle for us to get to consensus on what we were going to leave the public hearing open on.

It doesn't have to be a motion. Perhaps it can just be a consensus of the group that we'll leave the hearing open on the subject of item C, in its entirety.

MR. AMERI: I want to let you know that May 22nd, since you need at least five votes, I'm not going to be in town.

MS. BESWICK: Do we have five people for May 22nd?

MR. RUH: I'm here.

MS. BESWICK: I promise we won't go to the next day. Are you two here? Then we've got it, then. We've got it.

So, I guess, that's the question. So that -- for the purposes of the people who are in the room that want to submit comments, there are two things.

One, we need a deadline by which we get the comments.

MR. THIBEAULT: We have four weeks until the Board meets. Perhaps we can have comments by two weeks, and cut it off at that time.

MS. BESWICK: Cut it off by May 8th. So comments by the 8th.

And then -- but I think what we need to get consensus on here is -- item C, we all agree to.

MR. PON TELL: Correct.

MS. BESWICK: Do we want to -- it seems to me the other pieces we might not need public comment on, but we as

the Board might want to still address. Such as the appeal process and the individual changes, the biofilter piece, the goal piece.

MS. MC CHESNEY: I want to comment. Just by leaving, continuing the hearing and leaving it open for further comments on specific issues does not prevent you from having minor changes to the permit, the word changes that could be developed over the next two weeks, also.

And your deliberation, next time, you know, in May that you may want to change something else, you can still do that.

MS. BESWICK: I think we're trying to limit the public comment.

MS. MC CHESNEY: Right. You can say now that the public comment is only on item C. That's it. Those two items and anything relevant to those two items. That's fine.

MS. BESWICK: All of item C. There might be a need to do some alignment of impacts of changes to C.

Is that agreeable then? Steve?

MR. PON TELL: Yes.

So then, Madam Chairman, I don't know if it's an expression of the intent of the Board on just a couple of the other items. But going from 5 feet 10 feet. Maybe if that language can be incorporated in the modified -- I do think maybe some language, to give us something to look at,

in the less than half a percent chance the EO's decision were, in deed, to be appealed, but then there would be -- we would be a step in that appeal process.

I do think that the word "strategy" may not be the best word. If there's not -- not to wordsmith too much. It is my nature. And then maybe to figure out how to incorporate the biotreatment.

I don't know if it's the will of the Board to agree to, in principle, with those changes, they can be incorporated.

MS. BESWICK: You're okay with those pieces? Yes. That's understood, then, as part of the process.

MR. AMERI: That's it, yeah.

MS. MC CHESNEY: I did want to say something on the delegation to the executive officer on those issues about the reviewing the criteria that -- Section E. That you could -- one option is that the executive officer could get the application for approval and determine that this is not one that the executive officer wants to approve but rather bump it to the Board.

MS. BESWICK: That's the opposite of how we're trying to do things, Frances.

MS. MC CHESNEY: Instead of putting in that it must go to the Board on these certain circumstances -- which might be hard to define. You can leave it up to the EO to

choose to say, "This one is appropriate" -- and that's what happened in the Los Angeles -- what's referred to as the SUSUMP order. The executive officer did approve the SUSUMPs, then it went to the regional board who then approved what the executive officer did, maybe added some more.

You could leave it open that just the EO will then bump it to the Board instead of making the decision.

MR. PON TELL: I think staff --

MS. BESWICK: I like that, too.

MR. AMERI: Pretty much what we do with ACL, isn't it?

MS. BESWICK: No, I don't think that's what we do with ACLs.

You know what. Let's let them bring something back to us. With ACLs, they are always on our agenda. And sometimes they are not. They always start on our agenda. That's where they originate. Right? Right.

MR. PON TELL: I apologize --

MS. BESWICK: Thank you, Steve.

MR. AMERI: There are some results we don't hear.

MS. BESWICK: No, they're always on our agenda. Unless they're resolved before the agenda gets published. I see what you're saying, Fred.

MR. THIBEAULT: They still come to you for approval.

MS. BESWICK: Okay. I think we have consensus. I hope everyone is in accordance and understands. We will have this on our agenda on the 22nd. Comments by the 8th. And we'll take final action, theoretically, at that time, unless something complicated comes up.

All right. Then I'm going to move on to the next item, which is Item Number 13. Public Hearing on the Clean Water Act Section 305(b) Integrated Report/Clean Water Act Section 303(d) List of Impaired Waterbodies.

Pavlova has probably waited for us all this time.

All right. Good afternoon.

MS. PAVLOVA: Good afternoon, Madam Chair, members of the Board.

I'm here once again to talk to you about the 2008 integrated report for our region. As you might recall I first presented this topic to you at the January 23rd board meeting. And at that meeting I presented a brief background on the regulations governing the integrated report and showed you the preliminary results of the data assessment that we had done. We were at the time also looking for public comments.

And it -- also at that meeting you heard some of the comments from the public and staff went away with the task to work with the public, hold public workshops, and to

obtain and respond to public comments.

It has been about three months now since the last board meeting. And I'm here to say we've come a long way since then. We held two public workshops. We met individually with stakeholders. And we have shared our data, heard their concerns and recommendations. And, consequently, we have revised the integrated report where appropriate. And, of course, we considered in making those revisions the state listing policy. We believe that we have a better product now. And before you today there's an agenda package that includes the staff report that summarizes my talk, and among other things, resolution for your consideration.

First of all, I'm going to show you the steps that board staff took to arrive at the current report and hopefully answer any questions you have.

I will begin with giving you a brief regulatory background and also explain what an integrated report is and summarize the new integrating report and share with you the most recent comments we have received from the public. And these are comments that would be received after April 10th, which is when the agenda was sent out. I will also explain to you the next step we could take and give you board staff's recommendations.

To begin with, section 305B of the

Clean Water Act requires the states to prepare and submit every two years to the US EPA every quarter, assisting the state water quality. EPA, in turn, reviews and approves the report which is used in the preparing the state of the waters report to congress.

Section 303D of the Clean Water Act requires the states to develop and submit to EPA for approval a list of waterbodies that are not meeting water quality standards and are not expected to do so even with technology-based controls.

I would like to point out that a water quality standard is defined as the beneficial use, the water objectives necessary to protect that use and the anti degradation policy.

Now, with that in mind, the integrated report combines the Clean Water Act Section 305B report and the Section 303D list of impaired waters. Further, it also places the waterbodies assessed into one of five categories.

Category 1 are those waterbodies that meet all water quality standards and no use is threatened.

Category 2 are the waterbodies that are meeting some water quality standards while insufficient data and information to determine if other water quality standards are met.

Category 3 are the waterbodies for insufficient

data and information is available to determine any water quality standards being obtained.

Category 4 is where one of more water quality standards are impaired or threatened, but the TMDL is not necessary if any of the following is true. The TMDL is already approved or established by EPA. Implementation of other pollution control requirements is expected to obtain water quality standards. Or the waterbody impairment is not caused by a pollutant.

Category 5, which I think is the biggest point of interest, are those waterbodies that are impaired. They are not obtaining water quality standards and a TMDL, or total maximum daily load, is not needed.

Let me point out that TMDL is a calculation of the maximum amount of pollutants that a waterbody can receive and still safely meet water quality standards. It is calculated by including a load allocation from point sources and load allocations from non-point sources and a margin of safety.

In California, it is each regional board's responsibility to prepare an integrative report. And the State Board is closely overseeing this process. They will review each integrated report for their approval and ultimately compile each of these into one state-integrated report.

In preparing the preliminary integrated report as well as the final draft before you today, Staff reviewed the data from approximately 60 waterbodies in accordance with the listing policy. And, also, staff consulted with stakeholders, regional and state board staff, and presented the preliminary report to you at the January board meeting.

As I said earlier in this talk, soon after the January board meeting, staff held public workshops and met with individual stakeholders. Comments from this public outreach included letters of support for the work staff had done. And others mainly dealt with suggestions on how to assess the data. A copy of the comments received is included in Attachment 7 of your agenda package.

A table outlining each comment with the corresponding staff's response is in Attachment 6.

Consequently, the integrated report was revised where appropriate and, of course, a table outlining these revisions is in Attachment 4.

Here is a list of the entities who provided comments. We are -- like you mentioned earlier, we are very fortunate in the region to have the stakeholders' interest in this process because it allows us to prepare a better product. As I mentioned before, the integrated report integrates the 305B water quality assessment and the 303D list of impaired waterbodies and places each waterbody

assessed into one of five categories.

Beginning with Category 5, here is a summary of the proposed integrative report: We're proposing to add to the 303D list Bolsa Chica Channel for ammonia; Oregon Creek downstream of Irvine Boulevard for ammonia; East Garden Grove Wintersburg Channel for ammonia; Newport Sleuth for enterococcus; Peter's Canyon Channel for pH; Serrano Creek for pH; Chino Creek for PH; Chino Creek Reach One B for chemical oxygen demand; Chino Creek Reach Two for pH.

And at this point I'd like to make a correction on this slide and also on your agenda package. We are going to be proposing to remove City Creek from the current 303D list or Category 5. Primarily, that was an oversight on our part. The data doesn't reflect that there is impairment there for mercury or cardamon.

Cucamonga Creek Reach One for pH, copper, and zinc; Cucamonga Creek Reach Two for PH; Lake Elsinore for sediment toxicity; Rathbone Creek for cardamon and copper; San Antonio Creek for pH; Santa Ana River Reach Three for copper during the wet season; and Temescal Creek Reach One for pH.

Let me also point out that the TMDLs for these developments such these TMDLs are expected to be no later than 2021.

Just like we can add waterbodies to the 303D list, we can remove them from the list. For our region, assessment of the data has suggested that we take these waterbodies from the list: And that's Big Bear Lake for sediment, siltation, and metals; Grout Creek for copper; Knickerbocker Creek for metals; San Diego Creek for metals.

Moving along to Category 4. That includes waterbodies that are impaired, but no TMDL is required because an approved TMDL is in place. This category includes Newport Bay for bacterial indicators.

Category 3 includes waterbodies with insufficient quantity or quality of data to determine if any standards is being attained. These are Chino Creek Reach One for pesticides; San Haibane Creek for pH, chloride, total dissolved solids, sodium, sulfates, and total nitrogen.

Moving along to Category 2 which are the waterbodies meeting some standards, but we don't have enough information to determine if there are other standards met.

As you can see, this list pretty much includes beaches. Bonita Creek, San Mateo Creek, and Mill Creek in the Prado areas.

The water bodies meeting all water quality standards -- I wish we could tell you we have a long list, but at this point the data we assessed did not show -- did

not reveal any waterbodies in this category. None of the 60 waterbodies assessed fell in this category. And that may be because monitoring has focused mainly on problem areas and a lot of the data is focused on those areas. So it is not really that there aren't any.

Like I said before, we have received comments after April 10th, 2009, when we had sent out the agenda. So these comments that were received are here on these two slides for you to look at.

The main focus of these comments are from Orange County Public Works. They would like us to make sure that the ammonia listing for Bolsa Chica Channel and East Garden Grove Wintersburg Channel be limited to the title prism.

At this point regional board staff does not agree with that comment. Primarily because the samples that were collected in these channels were in the fresh water part of these channels, and we don't believe that the exceedences (sic) are caused by the title influence.

The other comment that we received was from Riverside County Flood Control District. They submitted a map that depicted the areas where there were fires. And they would like us to consider this map in the effects of the fires in assessing the Lake Elsinore sediment toxicity data.

The map was a very nice, well put-together map. It was very informative, but it did not indicate that there would have been an influence on the sampling that took place in 2003. As a result, it would not have influenced the data assessment for that period.

We also received a fairly lengthy letter from the Santa Ana River Association where they summarized their comments. These comments are fairly -- are, basically, not new. These are comments that, basically, were discussed with us during stakeholder meetings and individual meetings and via e-mails and phone calls. And as a result of these comments, we have revised our integrated report. So I, basically, summarized the comment on this slide.

As you can see, we have come a long way since the January 23rd board meeting. And there are yet a few more steps to go. Once this integrated report is approved by the regional board, it will be transmitted to the State Board with all the associated information.

The State Board will in turn review and approve the integrated reports from each regional board and will transmit all these as a single integrated report to US EPA for their approval.

Let me also add that we're not too far away from the next integrated report cycle. This next cycle begins at the end of this year, beginning of 2010 or end of

2009.

I also would like to bring up that we have an errata sheet included in your package. This recently added errata sheet amends the resolution. It gives the executive officer the authority to make non-substantial changes to the water quality assessment data base prior to transmitting it to the State Board. And we would also like to add to this errata sheet the deletion of City Creek listing for cardamon and mercury.

With that, I would like to conclude with Staff's recommendation to the Board to adopt Resolution Number R8-2009-0032, approving the 2008 integrated report, including the 303D list of impaired waters as presented and amended by the errata sheet.

That concludes my presentation.

MS. BESWICK: Thank you.

Any questions?

MR. AMERI: A lot of work since the last time we heard you.

MS. BESWICK: Thank you.

I have a few people who would like to comment.

I'm going to start with Tim Moore. He promised he isn't going to use as much time as he put on his card.

I know. Why should you be exempt?

MR. MOORE: It is proform to thank staff. And I am,

but that simply does not do it justice. It just doesn't. I would have bet a lot of money it could not be done what I saw Pavlova do for the last four weeks.

She took a year's worth of work, took our criticisms and suggestions, and redid the analyses for 60 locations and all that data and all the perimeters. Not once, but twice. And I don't know any engineering person that could have done that in the time that was allotted, and do it as well as she did.

It is so far and above the call of duty, I just can't simply say it is nice to work with your staff. This was a miracle. So kudos for Pavlova for pulling it off. And as a result I can stand here and say I think we have no serious objections to what's going forward to the State Board.

I'd like to, then, condense my comments to the two issues where we need some clarification.

I'd like to point to the NRDC's presentation this morning that pointed out the Pinto Creek decision. Which basically says that if you list a waterbody on the 303D list and have not developed TMDL for it, then there are pretty severe restrictions on what you can issue permits for with respect to new discharge.

And so there's always a big question what constitutes a new discharge. Is every new development a new

discharge? Is Riverside's treatment plant plans to expand their facility a new discharge or is that an expansion of existing discharge? You can get into really tight knots on this stuff.

And what you don't want to do is look at the list and say, "Well, you don't have do the TMDLs until 2021." The reality is, while that's true, between now and then, until the TMDLs are developed, you may have some serious restrictions on what permits you can issue. You want to be very thoughtful about that.

The other thing I wanted to do -- this came out of this morning's presentation -- is refer to these Watershed Action Plans. Because, once again, the new language of the new permit says if you have a stream or waterbody listed as impaired, but for which, yet, there is no TMDLs developed, then there is an expectation that the stakeholders will provide you a watershed action plan as to how they intend to monitor this. And what they intend to do about it until such time as a TMDL is developed.

What I want to do on the last two issues, the two proposed listings, is talking about that. I want to talk about what we intend to do over the next two years. Make sure that's acceptable to you and your staff, in a general sort of way. In which case, if it is, then we can accept the listing and don't have to go fuss with the

State Board or any of that. Because we think we can resolve the issues in short order.

The two we have concerns about are the Reach Three copper listing and the Lake Elsinore sediment toxicity listing.

In the case of Reach Three, we think what is going on here is we have a whole lot of data that is copper measured in the total recoverable form. And all that work we went to 16 years ago to develop a translator between total and dissolved was intentionally done very conservatively. And, frankly, the translator does a great job of figuring out what is going on during base flow conditions. But doesn't do a fantastic job during storm flow conditions, which are as you saw the wet weather conditions where we have the exceedences (sic).

We believe if we spend the next year or two gathering some more data, we can develop a wet weather translator that is appropriate for stormwater. So we don't have to rely on what we did 16 years ago. And once we do that, if things fall into place -- as EPA says we should expect them to, based on their generic formulas -- this listing will go away.

And so I want to suggest that that's what we intend to spend the next two years doing, looking at water effects ratios, looking at stormwater TD ratios, and perhaps

collecting some actual dissolved data instead of total recoverable data, and revisit this in two years.

Why am I bringing this up now? Because there's a difference of delisting and coming back -- and there's one set of mathematical probability criteria for doing that -- and another that says, two years from now, "You know, that listing we did two years ago probably wasn't correct. We didn't have all the data we need. And if we'd had this, we would have made a different decision."

I want to make sure that latter option is open. Because it's substantially easier and less costly to just fill in the blanks that are missing and go back and reevaluate all the data than it is to come up with whole new data showing that there is, now, no impairment and all the old data stays as it is with its voids.

So it is just an approach, I think, makes perfect sense. If I leave a placeholder here, since some people may not be here, I can refer to this and say, "Yeah, that seems reasonable." In the meantime, you list it and we'll work it out two years from now.

MR. AMERI: But when you list it, isn't it a big process later on if you found out in a year --

MR. MOORE: It can be. But it doesn't have to be.

Okay. There are two ways to delist. One of them is a really big, ugly, nasty, statistical thing that

requires an immense amount of data. And the other is to say, "You know, we had a little more data that helps us evaluate the old data we used the first time."

In this case what we need is how much of the copper in the middle Santa Ana River that we measured as total recoverable is actually in the more toxic, the toxic dissolved form. We can kind of guess at that now. But we don't have to.

If we get a good translator, we can go back to the old data, refigure things and just say, "We were overly conservative. We made conservative assumptions because we had no better data. Now that we have onsite specific data, we don't have to make that assumption. And our previous assumption was in error." That's just easier to do. Requires less data and less money, mostly.

All right. Lake Elsinore. There's no question whether it is failing the sediment toxicity test. So we're not here to dispute whether we see this phenomenon occurring.

What we have concern about is what is already written in the Staff's report, which is we don't know what is causing it. It might be being caused by some of the nutrient problems that have already been identified for Lake Elsinore, and for which we already have a TMDL. It might be being caused by the fact that all the data that was

collected for this study was collected in 2003 when the lake was very low. A lot of the water had evaporated which concentrated the residual salts.

And we know at high salinity levels this particular test level doesn't fair very well. So it may be a combination of those things. The hydrogen sulfide coming off the bottom from the organic material decaying from the nutrients. Might be some ammonia issues. Might be salinity. Might be all those things.

The key thing is this. If it is salinity, there's not much we can do about that. If it is nutrient related, we are already doing a lot about that.

The next natural step after this listing is to figure out what the specific cause is. I can tell you that having done that many, many times across the country, that's a 100 to $200,000 next step. It is very expensive for sediment toxicity. Very complicated.

What I would suggest is this. We spend a fortune on putting aerators into Lake Elsinore and adding supplemental reclaimed water flows to get the elevations up. And we genuinely believe these things, as I told you last December, that these things are going to make a big difference.

So our thinking is, we structure a reassessment process to look at whether or not those things solved the

problem. If it's ammonia or hydrogen sulfide related, it ought to have. And that we reassess in a wet year when the salinity's a non-issue. That will very quickly tell us that it either is or is not these other alternative explanations.

If it is not ammonia or hydrogen sulfide or salinity, then it's something more serious like perhaps a pesticide. In which case we're off to the races doing the TIE work, the toxicity identification work.

And we think that, you know, we wait for a wet year -- three, four, five years -- reassess, and if it is not what we think, then we -- if we think -- if the TMDL's going to solve it; it is going to solve it. If it's not, we do the TIE. And that still leaves us four to five years before the TMDL itself is due. But to do a TMDL, you have to know what is causing the problem.

What I'm suggesting is an approach that simplifies figuring out what is causing the problem. So we don't have to spend so much money in a rough year. Gets us to the exact same place on the exact same schedule.

That's the watershed action plan we would likely be proposing to you. If that feels right to you, then the listing itself doesn't give us great pains, and we'll go prepare -- what we do the next year and the year after. And what we do if it is this. And what we do if it is that. And it'll show the decision tree all the way to

the TMDL in 2021, if still necessary.

I want to make sure that that proactive approach is okay. And what we don't have to do is, especially with copper -- we don't really believe we have an impairment, but in Lake Elsinore we probably really do. But a question of what it is matters a lot as to what we can do about it.

So that's it in a nut shell.

MS. BESWICK: That was good Tim.

MR. MOOR: Okay. That's what we're suggesting. Doesn't change the recommendation -- but if I can get some clarification on that -- it changes the likelihood we ever need to go to Sacramento and argue this in front of the State Board.

MS. BESWICK: Any input for Tim?

What would you like someone up here saying?

Joanne, you would like to respond.

MS. SCHNEIDER: I was going to comment. I obviously don't want to step on the toes of my stormwater colleagues. I would suggest that what Tim proposed is exactly what should happen.

MS. BESWICK: That's a pretty strong endorsement, isn't it. I wouldn't say another word, if it were me.

Does that help?

MR. MOORE: It helps a lot. We want to make sure

we're doing the right thing. We don't want to get stuck in an unintended consequences, oops.

MS. BESWICK: All right. Great. Thank you. Enjoy your weekend in Southern California.

John Kemmerer. Thanks for waiting all this time.

MR. KEMMERER: Hi. Good afternoon, Madam Chair, members of the Board. So thanks for the opportunity -- my testimony on this is actually -- my understanding is that the staff is proposing the list be adopted and passed on to the State Board. And we don't at all object to that. We think the staff has done a great job in putting this together.

I want to let you know we do have a disagreement with conclusions on two of the waters that are being considered here. Those are, Temescal Creek Reach 6 and San Diego Reach 1 and 2. So in those cases there's a clear analysis given here. And it discusses that there's some elevated levels of bacteria.

Staff is making the recommendation that because of some standards that are going to be revised in the future, they're not going to be listed at this time. We think there's some legal vulnerabilities with that argument. And as was described, the process here is you guys adopt it. It goes to the State Board. It comes to us. And we approve

it. And we can add waters to it.

So we'll be taking a close look at these couple waters, and it is possible that we'll be adding them to the list based on our reviews.

MS. SCHNEIDER: I appreciate that. And we also have to note, the State Board staff also has an opportunity to make recommendations different from those we provided to you.

And what Mr. Kemmerer refers to specifically are some e coli measurements, as I recall, for Temescal and San Diego Creek. At the present time, of course, our bacterial quality objectives are not based on e coli. They are based on fico coliform. However, EPA does have national criteria based on e coli.

But the concern that Staff has in applying the e coli data is basically that the data is very limited. And we're talking about an analysis of samples collected once a month, perhaps twice a month, to a value assigned to a single sample maximum value as opposed to the more traditionally employed geo mean, which gives you a heightened level of confidence with respect to actual public health risk.

And EPA's guidance has, in fact, explicitly acknowledged that the single sample maximum values should be used, are intended for use for posting purposes, for notification purposes, and as triggers for additional

monitoring. Now, I will acknowledge that EPA does not limit the application for single sample maximum values for just those purposes. But acknowledges the states have at their discretion to use them for other water quality standard program uses.

In this case, Mr. Kemmerer is suggesting that we use them for impairment assessment purposes. We just -- given the high level of variability of single sample maximum values, we simply don't think they should be used for impairment purposes. This is a theme, actually, repeated in the California Ocean Plan with explicit language therein.

And I think the other concern is that in the specific application of the single sample maximum values, I think the EPA and, perhaps, the State Board staff are purposing to evaluate the data using a single sample maximum value that is calculated based on a couple of assumptions.

One being that we're talking about designated beach areas, which, in this case, we're not. Neither Temescal Creek nor San Diego Creek Reach One or Two, I think, in most people's judgment be designated beach areas.

And furthermore, the equation that is used to calculate the single sample maximum values has a variable that reflects the variation in data. And we know that there's a lot of variability for these particular waters.

That if we were to employ the greater variability in -- the equation would, in fact, result in a much higher single sample maximum value.

The single sample maximum values are to be used, and EPA is very explicit on this, really as statistical constructs to tell you whether or not you are actually meeting your geo mean, which is typically the way the objectives are expressed.

And you want a greater level of confidence and more stringent number for a single sample maximum where you want greater confidence that your geo mean is being met. That's where you have a very stringent single sample maximum value that applies to a designated beach area. Where as if you have an area that's very infrequently used, you can allow for higher single sample maximum because you're not so concerned about making sure your geo mean is met.

In our best professional judgment, to employ the single sample maximum data in this case simply does not make sense. We completely acknowledge we've got some high numbers there. That we need to follow up on. And what we proposed do is collect additional data and ask ourselves based on the additional data do we have a bacterial quality problem that warrants listing?

And as Pavlova has indicated, we're going to be in that process in the pretty near future. We will

respectfully disagree on that score.

MR. KEMMERER: I appreciate the explanation. The write-up I have is from, I believe it's from the proposal. It doesn't base the conclusion on the single sample maximum. It is the fact that there's this new process for new criteria.

MS. SCHNEIDER: We've supplemented that response substantially.

MR. KEMMERER: I'll take the response back.

MS. BESWICK: That was well put. Thank you.

Garry Brown and then Amanda Carr will follow.

MR. BROWN: Garry Brown, Orange County Coast Keeper.

First, we would like to thank Pavlova for all the work she has done, and the great work she's done on developing this report. And we are in total support of her work, and what she has done.

A lot of the data -- some of the data we submitted on these and -- of particular concern is -- to us is to make sure that the recommendation for the ammonia listing on Bolsa Chica Channel and the East Garden Grove Channel, we support that.

We don't see the prism as an issue because the samples weren't taken in a prism, they were taken further up.

We hope that you approve the list, the report.

Thank you.

MS. BESWICK: Thank you.

Amanda followed by Matt Yeager.

MS. CARR: Madam Chair, members of the Board, thank you for the opportunity. I'm the Chief of Water Quality Planning for County of Orange. So I sat through all the permit discussion as well. That was very important because my group does the TMDL. We're all interrelated.

Just wanted to offer a, sort of a clarification to our comment on the East Garden Grove Wintersburg and Bolsa Chica Channel limiting the listing. That was mainly based on a beneficial use issue that those channels are not listed in the basin plan, but the sections of channels that are listed in the basin plan are the titally (sic) influenced area.

We asked -- to be consistent with the basin plan and the designated uses for those areas -- that we limit the listing to the area that's listed within the basin plan. We realized that the samples were taken further up stream. But those areas do not have beneficial uses assigned to them and are not included in the basin plan. That's our viewpoint.

And then I also wanted to just quickly reiterate what Tim was saying in the beginning of the process. You know, working with Pavlova on this 303D listing process has been very, very clear, very helpful.

She has always been willing -- in fact, she came out to our offices, e-mailed me all her spread sheets, and we went through issues and discussed things very clearly. I thought it was a very clear and open process.

And, you know, a great regulatory process to work through. And I can only hope that our Region 9 folks, who we also work with, will be as cooperative in the listing process.

MS. BESWICK: Now, don't go telling Region 9 that you really like the way it was done in Region 8. They hear enough of that.

MS. CARR: Thank you for the time.

MS. BESWICK: Thank you very much for sitting through all of that.

Matt and then Jason and --

MR. YEAGER: Good morning, again, Madam Chair, members of the Board.

I got a call -- I remember getting a call -- or I came back to my office a few weeks ago and there was a message saying, "You better call Pavlova. She called and wants to talk to you." I thought -- not sure what to do.

Following that, I found that Pavlova was really great to work with, very collegial. We went through the data, again, echoing what Tim said.

Mike, I have a question. At this point if I

was to have a question with one of the remaining listings that I think might be incorrect, hypothetically, how would I -- what is the process -- I don't want to go any further than necessary if, in fact, there's something missing.

MS. SCHNEIDER: Well, I'll give it a try. You can correct me. I think that if you have additional, relevant information, then by all means share it with us. And if we're persuaded that it has merit, we can forward it to the State Board as well for their consideration. Of course, they have to go through a similar process.

MR. YEAGER: Can I do that Monday or whenever possible.

Again, thank you very much. Very collegial and worthwhile. Great work. Thank you very much.

MS. BESWICK: Thank you.

Jason?

MR. UHLEY: Jason Uhley, Riverside County Flood Control on behalf of Riverside County MS4 program.

I'd like to concur with Joanne's comments on Temescal. They were very eloquent.

We just also wanted to gush about Hope and Pavlova's work. I think that they really went above and beyond this. The additional stakeholder process was really helpful. And we believe it's really important because the 303D list is having an additional regulatory meeting for us.

And it's really important that we get the list right because it has -- it costs the city money if we get it wrong.

I hope that this level of effort will be continued forward.

Thank you, again, for that.

MS. BESWICK: Thank you for your comments.

Hope, would you like --

MS. SMYTHE: I need to make one quick response to Ms. Carr's comment about the title prisms and the beneficial uses in the basin plan.

For those two channels, they are not in the Basin Plan and do not have assigned beneficial uses. But the ammonia criteria that we looked at is related to the fishable goal of the Clean Water Act. And it's completely appropriate for us to apply the aquatic life beneficial use to those channels, even if they are not in the Basin Plan.

MS. SCHNEIDER: Those uses are presumed.

MS. SMYTHE: Exactly.

MS. BESWICK: Thank you.

That's the extent of the comment cards that I have.

Do we have any questions by the Board or staff?

If not, are you ready to take action on the list?

MR. RUH: I'll make a motion for the item as

presented.

MS. BESWICK: With the deletion of City Creek?

MR. RUH: Correct.

MR. AMERI: Second.

MS. BESWICK: Any discussion?

All in favor, please say aye.

BOARD MEMBERS: Aye.

MS. BESWICK: Any opposed?

I believe that's our agenda for today. So we'll reconvene on the 22nd. We'll all be there.

(Board meeting adjourned at 3:11 p.m.)

think we need to do that.

Mark Grey, followed by Eric Strecker.

MR. GREY: Chair Beswick, members of the Board, staff.

Mark Grey, representing the Construction Industry Coalition on Water Quality.

I'm going to -- Paul covered a number of the areas today. I'll endeavor to be as brief and snappy and entertaining as I can.

MS. BESWICK: You're off to a good start.

MR. GREY: Thank you.

First off, so you know who I'm representing. I'm the technical director for the Construction Industry Coalition on Water Quality. And I represent the management and the labor, the women and men who build most of the projects that we are providing conditions for in these permits in Southern California. And I represent the Associated General Contractors of California, the Building Industry Association of Southern California, the Engineering Contractors Association, and the Southern California Contractors Association.

Again, it is a coalition of management and labor, women and men who build the infrastructure and housing needs throughout Southern California.

MS. BESWICK: Can I add, then, is Paul in your

employ on this subject?

MR. GREY: Paul works with us, and also Eric, after me, works with us.

MS. BESWICK: Well, try and only cover things not already covered.

MR. GREY: Exactly. I've got a presentation.

There were some changes today. I'm going to cut to the chase on a couple topics that Paul -- I don't think he covered in detail.

First off, what I want to cover today -- next slide, please. I wanted to make remarks on the progress we made in the stakeholder group that was an excellent process. We did have a divide in that process. Paul talked about that divide.

Universal retention of the 85th percentile storm, which, for the audience and everyone else, that equates to three-quarters of an inch to, maybe, in the foothill areas up to an inch and a half of rain fall. Something we can all relate to.

We're talking about handling, in low impact development BMPs, three-quarters of an inch to an inch and a half, depending on your location. We reached this divide in the stakeholder group.

I'm going to present a couple slides on low impact development definition from US CPA and the

State Water Resources Control Board. Very important definitions that we're asking staff to help us clarify and make sure that's what you mean in the permit. That's my clarification point.

Next slide, please.

We have a great history of progress. Great history of collaboration, supporting stormwater management sound solutions in Orange County. We really -- I want to point out we support this master planning concept into the permit. Very important. Can guide us in infiltration, where infiltration suitability. Can guide us where harvesting and reuse makes sense. Relative to what agencies like Orange County Water District is doing. Where it is appropriate. Where is it is not. We are very supportive of master planning in this permit.

Next slide, please.

The divide -- Paul mentioned the divide. We don't believe that universal retention makes sense for low impact development. Filtration of water through engineering BMPs is an essential tool in using LID principles. This is widely recognized and is recognized in national programs.

And now if I could just jump to what would be slide five. Go back, please.

The US EPA LID definition, this appears in the green infrastructure glossary. We've provided the cite to

Gary, Mr. Thibeault and Mike Adackapara, part of the staff has the citation.

LID, a comprehensive stormwater management insight design technique. Within the LID framework, the goal of any construction project is to design a hydrologically functional site that mimics predevelopment conditions. This is achieved by using design techniques that infiltrate, filter, evaporate, restore, and runoff close to the source. I added the emphasis on hydrologically functional and filter. "Filter" is an important word. "Filter" means biofiltration. It means biotreatment. It means treat and release. That's what we're asking for in this permit. That the conception of LID includes not only infiltration, harvest and use, evapotranspiration, but biofiltration as well. Very important and critical.

Next slide, please.

State Board definition. This is our State Water Resources Control board. The goal of LID is to mimic the site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and retain runoff close to the source of rain fall.

I think you get our point. "Filter" is a very important word here.

I would like to jump to slide 7 and 8, please.

There's been quite a bit of talk, and what I'm

going to skip over that I'll provide in our comments. There's quite a bit of talk about national programs. How much water they handle, what LID BMPs are allowed in these national programs.

We've examined them very closely and provide on the record, really, what are in these national programs and what they require. I just offer that to staff and to the board members for your use.

Next slide, please.

Next slide after that.

Before I go here. I ask you for just a few clarifications. Number one, we are seeking clarification that the LID performance standard permit and anticipate the use of all LID BMPs, including LID treatment BMPs that release water.

I think I made that point over and over. I want to re-emphasize. That's very important to us. We hope you please confirm that the definition of low impact development BMPs that's used in this permit is constant with the EPA definition. We would appropriate that clarification. And I've got other comments on the slide that can you see.

Next slide.

Number two in section C2, this word "capture." That's very ambiguous and vague. We prefer it be

biotreatment. It could also be biofiltration or filtration. We feel strongly that the word "capture" provides a tremendous amount of ambiguity.

And I'm trying to be brief, Chair Beswick.

Number three, the last clarification that we seek. We request that the word "strategy" in section 12C3, which is obviously after two, replaced with the word "preference."

And there, somewhat, we think that this would support staff's intent, and we've talked to Staff in length and stakeholder groups and subgroups that we talked about LID BMP sizing about prioritizing various LID measures. And we think this change would support Staff's intent of prioritizing but not mandating the mimicking of predevelopment hydrology. This then would be a directional statement and not a mandate.

I conclude today in my remarks -- last slide, please. We support LID at the Construction Coalition on Water Quality. We support the full conception of it. Not allowing it to be zero discharge. That doesn't make sense. It doesn't mimic predevelopment hydrology. It doesn't necessarily match the water balance.

We feel there's a strong technical and legal foundation for that, allowing some runoff from the property.

And finally, as I pointed out, I asked you to

seek clarification on some points. Especially, the LID definition provided by US EPA and a couple word changes, that you can see from the deliberations today, that C -- 2 some of the language, especially the word "capture" caused confusion. We think by adding the word "biotreatment" or "filtration," that that would clear up that ambiguity.

Thank you very much. Welcome any comment or questions.

MS. BESWICK: Anyone have questions?

MR. AMERI: That's at least very important to me. Mike, could you provide us with an actual written definition of LID by EPA and by the State so we can actually -- not that we don't trust you.

MR. GREY: Thank you.

MR. ADACKAPARA: There are actually a lot of definitions for LID. Some of the definitions do include filter as an option. Some definitions do not include filter as an option. I don't know if there's one legally defensible definition.

There are so many definitions. Even if we look at EPA site. The EPA itself has several definitions for LID.

The State Board has come out with some definitions. Most of those definitions do include filter.

MR. AMERI: You're handing me to the website.

MS. BESWICK: Okay. While he's doing a search, we'll have Eric come up and address us. After Eric, we'll have Greg Woodside.

MR. STRECKER: Madam Chair and the Board, I'm pleased to be here today. It has been very intellectually stimulating to be involved in the consensus building process up to this point. But I'm going to be the technical nerd here and get into the engineering side of things. I'll try to be as fun as an engineer can be.

If I can go to the next slide.

Just a brief introduction on myself. I've been a registered civil engineer in the State of California since 1987. I've got almost 25 years experience helping folks think about both the applied research side of urban stormwater as well as actually getting things into the ground. I was a member of the Blue Ribbon Panel to the State Board on whether numerical effluent limits are feasible in the stormwater permits. And I've managed a number of other projects. And I won't go through the rest of those.

Next slide.

I think we need to step back and see what makes stormwater BMP effective or not. It's really a function of a number of parameters.

First one, what does the runoff look like? How

does it arrive? How do storms arrive? Do they come together? Are they spread out? Those kinds of thing.

Next thing you need to think about, what kind of volume am I going to have to store that water, either temporarily -- I guess it's all temporary -- until I can infiltrate it, evapotranspire it, harvest and reuse, or draw it down. So -- and I just alluded to the next part, how we look at BMP function. It is not about the size of the facility. It is about how fast I can recover the storage, so I'm ready for the next event.

If the tank is full or the bioretention system is full, the next event comes and I'm bypassing. And I don't get the treatment or capture onsite or whatever the goal is.

And finally, what's important is the treatment processes included. What are the physical, biological, and chemical treatment processes that I include in the system to get after the pollutants and parameters of concern. And that, to me, is an issue even with infiltrate. I want to make sure before I infiltrate I'm doing the right processes along with if I discharge from the site.

Next slide.

So let's talk about weather patterns -- it's actually applicable to the West Coast. The West Coast, if the high pressure ridge is up, we're not getting a lot of rain. We might get a freak thunderstorm once in a while. The high

pressure ridge is down, we get a series of storms coming through, pretty much, back to back. That's very different than other parts of the country. Say, if you go to the East Coast where the storm patterns are much more regular throughout the course of the year.

In addition, much of our runoff falls in January and February. And next highest portion is in December and March, so those are really when the rainfall comes.

So the results of that is when we look at harvest and using for irrigation onsite, it is very different. We are getting all the water at the same time. It's very hard to use that in a way for irrigation. And then evaporation opportunities are limited. We're getting rainfall at the same time we want to be evaporating.

Next slide.

One of the things I haven't heard in a lot of this debate is thinking about what is really the natural water balance. One of the things I'll fault LID with today, they haven't thought about ground water. Everybody's focused on mimicking hydrology. And hydrology, to me, as a practicing engineer, does not include just surface runoff. It also includes what infiltrates and impacts ground water.

So in Southern California -- and I can -- the citations are in some of the submittals I have given to

you -- roughly on the order of 80 to 95 percent of precipitation on undeveloped lands is evapotranspirated. And then somewhere between 2 to 10 percent is either runoff on an average annual basis or deeper infiltration.

You know, and when we put in impervious areas, we reduce the area we can use for evapotranspiration. And if we have a goal as a society in having dense developments that, again, limits the ET areas that are available. And we can help mitigate that by putting in things like green roofs and porous pavements.

But, you know, I look at how applicable those are in all conditions and whether they're going to work everywhere.

Next slide.

So let's talk about infiltration. The first question, can you do it? And much of the soils in Orange County have very limitability to quickly infiltrate. I don't know how many of you have dug a hole in the ground to plant a tree. And you put water in it and see how long it sits there.

I would also argue that soil amendments -- you can put soil amendments in the hole, all you're doing is reducing the storage of the hole. The water's still going to sit there for a long time. You really have to think about what are the underlying soils. You're not going to

fix the problem by just amending the soils on the site. You might increase the storage, but, ultimately, it will not fix the problem of getting the water in the ground.

So when that storage that's provided in infiltration is full, bypass occurs.

Next slide.

The next question you have to ask. Should or how much should I infiltrate?

So I think about things like where I have natural plumes like selenium out in Peter's Canyon Wash area. There's manmade plumes. We have areas upgrading of dry streams, if I shove a bunch of more water in the ground over natural conditions I might convert to a willow Arundo thicket. And I'd like to say, Mr. Toad isn't happy in that circumstance.

That was a joke. Sorry.

If I don't match ET rates, then I'm going to have infiltration -- if I use infiltration to match runoff, I'm going to have increased infiltration over natural conditions. Is that a good thing? I would say, if I was in an aquifer that's being managed, great.

You know, Central Valley, California, where they're pumping the heck out of that thing, I'd be infiltrating in a safe manner as much as I could. But in watersheds where that's not the case, I would be thinking

about that.

Next slide.

The next question is, if I'm going to do it, I need to do it carefully. I need to do it in areas above the water supply aquifer or unnaturally low for some circumstance, but up to a certain point to get back to where it should be, and it must be done in a way to protect the water supply. We need to work with water agencies and say, "Let's do this in a way you can live with." So bottom line, infiltration should be carefully thought through on a watershed-by-watershed basis.

Next slide.

Let's talk about evapotranspiration. After development, there's going to be less area of evapotranspiration available. So even with vegetative roofs and especially in high density projects. It's not appropriate to compare monthly precip to monthly ET rates when one's looking for using ET as a way to get rid of stormwater. Again, the storms arrive back to back. And storage within the soils are not going to recover enough when the next storm arrives.

On the next slide, this is the -- the magenta color is the average monthly precip in Irvine. And the green color is the average monthly evapotranspiration. And a point has been made in some of the submittals that when

you look at December/January, they're roughly equivalent, "Why can't we do it?"

The next slide shows weekly values. And here the blue, again, is rainfall on any given week, or average for a week and the evapotranspiration levels. So you start to get an understanding that I'm getting a lot of water when my evaporation rates are low.

The next slide.

Here's a natural site, you know, predevelopment. I have the whole site to use as my ET. I like to call it the sponge. You know, after I develop and put in bioretention areas, shown in blue -- let's say, in this example, even if I put green roofs on all the houses, that's not the same level of sponge pre and post. And so we have the difference between ET levels and precip as it comes, and then compounded with the fact we don't have as much area to use for evapotranspiration.

So the next slide.

We also have an issue from a vertical standpoint. Again, I've got the system spread out. I can amend soils in the bioretention area. I can amend soils out in the rest of the site as well to try to act as more of a sponge. And I should do those kinds of things. But I'm only going to have that certain area of a small bioretention area, in this particular case, to do my, you know, storage

of the runoff from the site and get it into the ground.

So next slide.

What are the general water balance implications? I'm not the top chart -- this will be different for every site. On the top chart, in semiarid climate, I'm showing a 70 percent ET. I mentioned earlier it can be much higher than that.

Let's say, you know, on site it is 10 percent surface discharge and 20 percent percolation. If I put in LID to match pre and post runoff, I might have 70 percent percolation. In the water supply reservoir, great. In somewhere where that's not appropriate, that's a potential habitat change issue or other issue, ground water table, elevation levels, and the rest of it.

So my point in all of this is we really need to think carefully, you know, where it is smart to infiltrate and how much ET can I really get on a site.

Next slide.

So let's talk about capture and reuse.

One of the projects I had the pleasure to work on with the Irvine Company is the Pelican Hills Resort. And that was a unique condition. We actually have cisterns -- you're seeing a picture of a 550,000-gallon cistern that was put in. We drained a Crystal Cove in this project. A highly sensitive project.

The Irvine Company asked me to come up with a way to have no increase of runoff. And they wanted to increase infiltration. I say, "What do I have left to play with?"

What I had was the evapotranspiration sponge. And looking at irrigation on just the site, I couldn't get there. Fortunately, I was next door to a 36-hole golf course; I could get there with the greens because they do water those relatively soon.

So the key for capture and reuse is having a use for the water in the first place. Can I use it for irrigation or toilet flushing or some other process water?

The second one is being able to use it. There's lots of code issues that we haven't talked about today.

And the third one is being able to get rid of the water fast enough. And if I can't get that tank drained within a 2- to 3- to 4-day period, the next storm will come along and start bypassing the system. So it will not be as effective.

Next slide.

So this is a slide, actually, where I did a double damp size tank. And this is a series of storms. I picked an example from 1962.

So you can see in February of '62, there were

quite a number of storms that came back to back. What it is showing, there's, you know, bypass events going on every event during that sequence there and then releasing runoff. And this was a tank designed for 1.6 inches of capture from the site. Not the damp size.

So next slide.

And what happens when I look at pollutant loadings? Now, I'm back to a damp size tank. But I provided you guys an example of a hundred acre residential development where I use a cistern for capture, and used for both irrigation and toilet flushing. I've probably over assumed irrigation because I used the simplifier approach to that, and it's probably less available than I came up with.

And toilet flushing I also used some numbers that when people -- for those of you who can't go to the men's restroom, there's no flush urinals in there. If I was going to make this work, I'd want high flush urinals in the winter and no flush in the summer, I guess.

So the bottom line is when I looked at over average annual pollutant loading basis on the capture and reuse, assuming I didn't treat the bypass, I would only capture -- remove 55 percent of the load of TSS, that's total subpoenaed solids. Or with bioretention with under drains I would remove about 63 percent.

I would say, in this case, I would argue that

the bioretention with under drains was a better solution.

Next slide.

And then if we look at the average concentrations coming out of the systems. With the cistern bypass, again, provided you don't require an extra treatment beyond the cistern size, then we're releasing at the inflow concentration. So we've had no treatment for that bypass.

So the other point I'd make is the bioretention with the under drains is resulting in a lower concentration on an average annual basis as well.

So the point here, again, we got to drain the tank fast enough, similar to the drain range for ET and infiltration systems.

And we're talking about the 85th percentile storm earlier. And that, actually, in studies around the country has shown to treat about 80 percent of the runoff. And that was assuming about a 36-hour drawdown time. And that's how that number was first developed. It was a study by Better Bonus at Urban Drainage in Denver. And along with Larry Rozner (phonetic) who's now at Colorado State.

Again, as a key element, it is not just the size of what you require, but also the drawdown rate was included in that.

We have irrigation, you know, use is limited

with these systems, seasonal issues. You know, there's a big push to do zero scaping. So drought tolerant plants. I have some suggestions, "Why don't you overwater for a long time?" I'm thinking, what's a plant pallet that likes to be dry and then also be flooded for a long time. There's issues there.

Competition for reclaimed water. You know, if we require folks to do this for toilet flushing. About the same time that IRWD has the worst time to get rid of reclaimed water is the same time we would be trying to use it for irrigation. And all of a sudden, we have a conflict between those two things.

One of the things I have looked at -- I have come up with a new name for a ratio. I'm calling it TUTIA. And I do think if you do have enough toilet flushing -- toilet users to impervious areas, you can actually show -- it can work.

I did this in a building in downtown Los Angeles. And we were going to combine it with the Gray Water System. And I could show it could work cost wise, got to a reasonable standpoint. Unfortunately, I ran into the City of Los Angeles building code folks; it was "over my dead body" in terms of that -- being able to do that.

I think there's some points where some of these

systems start to become more viable when you have enough processed water use.

Finally, this next slide -- just so you guys are aware of some of the infrastructure you would need. You've got to think about the conveyance and pretreatment to get the runoff into some sort of a storage tank. There's treatment issues. If you're going to use it for irrigation, particularly, in a pressurized system, you're going to have backflow valves, UV treatment, and the rest of it, pumping and piping and all those kinds of infrastructure issues.

And, again, I think in certain applications it makes sense. And other ones we might ask the question.

So next slide.

That just gives you a summary of some of the codes that we're going to have to think about. So in summary on harvest and use, I think, we need to be -- carefully consider where it makes sense or not.

Next slide.

You have seen this definition, so I'm not going to go into that, the first one.

The second one, I think, is important, though. There was a National Research Council report put out. It was called Urban Stormwater Management in the United States. In that report they retitled LID -- they use their own term, Aquatic Resource Conservation Design.

Next slide.

In that document, they're quote, "ACRD offers an array of techniques to reduce the quantity through infiltration and evapotranspiration and improve the quality of any remaining runoff. These practices included" -- and I'll point you to things like swails and filter strips and other things that are not retained on site type BMPs.

On the next slide they actually recognize that in some situations the practices may not be feasible. And then they recommend using the best combination of some of the more traditional controls.

Next slide.

The last thing I'll end with before I summarize, is I do think we need to take a watershed approach to this. Every watershed has unique soils, contamination issues, ground water quality, land uses, ground water elevations, receiving water sensitivities, and the rest.

And I get concerned when we have a one size fits all solution that starts limiting what I think might be the best solution. I think we need to work through the watershed approaches that address all of the elements I have up there.

So in summary -- next slide.

We need to think about the precipitation

patterns and how they effect the performance of these systems. Infiltration is not broadly feasible, effective, and/or desirable in all cases. Harvest and use and runoff due to runoff patterns and ET potential has limited application. We should try to do as much as we can. And I've tried to do it on my projects, but it is limited. And then LID and the permit should include all of the elements of LID, including source control -- we haven't talked a lot about that today -- retention, detention, and filtration.

I thank you very much for your time.

MS. BESWICK: That was great, actually.

Thanks for being as brisk as you could be with that. There was a lot of the information.

I'm asking Gery, -- I think it would be important to have you comment on this issue we've heard thoroughly discussed now about asking that people retain only onsite.

MR. THIBEAULT: I would like to point out, first of all -- Eric, I hope you were listening. Eric gave, you know, an awfully good proposal for his company to do the feasibility studies that Orange County needs. And I want to make it clear that what was just described here is what we've asked for in the permit. Someone to do the evaluation, to look at the feasibility.

If you're getting the impression that we're

MR. WOODSIDE: Good day.

Greg Woodside. I'm here for the Orange County Water District. I'm the planning and watershed management director.

Just a couple points. We're concerned -- we've commented and we've talked with your staff. We're concerned that if infiltration systems are not operated correctly, they're not maintained correctly, there could be impacts on ground water quality.

There have been studies in other areas in LA County about infiltration systems like these. And there are no adverse impacts to ground water quality found if they're maintained and operated correctly. That's what the studies showed.

We don't have that kind of data in Orange County. We appreciate the fact that the permit now has a pilot ground water monitoring program. We think that's important. We appreciate that inclusion.

We certainly feel that infiltration is not feasible in all locations. That's been discussed already.

But there are conditions, such as shallow ground water, where infiltration might not work.

We do --

MS. BESWICK: Say that again.

MR. WOODSIDE: There are conditions where

infiltration just may not work because of shallow ground water.

We do encourage infiltration to the extent practical at a regional level. We feel if it's at a regional level, or a subregional level, you know, more of a clustered implementation, it will be easier to monitor if there's any potential impact. We think that's something beneficial.

We have one technical point. It was mentioned earlier, the separation. There's the separation distance between the bottom of the infiltration system and the seasonal high ground. We have a little diagram here that shows what we're talking about.

So simplified graphic here. We have the ground surface. We have what is call beta zone or dry well type infiltration. That's symbolized by the well. And it's above the saturation zone, it's above the seasonal height ground water level, in the what we call beta zone, or unsaturated zone.

And the current draft has a five-foot separation between the bottom of the infiltration system and the high ground water elevation.

The previous draft was ten feet. And we would request that they go back to the ten feet.

MS. BESWICK: By the way, we have a monitor down

here. We're able to see what you're showing us.

MR. WOODSIDE: The question marks were there because there's a degree of uncertainty about what the elevation is for the seasonal high ground water table.

The Water District, ourselves, we have a lot of data. The data is deeper. We don't have a lot of data to say where the seasonal high ground water table is in some locations. Now, in some locations it is pretty well defined. But there's other locations where the seasonal high ground water table is not well defined. There's uncertainty about what depth it is.

We would strongly request we go back to ten feet, so that there can be a margin of safety there.

The data that's out there shows, if these systems are built in the unsaturated zone, they will work. We need to make sure that they're in the unsaturated zone, above the water table.

So we feel if we go back to the ten-foot separation distance, we'll account for some of the uncertainty in where that seasonal high water table is. And it would be more protected.

That's our one request.

MS. BESWICK: Can somebody talk about why we went from 10 to 5.

MR. THIBEAULT: I'll take that, Mark.

important.

So with that kind of, hopefully, a refraining to focus on MEP, to focus on your obligation to meet water quality standards, to recognize we do have to do things differently. Bart will come up and give you some of that context around the country. We'll show you an EPA definition of LID exactly like ours. And I will describe what we'd like to see done with the program.

Thank you.

MR. LOUNSBURY: Good morning, Madam Chair, members of the Board.

I'm Bart Lounsbury from the Natural Resources Defense Council, as David mentioned.

David hinted at this, but the reason we're so focused on LID today, and probably why a lot of the commenters here today are so focused on LID, is that the conversion of impervious surfaces and natural areas to impervious surfaces through development is the leading cause of water quality impairment in Orange County and, indeed, around the country in general.

And LID has been proven through many studies to be a superior technique for treating stormwater. The Ocean Protection Council of California, just last year, came out with a very strongly worded resolution, that I believe we sent to you in our packet, showing that LID is a practicable

and superior approach. And encouraging regional boards and various other entities to adopt LID as their approach to stormwater management.

US EPA has said the same thing. You heard that today from Mr. Kemmerer.

How do these practices function? Well, apparently there are many definitions out there. This is one from EPA which actually says that it is retention. It is infiltration, evapotranspiration, and reuse of stormwater.

Those are three different techniques. Mr. Strecker touched on this. They're all viable here in different scenarios. And where infeasible, we believe there are alternatives that can be taken. And that this permit does, to some extent, accommodate, but needs to accommodate better.

The State Water Resources Control Board has noted the extreme importance for having performance requirements for LID implementation.

So in this case what we've been arguing about, I think, a lot today is exactly that paragraph -- those couple paragraphs in the permit, where the performance requirement is established. That's why it is important.

US EPA also placed, as you heard from Mr. Kemmerer, very high degree of emphasis on assuring that

there are clear, measurable, and enforceable provisions for the implementation of LID. And where it is infeasible to implement LID onsite, there should be appropriate offsite mitigation options to achieve equivalent results.

Now, EPA also stated, that where onsite management is not feasible, conventional means should not be counted toward this type of numerical performance standard that should be established by the permit. And that's very important.

The types of techniques that we've been talking about fall into various categories. Maybe people who argue about what is LID and what is not. We agree some are much more effective than others. And those are ones we should privilege in this permit. And that's what we're trying to do through our comments on this permit today.

EPA, in fact, has also noted that in this region, typically, permits rely on deferring the creation of standards to plans that are drafted by the permittees and later submitted for approval by the EO or potentially not even for approved at all, necessarily. And those tend to rely on qualitative provisions rather than specific measurable criteria.

Which is particularly problematic because the permits themselves should have established those specific measurable criteria. Which would then defer plans that

don't even have the criteria in them. We want to make sure that this permit itself has the necessary criteria at the outset.

This has been so problematic, in fact, in the San Francisco Bay Region context, that EPA has threatened to consider objection to that permit. This is a letter -- from a letter they wrote to the San Francisco Regional Board this month.

So this is an extremely important issue for all of us. And EPA, appropriately, today is placing a very high degree of emphasis on ensuring that these kinds of standards are in the permit.

Why are we focused on LID? Because it is so vastly superior to conventional BMPs. We had Dr. Richard Horner, who is the preeminent expert on stormwater in this country. In fact, he was on the National Academy of Sciences Panel mentioned by Mr. Strecker.

We had him do a study for us in various areas around California, San Diego, Ventura County, the San Francisco Bay area, analyzing the feasibility of LID limitations and the benefits that would accrue from that implementation.

These are the results for Ventura County. They're very similar for San Francisco Bay, as well as

San Diego. And can you see here that LID BMPs are achieving significantly higher rates of pollution reduction, as compared to even the best performing BMPs.

He also -- Dr. Horner also studied specific case sites here -- this is a restaurant I think he did -- and how much runoff reduction would occur through the implementation of these BMPs in a feasible manner.

And you can see here that there would be approximately a 7 percent runoff loss on an undeveloped site. Which correlates with what Mr. Adackapara was saying. Then with no stormwater mitigation, 49 percent lost. Even with the best performing conventional BMPs, it's 26 percent loss. But under the designed storm conditions, with LID properly implemented, there would be no runoff loss on the site. This has vast benefits.

Also at another case study site, a large single-family home subdivision. In addition to removing pollution, obviously, from the system, it also saves water that results in cost saving for developers, for homeowners, and also reduction of even green house gas emission because of the extreme energy intensity of our water supplies here in Southern California.

I don't think there's any surprise everybody supports LID, including the National Association of Home Builders. No one here today said that LID is not a great

technique for managing stormwater.

So around the country new standards are being adopted. There's an emerging trend toward the types of retention standards that we think this permit needs to incorporate.

Anacostia in Washington DC, an urban area, has adopted this standard, which is to retain the first one inch of rainfall onsite. That's retention.

As someone mentioned earlier, the design storm, the 85th percentile storm in Orange County results in about .75 inches of stormwater in most locations. This is actually a more stringent standard.

And then wherever that's infeasible to meet, there should be offsight mitigation options. And they have multiplier ratios for those, in Anacostia.

The situation is very similar in the West Virginia draft phase 2 permit. Retain the first one inch onsite. If you can't do that, use offsite mitigation or in lieu payment at a 1.5 multiplier for the unretained portion.

That's something we think is very feasible, here. And we hope that that's what you'll ultimately do with this permit.

Philadelphia has the same standard. Retain and infiltrate the first one inch. They actually only allow

infiltration of the first one inch. We are supporting a standard that allows for infiltration of evapotranspiration and harvest and reuse.

We have various techniques to accommodate a wide range of sites. And even when that's infeasible there's always the option for offsite mitigation.

I think David will speak specifically to the concerns of this permit and the language it includes now.

MR. BECKMAN: Thank you, Bart.

Hopefully, that gives you some sense -- and what I want to emphasize, what is before you, even with the EPA changes, is less than what West Virginia -- a phase two, not even a phase one permit is considering -- less than highly urbanized area in Washington DC.

And you've had a chance to review the letter we sent. We have six or eight different standards that demonstrate to you that what you're asked to approve today, with the EPA changes, is significantly less stringent than many other places around country.

You wouldn't get that sense, I don't think, from this morning's presentation. But I think it's critical for your deliberation. Will Orange County adopt something less stringent than a phase two community in West Virginia? That's the question.

Now, we have a lot of concerns with the permit.

Even with the EPA changes, that we appreciate and we think strengthen the permit. You should understand that this is not the NRDC permit as Mr. Singarela suggested or an NRDC provision.

We have suggested something more stringent. We have concerns about the design storm. And more specifically, what happens if you can't retain the 85th percentile storm that you've selected onsite.

As Bart indicated, we think you should follow what every new communities that are considering what these requirements are doing. Which is very similar to a wetland situation, where you mitigate offsite.

Why do you do that? Because we are after a watershed level of performance. We don't want the exception for infeasibility to mean that folks don't do as much as they reasonably can, when you can go, maybe, on an adjacent parcel and accomplish what you couldn't accomplish given the circumstances of your development.

Why is that important? It's important because we won't maintain the water quality goals if we are constantly lowering the requirements based on a series of factors.

So we want that clear performance standard. I think the EPA suggestion goes a long way towards that goal. And just so you can see the difference between something

that's clear and something that's not.

This is West Virginia. And it is very clear. "You must implement and enforce site design standards and manage to keep the first one inch of rainfall from a 24-hour storm proceeded by 48 hours of no measured precipitation. Runoff volume can be achieved" -- and they give you the various ways to do it.

And then they clarify it. "The first one inch must be 100 percent managed with no discharge to service waters." Your permit is not that clear. And it should be.

That's the kind of language that results in good performance because that's the kind of language that we can all understand.

So that's one area of concern.

The EPA suggestion linking a lack of ability to comply with the standard onsite to these alternative programs is helpful. But those programs aren't developed.

One concern we have with this permit and, frankly, others is that the permits don't make the regional board make the decisions that the regional board should be making. You are the only folks in the room that are allowed to issue a permit. With all due respect to the executive officer, he is not.

By having the executive officer basically judge all the feasibility issues, all the alternatives, you're

basically giving up your responsibility, in my view, to decide decisions and be the deciders, so to speak.

Why is that a problem? For lots of legal reasons. But from a practical respect, how is the public supposed to engage in that process? How do you know if Mr. Thibeault makes the right decision, or doesn't make the right decision?

That is a significant issue. There's a lot of case law on it now that makes it clear the executive officer can't be in the position alone of judging the adequacy of provisions like this. Because they're, effectively, the management of the permit.

We want to see the programs spelled out in a public way. And you should make the decision on that. Not anybody else.

And I've basically covered this bullet as well.

Now, one of the things I'm going to try to do before turning it over to Garry is just to connect the dots.

Bart indicated why LID is so important. Why that retention standard is so critical. But there's a context even beyond LID that, I think, is important for the Board to consider in making its decision. And that's there are other issues in this watershed. There's the need to comply with TMDLs, for example.

How will you comply with the TMDLs if you don't

significantly reduce the amount of the pollution? If you don't require permittees and those they regulate to select the best BMPs, the likelihood of meeting the TMDL requirements is very low. And that creates other legal problems.

By selecting strong management provisions, you actually can assist the permittees in doing what we want them to do. Which is to improve water quality. All of the feasibility concerns that have been raised, as I said, can be dealt with with proper provisions. But they shouldn't ignore the vast amount of science and technical information out there that shows these provisions and ones much more stringent are feasible. That's the information before you.

That's why I would ask Mr. Kemmerer to respond. That the issue about the language in the first provision is not just about a delay. It's about the presumption that we need to prove in Orange County something that's -- prove the feasibility of LID in Orange County, but it's been proven to be feasible everywhere else. That this is some new thing. It is not.

In fact, it's being done here by builders in Orange County before the permit is being considered by you.

There's another issue. There's a new case that you probably haven't dealt with before because of -- the permit wasn't reissued in 2007. And that's the

Friends of Pinto Creek v. US EPA.

Long story short. In impaired watersheds like we have, unfortunately, in Orange County, there's a significant restriction on new development and new sources of pollution when there are no TMDLs in place. And there are restrictions when there are TMDLs.

Practically speaking, what's the best way to make sure the permit complies with these kinds of requirements? It is to require the techniques that maximally reduce water pollution. And that is retention of water in new development as opposed to its discharge.

Another problem we've highlighted, the permit doesn't comply with the basic requirement in the statute itself to effectively prohibit non-stormwater discharges.

And very briefly I'll touch on the issue here, or one example of the issue. And that is that you allow runoff during the dry season from lawns and irrigation. Irrigation water which studies demonstrate are highly polluted.

And that's inconsistent with what the act requires. And it's sort of ironic that your peer regional board that covers Southern Orange County, the San Diego Board, has just come out with its draft permit that has stacks of information about how highly polluted those discharges are.

And those are discharges that your permit allows with conditions that are, in our view, not acceptable. Those non-stormwater discharges need to be prohibited. The law requires them to be prohibited. And from a policy perspective, we're not going go get to the end result if we continue to ignore these pieces of the puzzle.

The final thing I would say is that we could understand, perhaps, a difference of opinion if there had been a compressive examination of the likely pollution reduction of this permit. In other words, if you tell us, "We're not going to do exactly what you want with LID, but we're going to retrofit. We're gonna do a bunch of other things. We are going to show you that we have a reasonable belief, based on science, that we'll be successful. We'll meet those water quality standards." That would be one thing.

And perhaps you as a board might think, "Why don't we be more flexible with development, if we know we're going do get there anyway. We're gonna meet our budget. We might spend a little more on a nicer dinner. But we're going to meet the budget, so we'll do it."

That's not in front of you. You can look anywhere you want, in the reams of information you've been given and in any comment by any party, and nowhere will you find an estimate of the effectiveness of this permit. And

that should trouble you from a policy perspective.

Because I would submit, not withstanding your best intention, you don't know what you're doing. How can you? How can you make a determination when you don't know what the effectiveness of the permit's likely to be?

The federal regulations require an estimate of what the purposed program will do in terms of pollution reduction. And we would submit that that's been too long ignored. Not just in this region, but in many other regions and, in deed, in many other places in the country.

And we would certainly submit to you that absent that kind of information, it's incumbent on you when you have information about superior approaches that are practicable with the National Association of Home Builders and NRDC, like, those should be in the permit.

So what that means is, we would like for you to implement the red line -- which we have copies of if you want, they were submitted with our last set of comments -- that shows you what we think should be done with the LID section. Certainly, at minimum, EPA's changes, the small ones -- the two small ones that they've made, should be part of your decision and should not be changed or watered down with the kind of suggestions that you've heard.

And we think, at the end of the day, you will have a permit you feel good about which is practicable and

much more likely to do the job as necessary than one you saw this morning or the one, with all due respect to my friends in the room, that some others would like you to adopt.

With that, I really appreciate the work. I'd also like to thank Mike. We're involved in this kind of process everywhere. I've been in the process and sometimes they start and three years later they're not over.

And while we certainly have some respectful disagreements on substance, we think you've done a terrific job in moving it along. Very professional. Very businesslike. I think it makes it a lot easier for everybody when you can actually get, hopefully, to a result as opposed to this constant process.

And you should be very appreciative of your staff. I think everyone in the room is.

Thank you very much.

Garry, you are going to close.

MR. BROWN: Hello. My name is Garry Brown, Orange County Coast Keeper.

First thing I want to do is kind of echo what David just said about the staff. Our organization for the last decade has worked closely with the Regional Board Staff and built a relationship with them. And it's a relationship we appreciate.

And when this came up, which every five years it does, we basically -- in Orange County, a group of us had been talking about this for some time. And in December we came, a small group of us, and asked if we could stop the comment period date of the end of December to, basically, take some time out and maybe change the paradigm.

We've had a long success of working with various developers in Orange County. I think at all times we have been somewhat reasonable. And we have a reputation for that. So we have, often, discussions on how we can make this better.

And in December, what I felt, personally, was that, you know, we can go through the process again and try to clamp it down some more. And we can probably -- we can guarantee it will be more expensive for developers, more expensive for the city. But can we guarantee the water quality is going to be better on the direction we're going? And the answer is no. I couldn't stand up and say the water quality will be better.

So, you know, to me, we need to change the paradigm. How the past permits have gone. And that's what this attempt has been -- to do. And that's why it hasn't got any discussion today.

But the section yesterday that was mailed and is on your errata sheet on the master watershed plans. And

I think that alleviates a lot of the discussion you have heard this morning and objection.

We look at -- how can we change the paradigm of the permit to, you know, make somewhat reasonable, but yet accomplish a higher standard of water quality. And our thought was let's develop a strong permit. Let's take susump, and let's have the 85th percentile. And let's retain that water. And I'm not going go repeat what you have heard a dozen times today. We have to have a strong permit.

And then the second -- like the second leg of a three-legged stool. Let's develop watershed master plans. And in the next two years -- and virtually everything Mr. Strecker said in all of the different nuances of Orange County. That if you're in Serrano Creek, we know there's erosion problems. If you're in San Diego Creek, we know where the plumes are. We know other issues. We know TMDLs. The whole point in the watershed master plans is to encapsulate everything that was basically discussed earlier as infeasibility or feasibility.

And so what we would like is to proceed with that, have a strong, almost default permit, have, basically, these watershed master plans so nobody can say one rule fits all. Because it will be one rule based on the circumstance and science of that particular watershed. That's the

direction we want to go.

The third leg of the stool, we want to go online hydromodification modeling with something like UCI. And have online historic rainfall data. The geologic data.

The ultimate would be if engineers, when they were designing a project, they go online and pull out all of the historic data, all of the rainfall data, and they would know how to size. And then when their plans go to plan check in the city, the plan checker would go on the same website and validate the information.

What we're looking at is a longer, wider vision than this permit. This permit is the first leg in, certainly, the watershed master plan.

Where it mandates is the second leg. And down the road, we want to develop the third leg. We think that, one, bottom line, we'll have a much more effective permit. We will have, actually, done significant in drastically improving water quality standards for Orange County.

You know, one of the concerns about using the word "infiltration" -- over the years we, as I said, we work with various developers. You have got very responsible developers. We started a relationship with Irvine Company, as you know, in an era of -- through litigation. And that turned into a partnership for developing water quality.

And we have touted their work at the

Newport Coast on water quality as being the best in the nation. My point is, if Irvine Company -- and what they have already proven they're efforts in water quality. Then you know, we won't have a problem. But not everyone's Irvine Company.

You now, MEP, for example. Our frustration with MEP is to the responsible developer, you know, that's fine. To the guy that's on a shoe string and trying to cut every corner he can, MEP translates into let's do the least for the cheapest.

My problem with this is that you add filtration, that's the way out. That's where the responsible developers and redevelopers will do what they need to do and do it right. The ones who are trying to skate by and do the least, you know, they're going to look at that and say, "Okay. We'll dig a ditch and throw some plant seeds in it." And that's a vegetative swell, and the runoff will come off. That's the way out. That's our concern.

We need to have a strong permit to begin with. And so we certainly would appreciate your deliberations in giving us that.

Thank you very much.

MS. BESWICK: Thank you.

MR. PON TELL: Madam Chair?

MS. BESWICK: Yes. Questions?

MR. PON TELL: Just two follow-up questions. On the one slide you showed -- I think it was Paul that showed the natural runoff being 7 percent, and LID runoff being zero percent. Is that desirable or is the goal 7 percent?

MR. LOUNSBURY: That's under the design storm condition.

So the goal there is not necessarily a hydromodification goal, which is more about matching peak flows and durations and what not, which is also in the permit. The goal with the LID provision should be mostly water quality.

So in that case, by reducing runoff to zero, you can be sure under the design storm condition, there's no pollution going to receiving water. That's not zero percent runoff overall because we're talking about a design storm scenario. Which, as people have noted, is not necessarily -- or does not take into account all the rainfall in the year. It is less than 95 percent of the rainfall that is captured.

MR. PON TELL: Can you say that again?

MR. LOUNSBURY: Sure. I think that -- and we've submitted many studies, so we can look through the records and find this exactly.

Not all of the rainfall in any given year is

captured within the 85th percentile design storm scenario. There will be runoff. Period, if you're just capturing the 85th percentile storm and retaining it onsite.

So that 7 percent discharge under natural conditions and zero percent discharge under the LID provision doesn't mean that every single site in Orange County will never discharge stormwater during the entire year.

Does that clarify?

MR. BECKMAN: That's perfect. I just wanted to add, one thing you have to keep in mind is, what is on a natural site and what is on a developed site.

The reason it is so important to limit water pollution or the flow of pollution is because once you've developed, it's no longer natural. There are pesticides and herbicides and potentially bacteria and other metals and all the other things you know from your work are in the water in Orange County.

The ability to limit the amount of pollution by limiting runoff is critical to the ultimate environmental goal. As Bart said, that's not -- because it is a design storm, it is not all water. You'll still get runoff from the site.

Most of the standards for hydromodification that US EPA adopted -- even the ones that are in the federal

energy bill that relate to federal sites, one of the newest -- they assume that if you retain, roughly, an inch of rainfall, that's a down payment on the hydromodification requirements.

In other words, in order to make that hydromodification graph look like it should, you have to do some runoff. That's generally the way the system, or the standards work. So what we're asking for here is something far less than what other communities are doing.

I think that's the point that's really, really important.

MR. PON TELL: Just a follow-up question. I guess what I'm confused by, you're comparing an arid community with non-arid community. So capturing an inch of water in a non-arid environment is a fraction of the total. Where capturing an inch of water in an arid environment is 100 percent of the total.

So I'm just kind of trying to grasp the net effect of making those kinds of comparison and adopting a policy then. If in any of those communities, you know, that one inch was 20 percent of the rainfall that was being captured, and then we were then to apply a 20 percent factor on the capture, it seems to me that might be an equally relevant way to evaluate.

MR. BECKMAN: I think there are a couple responses.

That's a good question. The way you can normalize the situation is through the design storm. And those communities, notwithstanding whatever -- maybe they have 30 inches of rain -- I think your point, right -- and maybe we have 10 inches here. So how do you deal with the question?

You deal with it, in part, with the design storm. The requirement in West Virginia, hypothetically, isn't to capture all of the rain they have during a certain month. It is an inch of rain. The standard here is less than that. In any case, it normalizes for the fact that there are different amounts of rainfall in different places.

It is, actually, more difficult to accomplish the standard in an area with more rain. Because as Mr. Strecker indicated, if you have a lot of rain, it can be, you know, the ability of soil to evaporate, the ability of systems to capture rain after repeated storms is more challenging than if you have only a few rain storms every year.

The other thing I would say, just to complete the answer, is we asked Dr. Horner to look at the questions of these standards that we're holding out to you as an example. And asked the question, is the evaporation rate in those places comparable to Southern California? Because that would be an important thing to consider.

If, for example, you couldn't evaporate water, or you couldn't somehow store it, then maybe the standards are not apples to apples. I think is part of what you're asking.

That's in our submittal most recently to you. We looked at all of the standards that we have put forward in our comments. And the conclusion, as you can see, is that Southern California is either on average the same as the other communities, or in some cases, is in a lot better situation to deal with the standards that we're advocating. Because of the fact that we get a lot of sun during -- between storms in Southern California.

We try to look at those apples to apples questions. And we are suggesting to you that this is an apple to apples situation. And, if anything, that supports a stronger standard than you're looking at today.

MR. PON TELL: I have two quick questions for staff.

One issue was raised about the non-stormwater discharges, to what extent I think it was implied that our requirement did not meet the standard that's required.

MR. ADACKAPARA: Our requirements actually are specified in section three of the -- roman numeral section three, that's page 32, and it actually prohibits non-stormwater discharges. And it is consistent with the federal regulations and the Clean Water Act.

MR. PON TELL: My second question.

There was a question about the, quote, unquote, "Ability to state with some level of certainty with regard to the overall effectiveness of the permit towards achieving the water quality standards."

MR. ADACKAPARA: Actually, in the report of waste discharge, that was submitted by the County. They have provided an effective analysis.

And in addition to that, Geosyntec, provided by somebody, of all the effectiveness analysis that has been included in the report of waste discharge. And also in other reports that the County has provided.

We did not provide a copy of the Geosyntec summary to you because it came in yesterday night. But they did provide that analysis.

MR. PON TELL: And based on that analysis --

MR. ADACKAPARA: Based on that analysis, the program seems to be effective. But some of the programs could not be -- they could not reach a conclusion about some of the programs that are being implemented. So they are proposing additional programs, additional best management practices.

And we are requiring in the permit additional controls so that the program becomes more effective.

MR. PON TELL: Thank you.

MS. BESWICK: Is that it, Steve?

State of California
California Regional Water Quality Control Board
Santa Ana Region

Minutes of the April 24, 2009 Board Meeting
City of Santa Ana
22 Civic Center Plaza
Santa Ana, CA

1. Chair Beswick called the meeting to order at 9:00 a.m.

Board Members Present	Board Members Absent
Carole Beswick, Chair	
Seymour Van Gundy, Vice-Chair	
Fred Ameri	
William Ruh	
Steven PonTell	
Richard Freschi	

Staff Members Present

Gerard J. Thibeault, Executive Officer
Kurt V. Berchtold, Assistant Executive Officer
Frances McChesney, Sr. Staff Counsel
David Rice, Regional Board Counsel
Joanne Schneider, Environmental Program Manager
Michael J. Adackapara, Supervising Water Resource Control Engineer
Mark E. Smythe, Chief of Storm Water (Coastal Waters)
Hope Smythe, Chief of Basin Planning (Inland Waters)
Milasol Gaslan, Chief of Storm Water (Inland Waters)
Mark G. Adelson, Chief of Regional Planning
Pavlova Vitale, Environmental Scientist
Maria Macario, Water Resources Control Engineer
Keith Elliott, Water Resources Control Engineer
Kevin Heinemann, Staff Information Systems Analyst
Felipa Carrillo, Executive Assistant

Public Attendance

Vaikko Allen, Contech
Larry Baldwin, City of La Palma
David Beckman, NRDC
Richard Boon, Co. of Orange
Doug Brodowski, City of Buena Park
Garry Brown, Orance County Coastkeeper
Tim Carlstydt, Co. of Orange
Amanda Carr, Co. of Orange
Jessica Chin, City of Riverside
Mary Lynn Coffee, City of Irvine
Jim Colston, OCSD
Rod Cruze, Cruze Environmental
Latoya Cyrus, CAA
Joseph Edwards, Irvine Co.
Don Lee, Tetra Tech
Bart Lounsbury, NRDC
Mike Loving, City of Irvine
Albert Martinez, Riverside Co. Flood Control
Larry McKenney, RBF Consulting
Christy Norris, Co. of Orange
Joe Parco, City of Santa Ana
Trung Phan, City of Fullerton
Mike Recupero, Rempu
Jeffrey Shu, SWRCB
Paul Singarella, Latham & Watkins
Devin Slaven, City of Lake Forest
Eric Strecker, Geosyntec Consultants/CICWQ
Robert Taylor, San Bernardino National Forest

SARB_012678

Gene Estrada, City of Orange
Jim Fitzpatrick, Pronto Wash of So Cal
James Fortuna, City of Orange
Mark Grey, CICWQ
Irwin Haydock, Public
Vaughan Herrick, City of La Habra
Peter Herzog, City of Lake Elsinore
David Hsich, City of Westminster
Loriana Hornik, City of Garden Grove
Humza Javed, City of Laguna Hills
John Kappelel, City of Newport Beach
Judith Keir, City of Huntington Beach
John Kemmerer, USEPA
Bao Tran, Kennedy/Jenks
Jason Uhley, Riverside County Flood Control
Ciam Villareal, RBF Consulting
Jenna Voss, Co. of Orange
Alex Waite, City of Tustin
Wallace Walrod, OCBD
Jennifer Weiland, Co. of Orange
Howard Wen, Fuscoe Engineering
Marsha Westropp, OCWD
Greg Woodside, OCWD
Michael Yang, City of Irvine
Matt Yeager, San Bernardino Co. SW Program
Shirin Zandpour, Latham & Watkins

2. Public Forum

There were no speakers.

3. State Water Resources Control Board Liaison Report

Tam Doduc, State Board Liaison, was not present; however, Chair Beswick advised that Ms. Doduc wanted to convey to the Board that the Governor was going to release bond money for projects across the State on Tuesday.

Mr. Thibeault added that State Board/Regional Board Management would be talking about the release of those funds and what projects are going to be on the priority list. He also added that the Statewide General Construction Stormwater Permit was released in draft form earlier this week.

Chair Beswick added that the State Board withdrew the proposed Septic Tank Regulations that they were working on, and they were going to redraft the document and then release it for public comments.

4. Approval of the Minutes

Action: It was moved by Member Ameri, seconded by Member Ruh, and unanimously approved that the Minutes of March 27, 2009 Board Meeting be approved as presented.

Agenda Update: It was noted that Items No. *7 and No. 15 had been postponed.

5. Consent Calendar

*6. Appeal of Staff's Denial of an Exemption from the Minimum Lot Size Requirement for the Subsurface Disposal Systems of Gilberto Galvan.

*8. Yucaipa Valley Water District Maximum Benefit Program – Resolution No. R8-2009-0034.

*9. San Timoteo Watershed Management Agency and City of Beaumont Maximum Benefit Program - Resolution No. R8-2009-0035.

*10. Cooperative Agreement for the Newport Bay Watershed and the Central Watershed Management Area - Third Amendment and Full Restatement of Cooperative Agreement - Resolution No. R8-2009-0041.

*11. Resolution Regarding Funding from the State Water Resources Control Board (SWRCB) Emergency, Abandoned and Recalcitrant Site Account – Resolution No. R8-2009-0037.

Action: It was moved by Member Ruh, seconded by Member Van Gundy, and unanimously approved that the Board adopt Resolutions No. R8-2009-0034, R8-2009-0035, R8-2009-0041, R8-2009-0037, and approve the exemption from the minimum lot size requirements requested by Gilberto Galvan.

12. Renewal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of Orange County, Urban Storm Water Runoff Management Program (NPDES No. CAS618030) - Order No. R8-2009-0030.
Information concerning this item is contained in a verbatim transcript of the proceedings.

Mark Smythe, Chief of Storm Water (Coastal Waters), began the staff presentation with a history of the last nineteen years of the Orange County storm water permit program and its evolution into the proposed draft permit.

He noted that after the 1972 amendment to the Federal Clean Water Act, the initial focus was to control the discharge of pollutants from traditional point sources such as sewage treatment plants and industrial process wastewater. Pollutants in storm water discharges were mostly unregulated until the 1987 Clean Water Act amendments. In 1990, the Santa Ana Regional Board adopted storm water permits for the three county areas within the Region. The permit requirements for the first two terms of the storm water permits remained pretty much the same. However, the third term permit adopted by the Board in 2002 included additional requirements for public education, municipal inspections of construction and industrial facilities and commercial establishments, structural treatment controls for new developments and significant redevelopments, and for TMDL implementation.

Mr. Smythe summarized the public notification and stakeholder participation process leading up to the April 24, 2009 public hearing. The first draft of the permit was issued on November 10, 2008 and a public workshop was conducted on November 21, 2008. Subsequently, a number of stakeholder meetings were conducted and two other drafts of the tentative order were issued. Staff also provided responses to the 173 comment letters and considered these comments in the formulation of the final draft presented to the Board on April 24, 2009.

Mr. Smythe briefly discussed the significant changes from the third term permit, including the incorporation of low impact development requirements in the new development and redevelopment section of the permit, and wasteload allocations in the TMDL section of the permit.

Mr. Smythe then discussed the errata, including the suggested changes from USEPA. Staff recommended adopting the permit with the changes included in the errata.

The Board received testimony from the stakeholders, including the permittees, USEPA, NRDC, Orange County Coastkeeper, BIA, Construction Industry Coalition on Water Quality, private citizens, Latham and Watkins, Nossaman LLP, Riverside and San Bernardino County storm water program managers, Geosyntec, RBF Consulting, Larry Walker Associates, Contech, Pronto Wash, and Orange County Water District. At the conclusion of the testimonies, the Board closed the public hearing on the permit, except for Section XII.C of the permit. The Board extended the public comment period on Section XII.C of the permit to May 8, 2009 and agreed to continue the public hearing on Section XII.C of the permit to May 22, 2009.

Speakers:

Peter Herzog, Richard Boon, Mike Burrows, John Kemmerer, Jason Uhley, Paul Singarella, Mark Grey, Eric Strecker, Greg Woodside, Garry Brown, Bart Lounsbury, David Beckman, Mary Lynn

Coffee, Gene Estrada, Larry McKenney, Jim Fitzpatrick, Irwin Haydock, Matt Yeager and Mike Recupero.

13. Public Hearing on Clean Water Act Section 305(b) Integrated Report/Clean Water Act Section 303(d) List of Impaired Waterbodies - Resolution No. R8-2009-0032
Information concerning this item is contained in a verbatim transcript of the proceedings.

Pavlova Vitale, staff Environmental Scientist, Basin Planning (Inland Waters), presented the 2008 Integrated Report for the Santa Ana Region. She began with a review of the regulatory background of Clean Water Act Sections 305 (b) and 303 (d). She provided a brief background on the regulations governing the Integrated Report.

Ms. Vitale explained the steps taken to prepare the Integrated Report, including the extensive opportunities for public participation.

Ms. Vitale addressed the proposed additions and deletions to the 303 (d) List. She said that staff had considered numerous recommendations made by stakeholders and the public, including suggestions from the Santa Ana River Dischargers Association, regarding the assessment of the metals data.

Ms. Vitale said that if the tentative Resolution is approved by the Regional Board, the Integrated Report will be transmitted to the State Board, and then to US EPA for their approval. She added that the next Integrated Report cycle for 2010 will begin at the end of 2009.

Staff recommended adoption of Resolution No. R8-2009-0032, as amended by the errata sheet and with the deletion of City Creek from the proposed 303(d) List. The errata sheet amends Resolution No. R8-2009-0032, in that it gives the Executive Officer the authority to make non-substantive changes to the water quality assessment database prior to transmitting it to the State Board.

Speakers:

Tim Moore recognized the exceptional work performed by Ms. Vitale in considering the comments received and re-evaluating the data.

He proposed to the Board a watershed action plan approach to address the matter of sediment toxicity in Lake Elsinore. Mr. Moore suggested concurrence that the approach outlined would conform to the approach now contemplated in the MS4 permits. Joanne Schneider agreed with Mr. Moore's suggestions.

John Kemmerer agreed that staff did a great job, but expressed disagreement with the conclusions regarding bacteria data in Temescal Creek Reach 6 and San Diego Creek Reach 1. He said US EPA would be taking a closer look at these two waters and would possibly add them to the list based on their review.

Ms. Schneider stated that Mr. Kemmerer was referring to the E. coli measurement for these waters. She described the technical basis for Board staff's recommendation not to list these waters based on the bacterial measurements. She acknowledged there are some high numbers that need follow up and that what is proposed is additional monitoring for impairment assessment in the future. Garry Brown, Amanda Carr, Matt Yeager and Jason Uhley all indicated support for the Resolution.

Action: It was moved by Member Ruh, seconded by Member Ameri, and unanimously approved that the Board adopt Resolution No. R8-2009-0032 as amended by the errata sheet and with the deletion of City Creek from the 303(d) List.

14. Revised Request for Cleanup and Abatement Account Funding Related to Perchlorate Contamination - Resolution No. R8-2009-0027
(This item was postponed from the March 27, 2009 meeting).

Mr. Berchtold advised the Board that about a year ago, the Regional Board had adopted a resolution requesting $3 million from the CAA to conduct a regional groundwater study related to the perchlorate problem in the Rialto area. He said that since the adoption of the Resolution, the West Valley Water District and the City of Rialto had submitted a revised project proposal.

Mr. Berchtold asked the Board to broaden the scope of how the previously approved funding could be used. He indicated that the revised project does not require additional money - only a change in how the funds could be used.

Mr. Berchtold noted corrections to the Resolution on page 2, first line at the top of the page where it says April 14, 2009 - it should actually read April 15, 2009, and that the same date appeared again after item eight, second line, and it should also read April 15, 2009.

Board staff recommended adoption of Resolution No. R8-2009-0027 with the noted corrections.

Action: It was moved by Member Ameri, seconded by Member Ruh, and unanimously approved that the Board adopt Resolution No. R8-2009-0027 as amended.

15. Presentation to the Board of the Results of the Most Recent Wasteload Allocation Analysis for the Santa Ana River - (information item).
This item was postponed to the May 22, 2009 meeting.

16. Regional Board Member and Executive Officer Communications

None.

17. Closed Session

The Board convened to a Closed Session during lunch to discuss a personnel matter.

18. Adjournment

The meeting was adjourned at 3:11 p.m., to the regular Board meeting of May 22, 2009 at 9:00 a.m., at the Loma Linda City Council Chambers, 25541 Barton Road, Loma Linda, CA.

Respectfully submitted:

GERARD J. THIBEAULT
Executive Officer

/fc

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the

jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

Inland Surface Streams

Santa Ana River, Reaches 1 and 2

Aliso Creek (tributary to Santa Ana River)

Carbon Canyon Creek (tributary to Santa Ana River)

Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

Silverado Creek (tributary to Santiago Creek)

Black Star Creek (tributary to Santiago Creek)

Ladd Creek (tributary to Santiago Creek)

San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

San Joaquin Freshwater Marsh (tributary to San Diego Creek)

Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

Santa Ana Delhi Channel (tributary to Newport Bay)

Big Canyon Wash (tributary to Newport Bay)

Buck Gully

Los Trancos Creek

Coyote Creek (tributary to San Gabriel River)

Other tributaries to the above listed rivers, creeks and channels

Bays, Estuaries, and Tidal Prisms

Anaheim Bay and Seal Beach National Wildlife Refuge

Sunset Bay

Bolsa Bay and Bolsa Chica Ecological Reserve

Upper and Lower Newport Bay

Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new

developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. Each watershed has unique receiving water issues, land uses, topography, soils and stream stability and habitat issues. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants (e.g., Orange County Flood Control Master Plan, Irvine Ranch Water District Natural Treatment System Master Plan, Orange County Watershed Plans, Nutrient and Selenium Management Program, etc.). As recommended in the 2008 National Academy of Sciences Report on Urban Stormwater Management, this order provides an option for the permittees to develop and impleemnt watershed master plans integrating water quality, hydromodification, water supply and habitat protection issues. The Regional Board recognizes that a watershed master plan should integrate all other related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary.

The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12.] The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13.]

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, “Management Guidelines for Use of Fertilizers and Pesticides”. The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

Seal Beach (listed for enteroccocus, PCBs);

Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the

Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban

runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.4~~6~~4(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This order requires the permittees to comply with the urban runoff/storm water wasteload allocations specified in (1) Regional Board-adopted and USEPA approved TMDLs (including TMDLs for nutrients, fecal coliform, diazinon and chlorpyrifos); (2) Regional Board-adopted TMDLs that are approved by the State Board and State Office of Administrative Law and that are thereby effective (approval of organochlorine compounds TMDLs by the State is pending); and, (3) USEPA-promulgated TMDLs (including toxics TMDLs for the Newport watershed). Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mitigative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. T~~o the maximum extent practicable, t~~hese LID BMPs must be implemented at the project site in a manner consistent with the maximum extent practicable standard. Where LID BMPs are not feasible at the project site, more traditional, but equally effective control measures should be implemented.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25]and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be an equally effective metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to

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[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of pollutants and could become a nuisance and/or cause the spreading of surface water pollution, and those treatment systems with a hydraulic connection to groundwater (e.g., detention basins, infiltration systems, constructed wetlands, etc.) could be sources of groundwater pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants. There are other site conditions that limit the applicability of infiltration, including site soils, contaminant plumes, potential mobilization of naturally occurring contaminants such as selenium, high groundwater levels, etc. Such factors should be considered in the design and implementation of storm water control measures.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.4~~6~~4(d)(vii)(B)) require that the Permits be consistent with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should

include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicitl discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections

and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.

7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.

2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
    i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
        a) Discharges composed entirely of storm water;
        b) Air conditioning condensate;
        c) Irrigation water;
        d) Passive foundation drains;

e) Passive footing drains;

f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Diverted stream flows;

i) Rising ground waters and natural springs;

j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

k) Flows from riparian habitats and wetlands;

l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section X~~I~~XI, Provision 5);

m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges from permittee owned and/or operated facilities and activities unless the stated conditions are met:

a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

c) Discharges from lawn, greenbelt and median watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

minimized through a Model Municipal Activity Maintenance Program designed to control irrigation runoff.

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.

5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).

6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.

7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.

8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

[33] See previous footnote.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.

2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.

3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

   d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

   So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.
3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.
4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis[34] and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[35]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

   f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[36];

[34] The reporting schedule may be revised with the approval of the Executive Officer.
[35] State Board WQO No. 2006-0003.

[36] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

g) Discharges of runoff from the washing of toxic materials[37] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.

2. The permittees shall control~~, to the maximum extent practicable,~~ the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.

3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.

4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.

5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s)

[37] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.

6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.

7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.

2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude [in decimals] or NAD83/WGS84[38] compatible formatting), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area

[38] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.

4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:

   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;

   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

   c) Visual observation for non-storm water discharges and potential pollutant sources;

   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement

action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.

7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.
3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions

[39] See Footnote 38.

issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.
5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period[40].

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction[41]. As

[40] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[42] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

Commercial facilities may include, but may not be limited to[43]:

a) Transport, storage or transfer of pre-production plastic pellets.
b) Automobile mechanical repair, maintenance, fueling or cleaning;
c) Airplane maintenance, fueling or cleaning;
d) Marinas and boat maintenance, fueling or cleaning;
e) Equipment repair, maintenance, fueling or cleaning;
f) Automobile impound and storage facilities;
g) Pest control service facilities;
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
j) Building materials retail and storage facilities;
k) Portable sanitary service facilities;
l) Painting and coating;
m) Animal facilities such as petting zoos and boarding and training facilities;
n) Nurseries and greenhouses;
o) Landscape and hardscape installation;
p) Pool, lake and fountain cleaning;
q) Golf courses;
r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct, or require to be completed, inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 12 months of adoption of this order,

[41] The inventory update schedule may be revised with the approval of the Executive Officer.

[42] See Footnote 38.

[43] Mobile cleaning services are addressed in X.8, below.

the permittees shall develop a prioritization and inspection schedule for the commercial facilities in Section X.1 for review and approval by the Executive Officer. Until that plan is approved, the following minimum criteria must be met for prioritization of commercial sites for inspections: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[44]; 20% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct, or require to be completed, commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.
4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or steam cleaning. The pilot program shall include at least two notifications of the

[44] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:

   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;

   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period[45].

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s consistent with ~~to~~ the maximum extent practicable standard so as to prevent discharges from the

[45] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[46] and USDA's Backyard Conservation Program[47].
3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[48] to encourage efficient water use and to minimize runoff[49].
5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[50].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

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[46] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[47] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[48] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[49] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[50] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.
2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.
3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.
4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.
5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.
6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24

months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process in conjunction with preparation of the DAMP finalization, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance

with the approved Model WQMP and shall incorporate LID principles in the WQMP.

a. All significant redevelopment projects, where significant redevelopment is defined as projects that include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in the addition or replacement of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in the addition or replacement of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b. New development projects that create 10,000 square feet or more of impervious surface (collectively over the entire project site) including commercial, industrial, residential housing subdivisions (i.e., detached single family home subdivisions, multi-family attached subdivisions (town homes), condominiums, apartments, etc.), mixed-use, and public projects. This category includes development projects on public or private land, which fall under the planning and building authority of the permittees.

c. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

d. Restaurants where the land area of development is 5,000 square feet or more.

e. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

f. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[51] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

g. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

[51] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

h. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" in a manner consistent with ~~to~~ the maximum extent practicable standard. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

i. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

j. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[52] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

[52] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

   A. Volume

   Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[53]; or,

   2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

   3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

   4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

   OR

   B. Flow

   Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

   2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

   3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

[53] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 ~~5~~ feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[54].

g) Within 18 months of adoption of this order, the principal permittee shall develop a pilot program to monitor the impact of groundwater infiltration systems on the quality of groundwater. This monitoring program may be conducted by: (1) analyzing the quality of the runoff prior to infiltration; (2) by monitoring the quality of the infiltrate through the vadose zone; or (3) by monitoring groundwater quality upstream and downstream of the infiltration systems. The results of the pilot study shall be submitted with the next annual report.

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

[54] This restriction applies only to sites that are known to have soil and/or groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for review and approval by the Executive Officer[55]. Priority development projects ~~that meet the feasibility criteria established pursuant to Section XII.E~~ shall implement LID principles described in this section, Section XII.C.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, ~~or~~ capture, or bio-filter[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance. Any portion of ~~this~~ the design capture volume that is not infiltrated, harvested and re-used, evapotranspired, ~~or~~ captured or bio-filtered[57] onsite by LID BMPs shall be treated and discharged using LID or conventional treatment control BMPs or mitigated as set forth in Section XII.C.7, below.

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

   a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

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[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

[56] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration are not feasible.

[57] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration are not feasible.

b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement

with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[58], New Urbanism[59] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.

7. If site conditions do not permit infiltration, harvesting and re-use, and/or evapotranspiration of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:

   a. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

   b. Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct

[58] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[59] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume.

c. Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

~~c)~~d. Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[60])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

   e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of

[60] Hydromodification is the alteration of natural flow characteristics.

5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected.

c) The site infiltrates at least the runoff from a two-year storm event. The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees ~~have the option to~~ shall address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan as described below:

   The Watershed Master Plans shall integrate water quality, hydromodification, water supply, and habitat for the following watersheds: Coyote Creek-San Gabriel River; Anaheim Bay-Huntington Harbour; Santa Ana River; and Newport Bay-Newport Coast. Components of the Plan shall include: (1) maps to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and areas where storm water and urban runoff infiltration is possible and appropriate; and, (2) a hydromodification model to make available as a tool to enable proponents of land development projects to readily select storm water preventive and mitigative site BMP measures.

The maps shall be prepared within 12 months of the adoption of this order and a model Plan for one watershed shall be prepared within 24 months of adoption of this order. The model Plan should specify hydromodification management standards for each sub-watershed and provide assessment tools. In the preparation of the model Plan, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board, and (6) and water districts.

The model Watershed Master Plan shall be submitted to the Executive Officer for approval. Watershed Master Plans shall be completed for all watersheds 24 months after approval of the model Watershed Master Plan.

The Watershed Master Plans shall be designed to meet applicable water quality standards and the Federal Clean Water Act.

~~that integrates water quality, hydromodification, water supply, and habitat. The Watershed Master Plan may be prepared for the whole watershed or for sub-watersheds. The Plan should include a map to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and specify hydromodification management standards for each sub-watershed. In the preparation of this Plan or plans, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; and (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board. The Watershed Master Plan or the sub-watershed plans shall be submitted to the Executive Officer for approval.~~

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.
2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted

waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

b) Projects funded or proposed to be funded with monies from the urban runoff fund;

c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

d) Current status and a schedule for project completion.

3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.

4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

a) Redevelopment projects that reduce the overall impervious footprint

b) Brownfield redevelopment

c) High density developments (>7 units per acre)

d) Mixed use and transit-oriented development (within ½ mile of transit)

e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses

f) Regional treatment systems with a capacity to treat flows from all upstream developments

g) Contribution to an urban runoff fund (see 1, above)

h) Offsite mitigation or dedications within the same watershed

i) City Center area

j) Historic Districts and Historic Preservation areas

k) Live-work developments

l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.

2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.

3. The permittees shall develop a database with information regarding each structural treatment control BMP installed after adoption of this order. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.

4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.

5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 25% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within every four year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record. The permittees may accept inspections conducted and certified by state licensed professional engineers in lieu of permittee inspections.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented in a manner consistent with ~~to~~ the maximum extent practicable standard for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain

projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.

2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.

3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.

4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.
6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.
7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.
2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.
3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:

   a) Parking facilities;

   b) Flood management and storm water conveyance systems (open channels);

c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and

d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.

4. All applicable public agency staff shall be trained as specified under Section XVI.

5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:

   a) Conduct annual integrated pest management self-audits;

   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

   c) Provide proper training to municipal and contract staff involved in the above activities;

   d) Within one year of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within one year of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall

keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.
13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.
14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.

5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.
2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training, such as Certificate of Completion, attendance sheets or other proof that training has been completed. .
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation

of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.

6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections[61].
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

[61] The reporting schedule may be revised with the approval of the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

1. As required under a consent decree, in 2002, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay, including metals, organochlorine compounds, selenium and organophosphate pesticides. EPA and the Los Angeles Regional Water Quality Control Board established technical TMDLs for metals in Coyote Creek. Technical TMDLs do not include implementation plans or compliance schedules.
2. In collaboration with stakeholders, Regional Board staff are developing revised TMDLs that are expected to supplant the toxics TMDLs promulgated by EPA for the Newport watershed. The TMDLs will include implementation plans and compliance schedules. Implementation plans for the Coyote Creek TMDLs are also being developed.
3. In summary, work related to the following established TMDLs is ongoing:
   a) Metals (San Diego Creek and Newport Bay (including Rhine Channel))
   b) Metals (Mercury, Chromium) (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay; also see Paragraphs 5 and 6, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)
4. The permittees in the Newport Watershed shall comply with the wasteload allocations specified in the established TMDLs and shown in Tables 1 A/B/C, 2

A/B/C/D and 3. These wasteload allocations shall remain in effect unless and until alternative wasteload allocations are established in TMDLs approved by the Regional Board, State Board, Office of Administrative Law and EPA.

Tables 1 A/B/C/D – Urban Runoff Waste Load Allocations for Metals (TMDLs promulgated by U.S. EPA)[62]

A- San Diego Creek and Tributaries – Concentration based TMDL

	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

D- Concentration-based Dissolved Metal TMDLs, WLAs and LAs for Newport Bay

	Dissolved saltwater TMDLs and allocations which apply to direct discharges to the bay, including storm drains/channels and metals loading associated with boats	
	Acute	Chronic

[62] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

Cd* (ug/L)	42	9.3
Cu (ug/L)	4.8	3.1
Pb (ug/L)	210	8.1
Zn (ug/L)	90	81

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[63]

A- San Diego Creek and Tributaries

Total DDT	Chlordane	Dieldrin	PCBs	Toxaphene
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	Chlordane	PCBs
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	Chlordane	Dieldrin	PCBs
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	Chlordane	Dieldrin	PCBs
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[64]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)

[63] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[64] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

5. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. These TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. These TMDLs have not yet been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program (TRIP) that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. These TMDLs will become effective upon approval by the State Board and Office of Administrative Law but will not supplant the EPA organochlorine compounds TMDLs until they are approved by EPA. Accordingly, upon approval of the Regional Board-adopted organochlorine compounds TMDLs by the State Board and the Office of Administrative Law, the permittees shall comply with both the EPA and Regional Board wasteload allocations specified in Tables 2 A/B/C/D and Table 4, respectively. In accordance with the Regional Board TMDLs, compliance with the allocations specified in Table 4 shall be achieved as soon as possible but no later than December 31, 2015. Upon approval of the Regional Board-approved organochlorine compounds TMDLs by EPA, the applicable wasteload allocations shall be those specified in Table 4.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs approved by Santa Ana Regional Water Quality Control Board)[65]

	Total DDT	**Chlordane**	**Total PCBs**	**Toxaphene**
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.8 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

6. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated the Toxicity Reduction and Investigation Program (TRIP) consistent with the Regional Board-approved implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables

[65] From Resolution No. R8-2007-0024, Table NB-OCs-10

5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations.

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[66]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l
Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

7. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs and that are intended to replace the EPA TMDLs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. This Order will be reopened to incorporate revised allocations based upon TMDLs, including implementation plans, for metals and selenium approved by the Regional Board, State Board and Office of Administrative Law. As for the organochlorine compounds, the EPA promulgated allocations for these constituents will also remain in effect unless and until EPA approves the Regional Board's TMDLs for these constituents.

[66] From Resolution No. R8-2007-0024, Table NB-OCs-4

8. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive selenium (and nitrogen) management plans, which are expected to form the basis, at least in part, for the selenium implementation plan (and a revised nutrient TMDL implementation plan). A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the selenium TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one month after approval of the selenium TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

9. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with the following wasteload allocations:

Table 6 – Municipal Storm Water Wasteload Allocations - Coyote Creek

	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		

Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

10. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 7 – Numeric Targets - Coyote Creek

(total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[67]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

C. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 8A – Fecal Coliform TMDL and Allocations for Newport Bay

To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2013	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL

[67] Based on saltwater CTR criterion in San Gabriel River estuary.

Natural Sources in all Discharges	In effect	for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 8B – Fecal Coliform TMDL and Allocations for Newport Bay

Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables 8A and 8B in accordance with the deadlines in Tables 8A and 8B. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of

completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.

3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 9A and 9B are extracted from the Implementation Plan[68]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 9 A and B.

Table 9A

Diazinon and Chlorpyrifos Allocations for San Diego Creek*

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Acute	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

Table 9B

Chlorpyrifos Allocations for Upper Newport Bay*

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

[68] Attachment to Resolution No. R8-2003-0039

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 10 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[69]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[70]	2007 Summer Allocation (Apr-Sept)[71]	2012 Winter Allocation (Oct-Mar)[72]
Newport Bay Watershed	lbs/year TN[73,74]	lbs/season TN	lbs/season TN	lbs/season TN
Urban runoff	277,131[75]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 11 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[76]

	2012 Allocation lbs/day TN[77]

[69] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[70] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[71] See previous footnote.

[72] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[73] TIN = (NO3+NH3).

[74] TN = (TIN + Organic N).

[75] Estimated annual average (summer and winter loading).

[76] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table 12 - Annual Total Phosphorous Load Allocations For The Newport Bay Watershed[78]

	2002 Allocation lbs/year TP[79]	2007 Allocation lbs/year TP[80]
TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 10, 11 and 12 in accordance with the schedules in Tables 10, 11 and 12. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

[77] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[78] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[79] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[80] See previous footnote

b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determinations shall be based on monitoring within the receiving waters. For sediment TMDLs, compliance determination shall be based on monitoring in the Creek.
2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that an exceedance ~~violation~~ has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
   a) Review of the formal training needs of municipal employees
   b) Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.
3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
   a) Each permittee's expenditures for the previous fiscal year,
   b) Each permittee's budget for the current fiscal year,
   c) A description of the source of funds, and
   d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.

5. Within one year of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:

   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;

   b) Changes in land use and/or population including land use map updates;

   c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

   d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).

3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

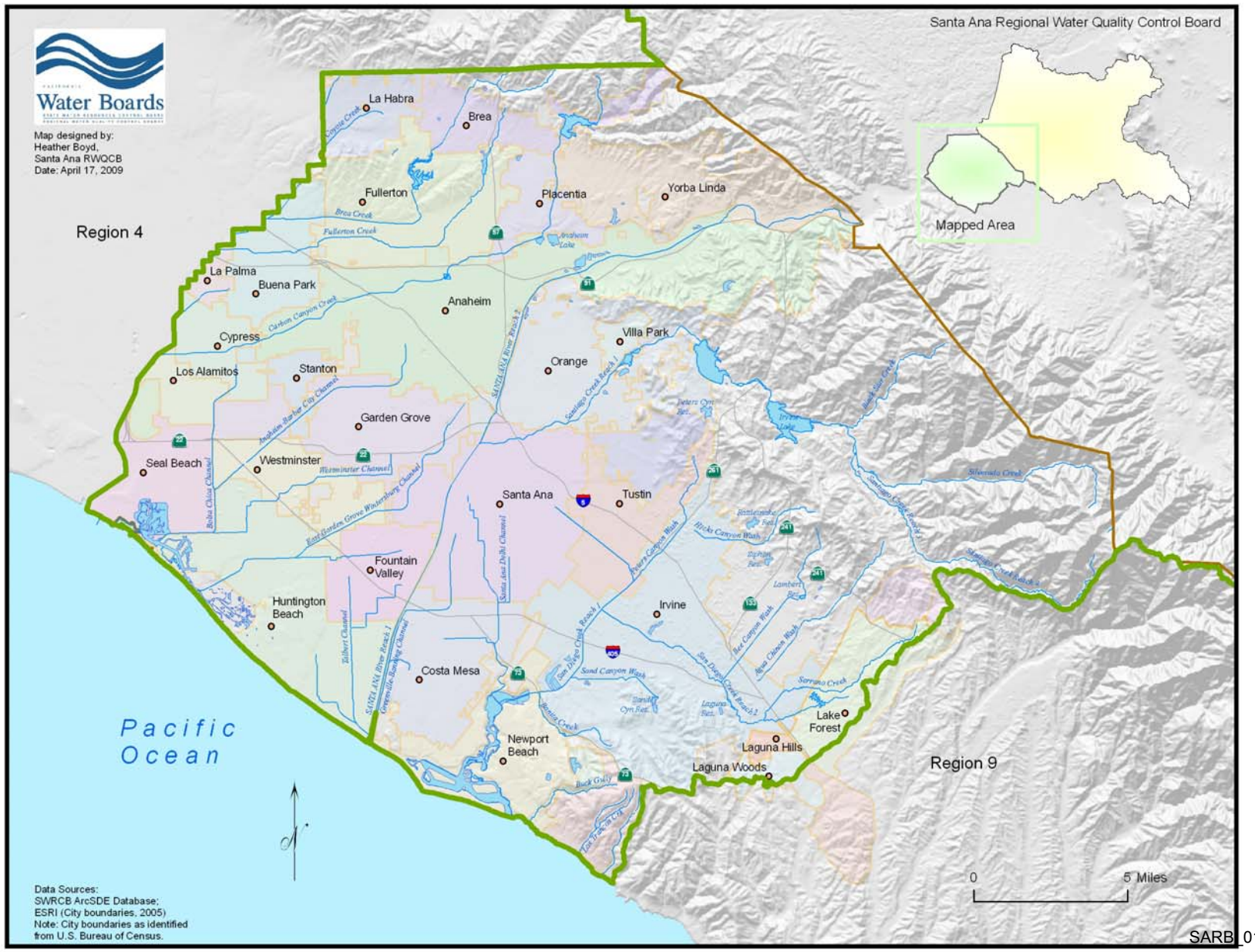
4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on ~~April 24~~May 22, 2009.

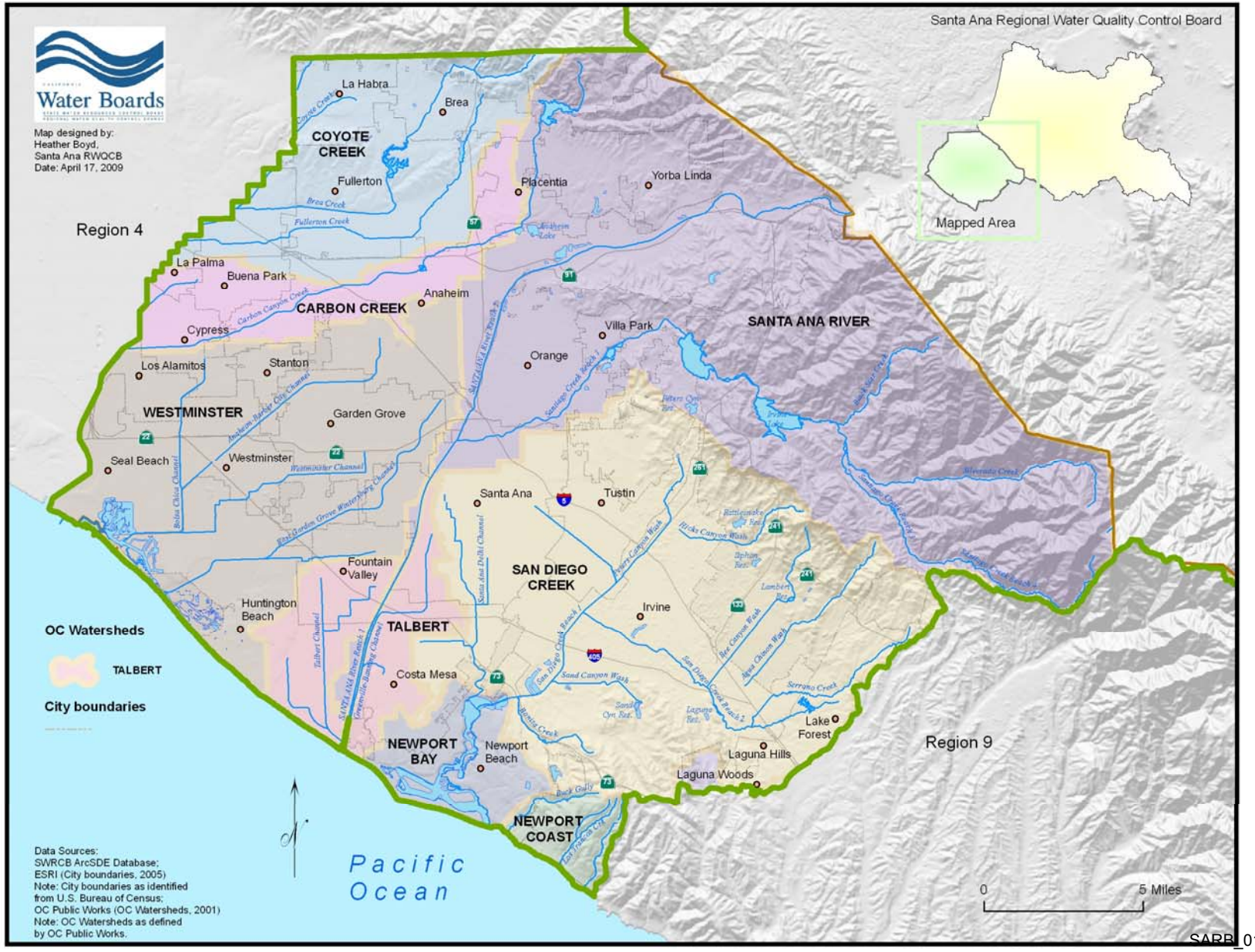
_____

Gerard J. Thibeault
Executive Officer

Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities **Attachment "A"**
Area wide Urban Storm Water Runoff



Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities **Attachment "B"**
Area wide Urban Storm Water Runoff



Order No. R8-2009-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

Orange Unified School District
Placentia Unified School District
Saddleback Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2009-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual Report

Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

Ordered by_____
Gerard J. Thibeault
Executive Officer

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the

jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

    Inland Surface Streams

    Santa Ana River, Reaches 1 and 2

    Aliso Creek (tributary to Santa Ana River)

    Carbon Canyon Creek (tributary to Santa Ana River)

    Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

    Silverado Creek (tributary to Santiago Creek)

    Black Star Creek (tributary to Santiago Creek)

    Ladd Creek (tributary to Santiago Creek)

    San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

    San Joaquin Freshwater Marsh (tributary to San Diego Creek)

    Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

    Santa Ana Delhi Channel (tributary to Newport Bay)

    Big Canyon Wash (tributary to Newport Bay)

    Buck Gully

    Los Trancos Creek

    Coyote Creek (tributary to San Gabriel River)

    Other tributaries to the above listed rivers, creeks and channels

    Bays, Estuaries, and Tidal Prisms

    Anaheim Bay and Seal Beach National Wildlife Refuge

    Sunset Bay

    Bolsa Bay and Bolsa Chica Ecological Reserve

    Upper and Lower Newport Bay

Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new

developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. Each watershed has unique receiving water issues, land uses, topography, soils and stream stability and habitat issues. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants (e.g., Orange County Flood Control Master Plan, Irvine Ranch Water District Natural Treatment System Master Plan, Orange County Watershed Plans, Nutrient and Selenium Management Program, etc.). As recommended in the 2008 National Academy of Sciences Report on Urban Stormwater Management, this order provides an option for the permittees to develop and impleemnt watershed master plans integrating water quality, hydromodification, water supply and habitat protection issues. The Regional Board recognizes that a watershed master plan should integrate all other related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary.

The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12]. The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13].

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, “Management Guidelines for Use of Fertilizers and Pesticides”. The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

Seal Beach (listed for enteroccocus, PCBs);

Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the

Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban

runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.44(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This order requires the permittees to comply with the urban runoff/storm water wasteload allocations specified in (1) Regional Board-adopted and USEPA approved TMDLs (including TMDLs for nutrients, fecal coliform, diazinon and chlorpyrifos); (2) Regional Board-adopted TMDLs that are approved by the State Board and State Office of Administrative Law and that are thereby effective (approval of organochlorine compounds TMDLs by the State is pending); and, (3) USEPA-promulgated TMDLs (including toxics TMDLs for the Newport watershed). Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mitigative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. These LID BMPs must be implemented at the project site in a manner consistent with the maximum extent practicable standard. Where LID BMPs are not feasible at the project site, more traditional, but equally effective control measures should be implemented.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25]and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be an equally effective metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to

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[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of pollutants and could become a nuisance and/or cause the spreading of surface water pollution, and those treatment systems with a hydraulic connection to groundwater (e.g., detention basins, infiltration systems, constructed wetlands, etc.) could be sources of groundwater pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants. There are other site conditions that limit the applicability of infiltration, including site soils, contaminant plumes, potential mobilization of naturally occurring contaminants such as selenium, high groundwater levels, etc. Such factors should be considered in the design and implementation of storm water control measures.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.44(d)(vii)(B)) require that the Permits be consistent with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should

include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicit discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections

and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.

7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.

2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
    i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
        a) Discharges composed entirely of storm water;
        b) Air conditioning condensate;
        c) Irrigation water;
        d) Passive foundation drains;

e) Passive footing drains;

f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Diverted stream flows;

i) Rising ground waters and natural springs;

j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

k) Flows from riparian habitats and wetlands;

l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XXI, Provision 5);

m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges from permittee owned and/or operated facilities and activities unless the stated conditions are met:

a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

c) Discharges from lawn, greenbelt and median watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

minimized through a Model Municipal Activity Maintenance Program designed to control irrigation runoff.

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.

5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).

6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.

7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.

8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

[33] See previous footnote.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.

2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.

3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

   d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

   So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.
3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.
4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis[34] and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[35]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

   f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[36];

[34] The reporting schedule may be revised with the approval of the Executive Officer.
[35] State Board WQO No. 2006-0003.

[36] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

g) Discharges of runoff from the washing of toxic materials[37] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.
2. The permittees shall control the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.
3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.
4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.

[37] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.

7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.

2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude [in decimals] or NAD83/WGS84[38] compatible formatting), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.

[38] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:

   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;

   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

   c) Visual observation for non-storm water discharges and potential pollutant sources;

   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions,

such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.

7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.
3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2

[39] See Footnote 38.

shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.
5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period[40].

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction[41]. As

[40] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

[41] The inventory update schedule may be revised with the approval of the Executive Officer.

required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[42] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

Commercial facilities may include, but may not be limited to[43]:

a) Transport, storage or transfer of pre-production plastic pellets.
b) Automobile mechanical repair, maintenance, fueling or cleaning;
c) Airplane maintenance, fueling or cleaning;
d) Marinas and boat maintenance, fueling or cleaning;
e) Equipment repair, maintenance, fueling or cleaning;
f) Automobile impound and storage facilities;
g) Pest control service facilities;
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
j) Building materials retail and storage facilities;
k) Portable sanitary service facilities;
l) Painting and coating;
m) Animal facilities such as petting zoos and boarding and training facilities;
n) Nurseries and greenhouses;
o) Landscape and hardscape installation;
p) Pool, lake and fountain cleaning;
q) Golf courses;
r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct, or require to be completed, inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 12 months of adoption of this order, the permittees shall develop a prioritization and inspection schedule for the

[42] See Footnote 38.

[43] Mobile cleaning services are addressed in X.8, below.

commercial facilities in Section X.1 for review and approval by the Executive Officer. Until that plan is approved, the following minimum criteria must be met for prioritization of commercial sites for inspections: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[44]; 20% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct, or require to be completed, commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.
4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or steam cleaning. The pilot program shall include at least two notifications of the individual businesses operating within the County regarding the minimum source

[44] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:

   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;

   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period[45].

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s consistent with the maximum extent practicable standard so as to prevent discharges from the MS4s

[45] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[46] and USDA's Backyard Conservation Program[47].
3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[48] to encourage efficient water use and to minimize runoff[49].
5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[50].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

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[46] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[47] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[48] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[49] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[50] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.
2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.
3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.
4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.
5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.
6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24

months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process in conjunction with preparation of the DAMP finalization, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance

with the approved Model WQMP and shall incorporate LID principles in the WQMP.

a. All significant redevelopment projects, where significant redevelopment is defined as projects that include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in the addition or replacement of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in the addition or replacement of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b. New development projects that create 10,000 square feet or more of impervious surface (collectively over the entire project site) including commercial, industrial, residential housing subdivisions (i.e., detached single family home subdivisions, multi-family attached subdivisions (town homes), condominiums, apartments, etc.), mixed-use, and public projects. This category includes development projects on public or private land, which fall under the planning and building authority of the permittees.

c. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

d. Restaurants where the land area of development is 5,000 square feet or more.

e. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

f. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[51] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

g. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

[51] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

h. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" in a manner consistent with the maximum extent practicable standard. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

i. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

j. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[52] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

[52] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

   A. Volume

   Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[53]; or,

   2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

   3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

   4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

   OR

   B. Flow

   Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

   2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

   3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

[53] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[54].

g) Within 18 months of adoption of this order, the principal permittee shall develop a pilot program to monitor the impact of groundwater infiltration systems on the quality of groundwater. This monitoring program may be conducted by: (1) analyzing the quality of the runoff prior to infiltration; (2) by monitoring the quality of the infiltrate through the vadose zone; or (3) by monitoring groundwater quality upstream and downstream of the infiltration systems. The results of the pilot study shall be submitted with the next annual report.

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

[54] This restriction applies only to sites that are known to have soil and/or groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for review and approval by the Executive Officer[55]. Priority development projects shall implement LID principles described in this section, Section XII.C.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, capture, or bio-filter[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance. Any portion of the design capture volume that is not infiltrated, harvested and re-used, evapotranspired, captured or bio-filtered[57] onsite by LID BMPs shall be treated and discharged using LID or conventional treatment control BMPs or mitigated as set forth in Section XII.C.7, below.

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

   a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

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[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

[56] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration are not feasible.

[57] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration are not feasible.

b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement

with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[58], New Urbanism[59] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.
6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.
7. If site conditions do not permit infiltration, harvesting and re-use, and/or evapotranspiration of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:
    a. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.
    b. Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct

[58] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[59] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume.

c. Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

d. Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire or treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[60])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

   e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of

[60] Hydromodification is the alteration of natural flow characteristics.

5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected.

c) The site infiltrates at least the runoff from a two-year storm event. The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees shall address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan as described below:

   The Watershed Master Plans shall integrate water quality, hydromodification, water supply, and habitat for the following watersheds: Coyote Creek-San Gabriel River; Anaheim Bay-Huntington Harbour; Santa Ana River; and Newport Bay-Newport Coast. Components of the Plan shall include: (1) maps to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and areas where storm water and urban runoff infiltration is possible and appropriate; and, (2) a hydromodification model to make available as a tool to enable proponents of land development projects to readily select storm water preventive and mitigative site BMP measures.

   The maps shall be prepared within 12 months of the adoption of this order and a model Plan for one watershed shall be prepared within 24 months of adoption of this order. The model Plan should specify hydromodification management

standards for each sub-watershed and provide assessment tools. In the preparation of the model Plan, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board, and (6) and water districts.

The model Watershed Master Plan shall be submitted to the Executive Officer for approval. Watershed Master Plans shall be completed for all watersheds 24 months after approval of the model Watershed Master Plan.

The Watershed Master Plans shall be designed to meet applicable water quality standards and the Federal Clean Water Act.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.
2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:
   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;
   b) Projects funded or proposed to be funded with monies from the urban runoff fund;
   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and
   d) Current status and a schedule for project completion.

3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.
4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:
   a) Redevelopment projects that reduce the overall impervious footprint
   b) Brownfield redevelopment
   c) High density developments (>7 units per acre)
   d) Mixed use and transit-oriented development (within ½ mile of transit)
   e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses
   f) Regional treatment systems with a capacity to treat flows from all upstream developments
   g) Contribution to an urban runoff fund (see 1, above)
   h) Offsite mitigation or dedications within the same watershed
   i) City Center area
   j) Historic Districts and Historic Preservation areas
   k) Live-work developments
   l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural

treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.

3. The permittees shall develop a database with information regarding each structural treatment control BMP installed after adoption of this order. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.
4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.
5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 25% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within every four year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record. The permittees may accept inspections conducted and certified by state licensed professional engineers in lieu of permittee inspections.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented in a manner consistent with the maximum extent practicable standard for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.

2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.

3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.

4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet

cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.
2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.
3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:
   a) Parking facilities;
   b) Flood management and storm water conveyance systems (open channels);
   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and
   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.
4. All applicable public agency staff shall be trained as specified under Section XVI.
5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:
   a) Conduct annual integrated pest management self-audits;
   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

c) Provide proper training to municipal and contract staff involved in the above activities;

d) Within one year of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within one year of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.

13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance

contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.

14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.

2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training, such as Certificate of Completion, attendance sheets or other proof that training has been completed. .
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections[61].
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

[61] The reporting schedule may be revised with the approval of the Executive Officer.

1. As required under a consent decree, in 2002, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay, including metals, organochlorine compounds, selenium and organophosphate pesticides. EPA and the Los Angeles Regional Water Quality Control Board established technical TMDLs for metals in Coyote Creek. Technical TMDLs do not include implementation plans or compliance schedules.
2. In collaboration with stakeholders, Regional Board staff are developing revised TMDLs that are expected to supplant the toxics TMDLs promulgated by EPA for the Newport watershed. The TMDLs will include implementation plans and compliance schedules. Implementation plans for the Coyote Creek TMDLs are also being developed.
3. In summary, work related to the following established TMDLs is ongoing:
   a) Metals (San Diego Creek and Newport Bay (including Rhine Channel))
   b) Metals (Mercury, Chromium) (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay; also see Paragraphs 5 and 6, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)
4. The permittees in the Newport Watershed shall comply with the wasteload allocations specified in the established TMDLs and shown in Tables 1 A/B/C, 2 A/B/C/D and 3. These wasteload allocations shall remain in effect unless and until alternative wasteload allocations are established in TMDLs approved by the Regional Board, State Board, Office of Administrative Law and EPA.

Tables 1 A/B/C/D – Urban Runoff Waste Load Allocations for Metals (TMDLs promulgated by U.S. EPA)[62]

A- San Diego Creek and Tributaries – Concentration based TMDL

[62] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

D- Concentration-based Dissolved Metal TMDLs, WLAs and LAs for Newport Bay

	Dissolved saltwater TMDLs and allocations which apply to direct discharges to the bay, including storm drains/channels and metals loading associated with boats	
	Acute	Chronic
Cd* (ug/L)	42	9.3
Cu (ug/L)	4.8	3.1
Pb (ug/L)	210	8.1
Zn (ug/L)	90	81

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[63]

A- San Diego Creek and Tributaries

[63] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

Total DDT	Chlordane	Dieldrin	PCBs	Toxaphene
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	Chlordane	PCBs
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	Chlordane	Dieldrin	PCBs
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	Chlordane	Dieldrin	PCBs
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[64]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

5. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. These TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. These TMDLs have not yet been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program (TRIP) that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. These TMDLs will become effective upon approval by the State Board and Office of Administrative Law but will not supplant the EPA organochlorine compounds TMDLs until they are approved by EPA. Accordingly, upon approval of the Regional Board-adopted organochlorine compounds TMDLs by the State Board and the Office of Administrative Law, the permittees shall comply with both the EPA and Regional Board wasteload allocations specified in Tables 2 A/B/C/D and Table 4, respectively. In accordance with the Regional Board TMDLs, compliance with the allocations specified in Table 4 shall be achieved as soon as possible but no later than December 31, 2015. Upon approval of the Regional Board-approved

[64] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

organochlorine compounds TMDLs by EPA, the applicable wasteload allocations shall be those specified in Table 4.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs approved by Santa Ana Regional Water Quality Control Board)[65]

	Total DDT	Chlordane	Total PCBs	Toxaphene
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.8 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

6. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated the Toxicity Reduction and Investigation Program (TRIP) consistent with the Regional Board-approved implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations.

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[66]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l

[65] From Resolution No. R8-2007-0024, Table NB-OCs-10

[66] From Resolution No. R8-2007-0024, Table NB-OCs-4

Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

7. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs and that are intended to replace the EPA TMDLs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. This Order will be reopened to incorporate revised allocations based upon TMDLs, including implementation plans, for metals and selenium approved by the Regional Board, State Board and Office of Administrative Law. As for the organochlorine compounds, the EPA promulgated allocations for these constituents will also remain in effect unless and until EPA approves the Regional Board's TMDLs for these constituents.

8. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive selenium (and nitrogen) management plans, which are expected to form the basis, at least in part, for the selenium implementation plan (and a revised nutrient TMDL implementation plan). A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the selenium TMDL implementation plan must be submitted by the stakeholders covered

by this order within 24 months of adoption of this order, or one month after approval of the selenium TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

9. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with the following wasteload allocations:

Table 6 – Municipal Storm Water Wasteload Allocations - Coyote Creek

	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

10. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 7 – Numeric Targets - Coyote Creek
(total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[67]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

[67] Based on saltwater CTR criterion in San Gabriel River estuary.

C. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 8A – Fecal Coliform TMDL and Allocations for Newport Bay

To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2013	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 8B – Fecal Coliform TMDL and Allocations for Newport Bay

Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.

stormwater, Discharges		
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables 8A and 8B in accordance with the deadlines in Tables 8A and 8B. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.

3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 9A and 9B are extracted from the Implementation Plan[68]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 9 A and B.

Table 9A

Diazinon and Chlorpyrifos Allocations for San Diego Creek*

Category	Diazinon (ng/l)	Chlorpyrifos (ng/l)

[68] Attachment to Resolution No. R8-2003-0039

	Acute	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

Table 9B

Chlorpyrifos Allocations for Upper Newport Bay*

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 10 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[69]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[70]	2007 Summer Allocation (Apr-Sept)[71]	2012 Winter Allocation (Oct-Mar)[72]

[69] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

Newport Bay Watershed	lbs/year TN[73,74]	lbs/season TN	lbs/season TN	lbs/season TN
Urban runoff	277,131[75]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 11 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[76]

	2012 Allocation lbs/day TN[77]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table 12 - Annual Total Phosphorous Load Allocations For The Newport Bay Watershed[78]

	2002 Allocation lbs/year TP[79]	2007 Allocation lbs/year TP[80]

[70] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[71] See previous footnote.

[72] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[73] TIN = (NO3+NH3).

[74] TN = (TIN + Organic N).

[75] Estimated annual average (summer and winter loading).

[76] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[77] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[78] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 10, 11 and 12 in accordance with the schedules in Tables 10, 11 and 12. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determinations shall be based on monitoring within the receiving waters. For sediment TMDLs, compliance determination shall be based on monitoring in the Creek.

2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan)

[79] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[80] See previous footnote

shall be submitted to the Executive Officer within 12 months of determining that an exceedance has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
    a) Review of the formal training needs of municipal employees
    b) Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.
3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
    a) Each permittee's expenditures for the previous fiscal year,
    b) Each permittee's budget for the current fiscal year,
    c) A description of the source of funds, and
    d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the

reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.

2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.
5. Within one year of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

(Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)

8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), **t**his order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:
   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;
   b) Changes in land use and/or population including land use map updates;
   c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

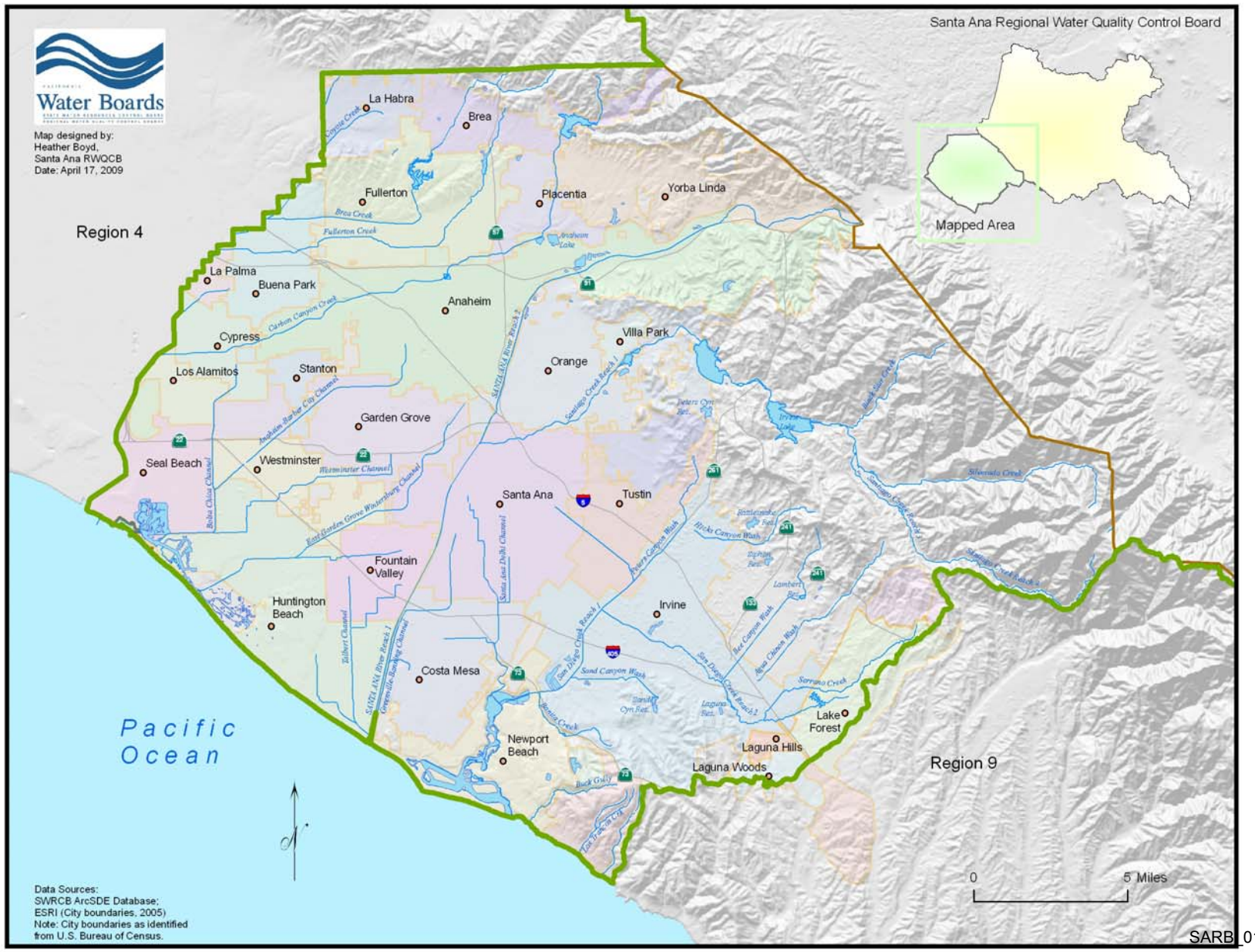
2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).
3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.
4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on May 22, 2009.

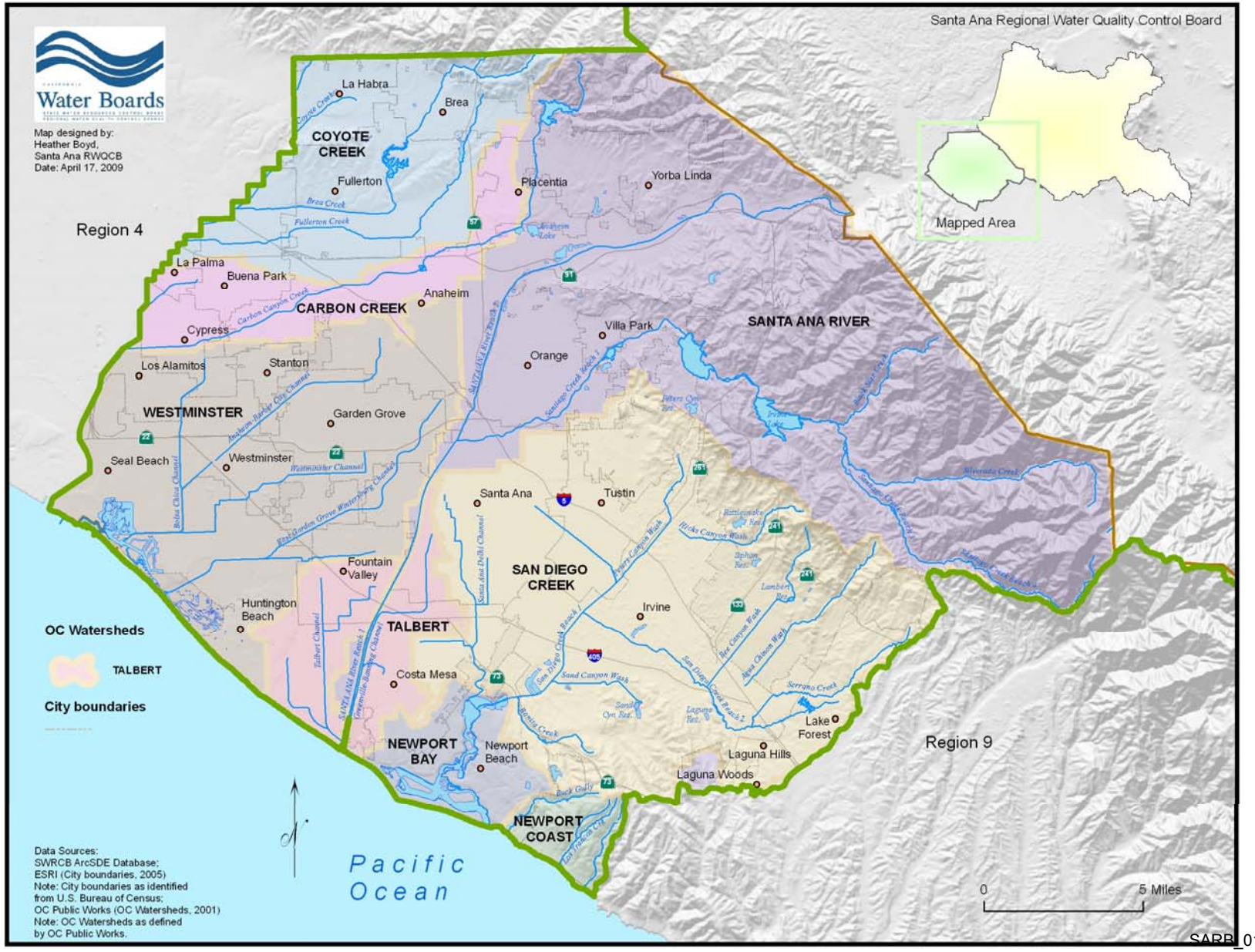
_____

Gerard J. Thibeault
Executive Officer

Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities **Attachment "A"**
Area wide Urban Storm Water Runoff



Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities **Attachment "B"**
Area wide Urban Storm Water Runoff



Order No. R8-2009-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

Orange Unified School District
Placentia Unified School District
Saddleback Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2009-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual Report

Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

Ordered by_____
Gerard J. Thibeault
Executive Officer

www.ci.irvine.ca.us

City of Irvine, One Civic Center Plaza, P.O. Box 19575, Irvine, California 92623-9575 (949) 724-6000

May 7, 2009

Gerard J. Thibeault
Executive Officer
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92601-3348

Subject: Fourth Draft of Order No. R8-2008-0030 (NPDES No. CAS618030), Orange County Area Wide Stormwater NPDES (National Pollutant Discharge Elimination System) Permit

Dear Mr. Thibeault:

The City of Irvine welcomes the opportunity to provide our input on Section XI.C, (Low Impact Development to Control Pollutants in Urban Runoff from New Development/Significant Redevelopment), of the fourth draft Tentative Order No. R8-2008-0030 (NPDES No. CAS618030). It's essential that compliance with the new development/significant redevelopment portions of the permit be technically and economically feasible. We therefore support the Fourth Draft comments submitted by the County of Orange, the Construction Industry Council on Water Quality (CICWQ) and Geosyntec.

If you have any questions or need additional information, please contact Mike Loving , Water Quality Administrator at mloving@ci.irvine.ca.us or at (949) 724-6315.

Sincerely,

Manuel Gomez
Director of Public Works

cc: Mark Carroll, P.E., City Engineer
Marcia Beckett, Fiscal & Environmental Programs Administrator
Mike Loving, Water Quality Administrator
Eric Tolles, Deputy Director of Community Development
Joe Kirkpatrick, Deputy Building Official
Michael Yang, Water Quality Engineer
Angie Burgh, Management Analyst
Glen Worthington, Great Park Manager of Planning
Chris Crompton, County of Orange

SARB_012869

PRINTED ON RECYCLED PAPER

May 8, 2009

Michael Adackapara
Sana Ana Regional Water Quality Control Board

RE: ORDER NO. R8-2009-0030

Dear Mr. Adackapara,

Thank you for the opportunity to comment on the latest proposed changes to the Orange County permit section XII.C. The proposed changes substantially change the meaning of the permit and I am glad that the Board decided to allow some time to consider their implication prior to adoption.

First, I wish to make a simple but important point regarding the definition of low impact development and to explore its implications in the context of this tentative permit. It was very interesting that the debate for the latter half of the hearing centered on the question of whether or not "filters" or "biofilters" are LID. To even ask this question shows a fundamental misunderstanding of what low impact development is. Put simply, it is a design **approach** that seeks to mimic predevelopment hydrology in the developed condition. LID can not be adequately defined as a specific list of runoff reducing BMPs. To be clear, runoff reduction BMPs play an important role in an LID strategy, but their implementation should be a near final step in a site design process that exhausts conservation and runoff prevention opportunities prior to their consideration.

This pivotal distinction is supported in LID definitions from the EPA, NRDC, the LID center and others.

For example, the first sentence on the EPA's LID page states:

> *"LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible."*[1]

The NRDC report entitled "Out of the Gutter – Reducing Runoff in the District of Columbia" describes LID as follows:

> *Low-Impact Development (LID)—a new way of thinking about stormwater management— is a highly effective strategy for controlling contaminated urban runoff.*

[1] Environmental Protection Agency. (2009) Low Impact Development Page. Retrieved from: http://www.epa.gov/nps/lid/

CONTECH CMP DETENTION SYSTEMS · CDS · The Stormwater Management StormFilter · Vortechs · CONSPAN DETENTION SYSTEMS

LID employs lot-level techniques that reduce the impact of development through the use of multiple systems that retain, detain, filter, treat, use, and reduce stormwater runoff.[2]

If LID is properly reframed as a design strategy, full implementation of LID requires that the principles and BMP selection hierarchy outlined in the tentative permit in finding 61 and draft 3 of section XII.C be followed. The assertion by NRDC that LID is feasible on all sites also makes sense when LID is viewed as a design process. However, LID feasibility on all sites is not realistic when LID is defined as mandatory retention of the design capture volume. Every site can and should follow the LID design process outlined in this permit which dictates that a site designer prioritize runoff prevention first through careful site design, then implement runoff reduction practices where feasible. Once those mitigation options are exhausted, any portion of the design storm that can't be reasonably retained must be treated using the most effective treatment controls that are feasible.

From this perspective, the language proposed for section XII.C.1 makes sense. It is intended to make it clear that LID "principles" be implemented immediately, as opposed to after feasibility criteria are developed. Clearly, this is possible and will have a beneficial impact on receiving water health.

The changes proposed in section XII.C.3 are also consistent with the LID approach as described above. However, the word "bio-filter" should be replaced with "filter".

The term bio-filter presumably refers to those structural treatment controls that include both filtration and some biological process. The term does not indicate any particular level of pollutant or runoff volume reduction. The addition of the word bio-filter as an acceptable means of treatment seems to exclude the use of media filters without a biological component. This is problematic, since some non-vegetated media filters are reliably more effective than some bio-filters. Therefore to allow bio-filters as a category and to exclude non-vegetated filters violates the maximum extent practicable standard.

A 2008 summary report of the International Stormwater BMP Database entitled "Analysis of Treatment System Performance[3]" illustrates this fact. In it, the effectiveness of common BMPs like media filters and bio-filters is reported for conventional stormwater pollutants. The bio-filter category in the database is dominated by vegetated swales and filter strips. The media filter category includes Austin and Delaware sand filters, and various other bed and cartridge based filters without vegetation. The report shows that media filters tend to outperform biofilters for important parameters like TSS and TP. Heavy metal removal rates are not substantially different

[2] NRDC. (2002). Out of the Gutter – Reducing polluted runoff in the District of Columbia. Retrieved from: http://www.nrdc.org/water/pollution/gutter/gutter.pdf

[3] This database is sponsored by EPA, the Water Environment Research Federation, the American Society of Civil Engineers and others. The summary report can be found on-line at www.bmpdatabase.org

between BMP types, although median average effluent concentrations of total zinc and total copper were lower for media filters.

Clearly there are highly effective media filter and biofilter designs that will maximize pollutant load reduction. For example, swale designs that capture the water quality storm, percolate it through vegetation and engineered soil, and finally collect that filtered water in an underdrain prior to release are most effective. This design is fundamentally different than conventional swales and grass filter strips that are designed to convey the design storm over land as shallow, low velocity flow with only incidental infiltration.

Non-vegetated filter design varies dramatically as well. On one end of the spectrum are the catch basin inserts and other BMPs with filter fabric barriers or a token amount of coarse media with virtually no contact time with runoff at design flow rates. On the other end of the spectrum are sand or engineered media filters which typically are designed with minutes to hours of contact time and are highly effective for most pollutants. The obvious challenge for either class of filters is to separate the designs likely to achieve adequate performance from those that are inadequate. This performance-based differentiation will be required regardless of whether or not the filtration options allowed by this permit are limited to those with a biological component. This differentiation can either be added to the permit in section XII.C.2, or to the updated DAMP.

Thankfully there are options for separating potentially suitable BMPs from those that are ineffective or still in the experimental stage without burdening the permittees with the task. For example, the Sacramento Stormwater Quality Partnership (SSQP)[4] has an evaluation program for proprietary treatment BMPs which has identified several suitable stand–alone treatment options. Outside of California, the Washington State Department of Ecology (DOE)[5] and the New Jersey Department of Environmental Protection (DEP)[6] have BMP performance verification programs that require extensive lab and field studies prior to approval for stand-alone treatment. A relatively simple approach to differentiating between filters would be to require that filters be fully approved for stand alone treatment through the Washington DOE, New Jersey DEP or SSQP prior to use.

An alternative language option could be borrowed from the stormwater quality credit criteria from the LEED 2009 rating system which requires:

> *BMPs used to treat runoff must be capable of removing 80% of the average annual postdevelopment total suspended solids (TSS) load based on existing monitoring reports. BMPs are considered to meet these criteria if:*

[4] Sacramento Stormwater Quality Partnership. Program information available at: http://www.msa.saccounty.net/sactostormwater/SSQP/development/treatment-options.asp
[5] Washington Department of Ecology. Program information available at: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html
[6] New Jersey Department of Environmental Protection. Program information available at: http://www.nj.gov/dep/stormwater/treatment.html

- *They are designed in accordance with standards and specifications from a state or local program that has adopted these performance standards,*

OR

- *There exists infield performance monitoring data demonstrating compliance with the criteria. Data must conform to accepted protocol (e.g., Technology Acceptance Reciprocity Partnership [TARP], Washington State Department of Ecology) for BMP monitoring.*[7]

The Stormwater Management StormFilter™ is a proprietary media filter that has been installed on nearly 100 projects in 17 Cities in Orange County. Each system contains one or more siphon actuated filter cartridges containing media targeting the anticipated pollutants of concern on site. Because the StormFilter is installed below grade and can support traffic loading it is commonly used on retrofit and redevelopment projects where the density of development is very high and where retention of the entire water quality event is infeasible.

Nationally there are more than 60,000 StormFilter cartridges in operation that have been installed in the past 10 years. Throughout that time, numerous field studies have been completed which document the performance and longevity of the system in typical urban applications. The StormFilter is one of a select few systems that has been approved for stand-alone use by the Washington DOE, the New Jersey DEP and by the Sacramento Stormwater Quality Partnership. Caltrans has also rated the effectiveness of the system for conventional stormwater pollutants based on existing monitoring reports in their annual publication entitled, "Treatment BMP Technology Report". The StormFilter entry from that report is attached to this comment letter along with a brief performance summary. Clearly, there is a small subset of urban development and redevelopment projects where this filter satisfies the maximum extent practicable standard.

Section XII.C.2 references the 85th percentile design storm as section XII.B.4.A.1. This reference should be changed to XII.B.4 so that it is inclusive of the flow based design storm. As currently written, the reference does not allow for flow based sizing which is a common method of filter sizing. The flow based design option is no less stringent than the "design capture volume" standard. Both standards ensure treatment of at least 85% of the average annual rainfall depth. Likewise, the reference to the "design capture volume" in the last sentence of this section should be changed to reference the 85th percentile design storm.

In summary, I urge you to replace the word "bio-filter" with "filter" in section XII.C.2 and to update references to the 85th percentile design storm. I would also strongly suggest that the Permittees be required to develop or adopt filter performance criteria and a means for evaluating filters relative to those criteria. If this change is not made, use of non-vegetated filters that have been proven to be highly effective for common pollutants of concern will be prohibited in clear violation of the maximum extent practicable standard.

[7]United States Green Building Council. (2009) "LEED 2009 for New Construction and Major Renovations". Sustainable Sites Credit 6.2

Thank you again for this opportunity to comment. Please let me know if you have any questions.

Sincerely,



Vaikko P. Allen II, CPSWQ, LEED-AP

Regulatory Relations Manager - Southwest
CONTECH Stormwater Solutions, Inc.
allenv@contech-cpi.com



Treatment BMP Technology Report

April 2008

CTSW-RT-08-167.02.02

Final Report

California Department of Transportation
Division of Environmental Analysis
1120 N Street, Sacramento, California 95814

SARB_012875

BMP Fact Sheet
Filtration
Cartridge/Canister

StormFilter™

Description:

The StormFilter™ is a combination of a small water quality inlet (baffle system) with a varying number of float-actuated canister filters. Filter media can vary. High flow bypass spills over the baffle in the first chamber. Pictured at right is the catch basin version of the StormFilter™.

Constituent Removal:

Constituent Group	Removal Efficiency	Level-of-Confidence
Total Suspended Solids	●	◒
Total Nitrogen	◒	◒
Total Phosphorus	◒	◒
Pesticides	NA	
Total Metals	◒	◒
Dissolved Metals	○	◒
Microbiological	◒	○
Litter	●	◒
BOD	○	○
TDS	○	○

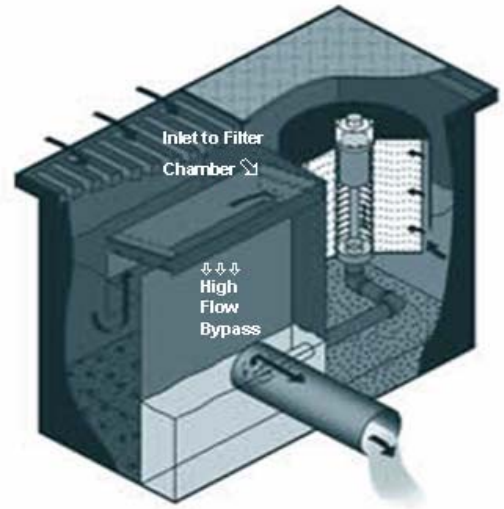
Notes:

Performance varies with media. Scores are based on average results for the media best suited for the constituent. Field data supersedes laboratory data.
Litter removal based on professional judgment.
Microbiological based on test of old model at Kearny Mesa. (See page C-23).
ZPG media at 7.5 gpm at two locations 82% TSS at two locations (Contech, 2004).
No TDS removal,49% Cu, 52% Zn, 38% diss Cu, 26% diss Zn, 49% total N (Contech, 2005).
ZPG media at 15 gpm: 46% TSS (NSF, 2004).
CSF media at 7.5 gpm and 3 storms: 87% TSS, 61% total Zn, 46% phosphorus (Contech, 2003).
Perlite media at 15 gpm: 80% TSS, 60% Cu, 73% Pb, 46% Zn, Inconclusive phosphorus removal (Contech, 2006)

Caltrans Evaluation Status:

Under evaluation for pilot study

Schematic:



Source: www.contech-cpi.com

Key Design Elements:

Flow Restriction (7.5 gpm or 15 gpm).
High flow bypass.
Media type.

Cost Effectiveness Relative to Detention Basins:

Cost Effectiveness:	Level-of-Confidence
◪	○

Notes:

Cost effectiveness determination pending further evaluation.

Rating Key for Cost Effectiveness Relative to Detention Basins

Benifit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Constituent Removal Efficiency and Level-of-Confidence

● High ◒ Medium ○ Low

BMP Fact Sheet
Filtration
Cartridge/Canister



StormFilter™

Maintenance Issues:

Requirements:

Inspecting the facility, removing litter and sediment and all spent filter cartridges, repairing or replacing inoperative controls, valve or filter canister, and cleaning the filter cartridges and canister if necessary.

Training:

Crews must be trained to repair or replace any cartridge filter or part associated with the facility or contract for maintenance.

Project Development Issues:

Right-of-Way-Requirements:

Space requirements depend on sizing criteria, typically smaller than basins.

Siting Constraints:

Must have sufficient hydraulic head.

Construction:

No unique requirements identified

Advantages:

Smaller footprint than for conventional sedimentation/gravity sand filters.
Noling, et al, report toxicity reduction for high levels of influent metals.

Constraints:

Removal of fine sediment in cartridge filters is not as effective as in open bed media filters.
Proprietary device.
Vector concerns.

Design, Construction, Maintenance and Cost Sources

Contech® Stormwater Solutions, Inc., www.contech-cpi.com/stormwater/products

U.S. Environmental Protection Agency, www.epa.gov/region1/assistance/ceitts/stormwater/techs/stormfilter.html

Literature Sources of Performance Demonstrations:

Contech Storm Water Solutions 2003. "Heritage Marketplace Field Evaluation: Stormwater Management StormFilter with CSF Leaf Media." (available by request of manufacturer)

Contech Storm Water Solutions 2005. "heritage Marketplace Field Evaluation: Stormwater Management StormFilter with ZPG Media" (available by request of manufacturer)

Contech Storm Water Solutions 2004. "Performance of the Stormwater Management StormFilter relative to Ecology Performance Goals for Basin Treatment" (available by request of manufacturer)

Contech Storm Water Solutions 2006. "Greenville Yards Storm water Treatment System Field Evaluation: Storm water Management Storm Filter with Perlite Media at 57 L/min/cart" (available by request of manufacturer)

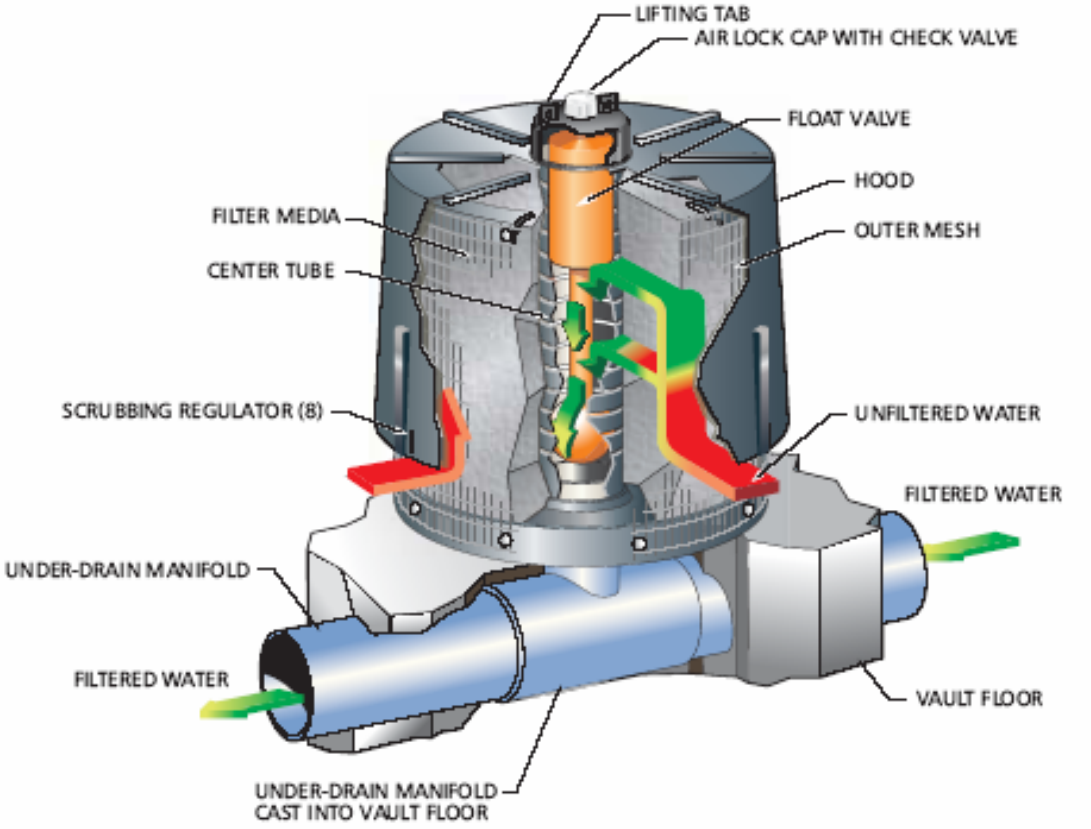
Calvin, N. and Barry, K. "Successful Demonstration of the Storm water management StormFilter® Enhanced Filtration System for Toxicity Reduction of shipyard Storm water conducted at National Steel and Shipbuilding Company (NASSCO)." Presented at: the Prevention of Pollution from Ships, Shipyards, Drydocks, Ports, and Harbors: 3rd International Symposium on November 5 - 7, 2003 at the University of New Orleans, LA http://www.hartcrowser.com/PDFs/Stormfilter.pdf

NSF International July, 2004. "Environmental Technology Verification Report: Storm water Source Area Treatment Device, the Storm water Management StormFilter® using ZPG Filter Media." www.epa.gov/etv/pdfs/vrvs/600etv06039/600etv06039s.pdf

Certifications, Verifications, or Designations:

ETV - Verification statement issued July 2004 for suspended solids.
TCEQ - Approval of Innovative Technology: Each cartridge must be limited to a maximum flow rate of 7.5 gpm.
TARP - Compliant or similar reliable data on this technology to be able to evaluate pollution removal efficiency claims for TSS, SSC.

Stormwater Management StormFilter® Performance Summary



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b. Phosphorus
c. Dissolved Metals
d. Oil and Grease

2) Agency – Field Evaluation Programs

a. State of Washington (TAPE)
    i. General Use Level Designation
b. State of New Jersey (TARP/Tier II)
    i. NJDEP Extension Approval – Conditional Interim Certification
    ii. NJCAT Verification

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Parameter Brief

Total Suspended Solids (TSS) Removal Using Different Particle Size Distributions with the Stormwater Management StormFilter®

Introduction

Total Suspended Solids (TSS) is commonly used in the stormwater industry as a surrogate pollutant and a measure of Best Management Practice (BMP) performance. Although a practical standard, it is becoming evident that the measurement of TSS can be complex. Historically, parameters such as particle size distribution and specific gravity have not been included as part of BMP performance due to the difficulty of measuring these parameters in the field. For example, in a situation where road-sanding material is being washed into a BMP, the removal of 80% of TSS is easily achieved as the majority of the mass of the particles is composed of large sand and grit particles with a high specific gravity. In other situations, the TSS particles are much finer and have lower specific gravity, such as runoff from parking lots and high travel roads that frequently have "gray" water resulting from suspensions of silts, tire and brake dust, and associated fractions of oil and grease at low concentrations.

TSS Definitions

CONTECH Stormwater Solutions Inc. has been investigating various particle size distributions (PSDs) for BMP acceptance or verification for various agencies: Washington State Department of Ecology (Ecology), New Jersey Corporation for Advanced Technology (NJ CAT), New Jersey State Department of Environmental Protection (NJ DEP), City of Portland, OR Bureau of Environmental Services (BES).

Five different PSDs are presented in Table 1. These particle sizes consist of natural soils (sandy loam and silt loam), manufactured sediment (SIL-CO-SIL 106), and two protocols for evaluating stormwater (APWA and City of Portland BES). The StormFilter was tested with the natural soils and SIL-CO-SIL sediments (finer distribution than the APWA or BES protocols). PSD testing was predominantly conducted in the Stormwater360 laboratory using simulated stormwater in a TSS concentration range between approximately 0 – 350 mg/L.

CONTECH Stormwater Solutions would recommend that a jurisdiction define TSS with a range of PSDs such as the sandy loam, silt loam, or SIL-CO-SIL 106 used in these laboratory investigations, as opposed to a uniform PSD (i.e. 80% removal of 125 microns). Manufactured sediments are commercially available and can easily be used in comparing different BMPs. The PSDs are idealized at a specific gravity of 2.65, while field studies by CONTECH Stormwater Solutions clearly show a high fraction of the TSS as organic in texture (seasonally) with a specific gravity at approximately 1.0. Investigations by CONTECH Stormwater Solutions show that PSDs in the Pacific Northwest tend to be characteristic of silt loams and PSDs in the NE tend to be sandy loams or loamy sands, especially where road sanding is practiced.

Table 1 has a summary of various PSDs that have been investigated by Stormwater360. For further information, Appendix A contains the graphical representation of each sediment type. Table 2 contains the TSS removal performance with these different sediments.

Table 1. Sediment Particle Size Distributions

Particle Size (microns)	Percent by mass (approximate)				
	Sandy loam [a]	Silt loam [a]	SIL-CO-SIL 106 [b]	APWA 1999 Protocol [c]	Portland BES [c]
500 – 1000	5.0	5.0	0	20.0	10.0
250 – 500	5.0	2.5	0	10.0	10.0
100 – 250	30.0	2.5	0	35.0	25.0
50 –100	15.0	5.0	20.0	10.0	25.0
2 – 50	40.0	65.0	80.0	25.0	30.0
1 – 2	5.0	20.0	0.0	0	0

[a] CONTECH Stormwater Solutions tested Oregon silt and sandy loams for New Jersey Corporation for Advanced Technology verification of TSS performance claims.

[b] CONTECH Stormwater Solutions tested SIL-CO-SIL 106 for Washington State Department of Ecology per the Technology Assessment Protocol – Ecology (2001).

[c] Hypothetical particle size distributions from these testing protocols. Particle sizes were presented in a range available in Appendix A; the table represents the least conservative (coarser) approximate particle size range.

Table 2. TSS removal using differing particle size distributions

Media Type	Cartridge Flow Rate (gpm)	Percent Removal (%)		
		Silt loam [a]	SIL-CO-SIL 106 [a]	Sandy loam [a]
Standard Perlite	15		72 – 78	77 - 80
Standard Perlite	7.5		78 – 83	
Coarse Fine Perlite	15			
Coarse Fine Perlite	7.5	68 – 75	79 – 82	
Fine Perlite	15		73 – 78	
Fine Perlite	7.5		85 – 88	
CSF® leaf [b]	15	68 – 79		
Coarse Perlite/Zeolite [c]	15	63 – 84		
ZPG™	15		80 – 82	
ZPG™	7.5		86 – 89	
Perlite/CSF® leaf	7.5		82 – 86	
Perlite/Metal Rx™	7.5		89 – 92	

[a] Linear regression was used in the data analysis, the table presents the upper and lower 95% confidence limits. Data was collected in the CONTECH Stormwater Solutions laboratory using simulated stormwater for TSS concentrations between 0 – 350 mg/L. Silt and sandy loam performance data was NJCAT-verified.

[b] Performance of the CSF leaf media was tested using both field and laboratory investigations. Laboratory studies used a Palatine loam sediment. Field data is from the Pacific Northwest.

[c] Performance of the coarse perlite / coarse zeolite media was tested using a Palatine loam sediment. Reported in Total Suspended Solids Removal using StormFilter Technology.

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Revision

RS-0091 04/14/06 Rebranded to Contech Stormwater Solutions, Inc.

PD-03-13.4 09/08/05 Added Standard Perlite at 15 and 7.5 gpm, and ZPG at 15 gpm to Table 1. Updated Reference Section.

PD-03-13.3 04/28/05 Added Perlite/CSF leaf & Perlite/MetalRX to Table 1. Updated Reference Section.

PD-03-013.2 12/02/04 Added ZPG™ to Table 1.

PD-03-013.1 12/15/03 Altered Table 1 - SIL-CO-SIL to reflect 20:80:0 (sand:silt:clay)
Added content to section 2, paragraph 3, last sentence.

PD-03-013.0 10/28/03

APPENDIX A

SIL-CO-SIL 106 Particle Size Distribution

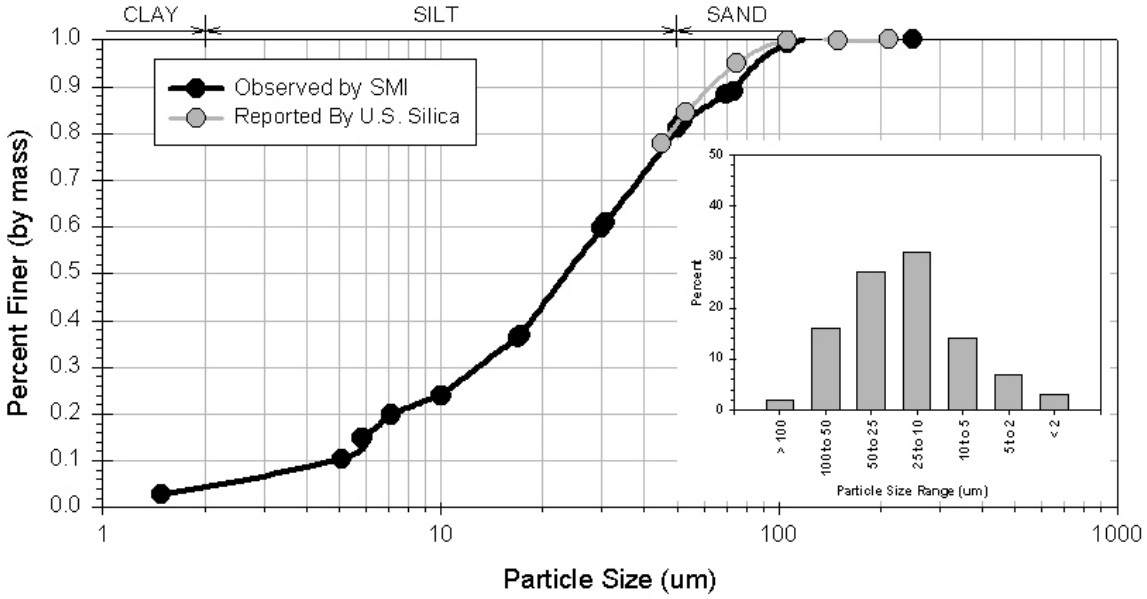

Figure 1. Particle size distribution for SIL-CO-SIL 106. Sand/silt/clay fractions according to USDA definitions are approximately 20%, 80%, and 0% for SIL-CO-SIL 106, indicating that the texture corresponds to a silt material. Specific gravity is 2.65.

Silt Loam Particle Size Distribution

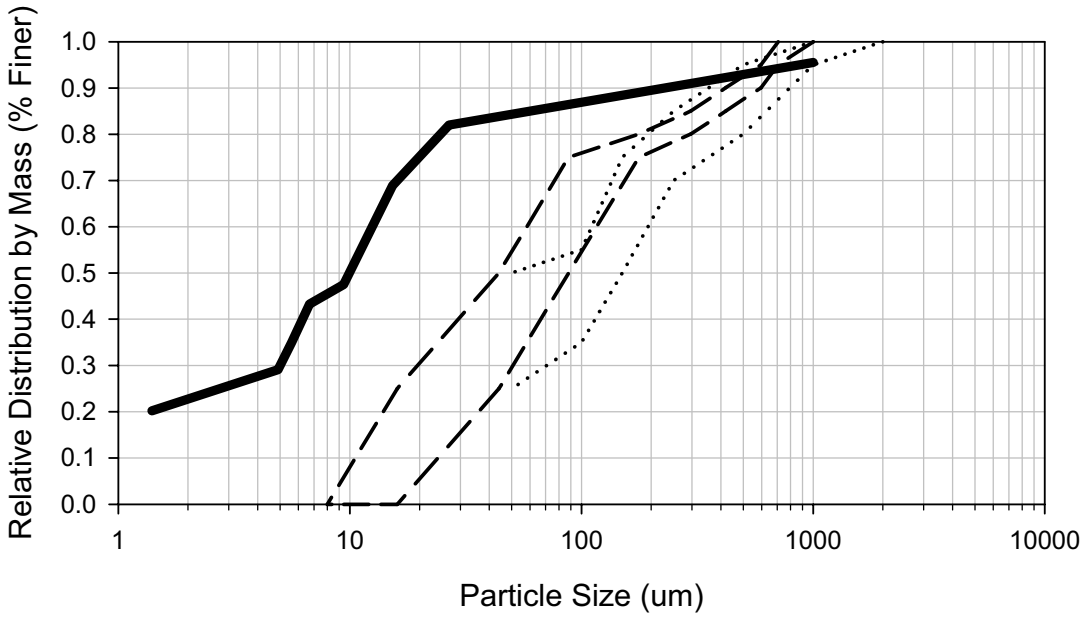

Figure 2. Particle size distribution (shown as solid line) for bulk soil sample "OSU Silt Loam GPS W.P. #10" used for testing. Sand/silt/clay fractions according to USDA definitions are approximately 15%, 65%, and 20%, indicating that the texture corresponds to a silt loam material. Dashed and dotted lines indicate particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

Sandy Loam Particle Size Distribution

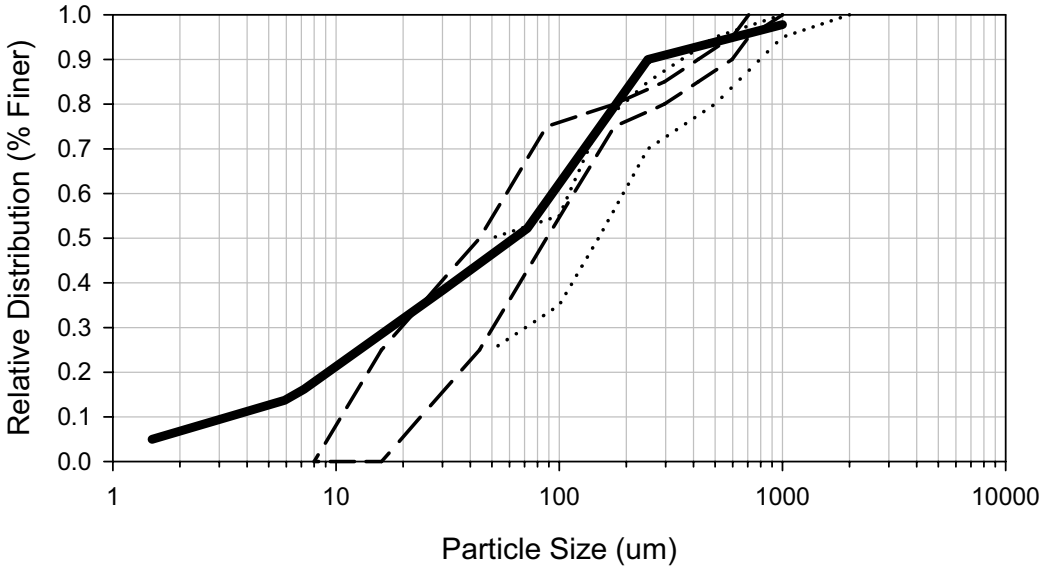

Figure 3. Particle size distribution (shown as solid line) for bulk soil sample "OSU Loam GPS W.P. #13" used for testing. Sand/silt/clay fractions according to USDA definitions are approximately 55%, 40%, and 5%, indicating that the texture corresponds to a sandy loam material. Dashed and dotted lines indicate particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

Parameter Brief

Performance of the Stormwater Management StormFilter® for Removal of Total Phosphorus

Phosphorus in the Urban Environment

Phosphorus loading to freshwater can promote algal blooms and eutrophication that threaten ecosystems by lowering dissolved oxygen levels. As shown in Figure 1, phosphorus cycles through the environment in forms organic, inorganic and soluble forms.

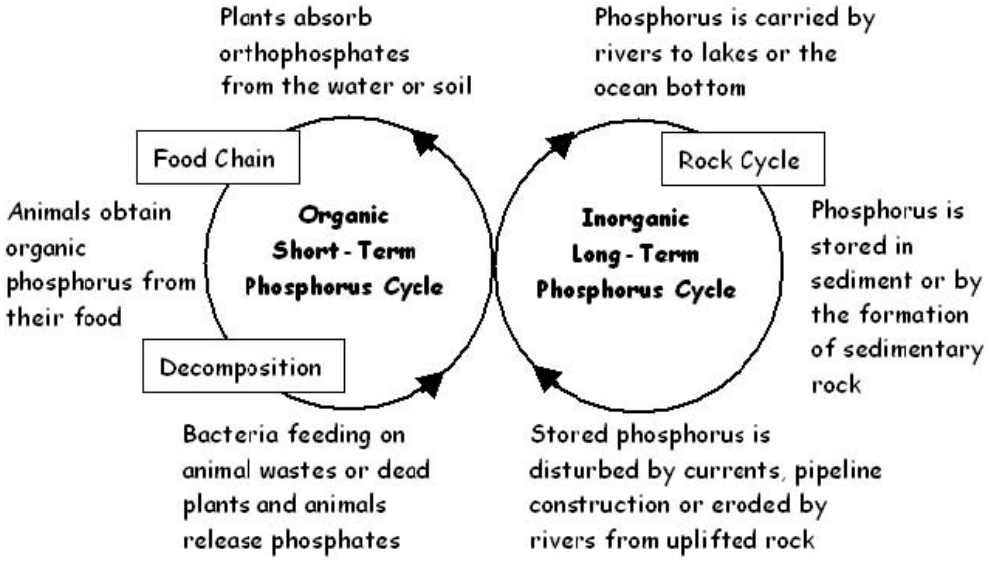

Figure 1. Inorganic and Organic Cycle (RiverWatch, 2001)

Total phosphorus (TP), expressed in milligrams/liter is the sum of inorganic phosphate, organic phosphate, and soluble phosphorus (Ortho-P). Organic phosphates are a part of plants and animals, their wastes or decomposing remains. Inorganic phosphorus originates from decomposing natural materials and man-made products.

Non-point source runoff (stormwater) increases phosphorus concentrations in lakes and streams by transporting sediment and organic matter (bud shatter, leaves, lawn clippings, etc.) from impervious surfaces. Additional phosphorus sources in stormwater are misapplied fertilizers, some detergents, and animal waste from birds and domestic pets.

Phosphorus in urban runoff is typically measured as TP and sometimes Ortho-P is measured as well. The non-soluble portion of the TP is commonly associated with the total suspended solids (TSS). Of this form, the phosphorus can be in an organic or inorganic form. TP concentrations in stormwater are variable but range from 0.01 to 7.3 mg/L (Minton, 2002). Concentrations of Ortho-P in urban runoff are frequently in concentrations ranging from 0.05 to 0.2 mg/L (Wigginton, 1999). USEPA guidelines indicate that Ortho-P concentrations in stream in excess of 0.10 mg/L can trigger algae blooms in fresh water lakes.

Removal of phosphorus can be accomplished by three mechanisms. The first is removal of organic and inorganic P associated with solids. The second is removal by biological uptake by plants or bacteria. The third is through chemical precipitation such as the reaction of Ortho-P with iron to form iron phosphate in aerobic conditions. Depending on the type of treatment system, organic phosphorus can transform to Ortho-P and be released later. For example, leaves trapped in a sump can decompose or fall senescence of wetland plant can release Ortho-P.

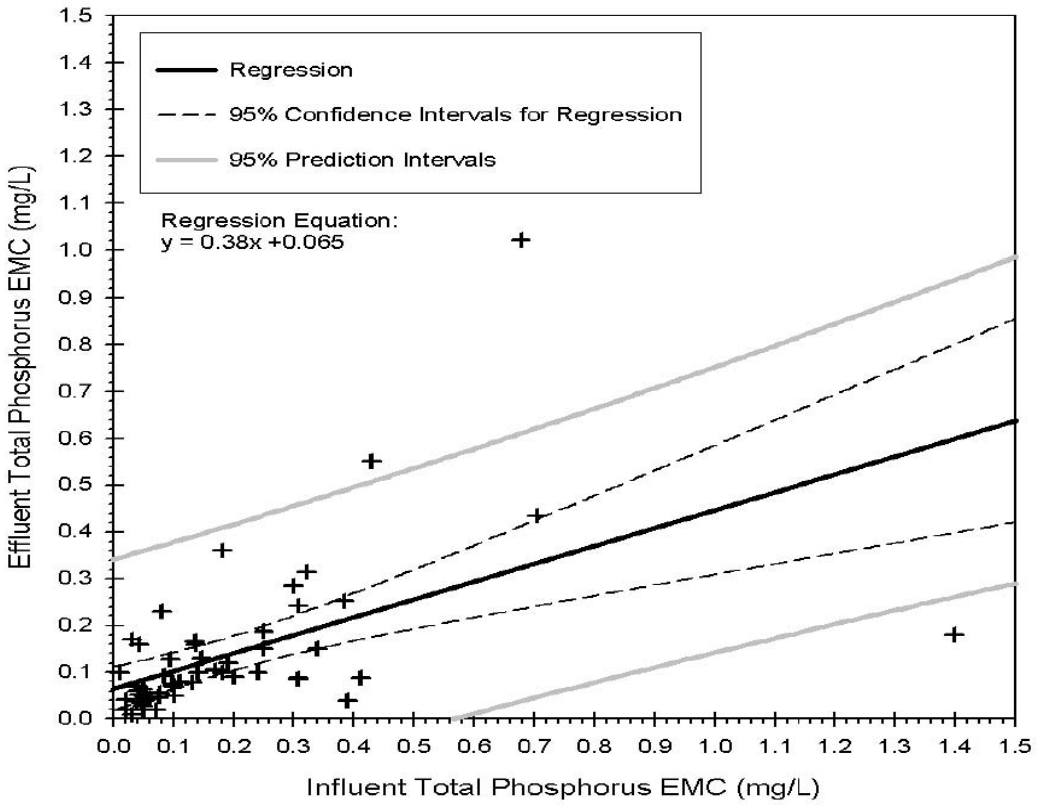

Figure 3. Total phosphorus removal performance summary collected from 9 sites, in multiple geographic locations, with different media. The linear regression produced an equation of y = 0.38x + 0.065, which translates to a 62% removal with a 95% confidence interval of 53% and 78% (lower and upper limits, respectively). Data was statistically significant with a $P < 0.001$. Data was current as of July 2003.

Results

Performance data for removal of total phosphorus were summarized from ongoing field evaluations. These field evaluations are a combination of first and third party investigations. Data were collected from 9 sites located in different geographic locations (primarily from the West Coast (WA, OR, CA) and a single Midwest site) and configured with different media types at different flow rates. Available reports are listed in the reference section. This performance summary focuses on Total Phosphorus removal only. The following information presented in Figure 3 contains data collected since 2001, mostly during the late spring, summer, and fall for total phosphorus removal by the Stormwater Management StormFilter.

Fifty-five data points are presented in Figure 3. The mean removal efficiency using linear regression was 62% with 95% confidence limits of 53% and 78% (lower and upper limits, respectively). Sixteen data points that were included in the analysis did not have a positive removal. Overall these systems demonstrated statistically significant removal ($P<0.001$; 99% probability of net removal) of Total Phosphorus.

Table 1. General Site Description

Site Description	WQ Flow Rate (cfs)	Unit Size	Media	No. of Cartridges	Location
Shopping Center	0.503	8 x 16	ZPG, CSF	23	Vancouver, WA
Carwash	0.070	CBSF	CSF	2	Vancouver, WA
Hotel	0.165	6 x 8	CSF	5	Vancouver, WA
Mixed Use	1.600	8 x 16 (2)	Perlite/Zeolite	48	Sammamish, WA
Shopping Center	0.033	CBSF	Perlite	1	Vancouver, WA
Commercial Office	0.594	8 x 16 (2)	Perlite/CSF	24;30	Olympia, WA
School	0.297	8 x 16	Perlite/Zeolite	14	Redmond, WA
Resort	1.650	CIP	Perlite/Zeolite	50	California
Roadway	0.300	6 x 12	ZPG	9	Midwest

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Parameter Brief

The Stormwater Management StormFilter® for Removal of Dissolved Metals

Introduction

Urban Stormwater often contains high levels of soluble and particulate heavy metals. Generated from traffic, industrial facilities, and sometimes residential sources, these metals are frequently found in concentrations that are deleterious to aquatic life and other biota that are dependent on aquatic life as a food sources. Two of the most common metals found both in the water column and sediments are zinc and copper. Zinc tends to exhibit toxicity effects in the fresh water environment and copper exhibits toxicity characteristics in the marine environment.

Metals are measured as both total metals and soluble metals. Total metals are the sum of dissolved metals and those metals associated with particulates. Soluble metals are commonly defined as those metals that pass through a 0.45 micron filter. Frequently the soluble metals are in a cationic form in that they posses a net positive charge. However, sometimes the charge of the soluble metal has been satisfied in that it could be associated with sub-micron particles such as ligands or colloids. In this event, the metal may not have a net positive charge.

Cation Exchange

Cation exchange is the exchange of a cation (positively charged atom) for another cation. The process involves the displacement of an atom within the media matrix by an atom within the water column. The displacement occurs if the incoming atom's affinity for the exchange site is higher than that of the current occupying atom. In general, the physically smaller the ion (when hydrated) and the greater the positive charge the more tightly it will be held by the media.

Predictions can be made using a periodic table of elements for commonly found metals in stormwater runoff. Staying within the same row of the table and proceeding left to right produces an increasing affinity for cation exchange. This trend is promoted due to the metal atom remaining in the same valence state (charge) while the overall diameter of the atom decreases. Since the diameter decreases, the "apparent charge" of the atom increases, thus producing the driving mechanism for cation exchange. For most purposes the following affinity series is true:

$$Al^{3+} > H^{+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Fe^{2+} > Cr^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$$

Primary Exchange Ions within CONTECH Stormwater Solutions Filtration Media

The media-bound ions utilized with cation exchange filtration are calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) with calcium and magnesium being the primary exchange ions due to their abundance within the media matrix.

As presented above, zinc, copper and iron (as well as others) will force the displacement of the calcium and magnesium ions from the media.

Media promoting cation exchange and measured cation exchange capacity (CEC):

- CSF® media (93.8 meq/100-grams)
- Zeolite (125 meq/100 grams)

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Performance Summary

Table 1. Soluble Metals Removal using organic media (CSF®, Metal Rx).

		Soluble Copper		Soluble Zn	
Site	**Media**	**Removal**	**Influent (ug/l)**	**Removal**	**Influent (ug/l)**
Nassco Shipyard	CSF	54%	61-401	64%	191-124
Charleston Boatyard	CSF	49%	11,000 (Total)	48%	3,560 (Total)
East Side Plating	Metal Rx	92%	58-268	43%	ND-569 (Total)

Table 2. Total Metals Removal

		Configuration (Removal efficiency)			
Parameter	**Influent (mg/l)**	**CSF Standard Grade 15 gpm**	**CSF Standard Grade 7.5 gpm**	**Perlite/Zeolite Coarse Grade 15 gpm**	**Perlite/Zeolite Fine Grade 15 gpm**
Total Copper	11	42%	49%	41%	54%
Total Lead	0.096	43%	47%	42%	60%
Total Zinc	3.56	41%	48%	31%	51%
Total Chromium	0.0384	49%	61%	57%	67%

Performance data has been summarized from field investigations (Table 1) and from laboratory (Table 2) investigations using captured stormwater runoff from the Charleston Boatyard.

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Parameter Brief

The Stormwater Management StormFilter® for Removal of Oil and Grease

Oils and Greases (O&G) are commonly found in stormwater runoff from automobiles and associated anthropogenic activities. O&G appears in many different forms in stormwater runoff: free, dissolved, emulsified, and attached to sediments. Total Petroleum Hydrocarbons (TPH) is the usual analytical measure of fuels, oils and grease (O&G) for stormwater. Typically the concentrations of TPH associated with runoff from streets and parking lots do not exceed concentrations that range from 2.7 to 27 mg/l (FHWA, 1996).

Frequently studies are conducted using high concentrations of oil, e.g. 5,000 mg/l in and 250 mg/l out, with claims of 95% removal. These concentrations are not representative of those associated with most stormwater runoff. In the event of these high concentrations, then an oil/water separation technology would be required as pretreatment.

Removal of TPH by media within the StormFilter cartridge is accomplished through adsorption. Adsorption is the attraction and adhesion of a free or dissolved contaminant to the media surface. This occurs at the surface as well as within the pores of the media granule. Adsorption requires that a contaminant come in contact with an active surface site on the media and time must be allowed for the contaminant to adhere. These reactions are usually promoted by polar interactions between the media and the pollutant. Adsorption can also occur within the dead end pores and channels of the media but is generally slower than a surface reaction due to limits of the contaminants diffusion into the pore. (Note: The contaminant's molecular size will limit diffusion in that the media's pore opening must be larger than the dissolved contaminant.) Commonly adsorbed pollutants include: gasoline, oil, grease, TNT, polar organics or organically bound metals and nutrients.

The media provided by CONTECH Stormwater Solutions Inc. for the removal of oils and grease are targeted to remove concentrations of 25 mg/l or less. Media promoting adsorption reactions are the CSF® leaf media, perlite, and granular activated carbon. For concentrations that continually are higher than 10 mg/l, an oil removing accessory such as a sorbent cartridge hood cover is recommended.

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BY:

January 26, 2005

Jim Lenhart, V.P.
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12021-B NE Airport Way
Portland, OR 97220

Dear Mr. Lenhart:

Subject: Designation of the StormFilter for General Statewide Use

On behalf of the Department of Ecology, I would like to congratulate you and your company for achieving a General Use Level Designation (GULD) for your StormFilter technology as a basic stormwater treatment. Our determination is based on your November 1, 2004 engineering report, prior submittals, and assessments by the Technical Review Committee and Ecology staff. We acknowledge the professional effort exhibited by your staff during the past several years in demonstrating the scale-up viability of this technology.

We plan to publish the GULD document on the web along with appropriate links to pertinent information on the StormFilter. In the near future, we also plan to add appropriate design and related information on the StormFilter in its Stormwater Management Manuals.

If you need additional information, please do not hesitate to call me at (360) 407-6405.

Sincerely,

David C. Peeler
Water Quality Program Manager

DP:DW:mw

cc: Dewey Weaver, Supervisor, WQ Program
Mark Blosser, PE, Chair-Technical Review Committee
Dave Pollock, CEO, SMI, Portland, OR

January 2005
GENERAL USE LEVEL DESIGNATION
FOR BASIC (TSS) TREATMENT
Stormwater Management, Inc.'s StormFilter
Using Zeolite-Perlite-Granular
Activated Carbon Media
And Operating at 7.5 GPM per Cartridge

Ecology Decision: Based on SMI's application submissions and recommendations by the Technical Review Committee (TRC), Ecology hereby issues a General Use Level Designation (GULD) for the SMI StormFilter:

- **As a basic stormwater treatment practice for total suspended solids (TSS) removal,**
- **Using ZPG™ media (zeolite/perlite/granular activated carbon), with the size distribution described below,**
- **Sized at a design rate of 7.5 GPM per cartridge (except as stated in Condition #1, below), and**
- **Internal bypassing needs to be consistent with the design guidelines in SMI's current design manual.**

This designation has no expiration date, but it may be amended or revoked by Ecology, and is subject to the conditions specified below.

Applicant: Stormwater Management, Inc., (SMI), Manufacturer and Vendor
James H. Lenhart, PE, Senior Vice President and Responsible Corporate Officer
(800) 548-4667

Address of Applicant: 12021-B NE Airport Way, Portland, OR 97220

Application Documents:

The applicant's master report, titled, "The Stormwater Management StormFilter Basic Treatment Application for General Use Level Designation in Washington", Stormwater Management, Inc., November 1, 2004, includes the following reports:

- (Public) "Evaluation of the Stormwater Management StormFilter Treatment System: Data Validation Report and Summary of the Technical Evaluation Engineering Report (TEER) by Stormwater Management Inc., October 29, 2004" Ecology's technology assessment protocol requires the applicant to hire an independent consultant to complete the following work:

  1. Complete the data validation report.
  2. Prepare a TEER summary, including a testing summary and conclusions compared with the supplier's performance claims.
  3. Provide a recommendation of the appropriate technology use level.
  4. Recommend relevant information to be posted on Ecology's website.

SARB_012897

5. Provide additional testing recommendations, if needed."

This report, authored by Dr. Gary Minton, Ph. D., P.E., Resource Planning Associates, satisfies the Ecology requirement.

- (Public) "Performance of the Stormwater Management StormFilter Relative to the Washington State Department of Ecology Performance Goals for Basic Treatment," is a summary of StormFilter performance that strictly adheres to the criteria listed in the Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE).
- "Heritage Marketplace Field Evaluation: Stormwater Management StormFilter with ZPG Media," is a report showing all of the information collected at Site A as stated in the SMI Quality Assurance Project Plan (QAPP). This document contains detailed information regarding each storm event collected at this site, and it provided a detailed overview of the data and project.
- "Lake Stevens Field Evaluation: Stormwater Management StormFilter with ZPG Media," is a report that corresponds to Site E as stated in the SMI QAPP. This document contains detailed information regarding each storm collected at this site, and includes a detailed overview of the data and project.
- (Public) "Evaluation of the Stormwater Management StormFilter for the removal of SIL-CO-SIL 106, a standardized silica product: ZPG at 7.5 GPM" is a report that describes laboratory testing at full design flow.
- "Factors Other Than Treatment Performance."
- "State of Washington Installations."

Above-listed documents noted as "public" are available by contacting SMI.

Applicant's Use Level Request: That Ecology grant a General Use Level Designation for Basic Treatment for the StormFilter using ZPG™ media (zeolite/perlite/granular activated carbon) at 7.5 GPM in accordance with Ecology's 2001 Stormwater Manual (SMI's September 28, 2004 letter).

Applicant's Performance Claim: The combined data from the two field sites reported in this TEER (Heritage Marketplace and Lake Stevens) indicate that the performance of a StormFilter system configured for inline bypass with ZPG media and a 28 liters per minute per cartridge (7.5 GPM) filtration rate meets Ecology performance goals for Basic Treatment.

Technical Review Committee Recommendations: The TRC, based on the weight of the evidence and using its best professional judgment, finds that

- StormFilter, using ZPG media and operating at no more than 7.5 GPM per cartridge, is expected to provide effective stormwater treatment achieving Ecology's Basic Treatment TSS removal performance goals, as demonstrated by field and laboratory testing performed in accordance with the protocol; and,
- StormFilter® is deemed satisfactory with respect to factors other than treatment performance (e.g., maintenance; see the protocol's Appendix B for complete list).

Findings of Fact:

- Influent TSS concentrations and particle size distributions were generally within the range of what would be considered "typical" for western Washington (silt to silt loam).
- Thirty-two (32) storm events were sampled at two sites for storms from April 2003 to March 2004, of which twenty-two (22) were deemed "qualified" and were therefore included in the data analysis set.
- Statistical analysis of these 22 storm events verifies the data set's adequacy.
- Analyzing all 22 qualifying events, the average influent and effluent concentrations and aggregate pollutant load reduction are 114 mg/L, 25 mg/L, and 82%, respectively.
- Analyzing all 22 qualifying events based on the *estimated average* flow rate during the event (versus the *measured peak* flow rate), and more heavily weighting those events near the design rate (versus events either far above or well below the design rate) does not significantly affect the reported results.
- For the 7 qualifying events with influent TSS concentrations greater than 100 mg/L, the average influent and effluent concentrations and aggregate pollutant load reduction are 241 mg/L, 34 mg/L, and 89%, respectively. If the 2 of 7 events that exceed the maximum 300 mg/L specified in Ecology's guidelines are excluded, the average influent and effluent concentrations and aggregate pollutant load reduction are 158 mg/L, 35 mg/L, and 78%, respectively.
- For the 15 qualifying events with influent TSS concentrations less than 100 mg/L, the average influent and effluent concentrations and aggregate pollutant load reduction are 55 mg/L, 20 mg/L, and 61%, respectively. If the 6 of 15 events that fall below the minimum 33 mg/L TSS specified in Ecology's guidelines are excluded, the average influent and effluent concentrations and aggregate pollutant load reduction are 78 mg/L, 26 mg/L, and 67%, respectively.
- For the 8 qualifying events with peak discharge exceeding design flow (ranging from 120 to 257% of the design rate), results ranged from 52% to 96% TSS removal, with an average of 72%.
- Due to the characteristics of the hydrographs, generally the field results reflect flows below (ranging between 20 and 60 percent of) the tested facilities' design rate. During these sub-design flow rate periods, some of the cartridges operate at or near their *individual* full design flow rate (generally between 4 and 7.5 GPM) because their float valves have opened. Float valves remain closed on the remaining cartridges, which operate at their base "trickle" rate of 1 to 1.5 GPM.
- Laboratory testing using U.S. Silica's Sil-Co-Sil 106 fine silica product showed an average 87% TSS removal for testing at 7.5 GPM per cartridge (100% design flow rate).
- Other relevant testing at I-5 Lake Union, Greenville Yards (New Jersey), and Ski Run Marina (Lake Tahoe) facilities shows consistent TSS removals in the 75 to 85% range. *Note that I-5 Lake Union was operated at 50%, 100%, and 125% of design flow*.
- SMI's application included a satisfactory "Factors other than treatment performance" discussion.

Note: Ecology's 80% TSS removal goal applies to 100 mg/l and greater influent TSS. Below 100 mg/L influent TSS, the goal is 20 mg/L effluent TSS.

Use Conditions. StormFilters shall be designed, installed, and maintained to comply with these conditions:

1. StormFilter systems containing ZPG (zeolite/perlite/granular activated carbon) mix are approved for basic treatment at 7.5 GPM maximum flow rate per cartridge at the 15-minute water quality design flow rate (as specified in Ecology's 2001 Stormwater Manual), as calculated using an acceptable continuous simulation runoff model (such as the latest versions of the Western Washington Hydrology Model or MGSFlood). Note that if the method outlined in Ecology's 1992 Stormwater Manual (single-event runoff model, such as Santa Barbara Unit Hydrograph, and 6-month storm peak flow) is used, this approval applies at 15 GPM per cartridge. This approval applies to urban land uses where stormwater influent TSS concentrations are expected to be 500 mg/L or less and TSS particles are not unusually fine (in the clay size range).

2. For StormFilter systems to be located downstream of a stormwater detention facility, the StormFilter size shall be calculated using both the flow-based and mass-based methods as described in the *Product Design Manual Version 3.1 (February 2004)*, or most *c*urrent version, and the designer shall select the result yielding the larger number of cartridges.

3. StormFilter systems shall be installed in such a manner that flows exceeding 7.5 GPM per cartridge are bypassed or will not resuspend captured sediments. StormFilter systems shall be designed in accordance with the performance goals in Ecology's 2001 Stormwater Manual and SMI's *Product Design Manual Version 3.1 (February 2004)*, or most *c*urrent version, unless otherwise specified. The design, pretreatment, land use application, and maintenance criteria in SMI's Design Manual must be closely followed.

4. Pretreatment of TSS and oil and grease may be necessary, and shall be provided in accordance with the most-current versions of the SMI's *Product Design Manual* or the applicable Ecology Stormwater Manual, and using the performance criteria and pretreatment practices provided on Ecology's "Evaluation of Emerging Stormwater Treatment Technologies" website.

5. StormFilter systems are typically designed to be maintained on an annual basis, which shall serve as the default maintenance frequency. Maintenance includes removing accumulated sediment from the vault, and replacing spent cartridges with recharged cartridges.

   In lieu of annual maintenance, inspections can be used to determine a site-specific maintenance schedule and/or requirements. When inspections are performed, the following findings shall serve as maintenance triggers:

   (a) Accumulated vault sediment depths exceed an average of 2 inches, or
   (b) Accumulated sediment depths on the tops of the cartridges exceed an average of 0.5 inches, or
   (c) Standing water remains in the vault between rain events.

   Note: If excessive floatables (trash and debris) are present, perform a minor maintenance consisting of gross solids removal, not cartridge replacement.

6. SMI shall maintain readily available those reports listed under “Application Documents” (above) as public, as well as the documentation submitted with its previous conditional use designation application. SMI shall provide links to this information from its corporate website, and make this information available upon request, at no cost and in a timely manner.

7. ZPG™ media used shall conform with the following specifications:

   Each cartridge contains a total of approximately 2.6 cubic feet of media. The ZPG™ cartridge consists of an outer layer of perlite that is approximately 1.3 cubic feet in volume and an inner layer, consisting of a mixture of 90% zeolite and 10% granular activated carbon, which is approximately 1.3 cubic feet in volume.

   Perlite Media: Perlite media shall be made of natural siliceous volcanic rock free of any debris or foreign matter. The expanded perlite shall have a bulk density ranging from 6.5 to 8.5 lbs per cubic foot and particle sizes ranging from 0.09” (#8 mesh) to 0.38” (3/8” mesh).

   Zeolite Media: Zeolite media shall be made of naturally occurring clinoptilolite. The zeolite media shall have a bulk density ranging from 44 to 50 lbs per cubic foot and particle sizes ranging from 0.13” (#6 mesh) to 0.19” (#4 mesh). Additionally, the cation exchange capacity (CEC) of zeolite shall range from approximately 1.0 to 2.2 meq/g.

   Granular Activated Carbon: Granular activated carbon (GAC) shall be made of lignite coal that has been steam-activated. The GAC media shall have a bulk density ranging from 28 to 31 lbs per cubic foot and particle sizes ranging from a 0.09” (#8 mesh) to 0.19” (#4 mesh).

Technology Description:

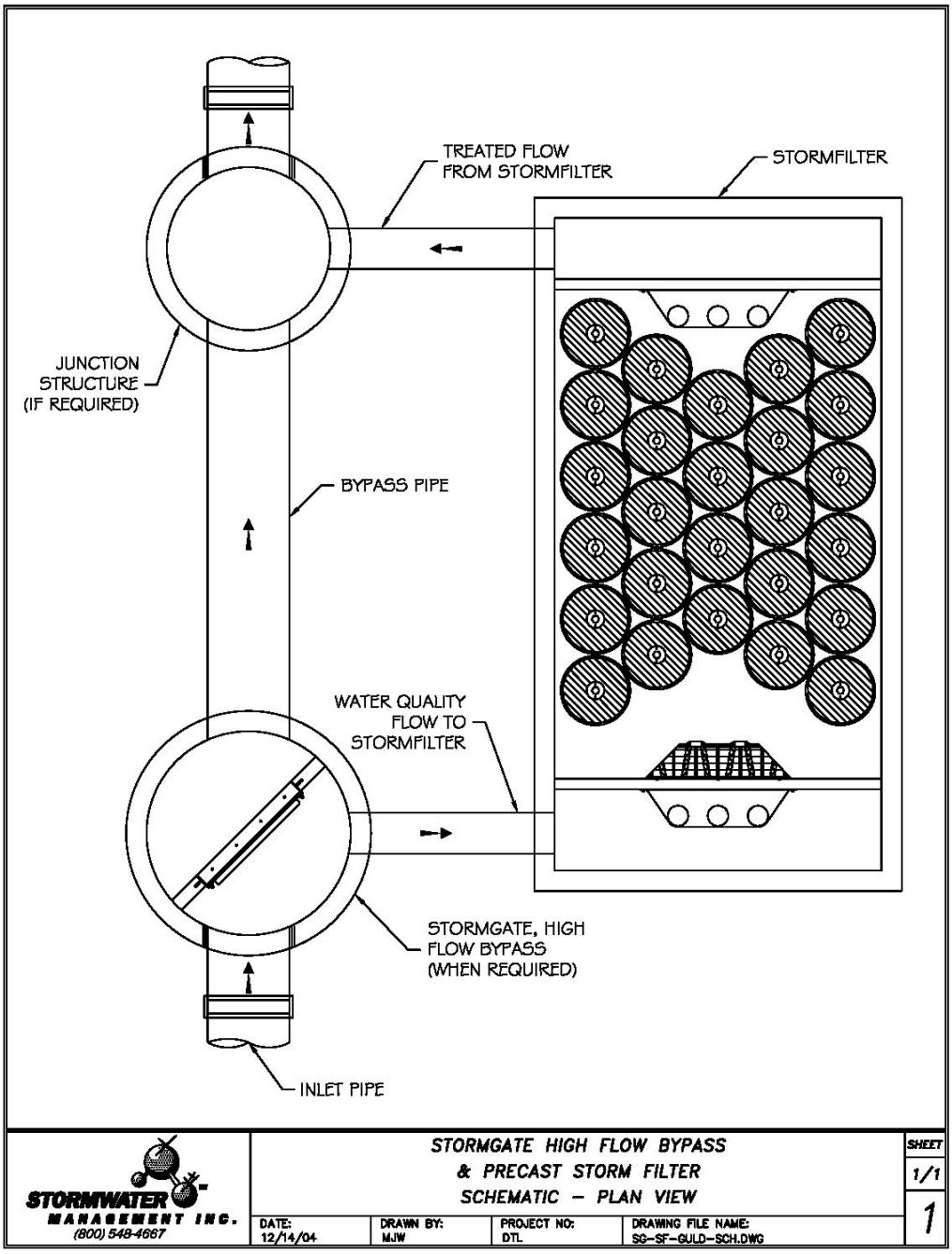
The Stormwater Management StormFilter® (StormFilter), a flow-through stormwater filtration system, improves the quality of stormwater runoff from the urban environment by removing pollutants. The StormFilter is used to treat runoff from a wide variety of sites including, but not limited to: retail and commercial development, residential streets, urban roadways, freeways, and industrial sites such as shipyards, foundries, etc.

Operation:

The StormFilter is typically comprised of a vault that houses rechargeable, media-filled, filter cartridges. Various media may be used, but this designation covers only the zeolite-perlite-granulated activated carbon (ZPG™) medium. Stormwater from storm drains is percolated through these media-filled cartridges, which trap particulates and may remove pollutants such as dissolved metals, nutrients, and hydrocarbons. During the filtering process, the StormFilter system also removes surface scum and floating oil and grease. Once filtered through the media, the treated stormwater is directed to a collection pipe or discharged to an open channel drainage way.

A bypass schematic for flow rates exceeding the water quality design flow rate is shown below.

Figure 1. SMI StormFilter Configuration with Bypass



StormFilter Configurations:

The StormFilter is offered in five basic configurations: precast, linear, catch basin, cast-in-place, and corrugated metal pipe form. The precast, linear, and catch basin models

use premanufactured units to ease the design and installation process; cast-in-place units are customized for larger flows and may be either uncovered or covered underground units. The corrugated metal pipe units can be customized to meet special site requirements.

The typical precast StormFilter unit is composed of three bays: the inlet bay, the filtration bay, and the outlet bay. Stormwater first enters the inlet bay of the StormFilter vault through the inlet pipe. Stormwater in the inlet bay is then directed through the flow spreader, which traps some floatables, oils, and surface scum, and over the energy dissipater into the filtration bay where treatment will take place. Once in the filtration bay, the stormwater begins to pond and percolate horizontally through the media contained in the StormFilter cartridges. After passing through the media, the treated water in each cartridge collects in the cartridge's center tube from where it is directed into the outlet bay by an underdrain manifold. The treated water in the outlet bay is then discharged through the single outlet pipe to a collection pipe or to an open channel drainage way. In some applications where heavy grit loads are anticipated, pretreatment by settling may be necessary.

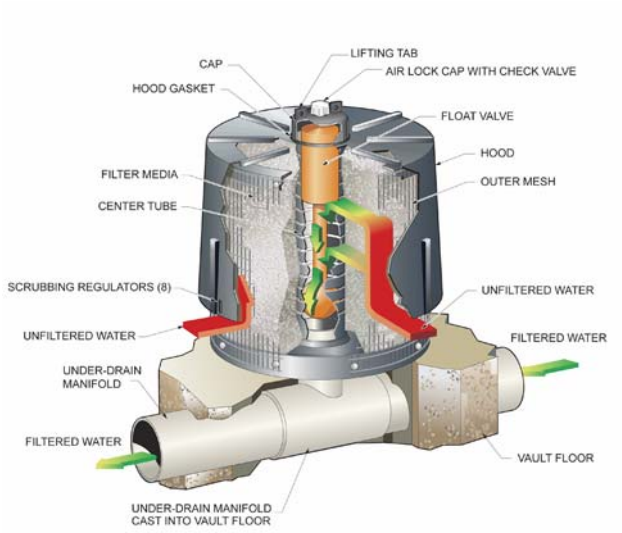


Figure 2. The StormFilter Cartridge

Cartridge Operation:

As the water level in the filtration bay begins to rise, stormwater enters the StormFilter cartridge. Stormwater in the cartridge percolates horizontally through the filter media and passes into the cartridge's center tube, where the float in the cartridge is in a closed (downward) position. As the water level in the filtration bay continues to rise, more water passes through the filter media and into the cartridge's center tube. The air in the cartridge is displaced by the water and purged from beneath the filter hood through the one-way check valve located in the cap. Once the center tube is filled with water (approximately 18 inches deep), there is enough buoyant force on the float to open the float valve and allow the treated water to flow into the underdrain manifold. As the treated water drains, it tries to pull in air behind it. This causes the check valve to close, initiating a siphon that draws polluted water throughout the full surface area and volume of the filter. Thus, the entire filter cartridge is used to filter water throughout the duration

of the storm, regardless of the water surface elevation in the filtration bay. This continues until the water surface elevation drops to the elevation of the scrubbing regulators. At this point, the siphon begins to break and air is quickly drawn beneath the hood through the scrubbing regulators, causing energetic bubbling between the inner surface of the hood and the outer surface of the filter. This bubbling agitates and cleans the surface of the filter, releasing accumulated sediments on the surface, flushing them from beneath the hood, and allowing them to settle to the vault floor.

Adjustable cartridge flow rate:

Inherent to the design of the StormFilter is the ability to control the individual cartridge flow rate with an orifice-control disk placed at the base of the cartridge. Depending on the treatment requirements and on the pollutant characteristics of the influent stream as specified in the SMI *Product Design Manual*, the flow rate may be adjusted through the filter cartridges. By decreasing the flow rate through the filter cartridges, the influent contact time with the media is increased and the water velocity through the system is decreased, thus increasing both the level of treatment and the solids removal efficiencies of the filters, respectively (de Ridder, 2002).

Recommended research and development:

Ecology encourages SMI to pursue continuous improvements to the StormFilter. To that end, the following actions are recommended:

- Determine, through laboratory testing, the relationship between accumulated solids and flow rate through the cartridge containing the ZPG™ media.
- Determine the system's capabilities to meet Ecology's enhanced, phosphorus, and oil treatment goals.
- Develop easy-to-implement methods of determining that a StormFilter facility requires maintenance (cleaning and filter replacement).

For Additional Information:

Applicant e-mail address: Contact Sean Darcy, seand@stormwaterinc.com
(800) 548-4667 or info@stormwaterinc.com

Applicant Web link: www.stormwaterinc.com

Ecology web link: http://www.ecy.wa.gov/programs/wq/stormwater/new_tech/

Ecology Contact: Stan Ciuba, P.E., Water Quality Program
sciu461@ecy.wa.gov
(360) 407-6435

Technical Review Committee: Mark Blosser, P.E., City of Olympia,
TRC Chairperson,
mblosser@ci.olympia.wa.us
(360) 753-8320

Richard J. Codey
Acting Governor

State of New Jersey
Department of Environmental Protection
Division of Science, Research and Technology
Bureau of Sustainable Communities and Innovative Technologies
PO Box 409
Trenton, NJ 08625-0409
Tel: 609-292-9692
FAX: 609-292-7340

Bradley M. Campbell
Commissioner

December 22, 2004

James H. Lenhart, P.E.
Senior Vice President
Stormwater Management, Inc. (SMI)
12021-B NE Airport Way
Portland, OR 97220

Re: Extension Approval to Conditional Interim Certification for the Stormwater Management StormFilter®.

Dear Mr. Lenhart:

The New Jersey Department of Environmental Protection (NJDEP) received your correspondence requesting an extension to the conditional interim certification of the Stormwater Management StormFilter® (StormFilter). The expiration date for the current interim certification is December 31, 2004. This interim conditional certification was given in accordance with the Energy and Environmental Technology Verification (EETV) Act at N.J.S.A. 13:1D-134 et seq. After careful consideration, the NJDEP approves the request to extend the conditional interim certification, which will now expire on December 30, 2006.

The conditional interim approval was based on the New Jersey Corporation for Advanced Technology (NJCAT) verification report. According to the report, the StormFilter System, with influent concentrations of 300 mg/l or less and where Total Suspended Solids (TSS) particle sizes are expected to be similar to those tested, should be able to meet the basic treatment goal of 80% removal of TSS. Based on the NJCAT verification report and the recent information submitted by Stormwater Management regarding the analyses from the treatment of four storm events at Greenville Yards, the NJDEP has decided on the following:

1) The StormFilter can be used as a stand alone unit for the period of time that the interim certification remains in effect.
2) This conditional interim certification is for the current design of the StormFilter, and any modification will require a new review before use.

3) All maintenance requirements must be implemented, and any training must be provided for personnel assigned to perform the maintenance, to ensure that the technology functions in accordance with the conditions of this conditional interim certification.
4) The StormFilter shall be designed in accordance with New Jersey's water quality standards and SMI's *Product Design Manual Version 3.0 (April 2002)*, or current edition, unless otherwise specified. The design, pretreatment, land use application, and maintenance criteria in SMI's Design Manual must be closely followed.

As part of the interim conditional approval, the StormFilter is currently being field tested, and the results will be analyzed and submitted for consideration in order to receive a final certification from the NJDEP. This phase of testing must satisfy the requirements of the Technology Acceptance and Reciprocity Partnership (TARP) Stormwater Best Management Practice Demonstration Tier II Protocol. For any questions regarding this correspondence, please contact Ravi Patraju of my staff at (609) 292-0125.

Marty Rosen,

Chief, Bureau of Sustainable Communities
and Innovative Technologies

Enclosure

c: Ernest Hahn, Assistant Commissioner, Land Use Management
Sam Wolfe, Assistant Commissioner, Environmental Regulation
Jeanne Herb, Director, Policy, Planning, and Science
Larry Baier, Director, Watershed Management Program
Narinder Ahuja, Director, Division of Water Quality
Mark Mauriello, Director, Land Use Regulations
Eileen Murphy, Director, Division of Science, Research, and Technology
Rhea Brekke, Executive Director, New Jersey Corporation for Advanced Technology

NJ Verified
Corporation for Advanced Technology

Technology Verification Fact Sheet
Stormwater Management, Inc.

June 19, 2002

Performance Claims

The technical performance claims made by Stormwater Management, Inc. are:

Claim 1 – **The StormFilter cartridge at 15 gallons per minute (gpm) using a coarse perlite media has been shown to have a TSS removal efficiency of 79% with 95% confidence limits of 78% and 80% respectively for a sandy loam comprised of 55% sand, 40% silt, 5% clay (USDA) in laboratory studies using simulated storm water.**

Claim 2 – **The StormFilter cartridge at 7.5 gallons per minute (gpm) using a fine and coarse perlite media has been shown to have a TSS removal efficiency of 71% with 95% confidence limits of 68% and 75% respectively for a silt loam comprised of 15% sand, 65% silt, 20% clay (USDA) in laboratory studies using simulated storm water.**

Claim 3 – **The StormFilter cartridge at 15 gpm using CSF® leaf media has a TSS removal efficiency of 73% with 95% confidence limits of 68% and 79%, respectively when evaluating field and laboratory data.**

Technology Description

Stormwater Management Inc., Portland, Oregon, has developed an innovative storm water treatment system - called StormFilter, to meet the requirements of the National Pollutant Discharge Elimination System (NPDES). To receive a NPDES permit, a municipality or specific industry has to develop a storm water management plan and identify Best Management Practices for storm water treatment and discharge. Best Management Practices are measures, systems, processes or controls that reduce pollutants at the source to prevent the pollution of storm water runoff discharge from the site. The StormFilter is a passive, flow through, storm water filtration system, improving the quality of storm water runoff by removing non point source pollutants, including total suspended solids (TSS), oil and grease, soluble metals, nutrients, organics, and trash and debris. It has been installed to treat storm water runoff from a wide variety of sites including retail and commercial developments, residential streets, urban roadways, freeways and industrial sites such as shipyards, foundries, etc.

The StormFilter is typically comprised of a vault that houses rechargeable, media-filled filter cartridges. Storm water from storm drains is percolated through media-filled cartridges, which removes particulates and adsorbs materials such as dissolved metals

and hydrocarbons. Surface scum, floating oil and grease are also removed. After passing through the filter media, the storm water flows into a collection pipe or discharges to an open channel drainage way. Inherent in the design of the StormFilter is the ability to control the individual cartridge flow rate with an orifice disk placed at the base of the cartridge. The maximum flow rate through each cartridge can be adjusted to between 5 and 15 gpm.

The StormFilter is sized to treat the peak flow of a design storm as it passes through the system. The peak flow is determined by calculations based on the contributing watershed hydrology and using a design storm magnitude. The design storm is usually based on the requirements set by the local regulatory agency. The particular size of a StormFilter is determined by the number of filter cartridges required to treat the peak water flow.

Technology Application

The StormFilter utilizes a variety of media to target and remove pollutants from storm water runoff. It is designed to offer a versatile approach to removing site-specific pollutants. By selecting a specific filter media, desired levels of sediments, soluble phosphorus, nitrates, soluble metals, and oil and grease can be removed. In many cases, a combination of media is used to effectively remove storm water pollutants.

Verification

Based on the evaluation of the results from laboratory studies and field data, it appears that sufficient data is available to support Stormwater Management Claims 1, 2, and 3.

Limitations

StormFilter is best utilized for the removal of suspended solids in storm water. The StormFilter uses filter cartridges housed in concrete vaults to produce a self-contained storm water filtering system. The design life of the structure is typically 50 years. Cartridge life is guaranteed as long as the maintenance contract is upheld. Typical life of a cartridge has been budgeted at 20 years. Each cartridge is designed to treat a peak flow of 5 to15 gpm. Since storm water flows by gravity, the StormFilter typically requires 2.3 feet of head differential between the invert of the inlet and the invert of the outlet.

Water tightness of the concrete vault should be considered in the design. Most external joints are not subject to water from the inside or high groundwater from the outside. Internal joints should be sealed with grout and inspected during maintenance.

Backwater can be a problem if downstream hydraulic calculations are not performed properly. Backwater will reduce the hydraulic potential across the filter reducing flow rate through the cartridge. Backwater may also saturate media for long periods of time.

Baseflows should be bypassed to ensure proper functioning of the cartridges and the filtration media. If baseflows occur, the filtration media may become exhausted prematurely. This will affect the life of the cartridges and maintenance may be required more often. Low flow bypasses can be installed retroactively.

Excessive solids loading, hydrocarbon loading, and/or debris should be addressed during the design phase to assess if pretreatment is needed. Heavy solids loading without pretreatment can cause clogging of the cartridges. Maintenance frequency increases if this occurs.

The StormFilter design incorporates some ponding of water which can be a breeding site for mosquitoes. Also, if the cartridges plug due to inadequate maintenance, additional standing water will result.

Inspections should be performed during mid-season to determine sediment loading on the system. This involves mobilization to the site, documentation of media and vault conditions and measurements of accumulated sediments. Other inspections are performed during the year if a field crew is in the area of the filter and as time permits.

Net Environmental Benefit

The New Jersey Department of Environmental Protection (NJDEP or Department) encourages the development of innovative environmental technologies (IET) and has established a performance partnership between their verification/certification process and NJCAT's third party independent technology verification program. The Department in the IET data and technology verification/certification process will work with any New Jersey-based company that can demonstrate a net beneficial effect (NBE) irrespective of the operational status, class or stage of an IET. The NBE is calculated as a mass balance of the IET in terms of its inputs of raw materials, water and energy use and its outputs of air emissions, wastewater discharges, and solid waste residues. Overall the IET should demonstrate a significant reduction of the impacts to the environment when compared to baseline conditions for the same or equivalent inputs and outputs.

Once StormFilter has been recommended and verified for interim use within the State of New Jersey, Stormwater Management will then proceed to install and monitor systems in the field for the purpose of achieving goals set by the Tier II Protocol and final certification. At that time a net environmental benefit evaluation will be completed. However, it should be noted that the StormFilter technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

Disclaimer

The New Jersey Department of Environmental Protection reserves the right to revise or terminate it's certification of the NJCAT verification at any time as a response to any complaints, violations of this verification's conditions, modifications of the Department's use criteria, any person's failure to comply with any conditions or requirement related to the use of the product, or other reasons.

This verification does not constitute an endorsement by the State of New Jersey or the New Jersey Department of Environmental Protection and may not be used for that purpose. This verification is granted only to the activity as specified and as conditioned herein. The procedures as outlined are verified without deviation from the information provided to the Department on which this verification is based.

New Jersey Corporation for Advanced Technology (NJCAT) Program

NJCAT is a not-for-profit corporation intended to promote the retention and growth of technology-based businesses in the emerging fields of energy and environmental technologies. NJCAT provides innovators with the regulatory, commercial and technical assistance required to bring promising new ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization
- Identify, evaluate and recommend specific technologies for which the regulatory and commercialization process should be facilitated
- Facilitate funding and commercial relationships/alliances to bring technologies to market and new business to the state, and
- Assist in the identification of markets and applications for commercialized technologies.

The Technology Verification Program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals form to implement a comprehensive evaluation of vendor specific performance claims. The result of successfully completing this program is documentation of independent third party confirmation of claims that provides valuable information to business and governmental decision-makers.

CITY of CYPRESS

5275 Orange Avenue, Cypress, California 90630
Phone 714-229-6700 www.ci.cypress.ca.us

May 8, 2009

Mr. Gerard J. Thibeault
Executive Director
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comments from the City Relative to the Tentative Order No. R8-2008-0030 (Draft 4th Term NPDES/Stormwater Permit)

Dear Mr. Thibeault:

We wish to comment on the recent draft of the NPDES permit that was discussed at the public workshop held on April 24, 2009. The City of Cypress is concerned with the last minute submittal by the United States Environmental Protection Agency and their recommended language modifications to Section XII.C of the draft permit. We are particularly concerned with the impact of the revised language on new development and redevelopment projects.

As you are aware, the language contained in the permit prior to the public workshop was a result of the ongoing discussions between the Regional Board staff and the Orange County Stakeholder group. The City has been in support of the actions taken by the group and even participated in the discussions. It is disturbing for the co-permittees to have assumed that the permit language would remain as was presented in the third draft, only to have the Regional Board provide for the last minute modifications without consulting with the other parties involved. This action contradicts the cooperative approach that was demonstrated during the drafting of the new permit. Additionally, there are other items in the permit that may have been conceded in exchange for the language developed. This does not lead to a cooperative development of the permit.

The City believes that consideration should be given to leaving the language contained in this section of the permit in the format as originally presented in the third draft. If it is the assumption that a development that cannot infiltrate 85 percent of a storm event under a LID program be subject to other non-LID requirements, we strongly disagree with the concept. The imposition of the other requirements could have serious economic impacts on cities and could potentially halt or significantly slow down development. It is understood that the application of the low impact development principles to construction projects can vary based on many pre-existing factors. This is one of the primary reasons why an evaluation period was included to measure what would work best in the northern Orange County region.

Doug Bailey, Mayor
Prakash Narain, M.D., Mayor Pro Tem **Phil Luebben**, Council Member
Leroy Mills, Council Member **Todd W. Seymore**, Council Member

As the Regional Board prepares to adopt the permit at the May 22, 2009, public hearing in Loma Linda, the City asks that the Regional Board staff should consider adopting the permit, as was originally agreed upon by the Orange County Stakeholder group.

We also ask for consideration of subsequent comments made by the County of Orange, as the Principal Permittee, on behalf of the cities, and concur with their findings and recommendations. Thank you for your consideration. If you have any questions, please do not hesitate to contact me direct at (714) 229-6740.

Sincerely,

Douglas A. Dancs, P.E.
Director of Public Works/City Engineer

cc: City Manager
Mark Smythe, Senior Environmental Scientist, SARWQCB

CITY OF ORANGE

PUBLIC WORKS DEPARTMENT

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May 8, 2009

Gerard J. Thibeault
Executive Officer
California Regional Water Quality Control Board Santa Ana Region
3737 Main St. Suite 500
Riverside, CA 92501- 3348

Subject: Fourth Draft Permit Version Dated May 1, 2009 for the Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and Incorporated Cities of Orange County, Tentative Draft Order R8–2008-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff

Dear Mr. Thibeault:

The City of Orange would like to take the opportunity to comment on the revised fourth draft permit's language to Section XII.C.1 and C.2. The City has great concerns with the proposed changes and concurs with the County of Orange's analysis and recommendations. As with other municipalities, we were greatly disappointed at the April 24th meeting to find that changes to the implementation language in the LID section were added at the last minute to satisfy EPA. The proposed changes have the potential to significantly alter the process and timing of how LID is incorporated in Priority projects.

First it should be noted that the proposed change to capture and infiltrate the 85th percentile storm event utilizing LID principles is a significant departure from the current permit. In implementing these changes, the Permittees will require time to transition and develop the new criteria and to educate municipal staff on how to implement LID to meet the new standards. The draft permit recognizes these needs and allows 12 months to update the Model WQMP and 12 months to develop feasibility criteria to be used in assessing the applicability of LID in projects.

Paragraph C.1

The concern with the proposed change in Section XII.C.1 is that deletion of the phrase "that meet the feasibility criteria established pursuant to Section XII.E1" can be interpreted to require the Permittees to begin immediate implementation of LID following permit adoption. Maintaining the language of the third draft permit makes it clear and unambiguous that Priority projects implement low impact development principles if it is feasible based on criteria established in Section XII.E. However, Section XII.E.1 allows

12 months for development of the feasibility criteria. Clearly, making a determination now that LID is not feasible that is inconsistent with future feasibility criteria is problematic. For this reason the timing and implementation of LID is very important.

The permit also recognizes that there are a number of constraints to implementing LID such as limited space, soil imperviousness, site stability (slopes), Brownfields and other factors that do not allow for the implementation of LID. All of these factors need to be considered in determining whether LID is feasible. Without the feasibility criteria, implementation of LID by the Permittees would not be practical.

Section XII.C.1 is also explicit in allowing the Permittees 12 months to update the Model WQMP to incorporate LID principles. How LID is to be considered and incorporated into Priority projects will be the basis of the Model WQMP update, which will also consider the feasibility criteria developed in Section XII.E.1. This effort will not be completed until 12 months after permit adoption. In the interim, Permittees will continue to implement the BMPs as required by the current permit as noted in the discussion on April 24th.

Recommendation: Maintain the existing language in Section XII.C.1 of the third draft permit or alternatively adopt the County of Orange recommended language.

Paragraph C.2

With regard to inserting "Projects that do not comply with this requirement shall meet the requirements established in section XII.E.1 for alternative or in-lieu compliance" to Section XII.C.2 as proposed by EPA, there is a concern that this language will require projects that cannot infiltrate, harvest, reuse or evapotranspire or capture the 85th percentile storm event to meet alternative or in-lieu criteria such as contributing to a fund or other acceptable program. This is a significant change from the language of the third draft permit which allowed captured runoff to be treated with conventional treatment controls as allowed by the DAMP.

The proposed change to the paragraph can be interpreted to read that projects that cannot fully infiltrate, harvest, reuse or evapotranspire or capture will need to meet in-lieu programs and still require treatment by conventional BMPs. If that is the case, many if not all of the projects in the City of Orange will be required to contribute to some sort of fund or will require waivers because most projects in the City are redevelopment type and full implementation of LID is not possible due to limited space. We do not believe this is the intent of the paragraph but the language can be interpreted in this manner. To avoid confusion it is suggested that EPA's language be deleted.

Recommendation: Delete the second sentence in Section XII.C.2 "Projects that do not comply with this requirement shall meet the requirements established in section XII.E

for alternative and in-lieu compliance." Alternatively, adopt the County of Orange recommended language.

LID Systems

There is also concern that allowing only BMPs that capture the 85th percentile storm event will not allow the use of systems such as grass swales or vegetated strips that are considered LID but are not typically designed as full capture systems. Their function is simply to filter the runoff based on flow rate not volume. If these types of systems are used at all, under the new criteria they will become infiltration trenches because runoff from the design storm event will not be allowed. This is contrary to the use of these systems in storm water BMP design.

Section III

Another item that needs to be clarified is the latest revision included in Section III.3.ii where the listed nonstorm water discharges are acceptable only if they are from permittee owned or operated activities. Item 3.ii.d regarding swimming pool discharges is of particular concern because while they may be allowed from municipal facilities, they will not be allowed in the larger residential applications.

Dechlorinated swimming pool discharges have been allowed in all previous municipal storm water permits in accordance with federal regulations. However, the discharges are not listed in 3.i and as written will potentially ban their discharge within a permittees jurisdiction. Please clarify if this is the intent and how this conclusion was reached. The third draft permit simply specified certain requirements and did not restrict their discharge to municipal activities.

Sincerely,

Joe DeFrancesco
Interim Public Works Director

cc: John Sibley, City Manager
Alice Angus, Director, Community Development
Chris Crompton, Manager, Environmental Resources County of Orange

May 8, 2009

Via electronic mail

Ms. Carole H. Beswick and Members of the Board
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Re: Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2009-0030

Dear Chair Beswick and Members of the Board:

We write on behalf of the Natural Resources Defense Council ("NRDC") and Orange County Coastkeeper ("Coastkeeper"). We have reviewed the May 1, 2009 draft of Tentative Order No. R8-2009-0030, NPDES Permit No. CAS618030. There has been an important development in MS4 permitting in California since your Board last met, as discussed below, and this development requires further edits to the language contained in Sections XII.C.1 and 2. We appreciate the opportunity to submit the following comments on Sections XII.C.1. and 2., as permitted by the May 1, 2009 transmittal letter from Division Chief Adackapara.

General Comment

As an initial matter, we wish to correct the impression that the language presented to the Board in the third draft of the Tentative Order last month reflected stakeholder consensus, an opinion expressed by a number of board members during the last hearing. It is true that the stakeholders engaged in a good faith effort which in some respects productively narrowed differences. It is, however, equally true that key disagreements remain: notably, Coastkeeper and NRDC continue to believe that good policy and law require a standard that *retains* on-site the design storm whenever possible. This does *not* equate to a "no discharge" requirement, because the design storm is relatively small, and many precipitation events will exceed it. It does mean, however, that Orange County would get the benefit of a superior pollution discharge standard whenever that could be implemented—a critical step forward, particularly because the water retained would be infiltrated or otherwise reused. Such an approach mirrors similar ones now being implemented or considered in locations as diverse

as Washington D.C., Philadelphia, West Virginia—and, through new federal buildings requirements, everywhere in the United States.

Critically in this connection, on May 7, 2009, the Los Angeles Regional Water Quality Control Board adopted NPDES No. CAS00402, a new MS4 permit for the County of Ventura and the incorporated cities therein. The adopted Ventura County MS4 permit requires onsite infiltration, capture and reuse, or evapotranspiration of the 85th percentile design storm—with no runoff. This latest development confirms that onsite retention of storm water is coextensive with the MEP standard. The adopted language circulated by Los Angeles Regional Water Board staff and adopted by a 5-1 vote of the Board is attached for your review.

Infiltration or reuse not only implements the MEP requirement (and others) contained in the Clean Water Act, it is also inarguably wise policy in drought-stricken California. Governor Schwarzenegger recently declared a state of emergency in California due to severe drought. The major Southern California water supplier will cut water deliveries across the region this summer by ten percent, the first such cut since the drought of the early 1990s.[1] Notably, the Governor's Proclamation orders public water agencies to essentially "find" more water through a variety of activities, including "…efforts to protect water quality or water supply."[2] As such, a standard that requires retention of the design storm with no runoff when possible is directly responsive to the Governor.

Thus, the Board has a decision to make: should it require the maximum practicable approach to reducing pollution in a County with many impaired watersheds or something less? The Board should clearly understand as it deliberates that Sections XII.C.1. and 2. currently reflect a proposal to do something less.

Specific Comments

Alternative Compliance

The additional phrase in Section XII.C.2. requiring alternative compliance if the onsite management requirements of the paragraph are not met should be clarified as follows:

Permit:

[1] Bettina Boxall, *Southern California water agency to cut supplies by 10%*, L.A. Times, April 15, 2009, available at, http://www.latimes.com/news/local/la-me-mwd-water15-2009apr15,0,4326528.story.

[2] Office of the Governor of the State of California, Gov. Schwarzenegger Takes Action to Address California's Water Shortage, February 27, 2009, available at, http://gov.ca.gov/index.php?/print-version/press-release/11556/.

> "Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance."
>
> Permit with clarification (underlined):
>
> "Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance, <u>which shall assure at least equivalent environmental performance</u>"

We have previously submitted extensive support for requiring environmentally equivalent offsite mitigation when the LID standard cannot be met onsite. This is a feature of many draft and adopted permits. CICWQ and BIA agree with this concept, as indicated on page 11 of CICWQ's February 2009 letter to Mr. Adackapara, in which CICWQ states: "if a project proponent cannot feasibly treat the SUSMP water quality volume using the prioritized application of LID/SUSMP BMPs on-site, then off-site mitigation of the remaining treatment volume must occur."[3]

Remove References to Bio-Filtration

Sections XII.C.1. and 2., now modified with language proposed by U.S. EPA, are an improvement. However, staff modified that language to allow use of bio-filtration to meet the basic LID performance standard. We disagree. For all of the reasons previously discussed in our comment letters and expert reports, and for the reasons set forth in the technical supporting literature we have included in the record, NRDC and Coastkeeper strongly believe that the words "or bio-filter" should be deleted from the third line and "or bio-filtered" should be deleted from the eighth line of Section XII.C.2. The action of the Los Angeles Regional Water Board, discussed above, supports our request.

We appreciate the footnotes in this Section that attempt to circumscribe the use of bio-filtration and require "properly engineered and maintained" systems. However, as Coastkeeper Executive Director Garry Brown testified, experience shows that this is easier said than actually implemented. As such, the change to EPA's requested language to allow for bio-filtration serves as an "out" that will minimize environmental performance. In contrast to objectively clear requirements to "infiltrate, harvest and reuse, or evapotranspire, "bio-filter" is a subjective term open to interpretation—as is the requirement to "properly" engineer or maintain the systems.

Indeed, while we oppose the allowance for bio-filtration as part of the main LID standard, we believe that if this language remains over our objections, clarifying language in

[3] Correspondence from Dr. Mark Grey to Mr. Michael Adackapara, February 13, 2009, at 11.

footnotes 56 and 57 should close the loopholes we have identified.[4] There is consensus amongst the parties, including the BIA and CICWQ, that bio-filtration LID BMPs can be subject to abuse and therefore must be built and maintained to strong and clear requirements. For example, CICWQ states in its February 13, 2009 letter to this Board that "we recommend that hard feasibility criteria should be specified in the model WQMP/DAMP upon its renewal—such that developers should not be able to bypass implementation of appropriate LID BMPs."[5] These same parties emphasized their willingness to subject LID bio-filtration BMPs to clear design and maintenance requirements during last month's hearing.

Therefore, if the Board does not delete references to bio-filtration in Section XII.C.2., it should at minimum, make the following clarifications:

1. Footnotes 56 and 57 should state, in addition to stipulating that bio-filtration only be considered if infiltration, harvesting and reuse, and evapotranspiration are not feasible, as follows:

   "LID bio-filtration BMPs shall be designed to accommodate the design flow at a surface loading rate no greater than 5 inches per hour and shall have a total volume, including pore spaces and prefilter detention volume, no less than the runoff volume generated by the design storm depth times 0.75. Maximum ponding depth shall be 12 inches; minimum drainage time shall be 12 hours.

   "Runoff from impervious areas also may be dispersed to pervious landscaped areas in a ratio not to exceed 2 parts impervious area to one part pervious landscaped area. Pervious landscaped areas must be designed to pond and infiltrate runoff produced by the design storm depth. Maximum ponding depth shall be 2 inches and minimum topsoil-turf thickness 3 inches."

2. All other references to "treatment" which have not been corrected to refer to "bio-treatment" in Section XII should be modified. There are four such references in Section XII.C.7. to "treatment areas" and "or treat" in 7.a. through 7.d.

[4] We respectively reserve our rights to challenge this provision irrespective of any such clarifications.

[5] Correspondence from Dr. Mark Grey to Mr. Michael Adackapara, February 13, 2009, at 6.

Conclusion

We urge the Regional Board to improve the Tentative Order in the ways specified prior to its adoption. We appreciate staff's efforts to date during the adoption process and would be pleased to respond to any questions they may have about our comments.

Sincerely,





David S. Beckman
Bart Lounsbury
Noah Garrison
Natural Resources Defense Council

Garry Brown
Orange County Coastkeeper

~~project.~~ or their designee approves initiation of the project design.

8-78 (Pg. 55) Bottom

~~III.~~New Development/ Redevelopment Performance Criteria
III.

1. Integrated Water Quality/Flow Reduction/Resources Management Criteria

   (a) Except as provided in subpart 5.E.III. 2 below, Permittees shall require all New Development and Redevelopment projects identified in subpart 5.E.I1 to control pollutants, pollutant loads, and runoff volume emanating from impervious surfaces through infiltration, storage for reuse, evapotranspiration, or bioretention/biofiltration by reducing the percentage of Effective Impervious' Area (EIA) to 5 percent or less of the total project area.

   (b) Impervious surfaces may be rendered "ineffective," and thus not count toward the 5 percent EIA limitation, if the stormwater runoff from those surfaces is fully retained onsite for the design storm event specified in provision (c), below. To satisfy the EIA limitation and low-impact development requirements, the permittees must require stormwater runoff to be infiltrated, reused, or evapotranspired onsite through a stormwater management technique allowed under the terms of this permit and implementing documents.

   (c) The permittees shall require all features constructed or otherwise utilized to render impervious surfaces "ineffective," as described in provision (b), above, to be properly sized to infiltrate, store for reuse, or evapotranspire, without any runoff at least the volume of water that results from:

      (1) The 85th percentile 24-hour runoff event determined as the maximized capture stormwater volume for the area using a 48 to 72-hour draw down time, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998);

      (2) The volume of annual runoff based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment by the method recommended in the Ventura County Technical Guidance Manual for Storm

REVISED TENTATIVE

Water Quality Control Measures (July 2002 and its revisions); or

(3) The volume of runoff produced from a 0.75 inch storm event.

(d) To address any impervious surfaces that may not be rendered "ineffective, " surface discharge of stormwater runoff if any, that results from New Development and Redevelopment projects identified in subpart 5. E.11 which have complied with subparts 5.E.Ill 1(a)-(c), above, shall be mitigated in accordance with subpart 5.E.III.3'

2. Alternative Compliance for Technical Infeasibility

(a) To encourage smart growth and infill development of existing urban centers where onsite compliance with post-construction requirements may be technically infeasible, the perrnittees may allow projects that are unable to meet the Integrated Water Quality/Flow Reduction/Resources Management Criteria in subpart 5.E.111.1, above, to comply with this permit through the alternative compliance measures described in subpart 5.E.Ill2.c, below.

(b) To utilize alternative compliance measures, the project applicant must demonstrate that compliance with the applicable post-construction requirements would be technically infeasible by submitting a site-specific hydrologic and/or design analysis conducted and endorsed by a registered professional engineer, geologist, architect, and/or landscape architect. Technical infeasibility may result from conditions including the following:

(1) Locations where seasonal high groundwater is within 5 feet of the surface;

(2) Locations within 100 feet of a groundwater well used for drinking water,.

(3) Brownfield development sites or other locations where pollutant mobilization is a documented concern;

(4) Locations with potential geotechnical hazards;

(5) Smart growth and infill or redevelopment locations where the density and/or nature of the project would

REVISED TENTATIVE

create significant difficulty for compliance with the onsite volume retention requirement; and

(6) Other site or implementation constraints identified in the LID Technical Guidance document required by subpart 5.E.IV.5.

(c) Alternative Compliance Measures. When a permittee finds that a project applicant has demonstrated technical infeasibility, the permittee shall identify alternative compliance measures that the project will need to comply with as a substitute for the otherwise applicable post-construction requirements listed in subparts 5. E.11I. I (a)-(c) of this permit. The Ventura County Technical Guidance Manual shall be revised to identify the alternative compliance measures and shall include the following requirements:

(1) Minimum onsite requirement. The project must reduce the percentage of Effective Impervious Area to no more than 30 percent of the total project area and treat all remaining runoff pursuant to the design and sizing requirements of subparts 5. E.III.1(b)-(d).

(2) Offsite mitigation volume. The difference in volume between the amount of stormwater infiltrated, reused, and/or evapotranspired by the project onsite and the otherwise applicable requirements of subparts 5. E.I1I.1(a)-(c) (the "offsite mitigation volume'), above, must be mitigated by the project applicant either by performing offsite mitigation that is approved by the permittee or by providing sufficient funding for public or private offsite mitigation to achieve equivalent stormwater volume and pollutant load reduction through infiltration, reuse, and/or evapotranspiration.

(3) Location of off site mitigation. Offsite mitigation projects must be located in the same sub-watershed (defined as draining to the same hydrologic area in the Basin Plan) as the new development or redevelopment project. A list of eligible public and private offsite mitigation projects available for funding shall be identified by the Permittees and provided to the project applicant. Off site mitigation projects include green streets projects, parking lot retrofits, other site specific LID BMPs, and regional BMPs. Project applicants seeking to utilize these alternative compliance provisions may propose other offsite mitigation projects, which the Permittees may approve if they meet the requirements of this subpart.

(4) Timing and Reporting Requirements for Offsite Mitigation Projects. The Permittee(s) shall develop a schedule for the completion of offsite mitigation projects, including milestone dates to identify fund, design, and construct the projects. Offsite mitigation projects shall be completed as soon as possible, and at the latest, within ~~[3,4]~~ years of the certificate of occupancy for the first project that contributed funds toward the construction of the offsite mitigation project, unless a longer period is otherwise authorized by the Executive Officer. For public offsite mitigation projects, the permittees must provide in their annual reports a summary of total offsite mitigation funds raised to date and a description (including location, general design concept, volume of water expected to be retained, and total estimated budget) of all pending public offsite mitigation projects. Funding sufficient to address the

offsite mitigation volume must be transferred to the permittee (for public offsite mitigation projects) or to an escrow account (for private offsite mitigation projects) within one year of the initiation of construction.

(5) The project applicant must demonstrate that the EM achieved onsite is as close to 5 percent EIA as technically feasible, given the site's constraints.

(d) Watershed equivalence. Regardless of the methods through which permittees allow project applicants to implement alternative compliance measures, the sub-watershed -wide (defined as draining to the same hydrologic area in the Basin Plan) result of all development must be at least the same level of water quality protection as would have been achieved if all projects utilizing these alternative compliance provisions had complied with subparts 5.E.III1(a)-(d) of the permit. The permittees shall provide in their annual report to the Regional Board a list of mitigation project descriptions and pollutant and flow reduction analyses (compiled from design specifications submitted by project applicants and approved by the permittee(s)) comparing the expected aggregate results of alternative compliance projects to the results that would otherwise have been achieved by meeting the 5 percent EIA requirement onsite.

Los Angeles Times



http://www.latimes.com/news/local/la-me-mwd-water15-2009apr15,0,4326528.story
From the Los Angeles Times

Southern California water agency to cut supplies by 10%

It is the first time such action has been taken since the early 1990s drought. Statewide water conditions remain below average for the third consecutive year, officials say.
By Bettina Boxall

April 15, 2009

The board of Southern California's major water wholesaler voted Tuesday to effectively cut water deliveries across the region by 10% this summer.

The Metropolitan Water District of Southern California has warned for months that the state's drought and environmentally driven cutbacks in water shipments from Northern California would leave demand higher than the supply.

"We're short," said Jeffrey Kightlinger, the water district's general manager.

The cuts are the agency's first since the early 1990s drought.

The Metropolitan Water District, which imports water from the Sacramento-San Joaquin delta and the Colorado River and sells it to local water districts, will achieve the reductions by imposing penalty rates. Local utilities that use more than their allocation will have to pay more.

In anticipation, Los Angeles is poised to adopt conservation rates aimed at getting residents to reduce their water use by 15%.

Statewide water conditions have improved in recent months but they remain below average for the third consecutive year.

Total storage in the Colorado River basin is also slightly better than last year. But a persistent drought in the basin has left the river's reservoirs at 54% of overall capacity. Lake Mead, which supplies Southern California, is 46% full, although it will get more water from upstream Lake Powell as the season progresses.

Last year, the Metropolitan Water District cut supplies to agricultural customers and it has suspended regional groundwater replenishment. All told, agency officials said they will deliver roughly 20% less water than three years ago.

The reduced deliveries have meant less sales revenue for the agency, which is also facing rising costs.

As a result, the agency will hike its prices by nearly 20% in September -- in addition to the penalty rates. The increase comes on top of a roughly 14% rate increase last year.

bettina.boxall@latimes.com

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Office of the Governor ARNOLD SCHWARZENEGGER THE PEOPLE'S GOVERNOR

PRESS RELEASE

02/27/2009 GAAS:079:09 FOR IMMEDIATE RELEASE

Gov. Schwarzenegger Takes Action to Address California's Water Shortage

Proclaims State of Emergency, Directs Government to Utilize Resources, Help People

To combat California's third consecutive year of drought, Governor Arnold Schwarzenegger today proclaimed a state of emergency and ordered immediate action to manage the crisis. In the proclamation, the Governor uses his authority to direct all state government agencies to utilize their resources, implement a state emergency plan and provide assistance for people, communities and businesses impacted by the drought.

"Even with the recent rainfall, California faces its third consecutive year of drought and we must prepare for the worst - a fourth, fifth or even sixth year of drought," Governor Schwarzenegger said. "Last year we experienced the driest spring and summer on record and storage in the state's reservoir system is near historic lows. This drought is having a devastating impact on our people, our communities, our economy and our environment - making today's action absolutely necessary. This is a crisis, just as severe as an earthquake or raging wildfire, and we must treat it with the same urgency by upgrading California's water infrastructure to ensure a clean and reliable water supply for our growing state."

The Governor's order directs various state departments to engage in activity to provide assistance to people and communities impacted by the drought. The proclamation:

- Requests that all urban water users immediately increase their water conservation activities in an effort to reduce their individual water use by 20 percent
- Directs the Department of Water Resources (DWR) to expedite water transfers and related efforts by water users and suppliers
- Directs DWR to offer technical assistance to agricultural water suppliers and agricultural water users, including information on managing water supplies to minimize economic impacts and implementing efficient water management practices
- Directs DWR to implement short-term efforts to protect water quality or water supply, such as the installation of temporary barriers in the Delta or temporary water supply connections
- Directs the Labor and Workforce Development Agency to assist the labor market, including job training and financial assistance
- Directs DWR to join with other appropriate agencies to launch a statewide water conservation campaign calling for all Californians to immediately decrease their water use
- Directs state agencies to immediately implement a water use reduction plan and take immediate water conservation actions and requests that federal and local agencies also implement water use reduction plans for facilities within their control

In particular, the order directs that by March 30, 2009, DWR shall provide an updated report on the state's drought conditions and water availability. According to the proclamation, if the emergency conditions have not been sufficiently mitigated, the Governor will consider additional steps. These could include the institution of mandatory water rationing and mandatory reductions in water use; reoperation of major reservoirs in the state to minimize impacts of the drought; additional regulatory relief or permit streamlining as allowed under the Emergency Services Act; and other actions necessary to prevent, remedy or mitigate the effects of the extreme drought conditions.

DWR and California's Department of Food and Agriculture will also recommend, within 30 days, measures to

reduce the economic impacts of the drought, including but not limited to water transfers, through-Delta emergency transfers, water conservation measures, efficient irrigation practices, and improvements to the California Irrigation Management Information System.

Last week, DWR announced that California's severe drought had prevented it from increasing its State Water Project (SWP) delivery allocations for the first time since 2001. This year's allocation as of February is at just 15 percent of SWP contractor's requests. This is only the second time in SWP history that the February allocation has been this low.

The drought conditions and water restrictions are causing additional devastating economic and business losses. Agricultural revenue losses exceed $300 million to date and could exceed $2 billion in the coming season, with a total economic loss of nearly $3 billion in 2009.

Full text of proclamation:

A PROCLAMATION
BY THE GOVERNOR OF THE STATE OF CALIFORNIA

WHEREAS the State of California is now in its third consecutive year of drought; and

WHEREAS in each year of the current drought, annual rainfall and the water content in the Sierra snowpack have been significantly below the amounts needed to fill California's reservoir system; and

WHEREAS the rainfall and snowpack deficits in each year of the current drought have put California further and further behind in meeting its essential water needs; and

WHEREAS statewide, 2008 was the driest spring and summer on record, with rainfall 76 percent below average; and

WHEREAS the Sacramento and San Joaquin River systems, which provide much of the state's reservoir inflow, were classified as Critically Dry for the 2008 water year; and

WHEREAS in the second year of this continuous drought, on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to begin taking action to address the water shortage; and

WHEREAS because emergency conditions existed in the Central Valley in the second year of the drought, I issued an Emergency Proclamation on June 12, 2008, finding that conditions of extreme peril to the safety of persons and property existed in the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern caused by severe drought conditions, and I ordered my administration to take emergency action to assist the Central Valley; and

WHEREAS the drought conditions and water delivery limitations identified in my prior Executive Order and Emergency Proclamation still exist, and have become worse in this third year of drought, creating emergency conditions not just in the Central Valley, but throughout the State of California, as the adverse environmental, economic, and social impacts of the drought cause widespread harm to people, businesses, property, communities, wildlife and recreation; and

WHEREAS despite the recent rain and snow, the three year cumulative water deficit is so large there is only a 15 percent chance that California will replenish its water supply this year; and

WHEREAS in the time since the state's last major drought in 1991, California added 9 million new residents, experienced a significant increase in the planting of permanent, high-value crops not subject to fallowing, and was subjected to new biological opinions that reduced the flexibility of water operations throughout the year; and

WHEREAS because there is no way to know when the drought will end, further urgent action is needed to address the water shortage and protect the people and property in California; and

WHEREAS rainfall levels statewide for the 2008-2009 water year are 24 percent below average as of the February 1, 2009 measurement; and

WHEREAS the second snow pack survey of the 2009 winter season indicated that snow pack water content is 39 percent below normal; and

WHEREAS as of February 23, 2009, storage in the state's reservoir system is at a historic low, with Lake Oroville 70 percent below capacity, Shasta Lake 66 percent below capacity, Folsom Lake 72 percent below capacity, and San Luis Reservoir 64 percent below capacity; and

WHEREAS low water levels in the state's reservoir system have significantly reduced the ability to generate hydropower, including a 62 percent reduction in hydropower generation at Lake Oroville from October 1, 2008 to January 31, 2009; and

WHEREAS a biological opinion issued by the United States Fish and Wildlife Service on December 15, 2008, imposed a 30 percent restriction on water deliveries from the State Water Project and the Central Valley Project to protect Delta Smelt; and

WHEREAS State Water Project water allocations have now been reduced to 15 percent of requested deliveries, matching 1991 as the lowest water allocation year in State Water Project history, and Central Valley Project water allocations for agricultural users have now been reduced to zero; and

WHEREAS the lack of water has forced California farmers to abandon or leave unplanted more than 100,000 acres of agricultural land; and

WHEREAS California farmers provide nearly half of the fresh fruits, nuts and vegetables consumed by Americans, and the crop losses caused by the drought will increase food prices, which will further adversely impact families and economies throughout California and beyond our borders; and

WHEREAS agricultural revenue losses exceed $300 million to date and could exceed $2 billion in the coming season, with a total economic loss of nearly $3 billion in 2009; and

WHEREAS it is expected that State Water Project and Central Valley Project water delivery reductions will cause more than 80,000 lost jobs; and

WHEREAS the income and job losses will adversely impact entire communities and diverse sectors of the economy supported by those jobs and income, including the housing market and commercial business; and

WHEREAS these conditions are causing a loss of livelihood for many thousands of people, an inability to provide for families, and increased harm to the communities that depend on them; and

WHEREAS this loss of income and jobs will increase the number of defaults, foreclosures and bankruptcies, and will cause a loss of businesses and property at a time when Californians are already struggling with a nationwide and worldwide economic downturn; and

WHEREAS the Central Valley town of Mendota, as one example, already reports an unemployment rate of more than 40 percent and lines of a thousand or more for food distribution; and

WHEREAS when jobs, property and businesses are lost, some families will move away from their communities, causing further harm to local economies, lower enrollments in local schools and reduced funding for schools; and

WHEREAS at least 18 local water agencies throughout the state have already implemented mandatory water conservation measures, and 57 agencies have implemented other water conservation programs or restrictions on water deliveries, with many agencies considering additional rationing and water supply reductions in 2009; and

WHEREAS the lack of water has forced local communities to draw water from their emergency water reserves, putting communities at risk of further catastrophe if emergency reserves are depleted or cut off; and

WHEREAS the state recently endured one of its worst wildfire seasons in history and the continuing drought conditions increase the risk of devastating fires and reduced water supplies for fire suppression; and

WHEREAS on February 26, 2009, the United States Department of Agriculture and the United States Department of Interior created a Federal Drought Action Team to assist California to minimize the social, economic, and environmental impacts of the current drought; and

WHEREAS the circumstances of the severe drought conditions, by reason of their magnitude, are beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist in California caused by the current and continuing severe drought conditions and water delivery restrictions.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, in accordance with the authority vested in me by the California Constitution and the California Emergency Services Act, and in particular California Government Code sections 8625 and 8571, **HEREBY PROCLAIM A STATE OF EMERGENCY** to exist in California.

IT IS HEREBY ORDERED that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of the California Emergency Management Agency (CalEMA) and the State Emergency Plan.

I FURTHER DIRECT THAT:

1. The California Department of Water Resources (DWR) shall, in partnership with other appropriate agencies, launch a statewide water conservation campaign calling for all Californians to immediately decrease their water use.

2. DWR shall implement the relevant mitigation measures identified in the Environmental Water Account Environmental Impact Report, Environmental Impact Statement, Supplement, and Addendums for the water transfers made through the 2009 Drought Water Bank. In addition, the California Air Resources Board shall, in cooperation with DWR and other agencies, expedite permitting and development of mitigation measures related to air quality impacts which may result from groundwater substitution transfers.

3. DWR and the State Water Resources Control Board (SWRCB) shall expedite the processing of water transfers and related efforts by water users and suppliers that cannot participate in the 2009 Drought Water Bank, provided the water users and suppliers can demonstrate that the transfer will not injure other legal users of water or cause unreasonable effects on fish and wildlife.

4. The SWRCB shall expedite the processing and consideration of the request by DWR for approval of the consolidation of the places of use and points of diversion for the State Water Project and federal Central Valley Project to allow flexibility among the projects and to facilitate water transfers and exchanges.

5. DWR shall implement short-term efforts to protect water quality or water supply, such as the installation of temporary barriers in the Delta or temporary water supply connections.

6. The SWRCB shall expedite the processing and consideration of requests by DWR to address water quality standards in the Delta to help preserve cold water pools in upstream reservoirs for salmon preservation and water supply.

7. To the extent allowed by applicable law, state agencies within my administration shall prioritize and streamline permitting and regulatory compliance actions for desalination, water conservation and recycling projects that provide drought relief.

8. The Department of General Services shall, in cooperation with other state agencies, immediately implement a water use reduction plan for all state agencies and facilities. The plan shall include immediate water conservation actions and retrofit programs for state facilities. A moratorium shall be placed on all new landscaping projects at state facilities and on state highways and roads except for those that use water efficient irrigation, drought tolerant plants or non-irrigated erosion control.

9. As a condition to receiving state drought financial assistance or water transfers provided in response to this emergency, urban water suppliers in the state shall be required to implement a water shortage contingency analysis, as required by California Water Code section 10632. DWR shall offer workshops and technical assistance to any agency that has not yet prepared or implemented the water shortage contingency analysis required by California law.

10. DWR shall offer technical assistance to agricultural water suppliers and agricultural water users, including information on managing water supplies to minimize economic impacts, implementing efficient water management

practices, and using technology such as the California Irrigation Management Information System (CIMIS) to get the greatest benefit from available water supplies.

11. The Department of Public Health shall evaluate the adequacy of emergency interconnections among the state's public water systems, and provide technical assistance and continued financial assistance from existing resources to improve or add interconnections.

12. DWR shall continue to monitor the state's groundwater conditions, and shall collect groundwater-level data and other relevant information from water agencies, counties, and cities. It is requested that water agencies, counties and cities cooperate with DWR by providing the information needed to comply with this Proclamation.

13. DWR and the Department of Food and Agriculture shall recommend, within 30 days from the date of this Proclamation, measures to reduce the economic impacts of the drought, including but not limited to, water transfers, through-Delta emergency transfers, water conservation measures, efficient irrigation practices, and improvements to CIMIS.

14. The Department of Boating and Waterways shall recommend, within 30 days from the date of this Proclamation, and in cooperation with the Department of Parks and Recreation, measures to reduce the impacts of the drought conditions to water-based recreation, including but not limited to, the relocation or extension of boat ramps and assistance to marina owners.

15. The Labor and Workforce Development Agency shall recommend, within 30 days from the date of this Proclamation, measures to address the impact of the drought conditions on California's labor market, including but not limited to, identifying impacted areas, providing one-stop service, assisting employers and workers facing layoffs, and providing job training and financial assistance.

16. DWR and the Department of Food and Agriculture shall be the lead agencies in working with the Federal Drought Action Team to coordinate federal and state drought response activities.

17. The emergency exemptions in Public Resources Code sections 21080(b)(3), 21080(b)(4) and 21172, and in California Code of Regulations, title 14, section 15269(c), shall apply to all actions or efforts consistent with this Proclamation that are taken to mitigate or respond to this emergency. In addition, Water Code section 13247 is suspended to allow expedited responses to this emergency that are consistent with this Proclamation. The Secretary for the California Environmental Protection Agency and the Secretary for the California Natural Resources Agency shall determine which efforts fall within these exemptions and suspension, ensuring that these exemptions and suspension serve the purposes of this Proclamation while protecting the public and the environment. The Secretaries shall maintain on their web sites a list of the actions taken in reliance on these exemptions and suspension.

18. By March 30, 2009, DWR shall provide me with an updated report on the state's drought conditions and water availability. If the emergency conditions have not been sufficiently mitigated, I will consider issuing additional orders, which may include orders pertaining to the following:

(a) institution of mandatory water rationing and mandatory reductions in water use;

(b) reoperation of major reservoirs in the state to minimize impacts of the drought;

(c) additional regulatory relief or permit streamlining as allowed under the Emergency Services Act; and

(d) other actions necessary to prevent, remedy or mitigate the effects of the extreme drought conditions.

I FURTHER REQUEST THAT:

19. All urban water users immediately increase their water conservation activities in an effort to reduce their individual water use by 20 percent.

20. All agricultural water suppliers and agricultural water users continue to implement, and seek additional opportunities to immediately implement, appropriate efficient water management practices in order to minimize economic impacts to agriculture and make the best use of available water supplies.

21. Federal and local agencies also implement water use reduction plans for facilities within their control, including immediate water conservation efforts.

I FURTHER DIRECT that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 27th day of February, 2009.

ARNOLD SCHWARZENEGGER
Governor of California

ATTEST:
DEBRA BOWEN
Secretary of State

Construction Industry Coalition on Water Quality

February 13, 2009

Michael Adackapara
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

RE: Tentative Order No. R8-2008-0030 (NPDES Permit No. CAS618030) Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department, and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff, Orange County

Dear Mr. Adackapara:

On behalf of the more than 3,000 member companies of the Construction Industry Coalition on Water Quality (CICWQ), we would like to thank the Santa Ana Regional Water Quality Control Board (Regional Board) for the opportunity to offer this public comment on the Draft Orange County Municipal Separate Storm Sewer System Permit, Tentative Order No. R8-2008-0030 (Draft Permit). We also appreciate the Regional Board's participation in the series of permit stakeholder meetings that we have had to date. This letter and attachments provide constructive suggestions that we have for the Draft Permit, and defines where we feel we have reached conceptual agreement on planning and land development provisions (most notably Low Impact Development and Hydromodification Control requirements) that have been discussed and debated thoroughly within a stakeholder group framework since December 2008.

I. Introduction

CICWQ is comprised of the four major construction and building industry trade associations in Southern California: the Associated General Contractors of California (AGC), the Building Industry Association of Southern California (BIA/SC), the Engineering Contractors Association (ECA) and the Southern California Contractors Association (SCCA). The membership of CICWQ is comprised of construction contractors, labor unions, landowners, developers, and homebuilders working throughout the region and state.

These organizations work collectively to provide the necessary infrastructure and support for the region's business and residential needs. Members of all of the above-referenced organizations are affected by the Draft Permit, as are thousands of construction employees and builders working to meet the demand for modern

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infrastructure and housing in Orange County. Our organizations support efforts to improve water quality in a cost effective manner. Our comments and suggestions on the Draft Permit as well as our active involvement in the stakeholder group process reflect our commitment to protect water quality while at the same time preserve our member's economic viability in this difficult economic environment. Our membership has invested significant resources into developing sound engineering approaches for Low Impact Development (LID) stormwater management techniques and for hydromodification control, facilitating the appropriate application of these valuable approaches to water quality management. Our comments reflect this commitment to sound engineering practices and consideration of site-specific feasibility considerations.

II. Preliminary Statement

The stakeholder discussions have demonstrated that the new terms and provisions of the Draft Permit are not self-defining. They could potentially invite misunderstanding because different people might impute different meanings and definitions for the same terms. Regardless of this potential, we believe that considerable progress has been made, and that significant common ground is being found. Most importantly, we share the common goal of moving the permit program in the direction of LID Best Management Practices ("BMPs"), and we appreciate the need to avoid hydromodification impacts to sensitive stream channels. We agree that conventional stormwater BMPs should not be used as the primary BMP approach for a site unless it is plainly infeasible or undesirable due to ecological or other societal considerations (e.g. ultra high density project) to use LID BMPs. We also continue to favor regional BMPs and off-site solutions when they can be demonstrated to achieve a high environmental benefit, recognizing at the same time that these options cannot be mandated when they are not generally available, and may not be for some time.

We also believe that there are certain realities for which the Draft Permit must account, including the following principal points:

- A 2-year, 24-hour design storm volume for LID BMPs is not realistic, and should be replaced with a capture volume corresponding to the current criterion in the existing permit and the Drainage Areawide Management Plan (DAMP). Our understanding is that all those participating in the stakeholder process, including the agency and the Non-Governmental Organizations ("NGOs"), are in agreement on this point.

- A 95 percent non-effective impervious area ("EIA") requirement does not make sense given that LID BMPs should apply to 100 percent of the capture volume. In addition, the term "EIA" lacks a common, understandable and implementable definition, and is too vague and ambiguous to be used as a logical standard. There seems to be willingness on the part of the agency and the NGOs to consider a capture volume approach, without the complication and confusion created by appending EIA to it. The NGOs have acknowledged that EIA lacks meaning

without a design storm volume specified and clear criteria of what would be considered non-effective impervious area. This is an important acknowledgement, which we appreciate, as it tends to show that EIA as a stand-alone concept does not have value or relevance.

- Mandating the complete on-site retention of capture volume (i.e. runoff that never leaves as surface flows) is not a reasonable approach. Total, 100 percent retention remains a practical infeasibility in most circumstances, and is not a goal that can be achieved for most projects within any reasonable cost, despite best efforts. Thus, the retention BMPs of infiltration, harvesting, and evapotranspiration ("ET") may be fairly described as a favored first tier of LID BMPs, but they should not be universally mandated to the exclusion of all other options. While we understand that the NGOs would prefer to see the retention BMPs applied everywhere, and every project retain the entire capture volume on site, there seems to be some level of appreciation that this ideal is not possible, or even necessarily desirable, as a universal mandate.

- Biofiltration, bioretention, filter strips, and other BMPs based on using vegetation to promote stormwater treatment should be added to the suite of LID BMPs available to project proponents. These BMPs may be specified as a second tier, but project proponents should have considerable discretion to use these BMPs, and should not be required to apply for a feasibility exception to do so. The Regional Board and NGOs seem amenable to including these BMPs in the universe of LID, especially if projects must use underdrains in these features due to the feasibility and desirability of infiltration.

- The use of conventional BMPs as the principal approach for stormwater management should be a last resort, available only when objective infeasibility criteria are satisfied, and when off-site opportunities are not readily available. When LID BMPs are infeasible, and off-site opportunities are not available, the use of conventional BMPs that have been demonstrated to be effective on the pollutants of concern should be a compliance option.

- The approach to hydromodification control needs to be carefully considered on a watershed specific basis. Each stream or stormwater conveyance system is unique along with unique characteristics of the watershed. Hydromodification impacts can come from not just increasing runoff volumes, but also reduction in sediment supply from upland areas. Finally, many of Orange County's streams and stormwater conveyances are geomorphically stable and do not require hydromodification controls. Therefore, we recommend that hydromodification controls be targeted to those watersheds that drain to sensitive systems and that these controls over time be tailored to specific watersheds. There should be a provision that if a hydromodification plan is submitted for a project that provides a technically accurate hydromodification assessment and control plan, that project

can implement those provisions rather than any generalized non-watershed specific requirements.

Finally, we are enthusiastic about advancing a variety of leading-edge issues through a watershed master planning process. These plans would facilitate progress on unresolved issues related to science, technology and feasibility. On a much more granular basis than is available today, watershed-specific master plans can help determine appropriate project BMP requirements, retrofit BMPs, source controls, and other watershed efforts to address specific, receiving water beneficial uses.

Such plans hold the promise of a better path towards achieving water quality standards, replacing the relatively fractured, site-by-site, *ad hoc* approach of the current paradigm, with an overall scheme for water quality improvement. Watershed-specific master plans will provide project proponents with a level of certainty that does not presently exist and make cost-effective and environmentally-superior, regional and sub-regional water quality solutions available. Examples of issues to be explored include opportunities for harvesting, mapping of sensitive channels, determining areas where infiltration should be promoted, and compiling information on groundwater quality and contamination. There also could be added focus on an integrated approach to addressing impairment, and protecting high-quality, specially-protected areas.

III. Comments

What follows are our comments, organized into three sections and supported with attachments where noted: (1) comments on Finding No. 62; (2) comments on Section XII: New Development (Including Significant Redevelopment); and (3) comments on areas of conceptual agreement, where we list areas within the Draft Permit structure upon which the stakeholder group (and *ad-hoc* technical subgroup) reached general consensus.

A. Comments on Finding No. 62

CICWQ does not support this finding, the implications of it, and the utility of using EIA in defining "requirements for new development and redevelopment projects." The finding supports EIA as a performance standard in sizing and implementing LID BMPs, yet does not reflect the current state of knowledge concerning the much greater efficacy of other performance standards for sizing LID BMPs.

BIA/SC communicated with the U.S. Environmental Protection Agency (EPA) regarding their intent in using EIA as a performance standard in designing and implementing LID BMPs. While EPA supports the use of "clear, measureable, and enforceable requirements" for LID performance, such as limitations on EIA, EPA's letter to BIA/SC dated July 31, 2008 (Attachment 1) clearly states that "use of the 5% EIA requirement is not the only acceptable, quantitative approach for incorporating LID into renewed MS4 permits in southern California." The EPA further states that "we are open to other quantitative means for measuring how LID tools reduce storm water discharges."

Therefore, Finding No. 62 does not accurately reflect the position of EPA regarding its advocacy of clear, quantitative measures for LID BMP performance in MS4 permits such as volume capture or other more common engineering approaches to sizing storm water handling facilities.

Additionally, CICWQ is concerned by the reference to Dr. Richard Horner's case study analysis which the Regional Board is using to support the inclusion of the 5% EIA limitation as a criterion for LID BMP implementation. The Finding accurately points out that this was a "limited study." The Finding should also point out, however, this is not a peer-reviewed analysis and it relies on many coarse-level assumptions about key LID BMP sizing parameters, such as generous consideration of the availability of landscaping areas for LID BMP features within several types of development projects, optimistic infiltration scenarios, and non-representative soil condition assumptions (soil data taken from the San Fernando Valley) that are applied broadly across Ventura County. We are enclosing a critique of the hydrological aspects of the Horner Case Study prepared by Geosyntec, Inc., dated May 28, 2008 (Attachment 2).

Moreover, CICWQ has pointed out during the stakeholder meetings that a limitation on EIA as a performance standard for sizing LID BMPs has created widespread confusion and misunderstanding in the development and building industry with respect to the definition of EIA, what this standard would require, and the reason for it. Proposing EIA as a performance standard has also created confusion among stormwater professionals from the principal permittee and co-permittees and consultants who support them within Orange County and within Regional Board staff as well. It is quite clear from the recent stakeholder meeting discussion that EIA does not have an agreed upon, logical definition. It may be a valid scientific concept under uncontrolled conditions (where there are no BMPs), and one that has meaning on a watershed scale where its definition first appeared, but it does not have a useful or proper role in project-level engineering design or project feature performance assessment.

We suggest striking Finding No. 62 or, at a minimum, revising it to present a reasonable, accurate and complete discussion of the debate regarding the LID BMP performance standard protocol.

B. Comments on Section XI: New Development (Including Significant Redevelopment)

1. <u>LID BMPs Should Be Preferred</u>

The CICWQ membership is committed to using appropriate LID design features and LID BMPs in new and redevelopment projects. While LID BMPs have been demonstrated to be effective stormwater management tools, they should not be limited simply to those that reduce stormwater runoff via infiltration or harvesting alone. In fact, LID includes a range of measures which can be employed on most projects and others, such as infiltration and harvesting/reuse, which have less universal application.

Projects should prioritize the selection of LID BMPs that remove stormwater pollutants, reduce stormwater runoff, and promote groundwater infiltration (where appropriate and technically and economically feasible), ET, and harvesting and reuse in an integrated approach to protecting water quality and managing water resources. It is our understanding that this approach is fairly close to the Board's originally intended language. We recommend that hard feasibility criteria should be specified in the model WQMP/DAMP upon its renewal – such that developers should not be able to bypass implementation of appropriate LID BMPs.

2. It is Neither Feasible Nor Appropriate to Mandate Universal Infiltration, Universal Infiltration Plus Harvesting, or Universal Infiltration Plus Harvesting Plus ET

We agree that LID BMPs that retain stormwater on site should be used when feasible and promoted in the Draft Permit. We do not think, however, that such BMPs should be mandated as a condition of permit compliance to the complete exclusion of other options. Such an approach would impose a universal hydrology standard mandating the on-site retention of a certain volume of water, regardless of likely water quality implications. If such an approach were achievable on a widespread basis using techniques and engineering approaches that are practicable, even to the maximum extent, we would agree to the approach. We have deep concerns, however, that such is not the case. We also have concerns that this could lead to other environmental problems. The use of retention BMPs should be promoted as preferred, but should not be mandated absent including BMPs that employ vegetation.

Retention BMPs, mandated to the exclusion of other options, have limited present utility as explained below. These points are made to illustrate the importance of maintaining a concept of LID BMPs that is broader than just retention – not to discourage the use of retention BMPs where appropriate.

- Infiltration – Infiltration BMPs can be land-intensive unless underground injection control wells can be used and many developments would not move forward as site constraints can limit the availability of land to dedicate for infiltration. Many areas subject to the Draft Permit are underlain by perched groundwater that is shallow and degraded. Infiltrating in these areas can mobilize and exacerbate preexisting contamination, create rising groundwater that then interferes with land development, or other problems. Infiltration can cause changes to habitat type, and to the hydrology of ephemeral streams, should the duration of flows be extended. It also can result in geotechnical instability and increased seismic risk, when rising groundwater increases the potential for liquefaction. Many soils in the area are not amenable to infiltration, given content such as silts and clay. Forebay areas where groundwater replenishment already is occurring by water authorities are in distinct locations, which may not correspond to where new projects are planned. New projects do not have the means to

transport retained stormwater to these forebay areas where infiltration may be desirable. Water authorities already have located and developed the most favorable zones in the forebay areas for ongoing groundwater replenishment. These authorities may resist increased infiltration over pressure zones on the basis of contamination risk, and infiltration in the forebays, as interfering with their jurisdiction.

- Harvesting – Harvesting is limited by reuse option, social acceptability, competing policy goals, and economic considerations, including the need to demonstrate that the water quality benefits of this approach warrant the significant investment entailed. A significant obstacle to harvesting is the limited availability of reuse options, whether on a local or regional basis. There are very few projects where a project proponent has a water demand that can be satisfied with captured stormwater. Typically, there would have to be open space, parks or golf courses immediately nearby or associated with the project to make this option even possible. The demand must be relatively immediate after collection so that the cisterns can be evacuated and made available for the next storm. This is particularly important in Southern California, where storms characteristically sweep through the area in a series. It is not possible to build cisterns so large that they capture the volume from the entire storm series, and there is no need to irrigate in between such storms.

- Other reuse options are extremely limited. Health codes limit the ability to reuse the water for toilet flushing, and building codes impede the construction of projects with the plumbing to accommodate this approach.

- The social acceptability of harvesting has not been demonstrated. Some places like Bermuda have been harvesting water in cisterns for decades. But there is no such precedent or history in Southern California. Who is going to maintain cisterns, monitor them during weekends, holidays and vacations? These questions are particularly acute should cisterns be required of homeowners.

- Harvesting stormwater is a policy goal that is in direct conflict with the California Legislature's goals for reclaiming and reusing wastewater. Recycled water is used largely for irrigation purposes, and in rare instances for indoor toilet flushing. The region covered by the Draft Permit enjoys the environmental and water conservation benefits of water reclamation facilities, but the demand is insufficient and recycled water goes unused. Harvesting will compete with recycled water, and offset its use to some extent. When and where is this socially desirable?

- No one has yet to address the cost of harvesting water. Certainly, at some cost, harvesting is not practicable. What are the appropriate benchmarks against which to measure this aspect? Should harvesting stormwater be used only if it is

comparable in cost to reclaimed water? What if it is five times more expensive per acre foot to produce harvested stormwater? Should it be promoted under that circumstance? Since there has been no economic study, it is difficult to gage this aspect of practicability. But this certainly counsels in the direction of folding harvesting into a broader array of BMP options.

- Finally, where is the water quality demonstration that harvesting produced water quality benefits that are commensurate with the investment? Harvesting only postpones the introduction of the stormwater into the environment. How does that postponement compare with vegetation-based BMPs that reduce the pollutant load but do not affect the timing of the discharge to any material extent?

- Evapotranspiration – Opportunities to enhance ET should be considered, but maybe limited. In some cases, soil amendments such as compost may be able to increase infiltration or shallow soil saturation and drying potential. The potential for ET, however, may be limited by excess irrigation that occupies the ET component of the hydrologic cycle. There may be exotic ET BMPs that are in development. But, practicability limits the options that are available today.

For the Regional Board's consideration, we have attached a white paper on infiltration prepared by Geosyntec Consultants (Attachment 3). The paper provides background on infiltration considerations and identifies some of the key factors necessary in properly implementing a storm water infiltration strategy. Most, if not all, of the concepts contained in the white paper have been discussed during stakeholder meetings.

3. Permittees Should Not Be Required To Make Up Capture Volume Off Site Or Pay A Fee If They Cannot Retain Capture Volume On Site

Off-site options available for project applicants are extremely limited and, in many cases, illusory. The San Diego Creek watershed enjoys a Natural Treatment System ("NTS") that the Regional Board approved as a regional treatment BMP for purposes of the existing permit. Certainly, the new permit should preserve this designation, and encourage other regional projects, particularly those that address existing as well as new development. But, to date, the NTS is the only regional treatment BMP approved by the Regional Board, and its capacity to detain and treat stormwater already is limited. In addition, the approval process for the NTS was arduous, and may have discouraged other entities from proposing regional solutions.

Diversion to the sanitary sewer can be considered on a case-by-case basis, but requires separate permitting involving sanitation districts. Historically, sanitation districts have been reluctant to accept stormwater, and most have policies limiting how much stormwater they will take into their respective systems. Also, it is not clear that such diversions are environmentally desirable in comparison with other options, such as using on-site vegetation BMPs which keep water in local creeks and channels, but only after natural treatment.

In short, in some circumstances off-site options and fee-based programs may be available to support a mandate that would impose a mitigation obligation on a project proponent that cannot retain the entire capture volume on site. With that said, project proponents should be required to explore such options, and adopt them only when it is practicable to do so in light of the context.

Finally, it should be pointed out that such off-site programs likely would need their own entitlements and a large financing mechanism. In the case of the NTS, entitlement and permitting took years, and the funding mechanism required an act of the California Legislature. These facts should illustrate to the Regional Board that it cannot expect such programs to be available until well into this next permit cycle, at the earliest. Any attempt to mandate acceleration would be technology-forcing and not practicable. With that said, we in the private sector long have favored regional solutions and certainly intend to pursue their promise. This is an important element of our interest in watershed master planning.

4. Permittees Should Decide Whether LID BMPs Are Not Feasible and Whether and What Types of Conventional Treatment Can Be Used

We also recommend that the permittees, which are the entities armed with the most local knowledge and appreciation of circumstances, should decide whether LID BMPs are not feasible in particular contexts and where conventional treatment can be used. Using this system, the developer can then reasonably choose, based upon the context, which of the four types of LID BMPs to employ: infiltration, harvesting, ET, or vegetative/landscaping solutions including bioretention or biofiltration with underdrains, or appropriate conventional BMPs. This holistic, basket-type approach is more practical and it is more flexible than requiring permittees to install only LID BMPs that reduce runoff via retention.

5. At Least 12 Months Are Needed To Develop A WQPM Guidance Document on LID Principles

Given discussion at the stakeholder meetings, Orange County should be given at least 12 months to develop a WQMP guidance document on LID principles including BMP specification, feasibility criteria, and engineering sizing criteria. Six months is inadequate to prepare the necessary technical materials and educate the co-permittees and development community on new requirements.

6. WQMP Content Needs To Be Revised

CICWQ suggests deleting the content of Section XII(B)(3)(a) based on conceptual agreements reached with the ad-hoc technical sub-group and replacing it with a statement requiring that the WQMP include strict, clear, technical performance standards for sizing LID BMPs based on treating current volume requirements in the

current SUSMP/DAMP. (*See* below, Section C: Comments on Areas of Conceptual Agreement).

7. Capture Volume Should Be SUSMP Volume

CICWQ suggests deleting all references to limiting EIA to 5% or less in Section XII(C)(3) based on conceptual agreements reached with the ad-hoc technical sub-group. To reiterate, we suggest replacing it with a statement requiring that the WQMP include strict, clear, technical performance standards for sizing LID BMPs based on treating current volume requirements in the current SUSMP/DAMP (24-hour, 85th percentile storm event).

We are also concerned with the following statement that appears repeatedly in Section XII(C)(3)(a-d):

> "The pervious areas to which runoff from the impervious areas are connected should have the capacity to percolate at least the excess runoff from a two-year storm event."

This statement implies 100% capture and infiltration of the excess runoff from a 2-year storm event (or other storm event if substituted). As stated above in our general comments on Section XII, a requirement to capture and infiltrate and/or detain 100% of the water quality treatment volume is infeasible under many different circumstances. We suggest striking this sentence wherever referenced and alternatively include permit conditions concerning LID BMP volume capture sizing standards in the first paragraph of Section XII(C)(3). We are including as Attachment 4 a comparison table showing the requirements of a volume capture standards for LID BMPs based on preferentially treating the 24-hour, 85th percentile storm event and those in the Draft Permit.

CICWQ does not support using EIA as an off-ramp for substituting treatment control BMPs for LID BMPs per Section XII(C)(4)(b), and urges striking this reference.

8. Hydromodification Control Strategies Should Be Implemented Pursuant To Geosyntec White Papers

CICWQ has been working with an array of permittees and developers in southern California to devise appropriate hydromodification control standards for more than two years. We support the use of hydromodification control measures where appropriate and where downstream receiving water conditions warrant installation of on-site, off-site, and/or in-stream control facilities. For the Board's consideration we have attached a white paper on hydromodification control approaches prepared by Geosyntec Consultants (Attachment 5). This paper provides background on hydromodification control considerations and provides a series of recommendation regarding approaches the permittee could use to identify and map sensitive receiving water bodies and develop appropriate hydromodification control strategies. In the baseline period before watershed

or water body based standards are adopted, we recommend using control strategies as defined in Attachment 4. This table compares the approach recommended by CICWQ to that of the current Draft Permit requirements.

Finally, we recommend that permittees have the ability to prepare their own hydromodification control requirements/plan that is receiving water specific.

C. Comments on Areas of Conceptual Agreement

CICWQ was encouraged by the formation of a stakeholder group process in December 2008, on-going discussions, and the formation of an ad-hoc technical group to attempt to reach general agreement on principles for selecting and sizing LID BMPs.

Based on general areas of discussion during stakeholder meetings and during the sub-group conference call on 1/27/09 and 2/3/09, a summary of those discussions and a four point list of areas of conceptual agreement are included:

1. Performance standards for implementing LID BMPs other than a fixed effective impervious area (EIA) percentage (3-5%) are acceptable to Coastkeeper and NRDC if a technically equivalent standard can be identified.

2. Sizing LID BMPs to capture the 85th percentile storm event (current OC SUSMP/DAMP criteria for water quality volume) is an acceptable alternative to EIA as a performance standard provided that technically-based, strict, and clear feasibility criteria are developed for any project that cannot meet the LID BMP requirements.

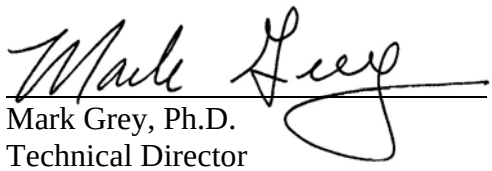
3. Prioritized LID/SUSMP BMPs for water quality volume capture are represented by: (a) infiltration, harvesting, or evapotranspiration BMPs; or (b) vegetated BMPs including bioretention and biofiltration. The water quality volume not captured by LID BMPs shall be treated consistent with SUSMP requirements. Note: There is debate regarding BMP selection options. Coastkeeper/NRDC support complete capture/accounting of the 85th% storm on site using LID BMPs from category (a) or meet off-site mitigation obligations; Permittees/CICWQ support complete treatment using category (a) and (b) BMPs.

4. If a project proponent cannot feasibly treat the SUSMP water quality volume using the prioritized application of LID/SUSMP BMPs on-site, then off-site mitigation of the remaining treatment volume must occur.

IV. Summary

CICWQ is pleased that an inclusive stakeholder process has ensued since the Draft Permit was first released in late November 2008. The process has shed significant light on areas where all stakeholders have common interests and common plans for tackling the pressing water quality improvement issues we all face. We will be an active participant in this group moving forward, and we trust that the Regional Board will continue to promote and engage in this process leading up to permit adoption. If you have any questions or want to discuss the content of our comment letter, please feel free to contact me at (909) 396-9993, ext. 252, (909) 525-0623, cell phone, or mgrey@biasc.org.

Respectfully,



Mark Grey, Ph.D.
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Construction Industry Coalition on Water Quality

United States
Environmental Protection
Agency

Water Planning Division
WH-554
Washington, DC 20460

December 1983

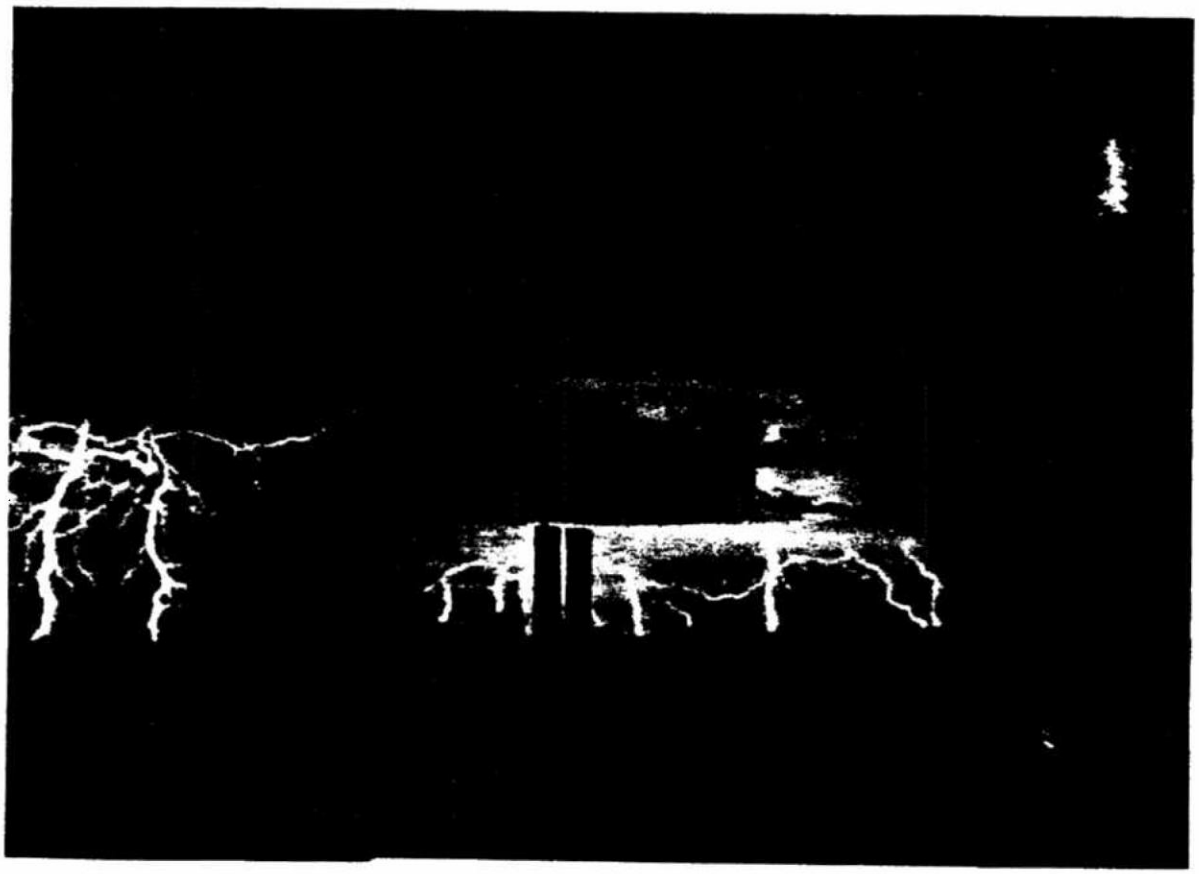
PB84-185552

Water

EPA

Results of the Nationwide Urban Runoff Program

Volume I - Final Report



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NATIONWIDE URBAN RUNOFF PROGRAM

CASTRO, CALIFORNIA

REGION IX, EPA

SARB_012946

INTRODUCTION

The San Francisco Bay-Delta Estuary is the single most important water body in the State of California. More than one-half of all of California's fishery resources either live in or directly depend on the Bay Delta Estuary for their survival. San Francisco Bay also provides scenic beauty and recreation to over 5 million people who live near its shore (California State Water Resources Control Board, 1980).

San Francisco Bay is the dominant feature and primary receiving water of the Bay-Delta system. Assessment of the water quality impact on San Francisco Bay from stormwater runoff is difficult because of the drainage from its vast tributary area. The Bay-Delta system receives runoff from about 40% of the land area of California, or about 63,000 sq. mi. About 3200 sq. mi. of the region drains directly to San Francisco Bay.

Castro Valley Creek and many other Bay Area creeks with similar flow volumes can be considered "urban feeder creeks". These may be characterized as having low summer flows and large winter flow variations and providing some natural habitats. It probably is not economically feasible to improve these creeks to a fishable/swimmable status.

Castro Valley, the study area for this project, is a small watershed considered typical of residential basins in the San Francisco Bay Delta Region (Sylvester, 1978). The U.S. Geological Survey and the Corps of Engineers (which initially began monitoring runoff in Castro Valley in 1971) considered Castro Valley a typical residential basin because of the general geology, soils, topography, hydrology, climate, vegetation and human activities in the basin. Assessment of the impact from stormwater runoff on the water quality of Castro Valley Creek shows that the runoff water quality commonly fails to meet beneficial use criteria for several toxic heavy metals.

Although it was beyond the scope of this project to investigate the effects of street cleaning on Bay water quality, the project was based on the assumption that, if street cleaning would improve water quality in Castro Valley Creek, then street cleaning on a larger scale may improve water quality in the Bay.

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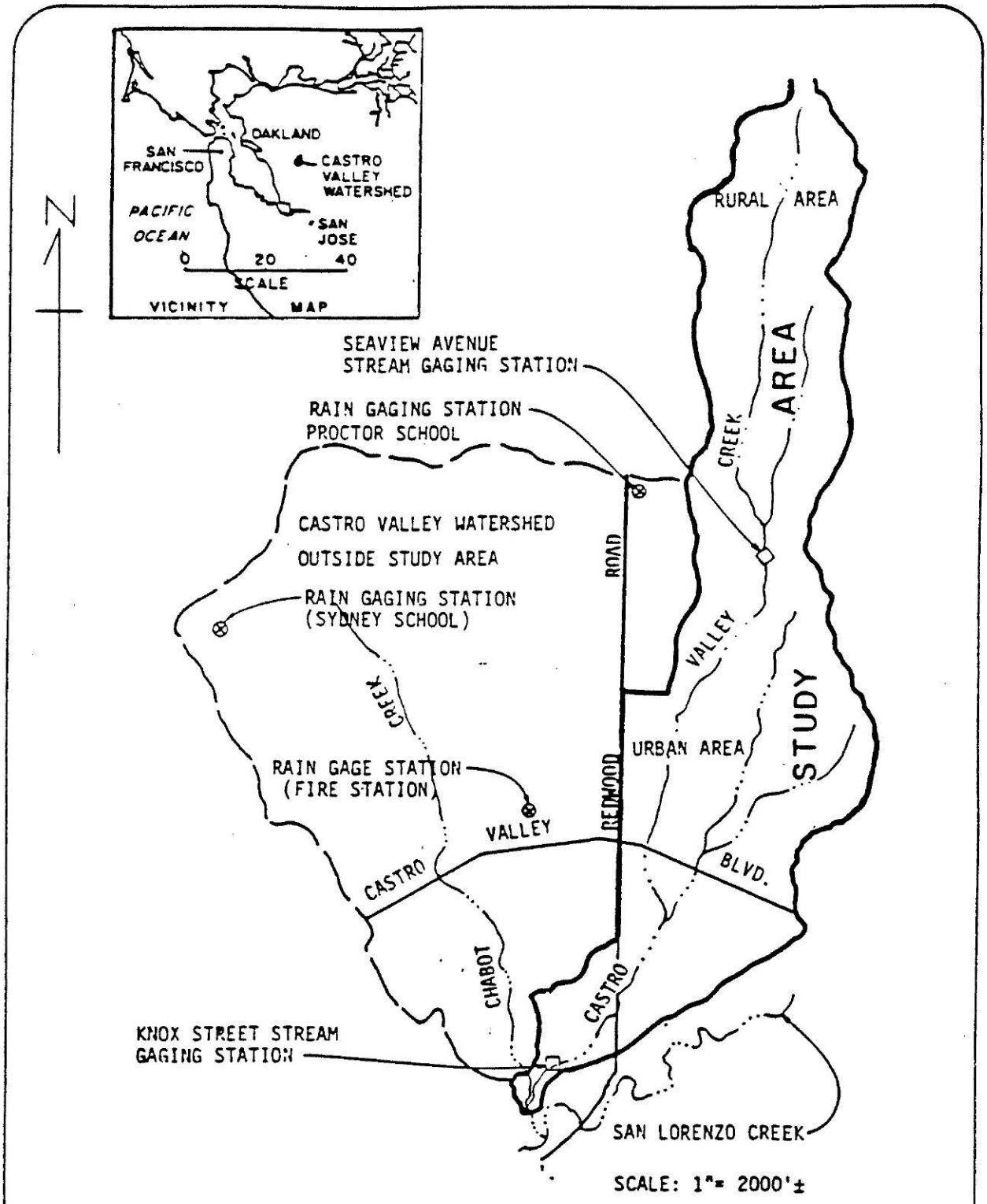

FIGURE 1 - STATE LOCUS, PROJECT AREA AND SAMPLING SITES FOR CASTRO VALLEY NURP PROJECT

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PHYSICAL DESCRIPTION

A. Area

Castro Valley is an unincorporated community within Alameda County. The project's study area was a 2.4 sq. mi. portion of this unincorporated area. The Castro Valley Creek branch of the Castro Valley Watershed was selected as the study area because it was a manageable size.

The study area is 1,542 acres and is predominantly residential, with urban, suburban and rural terrain in the flats and hills bordering San Francisco Bay south of Oakland and north of San Jose. The uppermost portion of the study area is rural with about 633 acres of grass and woodlands that is slowly being replaced by suburban development. The Seaview station monitors water quality and quantity from this essentially rural area. Below this station is the urban test area of about 909 acres. Length of the main creek channel between the rural station (Seaview) and the urban station (Knox) is 2.4 miles.

The majority of the residential land use in the urban area consists of single family housing with lot sizes varying from 5,000 square feet to 10,000 square feet. Residential land use of the 909-acre urban study area occupies about 636 acres (70 percent), commercial land use occupies about 64 acres (7 percent), and the remaining land is about 209 acres (23 percent) of open space and institutional land use. Development along the stream banks in Castro Valley is intense and houses are frequently constructed directly over the existing streambed. Some light commercial areas, more than six schools, and a short portion of Interstate Highway 580 are also in the area.

B. Population

Present population is estimated to be 15,000, located principally in the urban area of the watershed, but population in the upper rural area is steadily increasing.

C. Drainage

Topography within the drainage basin is highly variable, and the land slopes range from 10 percent to 70 percent in the upper end of the basin to slopes as low as 1 percent in the valley portion near San Lorenzo Creek. The Castro Valley Creek streambed in the lower portions of the drainage basin ranges from 20 to 50 feet in width and 8 feet to 10 feet in depth. The streambed is often strewn with litter and debris.

Most of the streets in the urban area are asphalt and in fair condition. The gutters are mainly concrete, and the curbs are mostly vertical (rather than rolled).

D. Sewerage System

100% of the drainage area is served by separate storm sewers.

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PROBLEM

A. Local Definition (Government)

As a result of P.L. 92-500, many regions of the nation undertook areawide planning studies (supported by 208 grants) to identify and define existing water quality problems. In the Bay Area, the problems investigated included fish kills, shellfish contamination, toxic pollutants, eutrophication, dredging and disposal, oil and chemical spills, and freshwater outflow from the Sacramento-San Joaquin Delta.

The following is a brief description of three of these problems and their probable causes in the San Francisco Bay Area:

- Shellfish beds are widespread, well-populated, and represent a presently under-utilized resource in San Francisco Bay. Commercial and recreational shellfish harvesting is prohibited because of contamination by bacteria, viruses and, in some cases, heavy metals. Storm runoff, sewage discharge and waste from boats are sources of contamination (Association of Bay Area Governments (ABAG), 1978.)

- Many fish kill incidents can be traced to specific pollution causes; however, the fish kills occur in the Bay for unknown reasons. The State is investigating the causes of death of striped bass and has also initiated a study of the aquatic habitat of the Bay.

- There is evidence that the Bay's aquatic life may be adversely affected by toxic materials, e.g., heavy metals, pesticides and organic compounds, which are showing up in analyses of Bay waters. The evidence points to pollutants that occur at low concentrations whose effects are cumulative and/or long-term (ABAG, 1978).

The primary use of many creeks in the Bay area is to convey stormwater runoff into San Francisco Bay. Although runoff contains large amounts of pollutants, its relationship to observed water quality problems in San Francisco Bay remains uncertain. However, Castro Valley Creek's contribution of large quantities of toxic pollutants into San Francisco Bay is seen as a significant water quality problem.

B. Local Perception (Public Awareness)

Because the primary use of Castro Valley Creek is to convey stormwater runoff into San Francisco Bay, public concern for the water quality of the Creek itself is not high. To the extent that it exists, public perception of a water quality problem focuses on the Bay as a scenic, recreational and commercial water resource for all communities within the Bay area. There is widespread and at times vocal citizen concern over Bay water quality. The Bay area 208 Study drew heavily upon public support and active citizen participation in carrying out its problem identification and prioritization tasks. However, the magnitude and technical/institutional complexity of Bay water quality problems tend to discourage remedial action by any one community.

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PROJECT DESCRIPTION

A. Major Objectives

The Castro Valley study was directed towards developing information on three subjects which were of particular concern to local decision makers. The objectives were to:

- demonstrate the effectiveness of street cleaning in improving water quality;
- provide information to local Public Works agencies on how to incorporate water quality as a factor into their street cleaning programs; and
- investigate the quantities of asbestos on urban streets and in urban runoff.

Again, the primary purpose of the project was to demonstrate whether removing the pollution load from the street surfaces by street cleaning has an effect on the quality of runoff from street surfaces. The project collected data to compare the monitored mass pollutant flows of the storms with the total pollutant removal of street cleaning programs. The project also investigated a related subject: comparison of the performance of regenerative air (RA) and mechanical street cleaning equipment.

B. Methodology

Project field activities began in October, 1978, and ended in April, 1980. In order to demonstrate the relationship between street cleaning and runoff water quality, the project measured:

(1) street cleaning effectiveness, to identify the quantity of pollutants removed and the initial and residual loadings before and after cleaning for a variety of street cleaning programs; (The street surface particulate sample was obtained by vacuuming portions of the street surfaces immediately before and after the area was cleaned. The two loadings were then compared to obtain measures of street cleaning effectiveness. These samples were then divided into eight discrete particle sizes, weighed, and finally composited over selected time periods by particle size and test area for chemical analyses.)

(2) street surface pollutant accumulation rates to identify the loading on the street at any time;

(3) precipitation, to know the quantity of rainfall; and

(4) runoff water quantity and quality, to identify the quantity of pollutants washed off the watershed for various types of rainstorms. Two monitoring stations were located on Castro Valley Creek. The upper station (Seaview) measured the runoff from the rural area, and the lower station (Knox) measured the runoff from

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both the urban area and the rural area. The contribution from only the urban test area was determined by subtracting the contribution of the rural station from that of the urban station.

Curve fitting analysis was used to correlate street surface pollutant loadings before rain events with changes in runoff water mass yields.

C. Monitoring

The Alameda County Flood Control District entered into an agreement with the United States Geological Survey to establish two water quality monitoring stations on Castro Valley Creek. The USGS was responsible for gathering flow and stage data and developing a rating curve for these stations. The Alameda County Flood Control District was responsible for collection of samples for chemical parameters and measurement of field parameters. The samples were sent to the USGS Laboratory in Denver, Colorado, for analysis.

The watershed has two distinct parts - the urban and non-urban areas. The rural area's contributions of sediments and pollutants were subtracted from the rest of the watershed to give an accurate accounting of pollutant and sediment loading in the urban study area. To accomplish this, a gaging and water quality monitoring station was established on Castro Valley Creek near the intersections of Seaview Avenue and Madison Avenue, the boundary line between the urban and rural areas of the watershed. Another gaging and monitoring station was established near the intersection of Knox Street and North 4th Street. This station was at the lower end of the watershed and measured the total flow and total pollutant loading of the watershed. In this way it was possible to separate the contributions of each portion of the watershed. Separation was critical since the study was concerned with the urban area.

Three rain gages were used to monitor precipitation in the project area (Figure 1). One was located near the intersection of Redwood Road and Proctor Road at Proctor School. This gage measured the rainfall in the upper watershed. Another was located at the Sydney School outside the study area and was used as a check against the Proctor gage. The third one was located at the Castro Valley Fire Station on San Miguel Avenue in central Castro Valley. From these stations, the rainfall record correlated well with the water quality and street surface data collected during the project.

For the street surface particulate sampling portion of the study, each subsample included all of the street surface materials that would be removed during a severe rain (including loose materials and caked-on mud in the gutter and street areas). The location of the subsample strip was carefully selected to ensure that it had no unusual loading conditions. For example, a subsample was not collected through the middle of a pile of leaves, but where the leaves were lying on the street in their normal distribution pattern. When possible, wet areas were also avoided. If a sample were wet and the particles caked around the intake nozzle, the caked mud from the gobbler was carefully scraped into the vacuum hose while the vacuum units were running at the end of the sampling period.

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Each subsample was collected in a narrow strip about 6 in. wide (the width of the gobbler) from one side of the street to the other (curb to curb). In heavily traveled streets where traffic was a problem, some subsamples consisted of two separate one-half street strips (curb to crown). On busy roadways with no parking and good street surfaces, most particulates were found within a few feet of the curb, and a good subsample was collected by vacuuming two adjacent strips from the curb as far into the traffic lanes as possible. Subsamples taken in areas of heavy parking were collected between vehicles along the curbs. Subsamples were collected, composited and submitted to a laboratory for chemical analysis.

To carry out the street cleaning task, several frequencies were evaluated during the first project year. The second project year, however, used a constant street cleaning frequency of 5 times per week for one month followed by two months with no street cleaning operations at all. This enabled the streets to become as dirty as they were likely to become during the first month and then remain at that level during the second month of no cleaning.

Equipment

At both runoff monitoring sites, stream level was monitored by a manometer-servo water level sensor and recorded on a Stevens digital tape recorder. The water quality samples were taken by a modified ISCO automatic wastewater sampler initiated by a continuous-recording modified ISCO Flowmeter with printer. The limited capacity of the samplers' sample holders was expanded during the record year by placing samplers on top of 55-gallon stainless steel drums. This allowed project personnel to monitor completely even the storms of longest duration. All of the water quality sampling equipment was powered by a 90 amp hr. 12 volt car battery. Field parameters were measured by an EXTECH ph meter and a YSI conductivity meter with thermometer.

For the collection of street surface particulate samples, a light-duty (half-ton capacity) trailer was used to carry the generator, tools, fire extinguisher, vacuum hose and wand, and two wet-dry vacuum units. A truck with a suitable hitch and signal light connections was used to pull the trailer. Two-horsepower (hp) industrial vacuum cleaners with one secondary filter and a primary dacron filter bag were selected. The vacuum units were heavy duty and made of stainless steel to prevent contamination of the samples. Both 2-hp vacuums were used together by using a wye connector. This combination extended the useful length of the 1.5-inch vacuum hose to 35 feet and increased the suction so that it was adequate to remove all particles of interest. A wand and gobbler (triangular in shape and about 6 inches across) are also needed. The generator which was used produced about 5000 watts of electrical power.

Most of the street cleaning tests were conducted using a modern, mechnical, four-wheel brush-type street cleaner that had dual gasoline engines and hydraulic controls. The speed during the cleaning program was about five to eight m.p.h. Broom replacement and other maintenance were conducted on a scheduled basis. Operating conditions were held constant during the study program and were not varied. A regenerative air street cleaner was tested for part of the project period and its performance compared with that of the conventional mechanical cleaner in order to provide information to public works officials concerned about replacing their street cleaners. Too little performance difference was observed under the test conditions to justify purchase of one type versus others.

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Controls

Project results showed that, when the streets were dirtiest (initial loadings of about 1000 or more pounds per curb mile), the cleaning efficiency was about 40%. Even though the range of percentage removal values varies appreciably, the residual (after street cleaning) loading values were no lower than about 200 pounds per curb mile, even with very intensive cleaning.

After about two or three passes per week, there is very little improvement in either initial or residual street surface loadings. Under these cases, the streets are about as clean as they are likely to get by street cleaning operations and any more frequent street cleaning is unproductive. It is much more cost effective to decrease the street cleaning effort in areas having frequent cleaning and to increase street cleaning efforts in areas with appreciably dirtier streets such as industrial areas.

When the urban runoff yield information was compared to the specific street surface initial loading values for each constituent, this analysis showed that a maximum of about 20 percent of the total solids and about 35 percent of the lead could have been prevented from reaching the receiving water. If maximum urban runoff improvements are going to be realized by street cleaning, then the streets should be cleaned during the winter months between adjacent storm periods. As expected, lead shows the greatest potential for control by street cleaning equipment, followed by total solids and then arsenic. Figure 2 illustrates this relationship and further shows that after about three passes per week, any more street cleaning is unproductive.

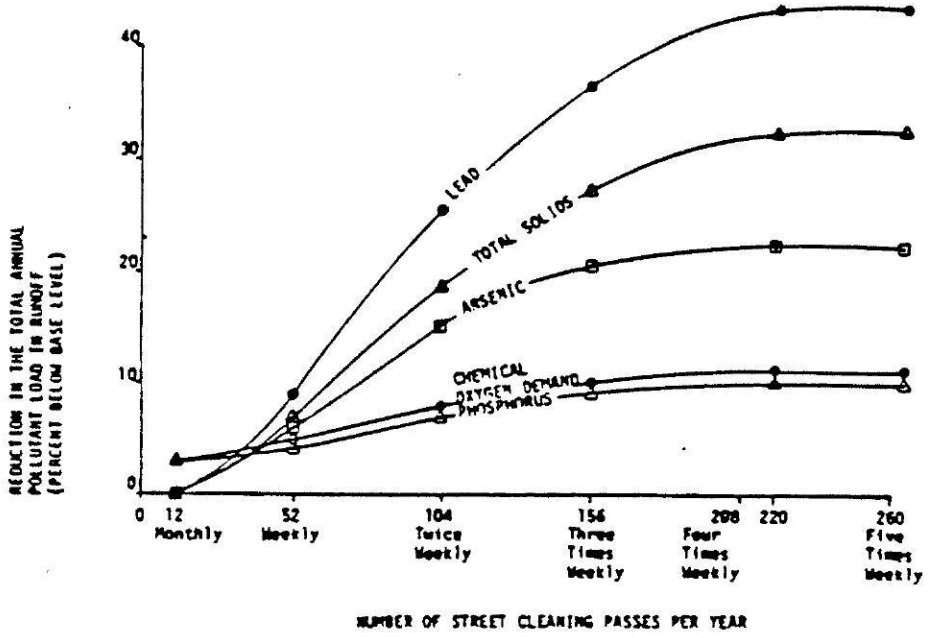

FIGURE 2 - IMPROVEMENT IN URBAN RUNOFF QUALITY AS A FUNCTION OF STREET CLEANING EFFORT.

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Results of the special asbestos study yielded some interesting results. In this case current optical techniques provided inadequate to identify asbestos in small quantities, especially for small fiber sizes. About 10% of the runoff which was monitored had detectable asbestos. The annual average asbestos fiber concentration in urban runoff in Castro Valley was about thirty million fibers per liter. This concentration is roughly equivalent to 3×10^{13} fibers per acre per year for an area without any known asbestos in the natural soils. Eighty per cent (80%) of the street surface samples contained detectable asbestos fibers. Street cleaning was found capable of achieving 10% removal of asbestos during weekly street cleaning and up to 50% removal when street cleaning was carried out three times per week.

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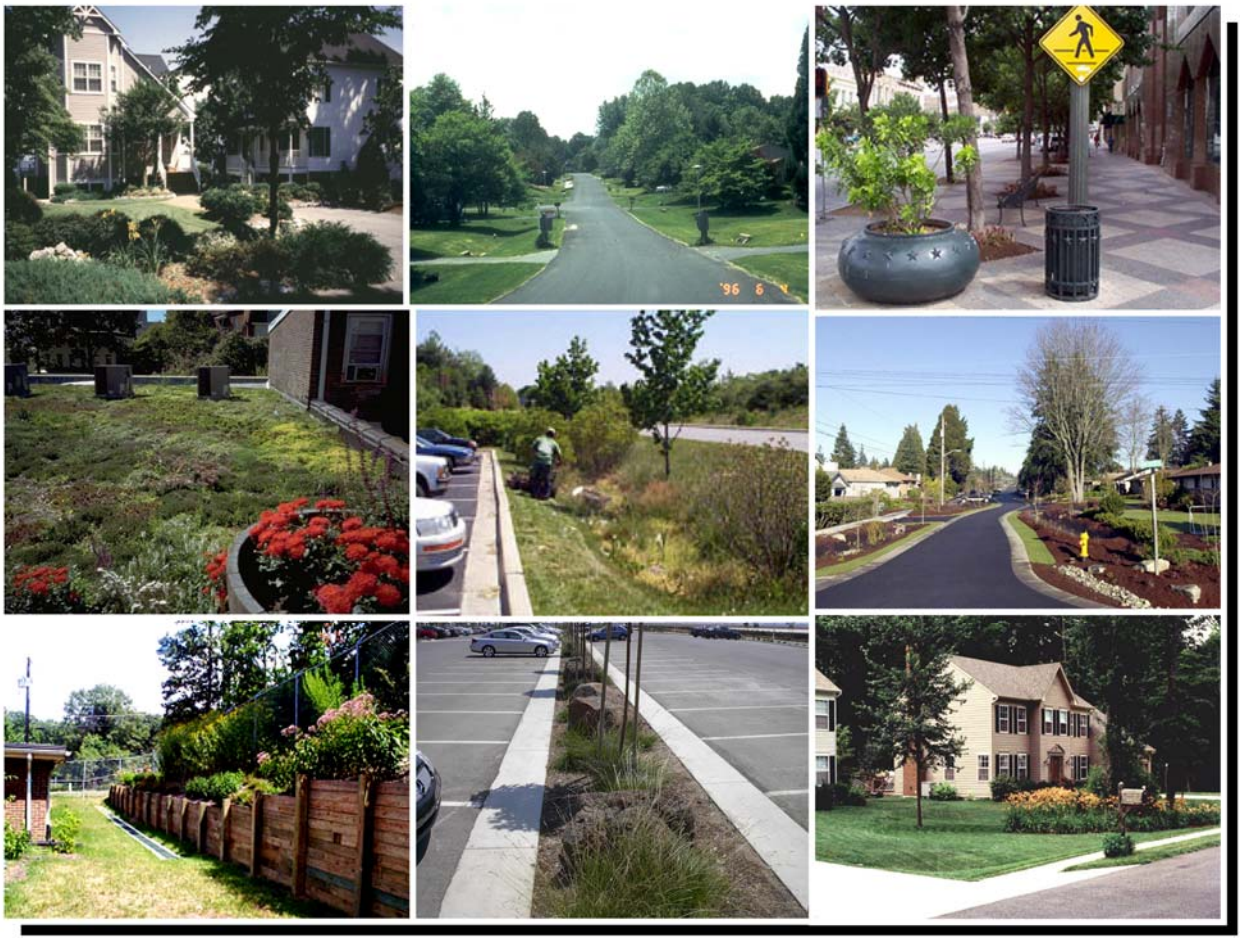
Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices



Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices

December 2007

EPA 841-F-07-006

Prepared under Contract No. 68-C-02-108

United States Environmental Protection Agency

Nonpoint Source Control Branch (4503T)

1200 Pennsylvania Ave., NW

Washington, DC 20460

Available for download at www.epa.gov/nps/lid

SARB_012958

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FOREWORD

One of the most exciting new trends in water quality management today is the movement by many cities, counties, states, and private-sector developers toward the increased use of Low Impact Development (LID) to help protect and restore water quality. LID comprises a set of approaches and practices that are designed to reduce runoff of water and pollutants from the site at which they are generated. By means of infiltration, evapotranspiration, and reuse of rainwater, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water.

Although the increase in application of these practices is growing rapidly, data regarding both the effectiveness of these practices and their costs remain limited. This document is focused on the latter issue, and the news is good. In the vast majority of cases, the U.S. Environmental Protection Agency (EPA) has found that implementing well-chosen LID practices saves money for developers, property owners, and communities while protecting and restoring water quality.

While this study focuses on the cost reductions and cost savings that are achievable through the use of LID practices, it is also the case that communities can experience many amenities and associated economic benefits that go beyond cost savings. These include enhanced property values, improved habitat, aesthetic amenities, and improved quality of life. This study does not monetize and consider these values in performing the cost calculations, but these economic benefits are real and significant. For that reason, EPA has included a discussion of these economic benefits in this document and provided references for interested readers to learn more about them.

Readers interested in increasing their knowledge about LID and Green Infrastructure, which encompasses LID along with other aspects of green development, should see www.epa.gov/npdes/greeninfrastructure and www.epa.gov/nps/lid. It is EPA's hope that as professionals and citizens continue to become more knowledgeable about the effectiveness and costs of LID, the use of LID practices will continue to increase at a rapid pace.

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EXECUTIVE SUMMARY

This report summarizes 17 case studies of developments that include Low Impact Development (LID) practices and concludes that applying LID techniques can reduce project costs and improve environmental performance. In most cases, LID practices were shown to be both fiscally and environmentally beneficial to communities. In a few cases, LID project costs were higher than those for conventional stormwater management practices. However, in the vast majority of cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs.

EPA has identified several additional areas that will require further study. First, in all cases, there were benefits that this study did not monetize and did not factor into the project's bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. Second, more research is also needed to quantify the environmental benefits that can be achieved through the use of LID techniques and the costs that can be avoided. Examples of environmental benefits include reduced runoff volumes and pollutant loadings to downstream waters, and reduced incidences of combined sewer overflows. Finally, more research is needed to monetize the cost reductions that can be achieved through improved environmental performance, reductions in long-term operation and maintenance costs, and/or reductions in the life cycle costs of replacing or rehabilitating infrastructure.

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INTRODUCTION

BACKGROUND

Most stormwater runoff is the result of the man-made hydrologic modifications that normally accompany development. The addition of impervious surfaces, soil compaction, and tree and vegetation removal result in alterations to the movement of water through the environment. As interception, evapotranspiration, and infiltration are reduced and precipitation is converted to overland flow, these modifications affect not only the characteristics of the developed site but also the watershed in which the development is located. Stormwater has been identified as one of the leading sources of pollution for all waterbody types in the United States. Furthermore, the impacts of stormwater pollution are not static; they usually increase with more development and urbanization.

Extensive development in the United States is a relatively recent phenomenon. For the past two decades, the rate of land development across the country has been twice the rate of population growth. Approximately 25 million acres were developed between 1982 and 1997, resulting in a 34 percent increase in the amount of developed land with only a 15 percent increase in population.[1,2] The 25 million acres developed during this 15-year period represent nearly 25 percent of the total amount of developed land in the contiguous states. The U.S. population is expected to increase by 22 percent from 2000 to 2025. If recent development trends continue, an additional 68 million acres of land will be developed during this 25-year period.[3]

Water quality protection strategies are often implemented at three scales: the region or large watershed area, the community or neighborhood, and the site or block. Different stormwater approaches are used at different scales to afford the greatest degree of protection to waterbodies because the influences of pollution are often found at all three scales. For example, decisions about where and how to grow are the first and perhaps most important decisions related to water quality. Growth and development can give a community the resources needed to revitalize a downtown, refurbish a main street, build new schools, and develop vibrant places to live, work, shop, and play. The environmental impacts of development, however, can pose challenges for communities striving to protect their natural resources. Development that uses land efficiently and protects undisturbed natural lands allows a community to grow and still protect its water resources.

Strategies related to these broad growth and development issues are often implemented at the regional or watershed scale. Once municipalities have determined where to grow and where to preserve, various stormwater management techniques are applied at the neighborhood or community level. These measures, such as road width requirements, often transcend specific development sites and can be applied throughout a neighborhood. Finally, site-specific stormwater strategies, such as rain gardens and infiltration areas, are incorporated within a particular development. Of course, some stormwater management strategies can be applied at several scales. For example, opportunities to maximize infiltration can occur at the neighborhood and site levels.

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Many smart growth approaches can decrease the overall amount of impervious cover associated with a development's footprint. These approaches include directing development to already degraded land; using narrower roads; designing smaller parking lots; integrating retail, commercial, and residential uses; and designing more compact residential lots. These development approaches, combined with other techniques aimed at reducing the impact of development, can offer communities superior stormwater management.

Stormwater management programs have struggled to provide adequate abatement and treatment of stormwater at the current levels of development. Future development will create even greater challenges for maintaining and improving water quality in the nation's waterbodies. The past few decades of stormwater management have resulted in the current convention of control-and-treatment strategies. They are largely engineered, end-of-pipe practices that have been focused on controlling peak flow rate and suspended solids concentrations. Conventional practices, however, fail to address the widespread and cumulative hydrologic modifications within the watershed that increase stormwater volumes and runoff rates and cause excessive erosion and stream channel degradation. Existing practices also fail to adequately treat for other pollutants of concern, such as nutrients, pathogens, and metals.

LOW IMPACT DEVELOPMENT

Low Impact Development (LID)[4] is a stormwater management strategy that has been adopted in many localities across the country in the past several years. It is a stormwater management approach and set of practices that can be used to reduce runoff and pollutant loadings by managing the runoff as close to its source(s) as possible. A set or system of small-scale practices, linked together on the site, is often used. LID approaches can be used to reduce the impacts of development and redevelopment activities on water resources. In the case of new development, LID is typically used to achieve or pursue the goal of maintaining or closely replicating the predevelopment hydrology of the site. In areas where development has already occurred, LID can be used as a retrofit practice to reduce runoff volumes, pollutant loadings, and the overall impacts of existing development on the affected receiving waters.

In general, implementing integrated LID practices can result in enhanced environmental performance while at the same time reducing development costs when compared to traditional stormwater management approaches. LID techniques promote the use of natural systems, which can effectively remove nutrients, pathogens, and metals from stormwater. Cost savings are typically seen in reduced infrastructure because the total volume of runoff to be managed is minimized through infiltration and evapotranspiration. By working to mimic the natural water cycle, LID practices protect downstream resources from adverse pollutant and hydrologic impacts that can degrade stream channels and harm aquatic life.

It is important to note that typical, real-world LID designs usually incorporate more than one type of practice or technique to provide integrated treatment of runoff from a site. For example, in lieu of a treatment pond serving a new subdivision, planners might incorporate a bioretention area in each yard, disconnect downspouts from driveway surfaces, remove curbs, and install grassed swales in common areas. Integrating small

practices throughout a site instead of using extended detention wet ponds to control runoff from a subdivision is the basis of the LID approach.

When conducting cost analyses of these practices, examples of projects where actual practice-by-practice costs were considered separately were found to be rare because material and labor costs are typically calculated for an entire site rather than for each element within a larger system. Similarly, it is difficult to calculate the economic benefits of individual LID practices on the basis of their effectiveness in reducing runoff volume and rates or in treating pollutants targeted for best management practice (BMP) performance monitoring.

The following is a summary of the different categories of LID practices, including a brief description and examples of each type of practice.

Conservation designs can be used to minimize the generation of runoff by preserving open space. Such designs can reduce the amount of impervious surface, which can cause increased runoff volumes. Open space can also be used to treat the increased runoff from the built environment through infiltration or evapotranspiration. For example, developers can use conservation designs to preserve important features on the site such as wetland and riparian areas, forested tracts, and areas of porous soils. Development plans that outline the smallest site disturbance area can minimize the stripping of topsoil and compaction of subsoil that result from grading and equipment use. By preserving natural areas and not clearing and grading the entire site for housing lots, less total runoff is generated on the development parcel. Such simplistic, nonstructural methods can reduce the need to build large structural runoff controls like retention ponds and stormwater conveyance systems and thereby decrease the overall infrastructure costs of the project. Reducing the total area of impervious surface by limiting road widths, parking area, and sidewalks can also reduce the volume of runoff that must be treated. Residential developments that incorporate conservation design principles also can benefit residents and their quality of life due to increased access and proximity to communal open space, a greater sense of community, and expanded recreational opportunities.

Examples of Conservation Design

- Cluster development
- Open space preservation
- Reduced pavement widths (streets, sidewalks)
- Shared driveways
- Reduced setbacks (shorter driveways)
- Site fingerprinting during construction

Infiltration practices are engineered structures or landscape features designed to capture and infiltrate runoff. They can be used to reduce both the volume of runoff discharged from the site and the infrastructure needed to convey, treat, or control runoff. Infiltration practices can also be used to recharge ground water. This benefit is especially important in areas where maintaining drinking water supplies and stream baseflow is of special concern because of limited precipitation or a high ratio of withdrawal to recharge rates. Infiltration of runoff can also help to maintain stream temperatures because the infiltrated water that moves laterally to replenish stream baseflow typically has a lower temperature than overland flows, which might be subject

Examples of Infiltration Practices

- Infiltration basins and trenches
- Porous pavement
- Disconnected downspouts
- Rain gardens and other vegetated treatment systems

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to solar radiation. Another advantage of infiltration practices is that they can be integrated into landscape features in a site-dispersed manner. This feature can result in aesthetic benefits and, in some cases, recreational opportunities; for example, some infiltration areas can be used as playing fields during dry periods.

Runoff storage practices. Impervious surfaces are a central part of the built environment, but runoff from such surfaces can be captured and stored for reuse or gradually infiltrated, evaporated, or used to irrigate plants. Using runoff storage practices has several benefits. They can reduce the volume of runoff discharged to surface waters, lower the peak flow hydrograph to protect streams from the erosive forces of high flows, irrigate landscaping, and provide aesthetic benefits such as landscape islands, tree boxes, and rain gardens. Designers can take advantage of the void space beneath paved areas like parking lots and sidewalks to provide additional storage. For example, underground vaults can be used to store runoff in both urban and rural areas.

Examples of Runoff Storage Practices

- Parking lot, street, and sidewalk storage
- Rain barrels and cisterns
- Depressional storage in landscape islands and in tree, shrub, or turf depressions
- Green roofs

Runoff conveyance practices. Large storm events can make it difficult to retain all the runoff generated on-site by using infiltration and storage practices. In these situations, conveyance systems are typically used to route excess runoff through and off the site. In LID designs, conveyance systems can be used to slow flow velocities, lengthen the runoff time of concentration, and delay peak flows that are discharged off-site. LID conveyance practices can be used as an alternative to curb-and-gutter systems, and from a water quality perspective they have advantages over conventional approaches designed to rapidly convey runoff off-site and alleviate on-site flooding. LID conveyance practices often have rough surfaces, which slow runoff and increase evaporation and settling of solids. They are typically permeable and vegetated, which promotes infiltration, filtration, and some biological uptake of pollutants. LID conveyance practices also can perform functions similar to those of conventional curbs, channels, and gutters. For example, they can be used to reduce flooding around structures by routing runoff to landscaped areas for treatment, infiltration, and evapotranspiration.

Examples of Runoff Conveyance Practices

- Eliminating curbs and gutters
- Creating grassed swales and grass-lined channels
- Roughening surfaces
- Creating long flow paths over landscaped areas
- Installing smaller culverts, pipes, and inlets
- Creating terraces and check dams

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Filtration practices are used to treat runoff by filtering it through media that are designed to capture pollutants through the processes of physical filtration of solids and/or cation exchange of dissolved pollutants. Filtration practices offer many of the same benefits as infiltration, such as reductions in the volume of runoff transported off-site, ground water recharge, increased stream baseflow, and reductions in thermal impacts to receiving waters. Filtration practices also have the added advantage of providing increased pollutant removal benefits. Although pollutant build-up and removal may be of concern, pollutants are typically captured in the upper soil horizon and can be removed by replacing the topsoil.

Examples of Filtration Practices

- Bioretention/rain gardens
- Vegetated swales
- Vegetated filter strips/buffers

Low impact landscaping. Selection and distribution of plants must be carefully planned when designing a functional landscape. Aesthetics are a primary concern, but it is also important to consider long-term maintenance goals to reduce inputs of labor, water, and chemicals. Properly preparing soils and selecting species adapted to the microclimates of a site greatly increases the success of plant establishment and growth, thereby stabilizing soils and allowing for biological uptake of pollutants. Dense, healthy plant growth offers such benefits as pest resistance (reducing the need for pesticides) and improved soil infiltration from root growth. Low impact landscaping can thus reduce impervious surfaces, improve infiltration potential, and improve the aesthetic quality of the site.

Examples of Low Impact Landscaping

- Planting native, drought-tolerant plants
- Converting turf areas to shrubs and trees
- Reforestation
- Encouraging longer grass length
- Planting wildflower meadows rather than turf along medians and in open space
- Amending soil to improve infiltration

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EVALUATIONS OF BENEFITS AND COSTS

To date, the focus of traditional stormwater management programs has been concentrated largely on structural engineering solutions to manage the hydraulic consequences of the increased runoff that results from development. Because of this emphasis, stormwater management has been considered primarily an engineering endeavor. Economic analyses regarding the selection of solutions that are not entirely based on pipes and ponds have not been a significant factor in management decisions. Where costs have been considered, the focus has been primarily on determining capital costs for conventional infrastructure, as well as operation and maintenance costs in dollars per square foot or dollars per pound of pollutant removed.

Little attention has been given to the benefits that can be achieved through implementing LID practices. For example, communities rarely attempt to quantify and monetize the pollution prevention benefits and avoided treatment costs that might accrue from the use of conservation designs or LID techniques. To be more specific, the benefits of using LID practices to decrease the need for combined sewer overflow (CSO) storage and conveyance systems should be factored into the economic analyses. One of the major factors preventing LID practices from receiving equal consideration in the design or selection process is the difficulty of monetizing the environmental benefits of these practices. Without good data and relative certainty that these alternatives will work and not increase risk or cost, current standards of practice are difficult to change.

This report is an effort to compare the projected or known costs of LID practices with those of conventional development approaches. At this point, monetizing the economic and environmental benefits of LID strategies is much more difficult than monetizing traditional infrastructure costs or changes in property values due to improvements in existing utilities or transportation systems. Systems of practices must be analyzed to determine net performance and monetary benefits based on the capacity of the systems to both treat for pollutants and reduce impacts through pollution prevention. For example, benefits might come in the form of reduced stream channel degradation, avoided stream restoration costs, or reduced drinking water treatment costs.

One of the chief impediments to getting useful economic data to promote more widespread use of LID techniques is the lack of a uniform baseline with which to compare the costs and benefits of LID practices against the costs of conventional stormwater treatment and control. Analyzing benefits is further complicated in cases where the environmental performance of the conservation design or LID system exceeds that of the conventional runoff management system, because such benefits are not easily monetized. The discussion below is intended to provide a general discussion of the range of economic benefits that may be provided by LID practices in a range of appropriate circumstances.

OVERVIEW OF BENEFITS

The following is a brief discussion of some of the actual and assumed benefits of LID practices. Note that environmental and ancillary benefits typically are not measured as part of development projects, nor are they measured as part of pilot or demonstration projects, because they can be difficult to isolate and quantify. Many of the benefits described below are assumed on the basis of limited studies and anecdotal evidence.

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The following discussion is organized into three categories: (1) environmental benefits, which include reductions in pollutants, protection of downstream water resources, ground water recharge, reductions in pollutant treatment costs, reductions in the frequency and severity of CSOs, and habitat improvements; (2) land value benefits, which include reductions in downstream flooding and property damage, increases in real estate value, increased parcel lot yield, increased aesthetic value, and improvement of quality of life by providing open space for recreation; and (3) compliance incentives.

Environmental Benefits

Pollution abatement. LID practices can reduce both the volume of runoff and the pollutant loadings discharged into receiving waters. LID practices result in pollutant removal through settling, filtration, adsorption, and biological uptake. Reductions in pollutant loadings to receiving waters, in turn, can improve habitat for aquatic and terrestrial wildlife and enhance recreational uses. Reducing pollutant loadings can also decrease stormwater and drinking water treatment costs by decreasing the need for regional stormwater management systems and expansions in drinking water treatment systems.

Protection of downstream water resources. The use of LID practices can help to prevent or reduce hydrologic impacts on receiving waters, reduce stream channel degradation from erosion and sedimentation, improve water quality, increase water supply, and enhance the recreational and aesthetic value of our natural resources. LID practices can be used to protect water resources that are downstream in the watershed. Other potential benefits include reduced incidence of illness from contact recreation activities such as swimming and wading, more robust and safer seafood supplies, and reduced medical treatment costs.

Ground water recharge. LID practices also can be used to infiltrate runoff to recharge ground water. Growing water shortages nationwide increasingly indicate the need for water resource management strategies designed to integrate stormwater, drinking water, and wastewater programs to maximize benefits and minimize costs. Development pressures typically result in increases in the amount of impervious surface and volume of runoff. Infiltration practices can be used to replenish ground water and increase stream baseflow. Adequate baseflow to streams during dry weather is important because low ground water levels can lead to greater fluctuations in stream depth, flows, and temperatures, all of which can be detrimental to aquatic life.

Water quality improvements/reduced treatment costs. It is almost always less expensive to keep water clean than it is to clean it up. The Trust for Public Land[5] noted Atlanta's tree cover has saved more than $883 million by preventing the need for stormwater retention facilities. A study of 27 water suppliers conducted by the Trust for Public Land and the American Water Works Association[6] found a direct relationship between forest cover in a watershed and water supply treatment costs. In other words, communities with higher percentages of forest cover had lower treatment costs. According to the study, approximately 50 to 55 percent of the variation in treatment costs can be explained by the percentage of forest cover in the source area. The researchers also found that for every 10 percent increase in forest cover in the source area, treatment and chemical costs decreased approximately 20 percent, up to about 60 percent forest cover.

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Reduced incidence of CSOs. Many municipalities have problems with CSOs, especially in areas with aging infrastructure. Combined sewer systems discharge sanitary wastewater during storm events. LID techniques, by retaining and infiltrating runoff, reduce the frequency and amount of CSO discharges to receiving waters. Past management efforts typically have been concentrated on hard engineering approaches focused on treating the total volume of sanitary waste together with the runoff that is discharged to the combined system. Recently, communities like Portland (Oregon), Chicago, and Detroit have been experimenting with watershed approaches aimed at reducing the total volume of runoff generated that must be handled by the combined system. LID techniques have been the primary method with which they have experimented to reduce runoff. A Hudson Riverkeeper report concluded, based on a detailed technical analysis, that New York City could reduce its CSO's more cost-effectively with LID practices than with conventional, hard infrastructure CSO storage practices. [7]

Habitat improvements. Innovative stormwater management techniques like LID or conservation design can be used to improve natural resources and wildlife habitat, maintain or increase land value, or avoid expensive mitigation costs.

Land Value and Quality of Life Benefits

Reduced downstream flooding and property damage. LID practices can be used to reduce downstream flooding through the reduction of peak flows and the total amount or volume of runoff. Flood prevention reduces property damage and can reduce the initial capital costs and the operation and maintenance costs of stormwater infrastructure. Strategies designed to manage runoff on-site or as close as possible to its point of generation can reduce erosion and sediment transport as well as reduce flooding and downstream erosion. As a result, the costs for cleanups and streambank restoration can be reduced or avoided altogether. The use of LID techniques also can help protect or restore floodplains, which can be used as park space or wildlife habitat.[8]

Real estate value/property tax revenue. Homeowners and property owners are willing to pay a premium to be located next to or near aesthetically pleasing amenities like water features, open space, and trails. Some stormwater treatment systems can be beneficial to developers because they can serve as a "water" feature or other visual or recreational amenity that can be used to market the property. These designs should be visually attractive and safe for the residents and should be considered an integral part of planning the development. Various LID projects and smart growth studies have shown that people are willing to pay more for clustered homes than conventionally designed subdivisions. Clustered housing with open space appreciated at a higher rate than conventionally designed subdivisions. EPA's *Economic Benefits of Runoff Controls*[9] describes numerous examples where developers and subsequent homeowners have received premiums for proximity to attractive stormwater management practices.

Lot yield. LID practices typically do not require the large, contiguous areas of land that are usually necessary when traditional stormwater controls like ponds are used. In cases where LID practices are incorporated on individual house lots and along roadsides as part of the landscaping, land that would normally be dedicated for a stormwater pond or other large structural control can be developed with additional housing lots.

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Aesthetic value. LID techniques are usually attractive features because landscaping is an integral part of the designs. Designs that enhance a property's aesthetics using trees, shrubs, and flowering plants that complement other landscaping features can be selected. The use of these designs may increase property values or result in faster sale of the property due to the perceived value of the "extra" landscaping.

Public spaces/quality of life/public participation. Placing water quality practices on individual lots provides opportunities to involve homeowners in stormwater management and enhances public awareness of water quality issues. An American Lives, Inc., real estate study found that 77.7 percent of potential homeowners rated natural open space as "essential" or "very important" in planned communities.[10]

Compliance Incentives

Regulatory compliance credits. Many states recognize the positive benefits LID techniques offer, such as reduced wetland impacts. As a result, they might offer regulatory compliance credits, streamlined or simpler permit processes, and other incentives similar to those offered for other green practices. For example, in Maryland the volume required for the permanent pool of a wet pond can be reduced if rooftop runoff is infiltrated on-site using LID practices. This procedure allows rooftop area to be subtracted from the total impervious area, thereby reducing the required size of the permanent pool. In addition, a LID project can have less of an environmental impact than a conventional project, thus requiring smaller impact fees.

COST CONSIDERATIONS

Traditional approaches to stormwater management involve conveying runoff off-site to receiving waters, to a combined sewer system, or to a regional facility that treats runoff from multiple sites. These designs typically include hard infrastructure, such as curbs, gutters, and piping. LID-based designs, in contrast, are designed to use natural drainage features or engineered swales and vegetated contours for runoff conveyance and treatment. In terms of costs, LID techniques like conservation design can reduce the amount of materials needed for paving roads and driveways and for installing curbs and gutters. Conservation designs can be used to reduce the total amount of impervious surface, which results in reduced road and driveway lengths and reduced costs. Other LID techniques, such as grassed swales, can be used to infiltrate roadway runoff and eliminate or reduce the need for curbs and gutters, thereby reducing infrastructure costs. Also, by infiltrating or evaporating runoff, LID techniques can reduce the size and cost of flood-control structures. Note that more research is needed to determine the optimal combination of LID techniques and detention practices for flood control.

It must be stated that the use of LID techniques might not always result in lower project costs. The costs might be higher because of the costs of plant material, site preparation, soil amendments, underdrains and connections to municipal stormwater systems, and increased project management.

Another factor to consider when comparing costs between traditional and LID designs is the amount of land required to implement a management practice. Land must be set aside for both traditional stormwater management practices and LID practices, but the former require the use of land *in addition to* individual lots and other community areas, whereas bioretention areas and swales can be incorporated into the landscaping of yards, in rights-

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of-way along roadsides, and in or adjacent to parking lots. The land that would have been set aside for ponds or wetlands can in many cases be used for additional housing units, yielding greater profits.

Differences in maintenance requirements should also be considered when comparing costs. According to a 1999 EPA report, maintenance costs for retention basins and constructed wetlands were estimated at 3 to 6 percent of construction costs, whereas maintenance costs for swales and bioretention practices were estimated to be 5 to 7 percent of construction costs.[11] However, much of the maintenance for bioretention areas and swales can be accomplished as part of routine landscape maintenance and does not require specialized equipment. Wetland and pond maintenance, on the other hand, involves heavy equipment to remove accumulated sediment, oils, trash, and vegetation in forebays and open ponds.

Finally, in some circumstances LID practices can offset the costs associated with regulatory requirements for stormwater control. In urban redevelopment projects where land is not likely to be available for large stormwater management practices, developers can employ site-dispersed BMPs in sidewalk areas, in courtyards, on rooftops, in parking lots, and in other small outdoor spaces, thereby avoiding the fees that some municipalities charge when stormwater mitigation requirements cannot otherwise be met. In addition, stormwater utilities often provide credits for installing runoff management practices such as LID practices.[12]

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CASE STUDIES

The case studies presented below are not an exhaustive list of LID projects nationwide. These examples were selected on the basis of the quantity and quality of economic data, quantifiable impacts, and types of LID practices used. Economic data are available for many other LID installations, but those installations often cannot be compared with conventional designs because of the unique nature of the design or the pilot status of the project. Table 1 presents a summary of the LID practices employed in each case study.

Table 1. Summary of LID Practices Employed in the Case Studies

Name	LID Techniques							
	Biore-tention	Cluster Building	Reduced Impervious Area	Swales	Permeable Pavement	Vegetated Landscaping	Wetlands	Green Roofs
2nd Avenue SEA Street	✓		✓	✓				
Auburn Hills	✓		✓	✓		✓	✓	
Bellingham Parking Lot Retrofits	✓							
Central Park Commercial Redesigns	✓			✓				
Crown Street	✓		✓	✓				
Gap Creek			✓			✓		
Garden Valley	✓	✓		✓	✓		✓	
Kensington Estates		✓	✓		✓	✓	✓	
Laurel Springs	✓	✓	✓	✓				
Mill Creek		✓	✓	✓				
Poplar Street Apartments	✓			✓			✓	
Portland Downspout Disconnection*			✓					
Prairie Crossing	✓		✓	✓		✓		
Prairie Glen	✓	✓	✓	✓		✓	✓	
Somerset	✓			✓				
Tellabs Corporate Campus	✓			✓		✓	✓	
Toronto Green Roofs								✓

*Although impervious area stays the same, the disconnection program reduces directly connected impervious area.

The case studies contain an analysis of development costs, which are summarized in Table 2. Note that some case study results do not lend themselves well to a traditional vs.

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LID cost comparison and therefore are not included in Table 2 (as noted). *Conventional development cost* refers to costs incurred or estimated for a traditional stormwater management approach, whereas *LID cost* refers to costs incurred or estimated for using LID practices. *Cost difference* is the difference between the conventional development cost and the LID cost. *Percent difference* is the cost savings relative to the conventional development cost.

Table 2. Summary of Cost Comparisons Between Conventional and LID Approaches[a]

Project	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Difference[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	–$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

[a] The Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs study results do not lend themselves to display in the format of this table.
[b] Negative values denote increased cost for the LID design over conventional development costs.
[c] Mill Creek costs are reported on a per-lot basis.

2ND AVENUE SEA STREET, SEATTLE, WASHINGTON



The 2nd Avenue Street Edge Alternative (SEA) Street project was a pilot project undertaken by Seattle Public Utilities to redesign an entire 660-foot block with a number of LID techniques. The goals were to reduce stormwater runoff and to provide a more "livable" community. Throughout the design and construction process, Seattle Public Utilities worked collaboratively with street residents to develop the final street design.[13]

The design reduced imperviousness, included retrofits of bioswales to treat and manage stormwater, and added 100 evergreen trees and 1,100 shrubs.[14] Conventional curbs and gutters were replaced with bioswales in the rights-of-way on both sides of the street, and the street width was reduced from 25 feet to 14 feet. The final constructed design reduced imperviousness by more than 18 percent. An estimate for the final total project cost was $651,548. A significant amount of community outreach was involved, which raised the level of community acceptance. Community input is important for any project, but because this was a pilot study, much more was spent on communication and redesign than what would be spent for a typical project.

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The costs for the LID retrofit were compared with the estimated costs of a conventional street retrofit (Table 3). Managing stormwater with LID techniques resulted in a cost savings of 29 percent. Also, the reduction in street width and sidewalks reduced paving costs by 49 percent.

Table 3. Cost Comparison for 2nd Avenue SEA Street [15]

Item	Conventional Development Cost	SEA Street Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$65,084	$88,173	–$23,089	–35%	–11%
Stormwater management	$372,988	$264,212	$108,776	29%	50%
Site paving and sidewalks	$287,646	$147,368	$140,278	49%	65%
Landscaping	$78,729	$113,034	–$34,305	–44%	–16%
Misc. (mobilization, etc.)	$64,356	$38,761	$25,595	40%	12%
Total	**$868,803**	**$651,548**	**$217,255**	**--**	**--**

* Negative values denote increased cost for the LID design over conventional development costs.

The avoided cost for stormwater infrastructure and reduced cost for site paving accounted for much of the overall cost savings. The nature of the design, which included extensive use of bioswales and vegetation, contributed to the increased cost for site preparation and landscaping. Several other SEA Street projects have been completed or are under way, and cost evaluations are expected to be favorable.

For this site, the environmental performance has been even more significant than the cost savings. Hydrologic monitoring of the project indicates a 99 percent reduction in total potential surface runoff, and runoff has not been recorded at the site since December 2002, a period that included the highest-ever 24-hour recorded rainfall at Seattle-Tacoma Airport.[16] The site is retaining more than the original design estimate of 0.75 inch of rain. A modeling analysis indicates that if a conventional curb-and-gutter system had been installed along 2nd Avenue instead of the SEA Street design, 98 times more stormwater would have been discharged from the site.[17]

AUBURN HILLS SUBDIVISION, SOUTHWESTERN WISCONSIN



Auburn Hills in southwestern Wisconsin is a residential subdivision developed with conservation design principles. Forty percent of the site is preserved as open space; this open space includes wetlands, green space and natural plantings, and walking trails. The subdivision was designed to include open swales and bioretention for stormwater management. To determine potential savings from using conservation design, the site construction costs were compared with the estimated cost of building the site as a conventional subdivision.[18] Reduced stormwater management costs accounted for approximately 56 percent of the total cost savings. A cost comparison is provided in Table 4. Other savings not shown in Table 4 were realized as a result of reduced sanitary sewer, water distribution, and utility construction costs.

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Table 4. Cost Comparison for Auburn Hills Subdivision [19]

Item	Conventional Development Cost	Auburn Hills LID Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$699,250	$533,250	$166,000	24%	22%
Stormwater management	$664,276	$241,497	$422,779	64%	56%
Site paving and sidewalks	$771,859	$584,242	$187,617	24%	25%
Landscaping	$225,000	$240,000	–$15,000	-7%	-2%
Total	**$2,360,385**	**$1,598,989**	**$761,396**	**—**	**—**

* Negative values denote increased cost for the LID design over conventional development costs.

The clustered design used in the development protected open space and reduced clearing and grading costs. Costs for paving and sidewalks were also decreased because the cluster design reduced street length and width. Stormwater savings were realized primarily through the use of vegetated swales and bioswales. These LID practices provided stormwater conveyance and treatment and also lowered the cost of conventional stormwater infrastructure. The increase in landscaping costs resulted from additional open space present on-site compared to a conventional design, as well as increased street sweeping. Overall, the subdivision's conservation design retained more natural open space for the benefit and use of the homeowners and aided stormwater management by preserving some of the site's natural hydrology.[20]

BELLINGHAM, WASHINGTON, PARKING LOT RETROFITS



The City of Bellingham, Washington, retrofitted two parking lots—one at City Hall and the other at Bloedel Donovan Park—with rain gardens in lieu of installing underground vaults to manage stormwater.[21] At City Hall, 3 parking spaces out of a total of 60 were used for the rain garden installation. The Bloedel Donovan Park retrofit involved converting to a rain garden a 550-square-foot area near a catch basin. Both installations required excavation, geotextile fabric, drain rock, soil amendments, and native plants. Flows were directed to the rain gardens by curbs. An overflow system was installed to accommodate higher flows during heavy rains.

The City compared actual rain garden costs to estimates for conventional underground vaults based on construction costs for similar projects in the area ($12.00 per cubic foot of storage). Rain garden costs included labor, vehicle use/rental, and materials. Table 5 shows that the City Hall rain garden saved the City $22,000, or 80 percent, over the underground vault option; the Bloedel Donovan Park installation saved $40,000, or 76 percent.

Table 5. Cost Comparison for Bellingham's Parking Lot Rain Garden Retrofits[22]

Project	Conventional Vault Cost	Rain Garden Cost	Cost Savings	Percent Savings
City Hall	$27,600	$5,600	$22,000	80%
Bloedel Donovan Park	$52,800	$12,800	$40,000	76%

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CENTRAL PARK COMMERCIAL REDESIGNS, FREDERICKSBURG, VA (A MODELING STUDY)



The Friends of the Rappahannock undertook a cost analysis involving the redesign of site plans for several stores in a large commercial development in the Fredericksburg, Virginia, area called Central Park.[23,24] Table 6 contains a side-by-side analysis of the cost additions and reductions for each site for scenarios where LID practices (bioretention areas and swales) were incorporated into the existing, traditional site designs. In five of the six examples, the costs for the LID redesigns were higher than those for the original designs, although they never exceeded $10,000, or 10 percent of the project. One example yielded a $5,694 savings. The fact that these projected costs for LID were comparable to the costs for traditional designs convinced the developer to begin incorporating LID practices into future design projects.[25]

Table 6. Site Information and Cost Additions/Reductions Using LID Versus Traditional Designs

Name	Total BMP Area (ft²)	Total Impervious Area Treated (ft²)	Percent of Impervious Area Treated	Cost Additions[a]	Cost Reductions[b]	Change in Cost After Redesign
Breezewood Station Alternative 1	4,800	64,165	98.4%	$36,696	$34,785	+ $1,911
Breezewood Station Alternative 2	3,500	38,775	59.5%	$24,449	$21,060	+ $3,389
Olive Garden	1,780	31,900	59.1%	$14,885	$11,065	+ $3,790
Kohl's, Best Buy, & Office Depot	14,400	354,238	56.3%	$89,433	$80,380	+ $9,053
First Virginia Bank	1,310	20,994	97.7%	$6,777	$1,148	+ $5,629
Chick-Fil-A[c]	1,326	28,908	82.2%	$6,846	$12,540	– $5,694

[a] Additional costs for curb, curb blocks, storm piping, inlets, underdrains, soil, mulch, and vegetation as a result of the redesign.
[b] Reduced cost for curb, storm piping, roof drain piping, and inlets as a result of the redesign.
[c] Cost reduction value includes the cost of a Stormceptor unit that is not needed as part of the redesign.

CROWN STREET, VANCOUVER, BRITISH COLUMBIA



In 1995 the Vancouver City Council adopted a Greenways program that is focused on introducing pedestrian-friendly green space into the City to connect trails, environmental areas, and urban space. As a part of this program, the City has adopted strategies to manage stormwater runoff from roadways. Two initiatives are discussed here.

The Crown Street redevelopment project, completed in 2005, retrofitted a 1,100-foot block of traditional curb-and-gutter street with a naturalized streetscape modeled after the Seattle SEA Street design. Several LID features were incorporated into the design. The total imperviousness of the street was decreased by reducing the street width from 28 feet to 21 feet with one-

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way sections of the road narrowed to 10 feet. Roadside swales that use vegetation and structural grass (grass supported by a grid and soil structure that prevents soil compaction and root damage) were installed to collect and treat stormwater through infiltration.[26]

Modeling predicts that the redesigned street will retain 90 percent of the annual rainfall volume on-site; the remaining 10 percent of runoff will be treated by the system of vegetated swales before discharging.[27,28] The City chose to use the LID design because stormwater runoff from Crown Street flows into the last two salmon-bearing creeks in Vancouver.[29] Monitoring until 2010 will assess the quality of stormwater runoff and compare it with both the modeling projections and the runoff from a nearby curb-and-gutter street.

The cost of construction for the Crown Street redevelopment was $707,000. Of this, $311,000 was attributed to the cost of consultant fees and aesthetic design features, which were included in the project because it was the first of its kind in Vancouver. These added costs would not be a part of future projects. Discounting the extra costs, the $396,000 construction cost is 9 percent higher than the estimated $364,000 conventional curb-and-gutter design cost.[30] The City has concluded that retrofitting streets that have an existing conventional stormwater system with naturalized designs will cost marginally more than making curb-and-gutter improvements, but installing naturalized street designs in new developments will be less expensive than installing conventional drainage systems.[31,32]

One goal of Vancouver's Greenways program is to make transportation corridors more pedestrian-friendly. A method used to achieve this goal is to extend curbs at intersections out into the street to lessen the crossing distance and improve the line of sight for pedestrians. When this initiative began, the City relocated stormwater catch basins that would have been enclosed within the extended curb. Now, at certain intersections, the City uses the new space behind the curb to install "infiltration bulges" to collect and infiltrate roadway runoff. The infiltration bulges are constructed of permeable soils and vegetation. (The City of Portland, Oregon, has installed similar systems, which they call "vegetated curb extensions.") The catch basins are left in place, and any stormwater that does not infiltrate into the soil overflows into the storm drain system.[33]

The infiltration bulges have resulted in savings for the City. Because the stormwater infiltration bulges are installed in conjunction with planned roadway improvements, the only additional costs associated with the stormwater project are the costs of a steel curb insert to allow stormwater to enter the bulge and additional soil excavation costs. These additional costs are more than offset by the $2,400 to $4,000 cost that would have been required to relocate the catch basins. To date, the City has installed nine infiltration bulges, three of which are maintained by local volunteers as part of a Green Streets program in which local residents adopt city green space.[34]

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GAP CREEK SUBDIVISION, SHERWOOD, ARKANSAS



Gap Creek's original subdivision plan was revised to include LID concepts. The revised design increased open space from the originally planned 1.5 acres to 23.5 acres. Natural drainage areas were preserved and buffered by greenbelts. Traffic-calming circles were used, allowing the developer to reduce street widths from 36 to 27 feet. In addition, trees were kept close to the curb line. These design techniques allowed the development of 17 additional lots.

The lots sold for $3,000 more and cost $4,800 less to develop than comparable conventional lots. A cost comparison is provided in Table 7. For the entire development, the combination of cost savings and lot premiums resulted in an additional profit to the developer of $2.2 million.[35,36]

Table 7. Cost Comparison for Gap Creek Subdivision[37]

Total Cost of Conventional Design	Gap Creek LID Cost	Cost Savings	Percent Savings	Savings per Lot
$4,620,600	$3,942,100	$678,500	15%	$4,800

GARDEN VALLEY, PIERCE COUNTY, WASHINGTON (A MODELING STUDY)



The Garden Valley subdivision is a 9.7-acre site in Pierce County, Washington. A large wetland on the eastern portion of the site and a 100-foot buffer account for 43 percent of the site area. Designers evaluated a scenario in which roadway widths were reduced and conventional stormwater management practices were replaced with swales, bioretention, and soil amendments. The use of these LID elements would have allowed the cost for stormwater management on the site to be reduced by 72 percent. A cost comparison is provided in Table 8.[38] Other costs expected with the LID design were a $900 initial cost for homeowner education with $170 required annually thereafter. Annual maintenance costs for the LID design (not included above) were expected to be $600 more than those for the conventional design, but a $3,000 annual savings in the stormwater utility bill was expected to more than offset higher maintenance costs.

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Table 8. Cost Comparison for Garden Valley Subdivision[39]

Item	Conventional Development Cost	Garden Valley LID Cost	Cost Savings*	Percent Savings*
Stormwater management	$214,000	$59,800	$154,200	72%
Site paving	$110,400	$200,900	–$90,500	–82%
Total	**$324,400**	**$260,700**	**$63,700**	**—**

* Negative values denote increased cost for the LID design over conventional development costs.

The design incorporated the use of narrower roadways coupled with Grasscrete parking along the roadside, which increased the overall site paving costs. However, this added cost was more than offset by the savings realized by employing LID for stormwater management. The LID practices were expected to increase infiltration and reduce stormwater discharge rates, which can improve the health and quality of receiving streams.

KENSINGTON ESTATES, PIERCE COUNTY, WASHINGTON (A MODELING STUDY)



A study was undertaken to evaluate the use of LID techniques at the Kensington Estates subdivision, a proposed 24-acre development consisting of single-family homes on 103 lots. The study assumed that conventional stormwater management practices would be replaced entirely by LID techniques, including reduced imperviousness, soil amendments, and bioretention areas. The design dictated that directly connected impervious areas on-site were to be minimized. Three wetlands and an open space tract would treat stormwater discharging from LID installations. Open space buffers were included in the design. The LID proposal also included rooftop rainwater collection systems on each house.[40,41]

The proposed LID design reduced effective impervious area from 30 percent in the conventional design to approximately 7 percent, and it was approximately twice as expensive as the traditional design. A cost comparison is provided in Table 9.

Table 9. Cost Comparison for Kensington Estates Subdivision[42]

Item	Conventional Development Cost	Kensington Estate LID Cost	Additional Cost
Stormwater management	$243,400	$925,400	$ 682,000
Site paving	$522,300	$577,500	$55,200
Total	**$765,700**	**$1,502,900**	**$737,200**

Although the study assumed that roadways in the LID design would be narrower than those in the conventional design, site paving costs increased because the LID design assumed that Grasscrete parking would be included along the roadside to allow infiltration. The use of Grasscrete increased the overall site paving costs.

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The avoidance of conventional stormwater infrastructure with the use of LID afforded significant cost savings. The LID measures eliminated the need for a detention pond and made more lots available for development. The significant cost for the rooftop rainwater collection systems was assumed to be offset somewhat by savings on stormwater utility bills.[43]

The study also anticipated that the use of LID would reduce stormwater peak flow discharge rates and soil erosion. Furthermore, greater on-site infiltration increases ground water recharge, resulting in increased natural baseflows in streams and a reduction in dry channels. Proposed clustering of buildings would allow wetlands and open space to be preserved and create a more walkable community. The reduced road widths were anticipated to decrease traffic speeds and accident rates.

LAUREL SPRINGS SUBDIVISION, JACKSON, WISCONSIN



The Laurel Springs subdivision in Jackson, Wisconsin, is a residential subdivision that was developed as a conservation design community. The use of cluster design helped to preserve open space and minimize grading and paving. The use of bioretention and vegetated swales lowered the costs for stormwater management.

The costs of using conservation design to develop the subdivision were compared with the estimated cost of developing the site with conventional practices (Table 10).[44] The total savings realized with conservation design were just over $504,469, or approximately 30 percent of the estimated conventional construction cost. Savings from stormwater management accounted for 60 percent of the total cost savings. Other project savings were realized with reduced sanitary sewer, water distribution, and utility construction costs.

Table 10. Cost Comparison for Laurel Springs Subdivision[45]

Item	Conventional Development Cost	Laurel Springs LID Cost	Cost Savings	Percent Savings	Percent of Total Savings
Site preparation	$441,600	$342,000	$99,600	23%	20%
Stormwater management	$439,956	$136,797	$303,159	69%	60%
Site paving and sidewalks	$607,465	$515,755	$91,710	15%	18%
Landscaping	$165,000	$155,000	$10,000	6%	2%
Total	**$1,654,021**	**$1,149,552**	**$504,469**	—	—

In addition to preserving open space and reducing the overall amount of clearing and grading, the cluster design also reduced street lengths and widths, thereby lowering costs for paving and sidewalks. Vegetated swales and bioswales largely were used to replace conventional stormwater infrastructure and led to significant savings. Each of these factors helped to contribute to a more hydrologically functional site that reduced the total amount of stormwater volume and managed stormwater through natural processes.

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MILL CREEK SUBDIVISION, KANE COUNTY, ILLINOIS



The Mill Creek subdivision is a 1,500-acre, mixed-use community built as a conservation design development. Approximately 40 percent of the site is identified as open space; adjacent land use is mostly agricultural. The subdivision was built using cluster development. It uses open swales for stormwater conveyance and treatment, and it has a lower percentage of impervious surface than conventional developments. An economic analysis compared the development cost for 40 acres of Mill Creek with the development costs of 30 acres of a conventional development with similar building density and location.[46]

When compared with the conventional development, the conservation site design techniques used at Mill Creek saved approximately $3,411 per lot. Nearly 70 percent of these savings resulted from reduced costs for stormwater management, and 28 percent of the savings were found in reduced costs for site preparation. A cost comparison is provided in Table 11. Other savings not included in the table were realized with reduced construction costs for sanitary sewers and water distribution.

Table 11. Cost Comparison for Mill Creek Subdivision[47]

Item	Conventional Development Cost per Lot	Mill Creek LID Cost per Lot	Cost Savings per Lot	Percent Savings per Lot	Percent of Total Savings
Site preparation	$2,045	$1,086	$959	47%	28%
Stormwater management	$4,535	$2,204	$2,331	51%	68%
Site paving and sidewalks	$5,930	$5,809	$121	2%	4%
Total	**$12,510**	**$9,099**	**$3,411**	—	—

The use of cluster development and open space preservation on the site decreased site preparation costs. The majority of the cost savings were achieved by avoiding the removal and stockpiling of topsoil. In addition to cost savings from avoided soil disturbance, leaving soils intact also retains the hydrologic function of the soils and aids site stormwater management by reducing runoff volumes and improving water quality. The site's clustered design was also responsible for a decrease in costs for paving and sidewalks because the designers intentionally aimed to decrease total road length and width.

The designers used open swales as the primary means for stormwater conveyance. Coupled with other site techniques to reduce runoff volumes and discharge rates, significant savings in stormwater construction were avoided because of reduced storm sewer installation; sump pump connections; trench backfill; and catch basin, inlet, and cleanout installation.

In addition to the cost savings, the conservation design at Mill Creek had a positive effect on property values: lots adjacent to walking/biking trails include a $3,000 premium, and lots adjacent to or with views of open space include a $10,000 to $17,500 premium. The

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600 acres of open space on the site include 127 acres of forest preserve with quality wetlands, 195 acres of public parks, and 15 miles of walking/biking trails.[48]

POPLAR STREET APARTMENTS, ABERDEEN, NORTH CAROLINA



The use of bioretention, topographical depressions, grass channels, swales, and stormwater basins at the 270-unit Poplar Street Apartment complex improved stormwater treatment and lowered construction costs. The design allowed almost all conventional underground storm drains to be eliminated from the design. The design features created longer flow paths, reduced runoff volume, and filtered pollutants from runoff. According to the U.S. Department of Housing and Urban Development, use of LID techniques resulted in a $175,000 savings (72 percent).[49]

PORTLAND DOWNSPOUT DISCONNECTION PROGRAM, PORTLAND, OREGON



The City of Portland, Oregon, implemented a Downspout Disconnection Program as part of its CSO elimination program. Every year, billions of gallons of stormwater mixed with sewage pour into the Willamette River and Columbia Slough through CSOs. When roof runoff flows into Portland's combined sewer system, it contributes to CSOs. The City has reduced the frequency of CSOs to the Columbia Slough and hopes to eliminate 94 percent of the overflows to the Willamette River by 2011.[50]

The Downspout Disconnection Program gives homeowners, neighborhood associations, and community groups the chance to work as partners with the Bureau of Environmental Services and the Office of Neighborhood Involvement to help reduce CSOs. Residents of selected neighborhoods disconnect their downspouts from the combined sewer system and allow their roof water to drain to gardens and lawns. Residents can do the work themselves and earn $53 per downspout, or they can have community groups and local contractors disconnect for them. Community groups earn $13 for each downspout they disconnect. (Materials are provided by the City.)

More than 44,000 homeowners have disconnected their downspouts, removing more than 1 billion gallons of stormwater per year from the combined sewer system. The City estimates that removing the 1 billion gallons will result in a $250 million reduction in construction costs for an underground pipe to store CSOs by reducing the capacity needed to handle the flows. The City has spent $8.5 million so far to implement this program and will continue to encourage more homeowners and businesses to disconnect their downspouts to achieve additional CSO and water quality benefits.

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PRAIRIE CROSSING SUBDIVISION, GRAYSLAKE, ILLINOIS



The Prairie Crossing subdivision is a conservation development on 678 acres, of which 470 acres is open space. The site was developed as a mixed-use community with 362 residential units and 73 acres of commercial property, along with schools, a community center, biking trails, a lakefront beach, and a farm. The site uses bioretention cells and vegetated swales to manage stormwater.[51]

A cost analysis was performed to compare the actual construction costs of Prairie Crossing with the estimated costs of a conventional design on the site with the same layout. Cost savings with conservation design were realized primarily in four areas: stormwater management, curb and gutter installation, site paving, and sidewalk installation. The total savings were estimated to be almost $1.4 million, or nearly $4,000 per lot (Table 12). Savings from stormwater management accounted for approximately 15 percent of the total savings. The cost savings shown are relative to the estimated construction cost for the items in a conventional site design based on local codes and standards.

Table 12. Cost Comparison for Prairie Crossing Subdivision[52]

Item	Cost Savings	Percent Savings
Reduced Road Width	$178,000	13%
Stormwater Management	$210,000	15%
Decreased Sidewalks	$648,000	47%
Reduced Curb and Gutter	$339,000	25%
Total	**$1,375,000**	**—**

Reduced costs for sidewalks accounted for nearly half of the total cost savings. This savings is attributed in part to the use of alternative materials rather than concrete for walkways in some locations. In addition, the design and layout of the site, which retained a very high percentage of open space, contributed to the cost savings realized from reducing paving, the length and number of sidewalks, and curbs and gutters. The use of alternative street edges, vegetated swales, and bioretention and the preservation of natural areas all reduced the need for and cost of conventional stormwater infrastructure.[53] Benefits are associated with the mixed-use aspect of the development as well: residents can easily access schools, commercial areas, recreation, and other amenities with minimal travel. Proximity to these resources can reduce traffic congestion and transportation costs. Also, mixed-use developments can foster a greater sense of community and belonging than other types of development. All of these factors tend to improve quality of life.

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PRAIRIE GLEN SUBDIVISION, GERMANTOWN, WISCONSIN



The Prairie Glen subdivision is nationally recognized for its conservation design approach. A significant portion of the site (59 percent) was preserved as open space. Wetlands were constructed to manage stormwater runoff, and the open space allowed the reintroduction of native plants and wildlife habitat. The site layout incorporated hiking trails, which were designed to allow the residents to have easy access to natural areas.[54]

To evaluate the cost benefits of Prairie Glen's design, the actual construction costs were compared with the estimated costs of developing the site conventionally. When compared with conventional design, the conservation design at Prairie Glen resulted in a savings of nearly $600,000. Savings for stormwater management accounted for 25 percent of the total savings. Table 13 provides a cost comparison. Other savings not included in the table were realized with reduced sanitary sewer, water distribution, and utility construction costs.

Table 13. Cost Comparison for Prairie Glen Subdivision[55]

Item	Conventional Development Cost	Prairie Glen LID Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$277,043	$188,785	$88,258	32%	22%
Stormwater management	$215,158	$114,364	$100,794	47%	25%
Site paving and sidewalks	$462,547	$242,707	$219,840	48%	54%
Landscaping	$50,100	$53,680	–$3,580	–7%	–1%
Total	**$1,004,848**	**$599,536**	**$405,312**	**—**	**—**

* Negative values denote increased cost for the LID design over conventional development costs.

The cluster design and preservation of a high percentage of open space resulted in a significant reduction in costs for paving and sidewalks. These reduced costs accounted for 54 percent of the cost savings for the overall site. Reduced costs for soil excavation and stockpiling were also realized. The use of open-channel drainage and bioretention minimized the need for conventional stormwater infrastructure and accounted for the bulk of the savings in stormwater management. Landscaping costs increased due to the added amount of open space on the site.

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SOMERSET SUBDIVISION, PRINCE GEORGE'S COUNTY, MARYLAND



The Somerset subdivision, outside Washington, D.C., is an 80-acre site consisting of nearly 200 homes. Approximately half of the development was built using LID techniques; the other half was conventionally built using curb-and-gutter design with detention ponds for stormwater management. Bioretention cells and vegetated swales were used in the LID portion of the site to replace conventional stormwater infrastructure. Sidewalks were also eliminated from the design. To address parking concerns, some compromises were made: because of local transportation department concern that roadside parking would damage the swales, roads were widened by 10 feet.[56] (Note that there are alternative strategies to avoid increasing impervious surface to accommodate parking, such as installing porous pavement parking lanes next to travel lanes.)

Most of the 0.25-acre lots have a 300- to 400-square-foot bioretention cell, also called a rain garden. The cost to install each cell was approximately $500—$150 for excavation and $350 for plants. The total cost of bioretention cell installation in the LID portion of the site was $100,000 (swale construction was an additional cost). The construction cost for the detention pond in the conventionally designed portion of the site was $400,000, excluding curbs, gutters, and sidewalks.[57,58] By eliminating the need for a stormwater pond, six additional lots could be included in the LID design. A comparison of the overall costs for the traditional and LID portions of the site is shown in Table 14.

Table 14. Cost Comparison for Somerset Subdivision

Conventional Development Cost	Somerset LID Cost	Cost Savings	Percent Savings	Savings per Lot
$2,456,843	$1,671,461	$785,382	32%	$4,000

In terms of environmental performance, the LID portion of the subdivision performed better than the conventional portion.[59] A paired watershed study compared the runoff between the two portions of the site, and monitoring indicated that the average annual runoff volume from the LID watershed was approximately 20 percent less than that from the conventional watershed. The number of runoff-producing rain events in the LID watershed also decreased by 20 percent. Concentrations of copper were 36 percent lower; lead, 21 percent lower; and zinc, 37 percent lower in LID watershed runoff than in conventional watershed runoff. The homeowners' response to the bioretention cells was positive; many perceived the management practices as a free landscaped area.

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TELLABS CORPORATE CAMPUS, NAPERVILLE, ILLINOIS



The Tellabs corporate campus is a 55-acre site with more than 330,000 square feet of office space. After reviewing preliminary planning materials that compared the costs of conventional and conservation design, the company chose to develop the site with conservation design approaches. Because the planning process included estimating costs for the two development approaches, this particular site provides good information on commercial/industrial use of LID.[60]

Development of the site included preserving trees and some of the site's natural features and topography. For stormwater management, the site uses bioswales, as well as other infiltration techniques, in parking lots and other locations. The use of LID techniques for stormwater management accounted for 14 percent of the total cost savings for the project. A cost comparison is provided in Table 15. Other cost savings not shown in Table 15 were realized with reduced construction contingency costs, although design contingency costs were higher.

Table 15. Cost Comparison for Tellabs Corporate Campus[61]

Item	Conventional Development Cost	Tellabs LID Cost	Cost Savings	Percent Savings	Percent of Total Savings
Site preparation	$2,178,500	$1,966,000	$212,500	10%	46%
Stormwater management	$480,910	$418,000	$62,910	13%	14%
Landscape development	$502,750	$316,650	$186,100	37%	40%
Total	**$3,162,160**	**$2,700,650**	**$461,510**	**—**	**—**

Savings in site preparation and landscaping had the greatest impact on costs. Because natural drainage pathways and topography were maintained to the greatest extent possible, grading and earthwork were minimized; 6 fewer acres were disturbed using the conservation design approach. Landscaping at the site maximized natural areas and restored native prairies and wetland areas. The naturalized landscape eliminated the need for irrigation systems and lowered maintenance costs when compared to turf grass, which requires mowing and regular care. In the end, the conservation approach preserved trees and open space and provided a half acre of wetland mitigation. The bioswales used for stormwater management complemented the naturalized areas and allowed the site to function as a whole; engineered stormwater techniques augmented the benefits of the native areas and wetlands.[62]

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TORONTO GREEN ROOFS, TORONTO, ONTARIO (A MODELING STUDY)



Toronto is home to more than 100 green roofs. To evaluate the benefits of greatly expanded use of green roofs in the city, a study was conducted using a geographic information system to model the effects of installing green roofs on all flat roofs larger than 3,750 square feet. (The model assumed that each green roof would cover at least 75 percent of the roof area.) If the modeling scenario were implemented, 12,000 acres of green roofs (8 percent of the City's land area) would be installed.[63] The study quantified five primary benefits from introducing the green roofs: (1) reduced stormwater flows into the separate storm sewer system, (2) reduced stormwater flows into the combined sewer system, (3) improved air quality, (4) mitigation of urban heat island effects, and (5) reduced energy consumption.[64]

The study predicted economic benefits of nearly $270 million in municipal capital cost savings and more than $30 million in annual savings. Of the total savings, more than $100 million was attributed to stormwater capital cost savings, $40 million to CSO capital cost savings, and nearly $650,000 to CSO annual cost savings. The cost of installing the green roofs would be largely borne by private building owners and developers; the cost to Toronto would consist of the cost of promoting and overseeing the program and would be minimal. Costs for green roof installations in Canada have averaged $6 to $7 per square foot. The smallest green roof included in the study, at 3,750 square feet, would cost between $22,000 and $27,000. The total cost to install 12,000 acres of green roofs would be $3 billion to $3.7 billion.[65,66] Although the modeled total costs exceed the monetized benefits, the costs would be spread across numerous private entities.

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CONCLUSION

The 17 case studies presented in this report show that LID practices can reduce project costs and improve environmental performance. In most cases, the case studies indicate that the use of LID practices can be both fiscally and environmentally beneficial to communities. As with almost all such projects, site-specific factors influence project outcomes, but in general, for projects where open space was preserved and cluster development designs were employed, infrastructure costs were lower. In some cases, initial costs might be higher because of the cost of green roofs, increased site preparation costs, or more expensive landscaping practices and plant species. However, in the vast majority of cases, significant savings were realized during the development and construction phases of the projects due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs.

EPA has identified several additional areas that will require further study. First, in all the cases, there were benefits that this study did not monetize and factor into the project's bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased number of total units developed, the value of increased marketing potential, and faster sales.

Second, more research is also needed to quantify the environmental benefits that can be achieved through the use of LID techniques and the costs that can be avoided by using these practices. For example, substantial downstream benefits can be realized through the reduction of the peak flows, discharge volumes, and pollutant loadings discharged from the site. Downstream benefits also might include reductions in flooding and channel degradation, costs for water quality improvements, costs of habitat restoration, costs of providing CSO abatement, property damage, drinking water treatment costs, costs of maintaining/dredging navigable waterways, and administrative costs for public outreach and involvement.

Finally, additional research is needed monetize the cost reductions that can be achieved through improved environmental performance, reductions in long-term operation and maintenance costs and/or reductions in the life cycle costs of replacing or rehabilitating infrastructure.

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identified practices seeks to maintain and use vegetation and open space, optimize natural hydrologic processes to reduce stormwater volumes and discharge rates, and use multiple treatment mechanisms to remove a large range of pollutants. In the context of this report, case studies ascribing to one of the above, or similar, labels were evaluated, and these terms are used interchangeably throughout the report.

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Resolution of the California Ocean Protection Council Regarding Low Impact Development

May 15, 2008, as amended

WHEREAS, ocean water quality is critical to the health of marine and coastal ecosystems; and

WHEREAS, ongoing, traditional development of California's watersheds continues to replace natural landscapes with impervious surfaces; roads and parking lots make up about half of all impervious surfaces; and

WHEREAS, runoff from urbanized areas contains and transports pollutants – including trash, heavy metals, oil and grease, fertilizers, and pathogens – to the ocean; and

WHEREAS, these pollutants contribute to beach closures, harmful algal blooms and reduced fish populations; and

WHEREAS, increased runoff from urbanized landscapes also erodes stream banks and damages habitat for fish and a wide variety of plants and animals; and

WHEREAS, polluted runoff impacts California's $46 billion, tourist-oriented, ocean-dependent economy; and

WHEREAS, rainwater is a valuable resource which should be conserved; and

WHEREAS, the Clean Water Act and Porter-Cologne Water Quality Control Act require that California reduce stormwater pollutant discharges from municipal storm drains, new developments and redevelopments, construction sites, Caltrans facilities, and industrial facilities; the Porter-Cologne Act also requires a California Ocean Plan for water quality regulation of ocean water, and prohibits waste discharges to Areas of Special Biological Significance (ASBS) which comprise one-third of the State's coastline; and

WHEREAS, the California Coastal Act requires that development in the coastal zone maintain and, where feasible, restore the biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes; and

WHEREAS, Low Impact Development (LID) is a stormwater management strategy aimed at maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements; LID employs a variety of natural and built features that reduce the rate of runoff, filter pollutants out of runoff, and facilitate the infiltration of water into the ground; and

WHEREAS, by reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and stabilize the flow rates of nearby streams; and

WHEREAS, LID design detains, treats and infiltrates runoff by minimizing impervious area, using pervious pavements and green roofs, dispersing runoff to landscaped areas, and routing runoff to rain gardens, cisterns, swales, and other small-scale facilities distributed throughout a site; and

WHEREAS, LID designs can alternatively, or in conjunction with the techniques set forth above, capture, retain, and treat stormwater for onsite reuse, such as for irrigating landscaping; and

WHEREAS, a recent U.S. Environmental Protection Agency report concluded that LID drainage designs can cost 15% to 80% *less* than more conventional drainage designs; other studies have shown LID facilities are less expensive to maintain than conventional stormwater treatment facilities; and

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WHEREAS, LID has also been shown to help reduce the frequency of combined sewer overflows, which plague at least one major California coastal community; and

WHEREAS, other states and federal government departments, including the Department of Defense, have been leaders in advancing LID implementation faster than California; and

WHEREAS, Caltrans should continue its efforts to lead in innovative stormwater design approaches; and

WHEREAS, some local governments are concerned that they lack sufficient funds to maintain and improve existing drainage infrastructure and fully implement stormwater pollution prevention programs; and

WHEREAS, in 2005, the Local Government Commission adopted the Ahwahnee Water Principles for Resource-Efficient Land Use, which state in relevant part that "community design should be compact, mixed use, walkable, and transit-oriented so that automobile-generated urban runoff pollutants are minimized and the open lands that absorb water are preserved to the maximum extent possible" and that "impervious surfaces such as driveways, streets and parking lots should be minimized so that land is available to absorb stormwater, reduce polluted urban runoff, recharge groundwater, and reduce flooding"; and

WHEREAS, the California Ocean Protection Act mandates that the Ocean Protection Council (OPC) – made up of the Secretaries for the Resources Agency and Cal/EPA, the chair of the State Lands Commission, one designee each from the California Senate and Assembly, and two public members appointed by the Governor – coordinate and improve the protection of California's ocean and coastal resources; and the Governor's Ocean Action Plan calls for the OPC to play a leadership role in managing and protecting California's oceans, bays, estuaries, and coastal wetlands, including integration of coastal water quality programs to increase their effectiveness.

NOW, *THEREFORE*, the California Ocean Protection Council hereby:

RESOLVES to promote the policy that new developments and redevelopments should be designed consistent with LID principles so that stormwater pollution and the peaks and durations of runoff are significantly reduced and, in the case of a new development, substantially the same as before development occurred on the site; and

RESOLVES to promote the retrofit of existing impervious areas throughout California with LID in all appropriate circumstances, and to support the Ahwahnee Water Principles for Resource-Efficient Land Use as described above; and

FINDS that LID is a practicable and superior approach that new and redevelopment projects can implement to minimize and mitigate increases in runoff and runoff pollutants and the resulting impacts on downstream uses, coastal resources and communities; and

RESOLVES to distribute this resolution widely, sending it to mayors, boards of supervisors, and appropriate agency managers of all coastal cities and counties and to appropriate federal agencies including resource protection agencies, the Army Corps of Engineers and the Department of Defense; and

FURTHER RESOLVES to advance LID implementation in California using the following approaches:

1. State Leadership

a. *State Government Leadership on LID* – For all state-funded (including bond-funded) development projects greater than one acre, LID should be considered to be the best

available technology standard for reducing pollutants from stormwater discharges. All existing State facilities should consider retrofitting to meet LID objectives, whenever feasible. The California Environmental Protection Agency (Cal/EPA) and the California Resources Agency should assemble the relevant boards and departments within their agencies to develop a set of LID standards to be used in development projects built with state funds, including bond funds.

b. *Department of Transportation (Caltrans)* – Caltrans is encouraged to continue to develop details and specifications for permeable pavements and other LID features and to incorporate LID where feasible in projects Caltrans funds or oversees, including local assistance programs. Caltrans should consider allocating a percentage of project budgets to the implementation of stormwater controls, with LID features as the highest priority. Caltrans should evaluate and revise as necessary any design standards which unnecessarily inhibit implementation of LID, such as street widths, required pavement and other materials, curb designs, and minimum parking requirements.

c. *Office of Planning and Research* – The Office of Planning and Research (OPR) is encouraged to provide technical guidance to public agencies to promote the use of LID consistent with stormwater National Pollution Discharge Elimination System (NPDES) standards and criteria. The guidance should be provided through an OPR technical advisory and revisions to the OPR guidance for preparation of local general plans, as appropriate. OPR is also encouraged to work with the Resources Agency to develop proposals for future CEQA Guideline amendments that encourage consideration of LID in the CEQA review process.

d. *Building Standards Commission* – The Building Standards Commission is encouraged to incorporate LID objectives and methods, and to incorporate or reference applicable NPDES permit criteria for stormwater treatment, flow control and use of LID in ongoing development of its Green Building Standards.

e. *Department of Water Resources* – The Department of Water Resources (DWR) is encouraged to provide incentives for LID implementation and habitat protection goals in its integrated regional water management (IRWM) and stormwater flood management funding programs to encourage watershed resource protection. The OPC encourages DWR to adopt language to include the fostering of LID as a Program Priority in their draft IRWM guidelines.

2. State Regulatory Actions

a. *State Water Board LID Policy* – The State Water Board is encouraged to adopt a statewide policy for addressing all elements associated with changes in runoff due to hydromodification impacts, including those specifically related to urbanization. This policy would include direction on when and how to use LID to avoid, minimize and mitigate runoff so that downstream water bodies are protected.

b. *NPDES Permit Requirements* – When crafting stormwater NPDES permit requirements, the State Water Board and Regional Water Boards should ensure that LID designs are utilized as the primary approach to satisfying post-construction runoff control requirements and that LID designs can be utilized to control pollutants and the rate and volume of runoff.

c. *LID Performance Evaluation and Monitoring* – Together with the Coastal Commission, the State Water Board is encouraged to conduct ongoing evaluation of the effectiveness

of their regulatory programs that promote LID (and other, similar approaches) implementation in regulated new development and redevelopment projects.

3. Incentives, Technical Support, and Research

The OPC will consider the following approaches, proposed by stakeholders and participants in public workshops sponsored by the OPC, to promote LID and to leverage funding with other agencies.

a. *Local Streets and Drainage Retrofits* – Encourage local governments to retrofit existing streets, highways, municipal parking lots, public buildings, and drainage systems with LID where feasible. Promote and consider funding research and technology transfer related to the retrofit of local facilities, including demonstration projects with interpretive displays and technical documentation of results.

b. *Technical Assistance to Local Government* – Promote and consider funding technical assistance for local agency public works, planning and engineering management and staff in the use of LID.

c. *Research and Development of LID* – Promote and consider funding technical research for development of a LID design manual, including example designs and specifications for LID features, and post-construction evaluations of the effectiveness of constructed LID features in removing pollutants and controlling runoff flows.

d. *Updating Local Development Policies* –Assist and consider funding for local governments to update standard details and specifications and other development policies to promote LID and remove barriers to LID.

e. *Local Incentives* – Promote local programs that provide incentives, including reduction of stormwater utility fees, to encourage the use of cisterns, rain gardens, and other LID strategies to retain runoff and, where feasible, reuse runoff for irrigation.

f. *Incentives for Stormwater Recharge* – Encourage water agencies to offer economic incentives for new regional and sub-regional stormwater recharge projects similar to incentives currently provided for water conservation and water reuse.

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Urban Stormwater Management in the United States

Committee on Reducing Stormwater Discharge Contributions to Water Pollution, National Research Council

ISBN: 0-309-12540-5, 610 pages, 6 x 9, (2008)

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Committee on Reducing Stormwater Discharge
Contributions to Water Pollution

Water Science and Technology Board

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Support for this project was provided by the U.S. Environmental Protection Agency under Award No. 68-C-03-081. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

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International Standard Book Number-13: 978-0-309-12539-0 (Book)
International Standard Book Number-10: 0-309-12539-1 (Book)
International Standard Book Number-13: 978-0-309-12540-6 (PDF)
International Standard Book Number-10: 0-309-12540-5 (PDF)
Library of Congress Control Number: 2008940395

Urban Stormwater Management in the United States is available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu. Cover photo courtesy of Roger Bannermann.

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Preface

Stormwater runoff from the built environment remains one of the great challenges of modern water pollution control, as this source of contamination is a principal contributor to water quality impairment of waterbodies nationwide. In addition to entrainment of chemical and microbial contaminants as stormwater runs over roads, rooftops, and compacted land, stormwater discharge poses a physical hazard to aquatic habitats and stream function, owing to the increase in water velocity and volume that inevitably result on a watershed scale as many individually managed sources are combined. Given the shift of the world's population to urban settings, and that this trend is expected to be accompanied by continued wholesale landscape alteration to accommodate population increases, the magnitude of the stormwater problem is only expected to grow.

In recognition of the need for improved control measures, in 1987 the U.S. Congress mandated the U.S. Environmental Protection Agency (EPA), under amendments to the Clean Water Act, to control certain stormwater discharges under the National Pollutant Discharge Elimination System. In response to this federal legislation, a permitting program was put in place by EPA as the Phase I (1990) and Phase II (1999) stormwater regulations, which together set forth requirements for municipal separate storm sewer systems and industrial activities including construction. The result of the regulatory program has been identification of hundreds of thousands of sources needing to be permitted, which has put a strain on EPA and state administrative systems for implementation and management. At the same time, achievement of water quality improvement as a result of the permit requirements has remained an elusive goal.

To address the seeming intractability of this problem, the EPA requested that the National Research Council (NRC) review its current permitting program for stormwater discharge under the Clean Water Act and provide suggestions for improvement. The broad goals of the study were to better understand the links between stormwater pollutant discharges and ambient water quality, to assess the state of the science of stormwater management, and to make associated policy recommendations. More specifically, the study was asked to:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent

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limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of best management practices (BMPs).

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

(5) Assess the design of the stormwater permitting program implemented under the Clean Water Act.

There are a number of related topics that one might expect to find in this report that are excluded, because EPA requested that the study be limited to problems addressed by the agency's stormwater regulatory program. Specifically, nonpoint source pollution from agricultural runoff, septic systems, combined sewer overflows, sanitary sewer overflows, and concentrated animal feeding operations are not addressed in this report. In addition, alteration of the urban base-flow hydrograph from a number of causes that are not directly related to storm events (e.g., interbasin transfers of water, leakage from water supply pipes, lawn irrigation, and groundwater withdrawals) is a topic outside the scope of the report and therefore not included in any depth.

In developing this report, the committee benefited greatly from the advice and input of EPA representatives, including Jenny Molloy, Linda Boornazian, and Mike Borst; representatives from the City of Austin; representatives from King County, Washington, and the City of Seattle; and representatives from the Irvine Ranch Water District. The committee heard presentations by many of these individuals in addition to Chris Crockett, City of Philadelphia Water Department; Pete LaFlamme and Mary Borg, Vermont Department of Environmental Conservation; Michael Barrett, University of Texas at Austin; Roger Glick, City of Austin; Michael Piehler, UNC Institute of Marine Sciences, Keith Stolzenbach, UCLA; Steve Burges, University of Washington; Wayne Huber, Oregon State University; Don Theiler, King County; Charlie Logue, Clean Water Services, Hillsboro, Oregon; Don Duke, Florida Gulf Coast University; Mike Stenstrom, UCLA; Gary Wolff, California Water Board; Paula Daniels, City of Los Angeles Public Works; Mark Gold, Heal the Bay; Geoff Brosseau, California Stormwater Quality Association; Steve Weisberg, Southern California Coastal Water Research Project; Chris Crompton, Southern California Stormwater Monitoring Coalition; David Beckman, NRDC; and Eric Strecker, Geosyntec. We also thank all those stakeholders who took time to

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share with us their perspectives and wisdom about the various issues affecting stormwater.

The committee was fortunate to have taken several field trips in conjunction with committee meetings. The following individuals are thanked for their participation in organizing and guiding these trips: Austin (Kathy Shay, Mike Kelly, Matt Hollon, Pat Hartigan, Mateo Scoggins, David Johns, and Nancy McClintock); Seattle (Darla Inglis, Chris May, Dan Powers, Scott Bawden, Nat Scholz, John Incardona, Kate McNeil, Bob Duffner, and Curt Crawford); and Los Angeles (Peter Postlmayr, Matthew Keces, Alan Bay, and Sat Tamaribuchi).

Completion of this report would not have been possible without the Herculean efforts of project study director Laura Ehlers. Her powers to organize, probe, synthesize, and keep the committee on track with completing its task were simply remarkable. Meeting logistics and travel arrangements were ably assisted by Ellen De Guzman and Jeanne Aquilino.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Michael Barrett, University of Texas; Bruce Ferguson, University of Georgia; James Heaney, University of Florida; Daniel Medina, CH2MHILL; Margaret Palmer, University of Maryland Chesapeake Biological Laboratory; Kenneth Potter, University of Wisconsin; Joan Rose, Michigan State University; Eric Strecker, Geosyntec; and Bruce Wilson, Minnesota Pollution Control Agency.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Michael Kavanaugh, Malcolm Pirnie, Inc., and Richard Conway, Union Carbide Corporation, retired. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and institution.

Claire Welty,
Committee Chair

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Summary

Urbanization is the changing of land use from forest or agricultural uses to suburban and urban areas. This conversion is proceeding in the United States at an unprecedented pace, and the majority of the country's population now lives in suburban and urban areas. The creation of impervious surfaces that accompanies urbanization profoundly affects how water moves both above and below ground during and following storm events, the quality of that stormwater, and the ultimate condition of nearby rivers, lakes, and estuaries.

The National Pollutant Discharge Elimination System (NPDES) program under the Clean Water Act (CWA) is the primary federal vehicle to regulate the quality of the nation's waterbodies. This program was initially developed to reduce pollutants from industrial process wastewater and municipal sewage discharges. These point sources were known to be responsible for poor, often drastically degraded conditions in receiving waterbodies. They were easily regulated because they emanated from identifiable locations, such as pipe outfalls. To address the role of stormwater in causing or contributing to water quality impairments, in 1987 Congress wrote Section 402(p) of the CWA, bringing stormwater control into the NPDES program, and in 1990 the U.S. Environmental Protection Agency (EPA) issued the Phase I Stormwater Rules. These rules require NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations over 100,000 and for runoff associated with industry, including construction sites five acres and larger. In 1999 EPA issued the Phase II Stormwater Rule to expand the requirements to small MS4s and construction sites between one and five acres in size.

With the addition of these regulated entities, the overall NPDES program has grown by almost an order of magnitude. EPA estimates that the total number of permittees under the stormwater program at any time exceeds half a million. For comparison, there are fewer than 100,000 non-stormwater (meaning wastewater) permittees covered by the NPDES program. To manage the large number of permittees, the stormwater program relies heavily on the use of general permits to control industrial, construction, and Phase II MS4 discharges. These are usually statewide, one-size-fits-all permits in which general provisions are stipulated.

To comply with the CWA regulations, industrial and construction permittees must create and implement a stormwater pollution prevention plan, and MS4 permittees must implement a stormwater management plan. These plans document the stormwater control measures (SCMs) (sometimes known as best management practices or BMPs) that will be used to prevent stormwater emanating from these sources from degrading nearby waterbodies. These SCMs range from structural methods such as detention ponds and bioswales to nonstructural methods such as designing new development to reduce the percentage of impervious surfaces.

A number of problems with the stormwater program as it is currently implemented have been recognized. First, there is limited information available on

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the effectiveness and longevity of many SCMs, thereby contributing to uncertainty in their performance. Second, the requirements for monitoring vary depending on the regulating entity and the type of activity. For example, a subset of industrial facilities must conduct "benchmark monitoring" and the results often exceed the values established by EPA or the states, but it is unclear whether these exceedances provide useful indicators of potential water quality problems. Finally, state and local stormwater programs are plagued by a lack of resources to review stormwater pollution prevention plans and conduct regular compliance inspections. For all these reasons, the stormwater program has suffered from poor accountability and uncertain effectiveness at improving the quality of the nation's waters.

In light of these challenges, EPA requested the advice of the National Research Council's Water Science and Technology Board on the federal stormwater program, considering all entities regulated under the program (i.e., municipal, industrial, and construction). The following statement of task guided the work of the committee:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of SCMs.

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

(5) Assess the design of the stormwater permitting program implemented under the CWA.

Chapter 2 of this report presents the regulatory history of stormwater control in the United States, focusing on relevant portions of the CWA and the federal and state regulations that have been created to implement the Act. Chapter 3 reviews the scientific aspects of stormwater, including sources of pollutants in stormwater, how stormwater moves across the land surface, and its impacts on receiving waters. Chapter 4 evaluates the current industrial and MS4 monitoring requirements, and it considers the multitude of models available for linking stormwater discharges to ambient water quality. Chapter 5 considers the vast

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suite of both structural and nonstructural measures designed to control stormwater and reduce its pollutant loading to waterbodies. In Chapter 6, the limitations and possibilities associated with a new regulatory approach are explored, as are those of a more traditional but enhanced scheme. This new approach, which rests on the broad foundation of correlative studies demonstrating the effects of urbanization on aquatic ecosystems, would reduce the impact of stormwater on receiving waters beyond any efforts currently in widespread practice.

THE CHALLENGE OF REGULATING STORMWATER

Although stormwater has been long recognized as contributing to water quality impairment, the creation of federal regulations to deal with stormwater quality has occurred only in the last 20 years. Because this longstanding environmental problem is being addressed so late in the development and management of urban areas, the laws that mandate better stormwater control are generally incomplete and are often in conflict with state and local rules that have primarily stressed the flood control aspects of stormwater management (i.e., moving water away from structures and cities as fast as possible). Many prior investigators have observed that stormwater discharges would ideally be regulated through direct controls on land use, strict limits on both the quantity and quality of stormwater runoff into surface waters, and rigorous monitoring of adjacent waterbodies to ensure that they are not degraded by stormwater discharges. Future land-use development would be controlled to minimize stormwater discharges, and impervious cover and volumetric restrictions would serve as proxies for stormwater loading from many of these developments. Products that contribute pollutants through stormwater—like de-icing materials, fertilizers, and vehicular exhaust—would be regulated at a national level to ensure that the most environmentally benign materials are used.

Presently, however, the regulation of stormwater is hampered by its association with a statute that focuses primarily on specific pollutants and ignores the volume of discharges. Also, most stormwater discharges are regulated on an individualized basis without accounting for the cumulative contributions from multiple sources in the same watershed. Perhaps most problematic is that the requirements governing stormwater dischargers leave a great deal of discretion to the dischargers themselves in developing stormwater pollution prevention plans and self-monitoring to ensure compliance. These problems are exacerbated by the fact that the dual responsibilities of land-use planning and stormwater management within local governments are frequently decoupled.

EPA's current approach to regulating stormwater is unlikely to produce an accurate or complete picture of the extent of the problem, nor is it likely to adequately control stormwater's contribution to waterbody impairment. The lack of rigorous end-of-pipe monitoring, coupled with EPA's failure to use flow or alternative measures for regulating stormwater, make it

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difficult for EPA to develop enforceable requirements for stormwater dischargers. Instead, the stormwater permits leave a great deal of discretion to the regulated community to set their own standards and to self-monitor. Current statistics on the states' implementation of the stormwater program, discharger compliance with stormwater requirements, and the ability of states and EPA to incorporate stormwater permits with Total Maximum Daily Loads are uniformly discouraging. Radical changes to the current regulatory program (see Chapter 6) appear necessary to provide meaningful regulation of stormwater dischargers in the future.

Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. These analogs for the traditional focus on the "discharge" of "pollutants" have great potential as a federal stormwater management tool because they provide specific and measurable targets, while at the same time they focus regulators on water degradation resulting from the increased volume as well as increased pollutant loadings in stormwater runoff. Without these more easily measured parameters for evaluating the contribution of various stormwater sources, regulators will continue to struggle with enormously expensive and potentially technically impossible attempts to determine the pollutant loading from individual dischargers or will rely too heavily on unaudited and largely ineffective self-reporting, self-policing, and paperwork enforcement.

EPA should engage in much more vigilant regulatory oversight in the national licensing of products that contribute significantly to stormwater pollution. De-icing chemicals, materials used in brake linings, motor fuels, asphalt sealants, fertilizers, and a variety of other products should be examined for their potential contamination of stormwater. Currently, EPA does not apparently utilize its existing licensing authority to regulate these products in a way that minimizes their contribution to stormwater contamination. States can also enact restrictions on or tax the application of pesticides or other particularly toxic products. Even local efforts could ultimately help motivate broader scale, federal restrictions on particular products.

The federal government should provide more financial support to state and local efforts to regulate stormwater. State and local governments do not have adequate financial support to implement the stormwater program in a rigorous way. At the very least, Congress should provide states with financial support for engaging in more meaningful regulation of stormwater discharges. EPA should also reassess its allocation of funds within the NPDES program. The agency has traditionally directed funds to focus on the reissuance of NPDES wastewater permits, while the present need is to advance the NPDES stormwater program because NPDES stormwater permittees outnumber wastewater permittees more than five fold, and the contribution of diffuse sources of pollution to degradation of the nation's waterbodies continues to increase.

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EFFECTS OF URBANIZATION ON WATERSHEDS

Urbanization causes change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture, or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a constructed drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed experience radically different flow regimes than prior to urbanization. Nearly all of the associated problems result from one underlying cause: loss of the water-retaining and evapotranspirating functions of the soil and vegetation in the urban landscape. In an undeveloped area, rainfall typically infiltrates into the ground surface or is evapotranspirated by vegetation. In the urban landscape, these processes of evapotranspiration and water retention in the soil are diminished, such that stormwater flows rapidly across the land surface and arrives at the stream channel in short, concentrated bursts of high discharge. This transformation of the hydrologic regime is a wholesale reorganization of the processes of runoff generation, and it occurs throughout the developed landscape. When combined with the introduction of pollutant sources that accompany urbanization (such as lawns, motor vehicles, domesticated animals, and industries), these changes in hydrology have led to water quality and habitat degradation in virtually all urban streams.

The current state of the science has documented the characteristics of stormwater runoff, including its quantity and quality from many different land covers, as well as the characteristics of dry weather runoff. In addition, many correlative studies show how parameters co-vary in important but complex and poorly understood ways (e.g., changes in macroinvertebrate or fish communities associated with watershed road density or the percentage of impervious cover). Nonetheless, efforts to create mechanistic links between population growth, land-use change, hydrologic alteration, geomorphic adjustments, chemical contamination in stormwater, disrupted energy flows and biotic interactions, and changes in ecological communities are still in development. Despite this assessment, there are a number of overarching truths that remain poorly integrated into stormwater management decision-making, although they have been robustly characterized for more than a decade and have a strong scientific basis that reaches even farther back through the history of published investigations.

There is a direct relationship between land cover and the biological condition of downstream receiving waters. The possibility for the highest levels of aquatic biological condition exists only with very light urban transformation of the landscape. Conversely, the lowest levels of biological condition are inevitable with extensive urban transformation of the landscape, commonly seen after conversion of about one-third to one-half of a contributing watershed into impervious area. Although not every degraded waterbody is a product of intense urban development, all highly urban watersheds produce severely degraded receiving waters.

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The protection of aquatic life in urban streams requires an approach that incorporates all stressors. Urban Stream Syndrome reflects a multitude of effects caused by altered hydrology in urban streams, altered habitat, and polluted runoff. Focusing on only one of these factors is not an effective management strategy. For example, even without noticeably elevated pollutant concentrations in receiving waters, alterations in their hydrologic regimes are associated with impaired biological condition. More comprehensive biological monitoring of waterbodies will be critical to better understanding the cumulative impacts of urbanization on stream condition.

The full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. Permanently increased stormwater volume is only one aspect of an urban-altered storm hydrograph. It contributes to high in-stream velocities, which in turn increase streambank erosion and accompanying sediment pollution of surface water. Other hydrologic changes, however, include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These all can affect both the physical and biological conditions of streams, lakes, and wetlands. Thus, effective hydrologic mitigation for urban development cannot just aim to reduce post-development peak flows to predevelopment peak flows.

Roads and parking lots can be the most significant type of land cover with respect to stormwater. They constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in these highly impervious areas, especially in regions of the country having mostly small rainfall events. As rainfall amounts become larger, pervious areas in most residential land uses become more significant sources of runoff, sediment, nutrients, and landscaping chemicals. In all cases, directly connected impervious surfaces (roads, parking lots, and roofs that are directly connected to the drainage system) produce the first runoff observed at a storm-drain inlet and outfall because their travel times are the quickest.

MONITORING AND MODELING

The stormwater monitoring requirements under the EPA Stormwater Program are variable and generally sparse, which has led to considerable skepticism about their usefulness. This report considers the amount and value of the data collected over the years by municipalities (which are substantial on a nationwide basis) and by industries, and it makes suggestions for improvement. The MS4 and particularly the industrial stormwater monitoring programs suffer from a paucity of data, from inconsistent sampling techniques, and from requirements

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that are difficult to relate to the compliance of individual dischargers. For these reasons, conclusions about stormwater management are usually made with incomplete information. Stormwater management would benefit most substantially from a well-balanced monitoring program that encompasses chemical, biological, and physical parameters from outfalls to receiving waters.

Many processes connect sources of pollution to an effect observed in a downstream receiving water—processes that can be represented in watershed models, which are the key to linking stormwater dischargers to impaired receiving waters. The report explores the current capability of models to make such links, including simple models and more involved mechanistic models. At the present time, stormwater modeling has not evolved enough to consistently say whether a particular discharger can be linked to a specific waterbody impairment. Some quantitative predictions can be made, particularly those that are based on well-supported causal relationships of a variable that responds to changes in a relatively simple driver (e.g., modeling how a runoff hydrograph or pollutant loading change in response to increased impervious land cover). However, in almost all cases, the uncertainty in the modeling and the data (including its general unavailability), the scale of the problems, and the presence of multiple stressors in a watershed make it difficult to assign to any given source a specific contribution to water quality impairment.

Because of a 10-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized. These results come from many thousands of storm events, systematically compiled and widely accessible; they form a robust dataset of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate stormwater pollutant concentrations from various land uses. Additional data are available from other stormwater permit holders that were not originally included in the database and from ongoing projects, and these should be acquired to augment the database and improve its value in stormwater management decision-making.

Industry should monitor the quality of stormwater discharges from certain critical industrial sectors in a more sophisticated manner, so that permitting authorities can better establish benchmarks and technology-based effluent guidelines. Many of the benchmark monitoring requirements and effluent guidelines for certain industrial subsectors are based on inaccurate and old information. Furthermore, there has been no nationwide compilation and analysis of industrial benchmark data, as has occurred for MS4 monitoring data, to better understand typical stormwater concentrations of pollutants from various industries.

Continuous, flow-weighted sampling methods should replace the traditional collection of stormwater data using grab samples. Data obtained from too few grab samples are highly variable, particularly for industrial monitoring

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programs, and subject to greater uncertainly because of experimenter error and poor data-collection practices. In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications. It should be replaced by more accurate and frequent continuous sampling methods that are flow weighted. Flow-weighted composite monitoring should continue for the duration of the rain event. Emerging sensor systems that provide high temporal resolution and real-time estimates for specific pollutants should be further investigated, with the aim of providing lower costs and more extensive monitoring systems to sample both streamflow and constituent loads.

Watershed models are useful tools for predicting downstream impacts from urbanization and designing mitigation to reduce those impacts, but they are incomplete in scope and do not offer definitive causal links between polluted discharges and downstream degradation. Every model simulates only a subset of the multiple interconnections between physical, chemical, and biological processes found in any watershed, and they all use a grossly simplified representation of the true spatial and temporal variability of a watershed. To speak of a "comprehensive watershed model" is thus an oxymoron, because the science of stormwater is not sufficiently far advanced to determine causality between all sources, resulting stressors, and their physical, chemical, and biological responses. Thus, it is not yet possible to create a protocol that mechanistically links stormwater dischargers to the quality of receiving waters. The utility of models with more modest goals, however, can still be high—as long as the questions being addressed by the model are in fact relevant and important to the functioning of the watershed to which that model is being applied, and sufficient data are available to calibrate the model for the processes included therein.

STORMWATER MANAGEMENT APPROACHES

A fundamental component of EPA's stormwater program is the creation of stormwater pollution prevention plans that document the SCMs that will be used to prevent the permittee's stormwater discharges from degrading local waterbodies. Thus, a consideration of these measures—their effectiveness in meeting different goals, their cost, and how they are coordinated with one another—is central to any evaluation of the stormwater program. The statement of task asks for an evaluation of the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality. Although the state of knowledge has yet to reveal the mechanistic links that would allow for a full assessment of that relationship, enough is known to design systems of SCMs, on a site-scale or local watershed scale, that can substantially reduce the effects of urbanization.

The characteristics, applicability, goals, effectiveness, and cost of nearly 20 different broad categories of SCMs to treat the quality and quantity of stormwa-

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ter runoff are discussed in Chapter 5, organized as they might be applied from the rooftop to the stream. SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. A multitude of case studies illustrates the use of SCMs in specific settings and demonstrates that a particular SCM can have a measurable positive effect on water quality or a biological metric. However, the implementation of SCMs at the watershed scale has been too inconsistent and too recent to be able to definitively link their performance to the prolonged sustainment—at the watershed level—of receiving water quality, in-stream habitat, or stream geomorphology.

Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds. SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.

Nonstructural SCMs such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.

SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the “first flush” of contaminants. SCMs designed to remove this class of storms from surface runoff (runoff-volume-reduction SCMs—rainwater harvesting, vegetated, and subsurface) can also help address larger watershed flooding issues.

Performance characteristics are starting to be established for most structural and some nonstructural SCMs, but additional research is needed on the relevant hydrologic and water quality processes within SCMs across

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different climates and soil conditions. Typical data such as long-term load reduction efficiencies and pollutant effluent concentrations can be found in the International Stormwater BMP Database. However, understanding the processes involved in each SCM is in its infancy, making modeling of these SCMs difficult. Seasonal differences, the time between storms, and other factors all affect pollutant loadings emanating from SCMs. Research is needed that moves away from the use of percent removal and toward better simulation of SCM performance. Research is particularly important for nonstructural SCMs, which in many cases are more effective, have longer life spans, and require less maintenance than structural SCMs. EPA should be a leader in SCM research, both directly by improving its internal modeling efforts and by funding state efforts to monitor and report back on the success of SCMs in the field.

The retrofitting of urban areas presents both unique opportunities and challenges. Promoting growth in these areas is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, it is more complex than Greenfields development because of the need to upgrade existing infrastructure, the limited availability and affordability of land, and the complications caused by rezoning. These sites may be contaminated, requiring cleanup before redevelopment can occur. Both innovative zoning and development incentives, along with the careful selection SCMs, are needed to achieve fair and effective storm-water management in these areas. For example, incentive or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Publicly owned, consolidated SCMs should be strongly considered as there may be insufficient land to have small, on-site systems. The performance and maintenance of the former can be overseen more effectively by a local government entity. The types of SCMs that are used in consolidated facilities—particularly detention basins, wet/dry ponds, and stormwater wetlands—perform multiple functions, such as prevention of streambank erosion, flood control, and large-scale habitat provision.

INNOVATIVE STORMWATER MANAGEMENT AND REGULATORY PERMITTING

There are numerous innovative regulatory strategies that could be used to improve the EPA's stormwater program. The course of action most likely to check and reverse degradation of the nation's aquatic resources would be to **base all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries.** Watershed-based permitting is the regulated allowance of discharges of water and wastes borne by those discharges to waters of the United States, with due consideration of: (1) the implications of those discharges for preservation or improvement of prevailing ecological conditions in the watershed's aquatic systems, (2) cooperation among political ju-

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risdictions sharing a watershed, and (3) coordinated regulation and management of all discharges having the potential to modify the hydrology and water quality of the watershed's receiving waters.

Responsibility and authority for implementation of watershed-based permits would be centralized with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees. Permitting authorities (designated states or, otherwise, EPA) would adopt a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses in the watershed's component waterbodies and additional goals in some cases aimed at recovering lost beneficial uses. Permittees, with support by the states or EPA, would then move to comprehensive impact source analysis as a foundation for targeting solutions. The most effective solutions are expected to lie in isolating, to the extent possible, receiving waterbodies from exposure to those impact sources. In particular, low-impact design methods, termed Aquatic Resources Conservation Design in this report, should be employed to the fullest extent feasible and backed by conventional SCMs when necessary.

The approach gives municipal co-permittees more responsibility, with commensurately greater authority and funding, to manage all of the sources discharging, directly or through municipally owned conveyances, to the waterbodies comprising the watershed. This report also outlines a new monitoring program structured to assess progress toward meeting objectives and the overlying goals, diagnosing reasons for any lack of progress, and determining compliance by dischargers. The proposal further includes market-based trading of credits among dischargers to achieve overall compliance in the most efficient manner and adaptive management to determine additional actions if monitoring demonstrates failure to achieve objectives.

As a first step to taking the proposed program nationwide, a pilot program is recommended that will allow EPA to work through some of the more predictable impediments to watershed-based permitting, such as the inevitable limits of an urban municipality's authority within a larger watershed.

Short of adopting watershed-based permitting, other smaller-scale changes to the EPA stormwater program are possible. These recommendations do not preclude watershed-based permitting at some future date, and indeed they lay the groundwork in the near term for an eventual shift to watershed-based permitting.

Integration of the three permitting types is necessary, such that construction and industrial sites come under the jurisdiction of their associated municipalities. Federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect

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water quality. The National Pretreatment Program, EPA's successful treatment program for municipal and industrial wastewater sources, could serve as a model for integration.

To improve the industrial, construction, and MS4 permitting programs in their current configuration, EPA should (1) issue guidance for MS4, industrial, and construction permittees on what constitutes a design storm for water quality purposes; (2) issue guidance for MS4 permittees on methods to identify high-risk industrial facilities for program prioritization such as inspections; (3) support the compilation and collection of quality industrial stormwater effluent data and SCM effluent quality data in a national database; and (4) develop numerical expressions of the MS4 standard of "maximum extent practicable." Each of these issues is discussed in greater detail in Chapter 6.

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Watershed-based permitting will require additional resources and regulatory program support. Such an approach shifts more attention to ambient outcomes as well as expanded permitting coverage. Additional resources for program implementation could come from shifting existing programmatic resources. For example, some state permitting resources may be shifted away from existing point source programs toward stormwater permitting. Strategic planning and prioritization could shift the distribution of federal and state grant and loan programs to encourage and support more watershed-based stormwater permitting programs. However, securing new levels of public funds will likely be required. All levels of government must recognize that additional resources may be required from citizens and businesses (in the form of taxes, fees, etc.) in order to operate a more comprehensive and effective stormwater permitting program.

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1
Introduction

URBANIZATION AND ITS IMPACTS

The influence of humans on the physical and biological systems of the Earth's surface is not a recent manifestation of modern societies; instead, it is ubiquitous throughout our history. As human populations have grown, so has their footprint, such that between 30 and 50 percent of the Earth's surface has now been transformed (Vitousek et al., 1997). Most of this land area is not covered with pavement; indeed, less than 10 percent of this transformed surface is truly "urban" (Grübler, 1994). However, urbanization causes extensive changes to the land surface beyond its immediate borders, particularly in ostensibly rural regions, through alterations by agriculture and forestry that support the urban population (Lambin et al., 2001). Within the immediate boundaries of cities and suburbs, the changes to natural conditions and processes wrought by urbanization are among the most radical of any human activity.

In the United States, population is growing at an annual rate of 0.9 percent (U.S. Census Bureau, *http://www.census.gov/compendia/statab/2007edition.html*); the majority of the population of the United States now lives in suburban and urban areas (Figure 1-1). Because the area appropriated for urban land uses is growing even faster, these patterns of growth all but guarantee that the influences of urban land uses will continue to expand over time. Cities and suburbia obviously provide the homes and livelihood for most of the nation's population. But, as this report makes clear, these benefits have been accompanied by significant environmental change. Urbanization of the landscape profoundly affects how water moves both above and below ground during and following storm events; the quality of that stormwater (defined in Box 1-1); and the ultimate condition of nearby rivers, lakes, and estuaries. Unlike agriculture, which can display significant interchange with forest cover over time scales of a century (e.g., Hart, 1968), there is no indication that once-urbanized land ever returns to a less intensive state. Urban land, however, does continue to change over time; by one estimate, 42 percent of land currently considered "urban" in the United States will be redeveloped by 2030 (Brookings Institute, 2004). In their words, "nearly half of what will be the built environment in 2030 doesn't even exist yet" (p. vi). This truth belies the common belief that efforts to improve management of stormwater are doomed to irrelevancy because so much of the landscape is already built. Opportunities for improvement have indeed been lost, but many more still await an improved management approach.

Measures of urbanization are varied, and the disparate methods of quantifying the presence and influence of human activity tend to confound analyses of environmental effects. Population density is a direct metric of human presence, but it is not the most relevant measure of the influence of those people on their surrounding landscape. Expressions of the built environment, most commonly

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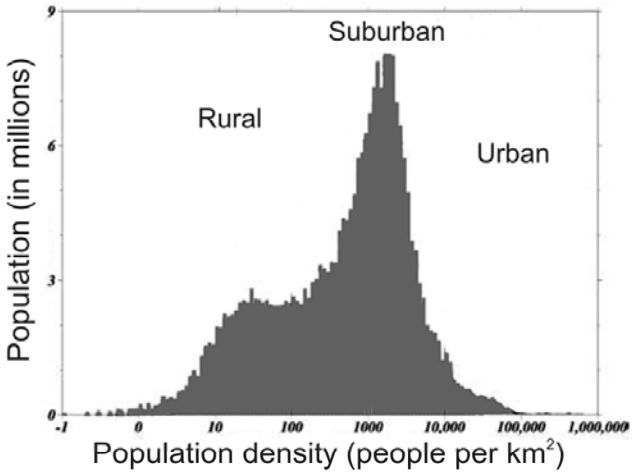

FIGURE 1-1 Histogram of population for the United States, based on 2000 census data. The median population density is about 1,000 people/km^2. SOURCE: Modified from Pozzi and Small (2005), who place the rural–suburban boundary at 100 people/km^2. Reprinted, with permission, from ASPRS (2005). Copyright 2005 by the American Society for Photogrammetry and Remote Sensing.

BOX 1-1
What Is "Stormwater"?

"Stormwater" is a term that is used widely in both scientific literature and regulatory documents. It is also used frequently throughout this report. Although all of these usages share much in common, there are important differences that benefit from an explicit discussion.

Most broadly, stormwater runoff is the water associated with a rain or snow storm that can be measured in a downstream river, stream, ditch, gutter, or pipe shortly after the precipitation has reached the ground. What constitutes "shortly" depends on the size of the watershed and the efficiency of the drainage system, and a number of techniques exist to precisely separate stormwater runoff from its more languid counterpart, "baseflow." For small and highly urban watersheds, the interval between rainfall and measured stormwater discharges may be only a few minutes. For watersheds of many tens or hundreds of square miles, the lag between these two components of storm response may be hours or even a day.

From a regulatory perspective, stormwater must pass through some sort of engineered conveyance, be it a gutter, a pipe, or a concrete canal. If it simply runs over the ground surface, or soaks into the soil and soon reemerges as seeps into a nearby stream, it may be water generated by the storm but it is not regulated stormwater.

This report emphasizes the first, more hydrologically oriented definition. However, attention is focused mainly on that component of stormwater that emanates from those parts of a landscape that have been affected in some fashion by human activities ("urban stormwater"). Mostly this includes water that flows over the ground surface and is subsequently collected by natural channels or artificial conveyance systems, but it can also include water that has infiltrated into the ground but nonetheless reaches a stream channel relatively rapidly and that contributes to the increased stream discharge that commonly accompanies almost any rainfall event in a human-disturbed watershed.

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road density or pavement coverage as a percentage of gross land area, are more likely to determine stormwater runoff-related consequences. An inverse metric, the percentage of mature vegetation or forest across a landscape, expresses the magnitude of related, but not identical, impacts to downstream systems. Alternatively, these measures of land cover can be replaced by measures of land use, wherein the types of human activity (e.g., residential, industrial, commercial) are used as proxies for the suite of hydrologic, chemical, and biological changes imposed on the surrounding landscape.

All of these metrics of urbanization are strongly correlated, although none can directly substitute for another. They also are measured differently, which renders one or another more suitable for a given application. Land use is a common measure in the realm of urban planning, wherein current and future conditions for a city or an entire region are characterized using equivalent categories across parcels, blocks, or broad regions. Road density can be reliably and rapidly measured, either manually or in a Geographic Information System environment, and it commonly displays a very good correlation with other measures of human activity. "Land cover," however, and particularly the percentage of impervious cover, is the metric most commonly used in studying the effects of urban development on stormwater, because it clearly expresses the hydrologic influence and watershed scale of urbanization. Box 1-2 describes the ways in which the percent of impervious cover in a watershed is measured.

There is no universally accepted terminology to describe land-cover or land-use conditions along the rural-to-urban gradient. Pozzi and Small (2005), for example, identified "rural," "suburban," and "urban" land uses on the basis of population density and vegetation cover, but they did not observe abrupt transitions that suggested natural boundaries (see Figure 1-1). In contrast, the Center for Watershed Protection (2005) defined the same terms but used impervious area percentage as the criterion, with such labels as "rural" (0 to 10 percent imperviousness), "suburban" (10 to 25 percent imperviousness), "urban" (25 to 60 percent imperviousness) and "ultra-urban" (greater than 60 percent imperviousness).

Beyond the problems posed by precise yet inconsistent definitions for commonly used words, none of the boundaries specified by these definitions are reflected in either hydrologic or ecosystem responses. Hydrologic response is strongly dependent on both land cover and drainage connectivity (e.g., Leopold, 1968); ecological responses in urbanizing watersheds do not show marked thresholds along an urban gradient (e.g., Figure 1-2) and they are dependent on not only the sheer magnitude of urban development but also the spatial configuration of that development across the watershed (Alberti et al., 2006). This report, therefore, uses such terms as "urban" and "suburban" under their common usage, without implying or advocating for a more precise (but ultimately limited and discipline-specific) definition.

Changing land cover and land use influence the physical, chemical, and biological conditions of downstream waterways. The specific mechanisms by which this influence occurs vary from place to place, and even a cursory review

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BOX 1-2
Measures of Impervious Cover

The percentage of impervious surface or cover in a landscape is the most frequently used measure of urbanization. Yet this parameter has its limitations, in part because it has not been consistently used or defined. Most significant is the distinction between ***total*** impervious area (TIA) and ***effective*** impervious area (EIA). TIA is the "intuitive" definition of imperviousness: that fraction of the watershed covered by constructed, non-infiltrating surfaces such as concrete, asphalt, and buildings. Hydrologically, however, this definition is incomplete for two reasons. First, it ignores nominally "pervious" surfaces that are sufficiently compacted or otherwise so low in permeability that the rate of runoff from them is similar or indistinguishable from pavement. For example, Burges and others (1998) found that the impervious unit-area runoff was only 20 percent greater than that from pervious areas—primarily thin sodded lawns over glacial till—in a western Washington residential subdivision. Clearly, this hydrologic contribution cannot be ignored entirely.

The second limitation of TIA is that it includes some paved surfaces that may contribute nothing to the stormwater-runoff response of the downstream channel. A gazebo in the middle of parkland, for example, probably will impose no hydrologic changes into the catchment except for a very localized elevation of soil moisture at the edge of its roof. Less obvious, but still relevant, would be the different downstream consequences of rooftops that drain alternatively into a piped storm-drain system with direct discharge into a natural stream or onto splash blocks that disperse the runoff onto the garden or lawn at each corner of the building. This metric therefore cannot recognize any stormwater mitigation that may result from alternative runoff-management strategies, for example, pervious pavements or rainwater harvesting.

The first of these TIA limitations, the production of significant runoff from nominally pervious surfaces, is typically ignored in the characterization of urban development. The reason for such an approach lies in the difficulty in identifying such areas and estimating their contribution, and because of the credible belief that the degree to which pervious areas shed water as overland flow should be related, albeit imperfectly, with the amount of *impervious* area: where construction and development are more intense and cover progressively greater fractions of the

of the literature demonstrates that many different factors can be important, such as changes to flow regime, physical and chemical constituents in the water column, or the physical form of the stream channel itself (Paul and Meyer, 2001). Not all of these changes are present in any given system—lakes, wetlands, and streams can be altered by human activity in many different ways, each unique to the activity and the setting in which it occurs. Nonetheless, direct influences of land-use change on freshwater systems commonly include the following (Naiman and Turner, 2000):

- Altering the composition and structure of the natural flora and fauna,
- Changing disturbance regimes,
- Fragmenting the land into smaller and more diverse parcels, and
- Changing the juxtaposition between parcel types.

Historically, human-induced alteration was not universally seen as a problem. In particular, dams and other stream-channel "improvements" were a

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watershed, it is more likely that the intervening green spaces have been stripped and compacted during construction and only imperfectly rehabilitated for their hydrologic functions during subsequent "landscaping."

The second of these TIA limitations, inclusion of non-contributing impervious areas, is formally addressed through the concept of EIA, defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream) system. Thus, any part of the TIA that drains onto pervious (i.e., "green") ground is excluded from the measurement of EIA. This parameter, at least conceptually, captures the hydrologic significance of imperviousness. EIA is the parameter normally used to characterize urban development in hydrologic models.

The direct measurement of EIA is complicated. Studies designed specifically to quantify this parameter must make direct, independent measurements of both TIA and EIA (Alley and Veenhuis, 1983; Laenen, 1983; Prysch and Ebbert, 1986). The results can then be generalized either as a correlation between the two parameters or as a "typical" value for a given land use. Sutherland (1995) developed an equation that describes the relationship between EIA and TIA. Its general form is:

$$EIA = A\ (TIA)^B$$

where A and B are a unique combination of numbers that satisfy the following criteria:

TIA = 1 then EIA = 0%
TIA = 100 then EIA = 100%

A commonly used version of this equation ($EIA = 0.15\ TIA^{1.41}$) was based on samples from highly urbanized land uses in Denver, Colorado (Alley and Veenhuis, 1983; Gregory et al., 2005). These results, however, are almost certainly region- and even neighborhood-specific, and, although highly relevant to watershed studies, they can be quite laborious to develop.

common activity of municipal and federal engineering works of the mid-20th century (Williams and Wolman, 1984). "Flood control" implied a betterment of conditions, at least for streamside residents (Chang, 1992). And fisheries "enhancements," commonly reflected by massive infrastructure for hatcheries or artificial spawning channels, were once seen as unequivocal benefits for fish populations (White, 1996; Levin et al., 2001).

By almost any currently applied metric, however, the net result of human alteration of the landscape to date has resulted in a degradation of the conditions in downstream watercourses. Many prior researchers, particularly when considering ecological conditions and metrics, have recognized a crude but monotonically declining relationship between human-induced landscape alteration and downstream conditions (e.g., Figure 1-2; Horner et al., 1997; Davies and Jackson, 2006). These include metrics of physical stream-channel conditions (e.g., Bledsoe and Watson, 2001), chemical constituents (e.g., Figure 1-3; House et al., 1993), and biological communities (e.g., Figure 1-4; Steedman, 1988; Wang et al., 1997).

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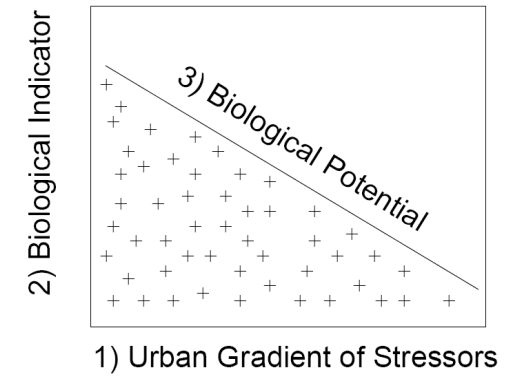

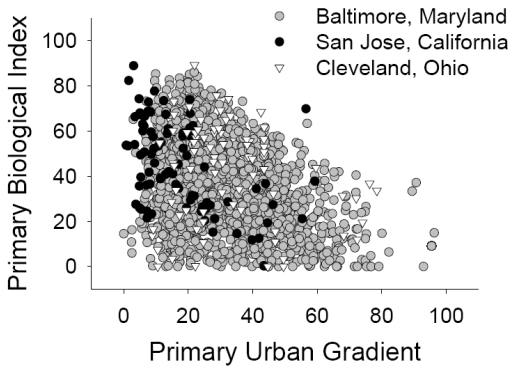

FIGURE 1-2 Conceptual model (top) and actual response (bottom) of a biological system's response to stress. The "Urban Gradient of Stressors" might be a single metric of urbanization, such as percent watershed impervious or road density; the "Biological Indicator" may be single-metric or multi-metric measures of the level of disturbance in an aquatic community. The right-declining line traces the limits of a "factor-ceiling distribution" (Thomson et al., 1986), wherein individual sites (i.e., data points) have a wide range of potential values for a given position along the urban gradient but are not observed above a maximum possible limit of the biological index. The bottom graph illustrates actual biological responses, using a biotic index developed to show responses to urban impacts plotted against a standardized urban gradient comprising urban land use, road density, and population. SOURCE: Top figure reprinted, with permission, from Davies and Jackson (2006). Copyright by the Ecological Society of America. Bottom figure reprinted, with permission, from Barbour et al. (2006). Copyright by the Water Environment Research Foundation.

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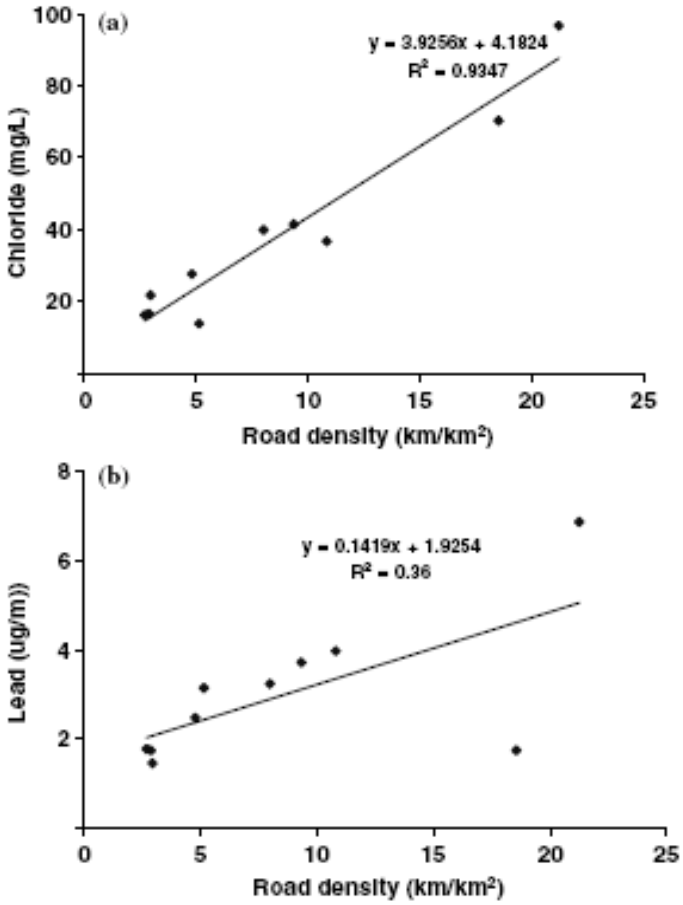

FIGURE 1-3 Example relationships between road density (a surrogate measure of urban development) and common water quality constituents. Direct causality is not necessarily implied by such relationships, but the monotonic increase in concentrations with increasing "urbanization," however measured, is near-universal. SOURCE: Reprinted, with permission, from Chang and Carlson (2005). Copyright 2005 by Springer.

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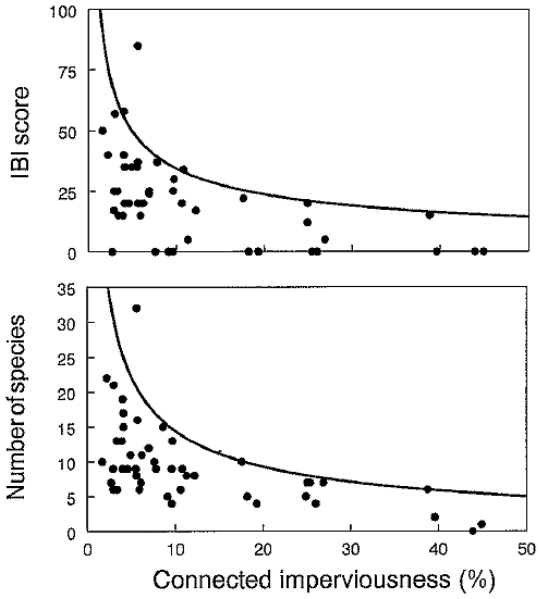

FIGURE 1-4 Plots of Effective Impervious Area (EIA, or "connected imperviousness") against metrics of biologic response in fish populations. SOURCE: Reprinted, with permission, from Wang et al. (2001). Copyright 2001 by Springer.

The association between watercourse degradation and landscape alteration in general, and urban development in particular, seems inexorable. The scientific and regulatory challenge of the last three decades has been to decouple this relationship, in some cases to reverse its trend and in others to manage where these impacts are to occur.

WHAT'S WRONG WITH THE NATION'S WATERS?

Since passage of the Water Quality Act of 1948 and the Clean Water Act (CWA) of 1972, 1977, and 1987, water quality in the United States has measurably improved in the major streams and rivers and in the Great Lakes. However, substantial challenges and problems remain. Major reporting efforts that have examined state and national indicators of condition, such as CWA 305(b) reports (EPA, 2002) and the Heinz State of the Nation's Ecosystem report (Heinz Center, 2002), or environmental monitoring that was designed to provide statistically valid estimates of condition (e.g., National Wadeable Stream Assessment; EPA, 2006), have confirmed widespread impairments related to diffuse sources of pollution and stressors.

The National Water Quality Inventory (derived from Section 305b of the CWA) compiles data in relation to use designations and water quality standards.

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As discussed in greater detail in Chapter 2, such standards include both (1) a description of the use that a waterbody is supposed to achieve (such as a source of drinking water or a cold water fishery) and (2) narrative or numeric criteria for physical, chemical, and biological parameters that allow the designated use to be achieved. As of 2002, 45 percent of assessed streams and rivers, 47 percent of assessed lakes, 32 percent of assessed estuarine areas, 17 percent of assessed shoreline miles, 87 percent of near-coastal ocean areas, 51 percent of assessed wetlands, 91 percent of assessed Great Lakes shoreline miles, and 99 percent of assessed Great Lakes open water areas were not meeting water quality standards set by the states (2002 EPA Report to Congress).[1]

The U.S. Environmental Protection Agency (EPA) has also embarked on a five-year statistically valid survey of the nation's waters (http://www.epa.gov/owow/monitoring/guide.pdf). To date, two waterbody types—coastal areas and wadeable streams—have been assessed. The most recent data indicate that 42 percent of wadeable streams are in poor biological condition and 25 percent are in fair condition (EPA, 2006). The overall condition of the nation's estuaries is generally fair, with Puerto Rico and Northeast Coast regions rated poor, the Gulf Coast and West Coast regions rated fair, and the Southeast Coast region rated good to fair (EPA, 2007). These condition ratings for the National Estuary Program are based on a water quality index, a sediment quality index, a benthic index, and a fish tissue contaminants index.

The impairment of waterbodies is manifested in a multitude of ways. Indeed, EPA's primary process for reporting waterbody condition (Section 303(d) of the CWA—see Chapter 2) identifies over 200 distinct types of impairments. As shown in Table 1-1, these have been categorized into 15 broad categories, encompassing about 94 percent of all impairments. 59,515 waterbodies fall into one of the top 15 categories, while the total reported number of waterbodies impaired from all causes is 63,599 (which is an underestimate of the actual total because not all waterbodies are assessed). Mercury, microbial pathogens, sediments, other metals, and nutrients are the major pollutants associated with impaired waterbodies nationwide. These constituents have direct impacts on aquatic ecosystems and public health, which form the basis of the water quality standards set for these compounds. Sediments can harm fish and macroinvertebrate communities by introducing sorbed contaminants, decreasing available light in streams, and smothering fish eggs. Microbial pathogens can cause disease to humans via both ingestion and dermal contact and are frequently cited as the cause of beach closures and other recreational water hazards in lakes and estuaries. Nutrient over-enrichment can promote a cascade of events in waterbodies from algal blooms to decreases in dissolved oxygen and associated fish kills. Metals like mercury, pesticides, and other organic compounds that enter

[1] EPA does not yet have the 2004 assessment findings compiled in a consistent format from all the states. EPA is also working on processing the states 2006 Integrated Reports as the 303(d) portions are approved and the states submit their final assessment findings. Susan Holdsworth, EPA, personal communication, September 2007.

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waterways can be taken up by fish species, accumulating in their tissues and presenting a health risk to organisms (including humans) that consume the fish.

However, Table 1-1 can be misleading if it implies that degraded *water quality* is the primary metric of impairment. In fact, many of the nation's streams, lakes, and estuaries also suffer from fundamental changes in their flow regime and energy inputs, alteration of aquatic habitats, and resulting disruption of biotic interactions that are not easily measured via pollutant concentrations. Such waters may not be listed on State 303(d) lists because of the absence of a corresponding water quality standard that would directly indicate such conditions (like a biocriterion). Figure 1-5A, B, and C show examples of such impacted waterbodies.

TABLE 1-1 Top 15 Categories of Impairment Requiring CWA Section 303(d) Action

Cause of Impairment	Number of Waterbodies	Percent of the Total
Mercury	8,555	14%
Pathogens	8,526	14%
Sediment	6,689	11%
Metals (other than mercury)	6,389	11%
Nutrients	5,654	10%
Oxygen depletion	4,568	8%
pH	3,389	6%
Cause unknown - biological integrity	2,866	5%
Temperature	2,854	5%
Habitat alteration	2,220	4%
PCBs	2,081	3%
Turbidity	2,050	3%
Cause unknown	1,356	2%
Pesticides	1,322	2%
Salinity/TDS/chlorides	996	2%

Note: "Waterbodies" refers to individual river segments, lakes, and reservoirs. A single waterbody can have multiple impairments. Because most waters are not assessed, however, there is no estimate of the number of unimpaired waters in the United States. SOURCE: EPA, National Section 303(d) List Fact Sheet (http://iaspub.epa.gov/waters/national_rept.control). The data are based on three-fourths of states reporting from 2004 lists, with the remaining from earlier lists and one state from a 2006 list.

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FIGURE 1-5A Headwater tributary in Philadelphia suffering from Urban Stream Syndrome. SOURCE: Courtesy of Chris Crockett, Philadelphia Water Department.

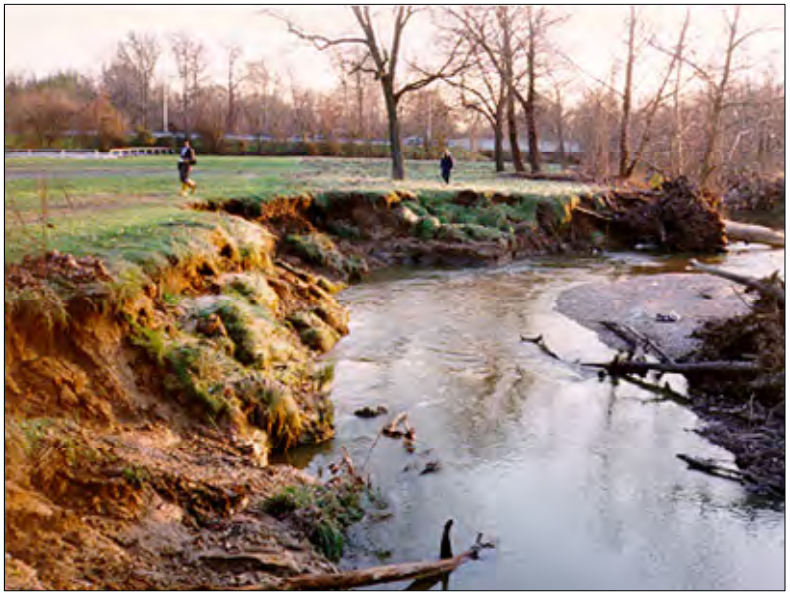

FIGURE 1-5B A destabilized stream in Vermont. SOURCE: Courtesy of Pete LaFlamme, Vermont Department of Environmental Conservation.

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FIGURE 1-5C An urban stream, the Lower Oso Creek in Orange County, California, following a storm event. Oso Creek was formerly an ephemeral stream, but heavy development in the contributing watershed has created perennial flow—stormwater flow during wet weather and minor wastewater discharges and authorized non-stormwater discharges such as landscape irrigation runoff during dry weather. Courtesy of Eric Stein, Southern California Coastal Research Water Project.

Over the years, the greatest successes in improving the nation's waters have been in abating the often severe impairments caused by municipal and industrial point source discharges. The pollutant load reductions required of these facilities have been driven by the National Pollutant Discharge Elimination System (NPDES) permit requirements of the CWA (see Chapter 2). Although the majority of these sources are now controlled, further declines in water quality remain likely if the land-use changes that typify more diffuse sources of pollution are not addressed (Palmer and Allan, 2006). These include land-disturbing agricultural, silvicultural, urban, industrial, and construction activities from which hard-to-monitor pollutants emerge during wet-weather events. Pollution from these landscapes has been almost universally acknowledged as the most pressing challenge to the restoration of waterbodies and aquatic ecosystems nationwide. All population and development forecasts indicate a continued worsening of the environmental conditions caused by diffuse sources of pollution under the nation's current growth and land-use trajectories.

Recognition of urban stormwater's role in the degradation of the nation's waters is but the latest stage in the history of this byproduct of the human envi-

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ronment. Runoff conveyance systems have been part of cities for centuries, but they reflected only the desire to remove water from roads and walkways as rapidly and efficiently as possible. In some arid environments, rainwater has always been collected for irrigation or drinking; elsewhere it has been treated as an unmetered, and largely benign, waste product of cities. Minimal (unengineered) ditches or pipes drained developed areas to the nearest natural watercourse. Where more convenient, stormwater shared conveyance with wastewater, eliminating the cost of a separate pipe system but commonly resulting in sewage overflows during rainstorms. Recognition of downstream flooding that commonly resulted from upstream development led to construction of stormwater storage ponds or vaults in many municipalities in the 1960s, but their performance has typically fallen far short of design objectives (Booth and Jackson, 1997; Maxted and Shaver, 1999; Nehrke and Roesner, 2004). Water-quality treatment has been a relatively recent addition to the management of stormwater, and although a significant fraction of pollutants can be removed through such efforts (e.g., Strecker et al., 2004; see http://www.bmpdatabase.org), the constituents remaining even in "treated" stormwater represent a substantial, but largely unappreciated, impact to downstream watercourses.

Of the waterbodies that have been assessed in the United States, impairments from urban runoff are responsible for about 38,114 miles of impaired rivers and streams, 948,420 acres of impaired lakes, 2,742 square miles of impaired bays and estuaries, and 79,582 acres of impaired wetlands (2002 305(b) report). These numbers must be considered an underestimate, since the urban runoff category does not include stormwater discharges from municipal separate storm sewer systems (MS4s) and permitted industries, including construction. Urban stormwater is listed as the "primary" source of impairment for 13 percent of all rivers, 18 percent of all lakes, and 32 percent of all estuaries (2000 305(b) report). Although these numbers may seem low, urban areas cover just 3 percent of the land mass of the United States (Loveland and Auch, 2004), and so their influence is disproportionately large. Indeed, developed and developing areas that are a primary focus of stormwater regulations contain some of the most degraded waters in the country. For example, in Ohio few sites with greater than 27 percent imperviousness can meet interim CWA goals in nearby waterbodies, and biological degradation is observed with much less urban development (Miltner et al., 2004). Numerous authors have found similar patterns (see Meyer et al., 2005).

Although no water quality inventory data have been made available from the EPA since 2002, the dimensions of the stormwater problem can be further gleaned from several past regional and national water quality inventories. Many of these assessments are somewhat dated and are subject to the normal data and assessment limitations of national assessment methods, but they indicate that stormwater runoff has a deleterious impact on nearly all of the nation's waters. For example:

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- Harvesting of shellfish is prohibited, restricted, or conditional in nearly 40 percent of all shellfish beds nationally due to high bacterial levels, and urban runoff and failing septic systems are cited as the prime causes. Reopening of shellfish beds due to improved wastewater treatment has been more than offset by bed closures due to rapid coastal development (NOAA, 1992; EPA, 1998).

- In 2006 there were over 15,000 beach closings or swimming advisories due to bacterial levels exceeding health and safety standards, with polluted runoff and stormwater cited as the cause of the impairment 40 percent of the time (NRDC, 2007).

- Pesticides were detected in 97 percent of urban stream water samples across the United States, and exceeded human health and aquatic life benchmarks 6.7 and 83 percent of the time, respectively (USGS, 2006). In 94 percent of fish tissues sampled in urban areas nationwide, organochlorine compounds were detected.

- Urban development was responsible for almost 39 percent of freshwater wetland loss (88,960 acres) nationally between 1998 and 2004 (Dahl, 2006), and the direct impact of stormwater runoff in degrading wetland quality is predicted to affect an even greater acreage (Wright et al., 2006).

- Eastern brook trout are present in intact populations in only 5 percent of more than 12,000 subwatersheds in their historical range in eastern North America, and urbanization is cited as a primary threat in 25 percent of the remaining subwatersheds with reduced populations (Trout Unlimited, 2006).

- Increased flooding is common throughout urban and suburban areas, sometimes as a consequence of improperly sited development (Figure 1-6A) but more commonly as a result of increasing discharges over time resulting from progressive urbanization farther upstream (Figure 1-6B). According to FEMA (undated), property damage from all types of flooding, from flash floods to large river floods, averages $2 billion a year.

- The chemical effects of stormwater runoff are pervasive and severe throughout the nation's urban waterways, and they can extend far downstream of the urban source. Stormwater discharges from urban areas to marine and estuarine waters cause greater water column toxicity than similar discharges from less urban areas (Bay et al., 2003).

- A variety of studies have shown that stormwater runoff is a vector of pathogens with potential human health implications in both freshwater (Calderon et al., 1991) and marine waters (Dwight et al., 2004; Colford et al., 2007).

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A



B



FIGURE 1-6 (A) New residential construction in the path of episodic stream discharge (Issaquah, Washington); (B) recent flooding of an 18th-century tavern in Collegeville, Pennsylvania following a storm event in an upstream developing watershed. SOURCES: Top, Derek Booth, Stillwater Sciences, Inc., and bottom, Robert Traver, Villanova University.

WHY IS IT SO HARD TO REDUCE THE IMPACTS OF STORMWATER?

"Urban stormwater" is the runoff from a landscape that has been affected in some fashion by human activities, during and immediately after rain. Most visibly, it is the water flow over the ground surface, which is collected by natural channels and artificial conveyance systems (pipes, gutters, and ditches) and ultimately routed to a stream, river, lake, wetland, or ocean. It also includes water that has percolated into the ground but nonetheless reaches a stream channel relatively rapidly (typically within a day or so of the rainfall), contributing to the high discharge in a stream that commonly accompanies rainfall. The subsurface

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flow paths that contribute to this stormflow response are typically quite shallow, in the upper layers of the soil, and are sometimes termed "interflow." They stand in contrast to deeper groundwater paths, where water moves at much lower velocities by longer paths and so reaches the stream slowly, over periods of days, weeks, or months. This deeper flow sustains streamflow during rainless periods and is usually called baseflow, as distinct from "stormwater." A formal distinction between these types of runoff is sometimes needed for certain computational procedures, but for most purposes a qualitative understanding is sufficient.

These runoff paths can be identified in virtually all modified landscapes, such as agriculture, forestry, and mining. However, this report focuses on those settings with the particular combination of activities that constitute "urbanization," by which we mean to include the commonly understood conversion (whether incremental or total) of a vegetated landscape to one with roads, houses, and other structures.

Although the role of urban stormwater in degrading the nation's waters has been recognized for decades (e.g., Klein, 1979), reducing that role has been notoriously difficult. This difficulty arises from three basic attributes of what is commonly termed "stormwater":

1. It is produced from literally everywhere in a *developed* landscape;
2. Its production and delivery are episodic, and these fluctuations are difficult to attenuate; and
3. It accumulates and transports much of the collective waste of the urban environment.

Wherever grasslands and forest are replaced by urban development in general, and impervious surfaces in particular, the movement of water across the landscape is radically altered (see Figure 1-7). Nearly all of the associated problems result from one underlying cause: loss of the water-retaining function of the soil and vegetation in the urban landscape. In an undeveloped, vegetated landscape, soil structure and hydrologic behavior are strongly influenced by biological activities that increase soil porosity (the ratio of void space to total soil volume) and the number and size of macropores, and thus the storage and conductivity of water as it moves through the soil. Leaf litter on the soil surface dissipates raindrop energy; the soil's organic content reduces detachment of small soil particles and maintains high surface infiltration rates. As a consequence, rainfall typically infiltrates into the ground surface or is evapotranspired by vegetation, except during particularly intense rainfall events (Dunne and Leopold, 1978).

In the urban landscape, these processes of evapotranspiration and water retention in the soil may be lost for the simple reason that the loose upper layers of the soil and vegetation are gone—stripped away to provide a better foundation for roads and buildings. Even if the soil still exists, it no longer functions if precipitation is denied access because of paving or rooftops. In either case, a stormwater

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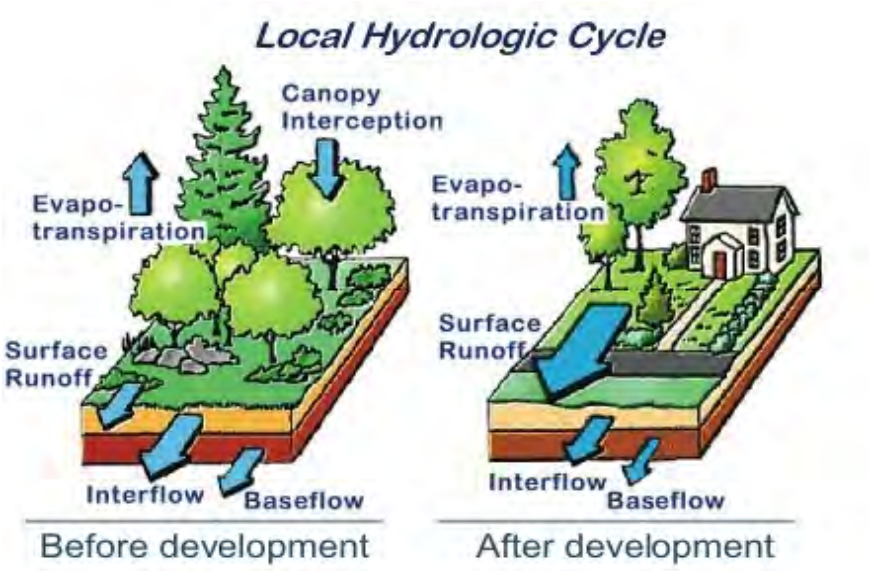

FIGURE 1-7 Schematic of the hydrologic pathways in humid-region watersheds, before and after urban development. The sizes of the arrows suggest relative magnitudes of the different elements of the hydrologic cycle, but conditions can vary greatly between individual catchments and only the increase in surface runoff in the post-development condition is ubiquitous. SOURCE: Adapted from Schueler (1987) and Maryland Department of the Environment; http://www.mde.state.md.us/Programs/WaterPrograms.

runoff reservoir of tremendous volume is removed from the stormwater runoff system; water that may have lingered in this reservoir for a few days or many weeks, or been returned directly to the atmosphere by evaporation or transpiration by plants, now flows rapidly across the land surface and arrives at the stream channel in short, concentrated bursts of high discharge.

This transformation of the hydrologic regime from one where subsurface flow once dominated to one where overland flow now dominates is not simply a readjustment of runoff flow paths, and it does not just result in a modest increase in flow volumes. It is a wholesale reorganization of the processes of runoff generation, and it occurs throughout the developed landscape. As such, it can affect every aspect of that runoff (Leopold, 1968)—not only its rate of production, its volume, and its chemistry, but also what it indirectly affects farther downstream (Walsh et al., 2005a). This includes erosion of mobile channel boundaries, mobilization of once-static channel elements (e.g., large logs), scavenging of contaminants from the surface of the urban landscape, and efficient transfer of heat from warmed surfaces to receiving waterbodies. These changes have commonly inspired human reactions—typically with narrow objectives but carrying additional, far-ranging consequences—such as the piping of once-exposed channels, bank armoring, and construction of large open-water detention ponds (e.g., Lieb and Carline, 2000).

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This change in runoff regime is also commonly accompanied by certain land-use activities that have the potential to generate particularly harmful or toxic discharges, notably those commercial activities that are the particular focus of the industrial NPDES permits. These include manufacturing facilities, transport of freight or passengers, salvage yards, and a more generally defined category of "sites where industrial materials, equipment, or activities are exposed to stormwater" (e.g., EPA, 1992).

Other human actions are associated with urban landscapes that do not affect stormwater directly, but which can further amplify the negative consequences of altered flow. These actions include clearing of riparian vegetation around streams and wetlands, introduction of atmospheric pollutants that are subsequently deposited, inadvertent release of exotic chemicals into the environment, and channel crossings by roads and utilities. Each of these additional actions further degrades downstream waterbodies and increases the challenge of finding effective methods to reverse these changes (Boulton, 1999). There is little doubt as to why the problem of urban stormwater has not yet been "solved"—because every functional element of an aquatic ecosystem is affected. Urban stormwater has resulted in such widespread impacts, both physical and biological, in aquatic systems across the world that this phenomenon has been termed the "Urban Stream Syndrome" (see Figure 1-5; Walsh et al., 2005b).

Of the many possible ways to consider these conditions, Karr (1991) has recommended a simple yet comprehensive grouping of the major stressors arising from urbanization that influence aquatic assemblages (Figure 1-8). These include chemical pollutants (water quality and toxicity); changes to flow magnitude, frequency, and seasonality of various discharges; the physical aspects of stream, lake, or wetland habitats; the energy dynamics of food webs, sunlight, and temperature; and biotic interactions between native and exotic species. Stormwater and stormwater-related impacts encompass all of these categories, some directly (e.g., water chemistry) and some indirectly (e.g., habitat, energy dynamics). Because of the wide-ranging effects of stormwater, programs to abate stormwater impacts on aquatic systems must deal with a broad range of impairments far beyond any single altered feature, whether traditional water-chemistry parameters or flow rates and volumes.

The broad spatial scale of where and how these impacts are generated suggests that solutions, if effective, should be executed at an equivalent scale. Although the "problem" of stormwater runoff is manifested most directly as an altered hydrograph or elevated concentrations of pollutants, it is ultimately an expression of land-use change at a landscape scale. Symptomatic solutions, applied only at the end of a stormwater collection pipe, are not likely to prove fully effective because they are not functioning at the scale of the original disturbance (Kloss and Calarusse, 2006).

The landscape-scale generation of stormwater has a number of consequences for any attempt to reduce its effects on receiving waters, as described below.

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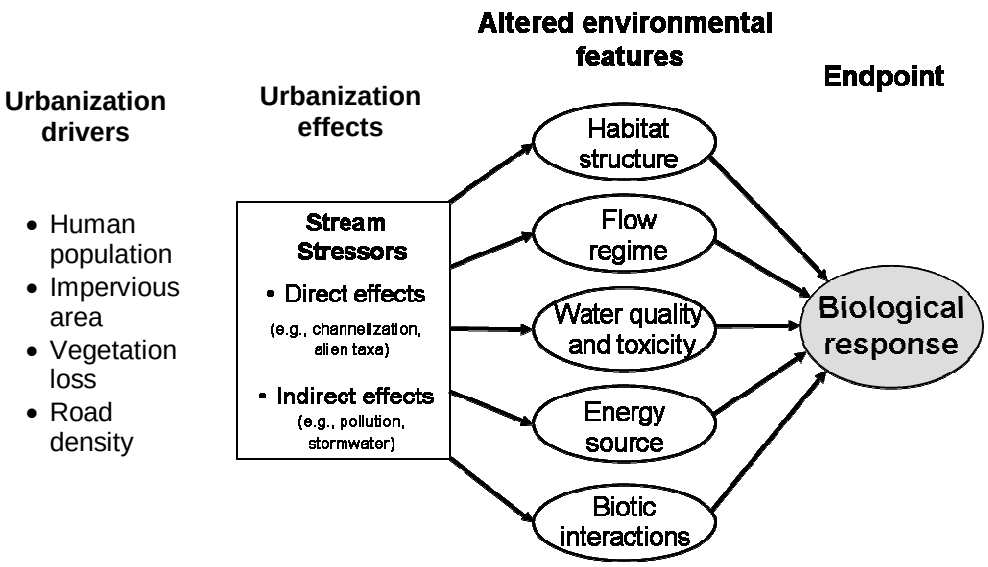

FIGURE 1-8 Five features that are affected by urban development and, in turn, affect biological conditions in urban streams. SOURCES: Modified from Karr (1991), Karr and Yoder (2004), and Booth (2005). Reprinted, with permission, from Karr (1991). Copyright 2001 by Ecological Society of America. Reprinted, with permission, from Karr and Yoder (2004). Copyright 2004 by American Society of Civil Engineers. Reprinted, with permission, from Booth (2005). Copyright 2005 by the North American Benthological Society.

Sources and Volumes

The "source" of stormwater runoff is dispersed, making collection and centralized treatment challenging. To the extent that collection is successful, however, the flip side of this condition—very large volumes—becomes manifest. Either an extensive infrastructure brings stormwater to centralized facilities, whose operation and maintenance may be relatively straightforward (e.g., Anderson et al., 2002) but of modest effectiveness, or stormwater remains dispersed for management, treatment, or both across the landscape (e.g., Konrad and Burges, 2001; Holman-Dodds et al., 2003; Puget Sound Action Team, 2005; Walsh et al., 2005a; Bloom, 2006; van Roon, 2007), better mimicking the natural processes of runoff generation but requiring a potentially unlimited number of "facilities" that may have their own particular needs for space, cost, and maintenance.

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Treatment Challenges

Regardless of the scale at which treatment is attempted, technological difficulties are significant because of the variety of "pollutants" that must be addressed. These include physical objects, from large debris to microscopic particles; chemical constituents, both dissolved and immiscible; and less easily categorized properties such as temperature. Wastewater treatment plants manage a similarly broad range of pollutants, but stormwater flows have highly unsteady inflows and, when present, typically much greater volumes to treat.

Industrial sources of stormwater pose a particularly challenging problem because potential generators of polluted or toxic runoff are widespread and are regulated under NPDES permitting by their *activities*, not by the specific category of industrial activity under which they fall. This complicates any systematic effort to identify those entities that should be regulated (Duke et al., 1999). Even for the limited number of regulated generators, pollution prevention measures are of uncertain effectiveness.

Soil erosion from construction sites is another pollution source that has proven difficult to effectively control. Although most bare sites are relatively small and only short-lived, at any given time there can be many sites under construction, each of which can deliver sediment loads to downstream waterbodies at rates that exceed background levels by many orders of magnitude (e.g., Wolman and Schick, 1967). Relatively effective approaches and technologies exist to dramatically reduce the magnitude of these sediment discharges (e.g., Raskin et al., 2005), but they depend on conscientious installation and regular maintenance. Enforcement of such requirements, normally a low-priority activity of local departments of building or public works, is commonly lacking.

Another difference between the stormwater and wastewater streams is that stormwater treatment must address not only "pollutants" but also physically and ecologically deleterious changes in flow rate and total runoff volume. Treating these changes constitutes a particularly difficult task for two reasons. First, there is simply more runoff, as a rule, and so replicating the predevelopment hydrograph is not an option—the increased volume of runoff guarantees that some discharges, some of the time, must be allowed to increase. Second, there is little agreement on what constitutes "adequate" or "effective" treatment for the various attributes of flow. Even the most basic metrics, such as the magnitude of peak flow, can require extensive infrastructure to achieve (e.g., Booth and Jackson, 1997); other flow metrics that correlate more directly with undesired effects on physical and biological systems can require even greater efforts to match. In many cases, the urban-induced transformation of the flow regime makes true "mitigation" virtually impossible.

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Widespread Cause and Effects

The spatial scale of stormwater generation and its impacts is wide-ranging. "Generators" are literally landscape-wide, and impacts can occur at every location in the path followed by urban runoff, from source to receiving waterbody (Hamilton et al., 2004). There are few ways to demonstrate causal connections between distributed landscape sources and cumulative downstream effects (Allan, 2004), and so site-specific mitigation typically provides little lasting improvement in the watershed as a whole (Maxted and Shaver, 1997).

Stormwater Measurements

The desired attributes of stormwater runoff are normally expressed through a combination of physical and chemical parameters. These parameters are commonly presumed to have direct correlation to attributes of human or ecological concern, such as the condition of human or fish communities, or the stability of a stream channel, even though these parameters do not directly measure those effects. The most commonly measured physical parameters are hydrologic and simply measure the rate of flow past a specified location. Both the absolute, instantaneous magnitude of that flow rate (i.e., the discharge) and the variations in that rate over multiple time scales (i.e., how rapidly the discharge varies over an hour, a day, a season, etc.) can be captured by analysis of a continuous time series of a flow. Obviously, however, a nearly unlimited number of possible metrics, capturing a multitude of temporal scales, could be defined (Poff et al., 1997, 2006; Cassin et al., 2004; Konrad et al., 2005; Roy et al., 2005; Chang, 2007). Commonly only a single parameter—the peak storm discharge for a given return period (Hollis, 1975)—has been emphasized in the past. Mitigation of urban-induced flow increases have followed this narrow approach, typically by endeavoring to reduce peak discharge by use of detention ponds but leaving the underlying increase in runoff volumes—and the associated augmentation of both frequency and duration of high discharges—untouched. This partly explains why evaluation of downstream conditions commonly document little improvement resulting from traditional flow-mitigation measures (e.g., Maxted and Shaver, 1997; Roesner et al., 2001; May and Horner, 2002).

Other physical parameters, less commonly measured or articulated, can also express the conditions of downstream watercourses. Measures of size or complexity, particularly for stream channels, are particularly responsive to the changes in flow regime and discharge. Booth (1990) suggested that discriminating between *channel expansion*, the proportional increase in channel cross-sectional area with increasing discharge, and *channel incision*, the catastrophic vertical downcutting that sometimes accompanies urban-induced flow increases, captures important end-members of the physical response to hydrologic change. The former (proportional expansion) is more thoroughly documented (Hammer, 1972; Hollis and Luckett, 1976; Morisawa and LaFlure, 1982; Neller, 1988;

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Whitlow and Gregory, 1989; Booth and Jackson, 1997; Moscrip and Montgomery, 1997; Booth and Henshaw, 2001); the latter (catastrophic incision) is more difficult to quantify but has been recognized in both urban and agricultural settings (e.g., Simon, 1989). Both types of changes result not only in a larger channel but also in substantial simplification and loss of features normally associated with high-quality habitat for fish and other in-stream biota. The sediment released by these "growing channels" also can be the largest component of the overall sediment load delivered to downstream waterbodies (Trimble, 1997; Nelson and Booth, 2002).

Chemical parameters (or, historically, "water-quality parameters"; see Dinius, 1987; Gergel et al., 2002) cover a host of naturally and anthropogenically occurring constituents in water. In flowing water these are normally expressed as instantaneous measurements of concentration. In waterbodies with long residence times, such as lakes, these may be expressed as either concentrations or as loads (total accumulated amounts, or total amounts integrated over an extended time interval). The CWA defined a list of priority pollutants, of which a subset is regularly measured in many urban streams (e.g., Field and Pitt, 1990). Parameters that are not measured may or may not be present, but without assessment they are rarely recognized for their potential (or actual) contribution to waterbody impairment.

Other attributes of stormwater do not fit as neatly into the categories of water quantity or water quality. Temperature is commonly measured and is normally treated as a water quality parameter, although it is obviously not a chemical property of the water (LeBlanc et al., 1997; Wang et al., 2003). Similarly, direct or indirect measures of suspended matter in the water column (e.g., concentration of total suspended solids, or secchi disk depths in a lake) are primarily physical parameters but are normally included in water quality metrics. Flow velocity is rarely measured in either context, even though it too correlates directly to stream-channel conditions. Even more direct expressions of a flow's ability to transport sediment or other debris, such as shear stress or unit stream power, are rarely reported and virtually never regulated.

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Urban runoff degrades aquatic systems in multiple ways, which confounds our attempts to define causality or to demonstrate clear linkages between mitigation and ecosystem improvement. It is generally recognized from the conceptual models that seek to describe this system that no single element holds the key to ecosystem condition. All elements must be functional, and yet every element can be affected by urban runoff in different ways. These impacts occur at virtually all spatial scales, from the site-specific to the landscape; this breadth and diversity challenges our efforts to find effective solutions.

This complexity and the continued growth of the built environment also present fundamental social choices and management challenges. Stormwater control measures entail substantial costs for their long-term maintenance, moni-

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toring to determine their performance, and enforcement of their use—all of which must be weighed against their (sometimes unproven) benefits. Furthermore, the overarching importance of impervious surfaces inextricably links stormwater management to land-use decisions and policy. For example, where a reversal of the effects of urbanization cannot be realized, more intensive land-use development in certain areas may be a paradoxically appropriate response to reduce the overall impacts of stormwater. That is, increasing population density and impervious cover in designated urban areas may reduce the creation of impervious surface and the associated ecological impacts in areas that will remain undeveloped as a result. In these highly urban areas (with very high percentages of impervious surface), aquatic conditions in local streams will be irreversibly changed and the Urban Stream Syndrome may be unavoidable to some extent. Where these impacts occur and what effort and cost will be used to avoid these impacts are both fundamental issues confronting the nation as it attempts to address stormwater.

IMPETUS FOR THE STUDY AND REPORT ROADMAP

In 1972 Congress amended the Federal Water Pollution Control Act (subsequently referred to as the Clean Water Act) to require control of discharges of pollutants to waters of the United States from point sources. Initial efforts to improve water quality using NPDES permits focused primarily on reducing pollutants from industrial process wastewater and municipal sewage discharges. These point source discharges were clearly and easily shown to be responsible for poor, often drastically degraded conditions in receiving waterbodies because they tended to emanate from identifiable and easily monitored locations, such as pipe outfalls.

As pollution control measures for industrial process wastewater and municipal sewage were implemented and refined during the 1970s and 1980s, more diffuse sources of water pollution have become the predominant causes of water quality impairment, including stormwater runoff. To address the role of stormwater in causing water quality impairments, Congress included Section 402(p) in the CWA; this section established a comprehensive, two-phase approach to stormwater control using the NPDES program. In 1990 EPA issued the Phase I Stormwater Rule (55 Fed. Reg. 47990; November 16, 1990) requiring NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations over 100,000 and for runoff associated with industrial activity, including runoff from construction sites five acres and larger. In 1999 EPA issued the Phase II Stormwater Rule (64 Fed. Reg. 68722; December 8, 1999), which expanded the requirements to small MS4s in urban areas and to construction sites between one and five acres in size.

Since EPA's stormwater program came into being, several problems inherent in its design and implementation have become apparent. As discussed in more detail in Chapter 2, problems stem to a large extent from the diffuse nature

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of stormwater discharges combined with a regulatory process that was created for point sources (the NPDES permitting approach). These problems are compounded by the shear number of entities requiring oversight. Although exact numbers are not available, EPA estimates that the number of regulated MS4s is about 7,000, including 1,000 Phase I municipalities and 6,000 from Phase II. The number of industrial permittees is thought to be around 100,000. Each year, the construction permit covers around 200,000 permittees each for both Phase I (five acres or greater) and Phase II (one to five acres) projects. Thus, the total number of permittees under the stormwater program at any time numbers greater than half a million. There are fewer than 100,000 non-stormwater (meaning wastewater) permittees covered by the NPDES program, such that stormwater permittees account for approximately 80 percent of NPDES-regulated entities. To manage this large number of permittees, the stormwater program relies heavily on the use of general permits to control industrial, construction, and Phase II MS4 discharges, which are usually statewide, one-size-fits-all permits in which general provisions are stipulated.

An example of the burden felt by a single state is provided by Michigan (David Drullinger, Michigan Department of Environmental Quality Water Bureau, personal communication, September 2007). The Phase I Stormwater regulations that became effective in 1990 regulate 3,400 industrial sites, 765 construction sites per year, and five large cities in Michigan. The Phase II regulations, effective since 1999, have extended the requirements to 7,000 construction sites per year and 550 new jurisdictions, which are comprised of about 350 "primary jurisdictions" (cities, villages, and townships) and 200 "nested jurisdictions" (county drains, road agencies, and public schools). Often, only a handful of state employees are allocated to administer the entire program (see the survey in Appendix C).

In order to comply with the CWA regulations, permittees must fulfill a number of requirements, including the creation and implementation of a stormwater pollution prevention plan, and in some cases, monitoring of stormwater discharges. Stormwater pollution prevention plans document the stormwater control measures (SCMs; sometimes known as best management practices or BMPs) that will be used to prevent or slow stormwater from quickly reaching nearby waterbodies and degrading their quality. These include structural methods such as detention ponds and nonstructural methods such as designing new development to reduce the percentage of impervious surfaces. Unfortunately, data on the degree of pollutant reduction that can be assigned to a particular SCM are only now becoming available (see Chapter 5).

Other sources of variability in EPA's stormwater program are that (1) there are three permit types (municipal, industrial, and construction), (2) some states and local governments have assumed primacy for the program from EPA while others have not, and state effluent limits or benchmarks for stormwater discharges may differ from the federal requirements, and (3) whether there are monitoring requirements varies depending on the regulating entity and the type of activity. For industrial stormwater there are 29 sectors of industrial activity

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covered by the general permit, each of which is characterized by a different suite of possible contaminants and SCMs.

Because of the industry-, site-, and community-specific nature of stormwater pollution prevention plans, and because of the lack of resources of most NPDES permitting authorities to review these plans and conduct regular compliance inspections, water quality-related accountability in the stormwater program is poor. Monitoring data are minimal for most permittees, despite the fact that they are often the only indicators of whether an adequate stormwater program is being implemented. At the present time, available monitoring data indicate that many industrial facilities routinely exceed "benchmark values" established by EPA or the states, although it is not clear whether these exceedances provide useful indicators of stormwater pollution prevention plan inadequacies or potential water quality problems. These uncertainties have led to mounting and contradictory pressure from permittees to eliminate monitoring requirements entirely as well as from those hoping for greater monitoring requirements to better understand the true nature of stormwater discharges and their impact.

To improve the accountability of it Stormwater Program, EPA requested advice on stormwater issues from the National Research Council's (NRC's) Water Science and Technology Board as the next round of general permits is being prepared. Although the drivers for this study have been in the industrial stormwater arena, this study considered all entities regulated under the NPDES program (municipal, industrial, and construction). The following statement of task guided the work of the committee:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of SCMs.

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

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(5) Assess the design of the stormwater permitting program implemented under the CWA.

The report is intended to inform decision makers within EPA, affected industries, public stormwater utilities, other government agencies and the private sector about potential options for managing stormwater.

EPA requested that the study be limited to those issues that fall under the agency's current regulatory scheme for stormwater, which excludes nonpoint sources of pollution such as agricultural runoff and septic systems. Thus, these sources are not extensively covered in this report. The reader is referred to NRC (2000, 2005) for more detailed information on the contribution of agricultural runoff and septic systems to waterbody impairment and on innovative technologies for treating these sources. Also at the request of EPA, concentrated animal feeding operations and combined sewer overflows were not a primary focus. However, the committee felt that in order to be most useful it should opine on certain critical effects of regulated stormwater beyond the delivery of traditional pollutants. Thus, changes in stream flow, streambank erosion, and habitat alterations caused by stormwater are considered, despite the relative inattention given to them in current regulations.

Chapter 2 presents the regulatory history of stormwater control in the United States, focusing on relevant portions of the CWA and the regulations that have been created to implement the Act. Federal, state, and local programs for or affecting stormwater management are described and critiqued. Chapter 3 deals with the first item in the statement of task. It reviews the scientific aspects of stormwater, including sources of pollutants in stormwater, how stormwater moves across the land surface, and its impacts on receiving waters. It reflects the best of currently available science, and addresses biological endpoints that go far beyond ambient water quality criteria. Methods for monitoring and modeling stormwater (the subject of the second item in the statement of task) are described in Chapter 4. The material evaluates the usefulness of current benchmark and MS4 monitoring requirements, and suggestions for improvement are made. The latter half of the chapter considers the multitude of models available for linking stormwater discharges to ambient water quality. This analysis makes it clear that stormwater pollution cannot yet be treated as a deterministic system (in which the contribution of individual dischargers to a waterbody impairment can be identified) without significantly greater investment in model development. Addressing primarily the third item in the statement of task, Chapter 5 considers the vast suite of both structural and nonstructural measures designed to control stormwater and reduce its pollutant loading to waterbodies. It also takes on relevant larger-scale concepts, such as the benefit of stormwater management within a watershed framework. In Chapter 6, the limitations and possibilities associated with a new regulatory approach are explored, as are those of an enhanced but more traditional scheme. Numerous suggestions for improving the stormwater permitting process for municipalities, industrial sites, and con-

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struction are made. Along with Chapter 2, this chapter addresses the final two items in the committee's statement of task.

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2
The Challenge of Regulating Stormwater

Although stormwater has long been regarded as a major culprit in urban flooding, only in the past 30 years have policymakers appreciated the significant role stormwater plays in the impairment of urban watersheds. This recent rise to fame has led to a cacophony of federal, state, and local regulations to deal with stormwater, including the federal Clean Water Act (CWA) implemented by the U.S. Environmental Protection Agency (EPA). Perhaps because this longstanding environmental problem is being addressed so late in the development and management of urban watersheds, the laws that mandate better stormwater control are generally incomplete and were often passed for other purposes, like industrial waste control.

This chapter discusses the regulatory programs that govern stormwater, particularly the federal program, explaining how these programs manage stormwater only impartially and often inadequately. While progress has been made in the regulation of urban stormwater—from the initial emphasis on simply moving it away from structures and cities as fast as possible to its role in degrading neighboring waterbodies—a significant number of gaps remain in the existing system. Chapter 6 returns to these gaps and considers the ways that at least some of them may be addressed.

FEDERAL REGULATORY FRAMEWORK FOR STORMWATER

The Clean Water Act

The CWA is a comprehensive piece of U.S. legislation that has a goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Its long-term goal is the elimination of polluted discharges to surface waters (originally by 1985), although much of its current effort focuses on the interim goal of attaining swimmable and fishable waters. Initially enacted as the Federal Water Pollution Control Act in 1948, it was revised by amendments in 1972 that gave it a stronger regulatory, water chemistry-focused basis to deal with acute industrial and municipal effluents that existed in the 1970s. Amendments in 1987 broadened its focus to deal with more diffuse sources of impairments, including stormwater. Improved monitoring over the past two decades has documented that although discharges have not been eliminated, there has been a widespread lessening of the effects of direct municipal and industrial wastewater discharges.

A timeline of federal regulatory events over the past 125 years relevant to stormwater, which includes regulatory precursors to the 1972 CWA, is shown in Table 2-1. The table reveals that while there was a flourish of regulatory activity related to stormwater during the mid-1980s to 1990s, there has been much less regulatory activity since that time.

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TABLE 2-1 Legal and Regulatory Milestones for the Stormwater Program

1886	**Rivers and Harbors Act.** A navigation-oriented statute that was used in the 1960s and 1970s to challenge unpermitted pollutant discharges from industry.
1948 *1952* *1955*	**Federal Water Pollution Control Act.** Provided matching funds for wastewater treatment facilities, grants for state water pollution control programs, and limited federal authority to act against interstate pollution.
1965	**Water Quality Act.** Required states to adopt water quality standards for interstate waters subject to federal approval. It also required states to adopt state implementation plans, although failure to do so would not result in a federally implemented plan. As a result, enforceable requirements against polluting industries, even in interstate waters, was limited.
1972	**Federal Water Pollution Control Act.** First rigorous national law prohibiting the discharge of pollutants into surface waters without a permit. • Goal is to restore and maintain health of U.S. waters • Protection of aquatic life and human contact recreation by 1983 • Eliminate discharge of pollutants by 1985 • Wastewater treatment plant financing
	Clean Water Act Section 303(d) • Contains a water quality-based strategy for waters that remain polluted after the implementation of technology-based standards. • Requires states to identify waters that remain polluted, to determine the total maximum daily loads that would reverse the impairments, and then to allocate loads to sources. If states do not perform these actions, EPA must.
	Clean Water Act Section 208 • Designated and funded the development of regional water quality management plans to assess regional water quality, propose stream standards, identify water quality problem areas, and identify wastewater treatment plan long-term needs. These plans also include policy statements which provide a common consistent basis for decision making.
1977 *1981*	**Clean Water Act Sections 301 and 402** • Control release of toxic pollutants to U.S. waters • Technology treatment standards for conventional pollutants and priority toxic pollutants. • Recognition of technology limitations for some processes.
1977	*NRDC vs. Costle.* Required EPA to include stormwater discharges in the National Pollution Discharge Elimination System (NPDES) program.
1987	**Clean Water Act Amended Sections 301 and 402** • Control toxic pollutants discharged to U.S. waters. • Manage urban stormwater pollution. • Numerical criteria for all toxic pollutants. • Integrated control strategies for impaired waters. • Stormwater permit programs for urban areas and industry. • Stronger enforcement penalties. • Anti-backsliding provisions.

Table continues next page

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TABLE 2-1 continued

1990	**EPA's Phase I Stormwater Permit Rules are Promulgated** • Application and permit requirements for large and medium municipalities • Application and permit requirements for light and heavy industrial facilities based on Standard Industrial Classification (SIC) Codes, and construction activity ≥ 5 acres
1999	**EPA's Phase II Stormwater Permit Rules are Promulgated** • Permit requirements for census-defined urbanized areas • Permit requirements for construction sites 1 to 5 acres
1997-2001	**Total Maximum Daily Load (TMDL) Program Litigation** • Courts order EPA to establish TMDLs in a number of states if the states fail to do so. The TMDLs assign Waste Load Allocations for stormwater discharges which must be incorporated as effluent limitations in stormwater permits.
2006-2008	**Section 323 of the Energy Policy Act of 2005** • EPA promulgates rule (2006) to exempt stormwater discharges from oil and gas exploration, production, processing, treatment operations, or transmission facilities from NPDES stormwater permit program. • In 2008, courts order EPA to reverse the rule which exempted certain activities in the oil and gas exploration industry from storm water regulations. In *Natural Resources Defense Council vs. EPA* (9th Cir. 2008), the court held that it was "arbitrary and capricious" to exempt from the Clean Water Act stormwater discharges containing sediment contamination that contribute to a violation of water quality standards.
2007	**Energy Independence and Security Act of 2007** • Requires all federal development and redevelopment projects with a footprint above 5,000 square feet to achieve predevelopment hydrology to the "maximum extent technically feasible."

The Basic NPDES Program: Regulating Pollutant Discharges

The centerpiece of the CWA is its mandate "that all *discharges* into the nation's waters are unlawful, unless specifically authorized by a permit" [42 U.S.C. §1342(a)]. Discharges do not include all types of pollutant flows, however. Instead, "discharges" are defined more narrowly as "point sources" of pollution, which in turn include only sources that flow through a discrete conveyance, like a pipe or ditch, into a lake or stream [33 U.S.C. §§ 1362(12) and (14)]. Much of the focus of the CWA program, then, is on limiting pollutants emanating from these discrete, point sources directly into waters of the United States. Authority to control nonpoint sources of pollution, like agricultural runoff (even when drained via pipes or ditches), is generally left to the states with more limited federal oversight and direction.

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All point sources of pollutants are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit and ensure that their pollutant discharges do not exceed specified effluent standards. Congress also commanded that rather than tie effluent standards to the needs of the receiving waterbody—an exercise that was far too scientifically uncertain and time-consuming—the effluent standards should first be based on the best available pollution technology or the equivalent. In response to a very ambitious mandate, EPA has promulgated very specific, quantitative discharge limits for the wastewater produced by over 30 industrial categories of sources based on what the best pollution control technology could accomplish, and it requires at least secondary treatment for the effluent produced by most sewage treatment plants. Under the terms of their permits, these large sources are also required to self-monitor their effluent at regular intervals and submit compliance reports to state or federal regulators.

EPA quickly realized after passage of the CWA in 1972 that if it were required to develop pollution limits for all point sources, it would need to regulate hundreds of thousands and perhaps even millions of small stormwater ditches and thousands of small municipal stormwater outfalls, all of which met the technical definition of "point source". It attempted to exempt all these sources, only to have the D.C. Circuit Court read the CWA to permit no exemptions [*NRDC vs. Costle*, 568 F.2d 1369 (D.C. Cir. 1977)]. In response, EPA developed a "general" permit system (an "umbrella" permit that covers multiple permittees) for smaller outfalls of municipal stormwater and similar sources, but it generally did not require these sources to meet effluent limitations or monitor their effluent.

It should be noted that, while the purpose of the CWA is to ensure protection of the physical, biological, and chemical integrity of the nation's waters, the enforceable reach of the Act extends only to the discharges of "pollutants" into waters of the United States [33 U.S.C. § 1311(a); cf. PUD No. 1 of Jefferson County v. Washington Department of Ecology, 511 U.S. 700 (1994) (providing states with broad authority under section 401 of the CWA to protect designated uses, not simply limit the discharge of pollutants)]. Even though "pollutant" is defined broadly in the Act to include virtually every imaginable substance added to surface waters, including heat, it has not traditionally been read to include water volume [33 U.S.C. § 1362(6)]. Thus, the focus of the CWA with respect to its application to stormwater has traditionally been on the water quality of stormwater and not on its quantity, timing, or other hydrologic properties. Nonetheless, because the statutory definition of "pollutant" includes "industrial, municipal, and agricultural waste discharged into water," using transient and substantial increases in flow in urban watersheds as a proxy for pollutant loading seems a reasonable interpretation of the statute. EPA Regions 1 and 3 have considered flow control as a particularly effective way to track sediment loading, and they have used flow in TMDLs as a surrogate for pollutant loading (EPA Region 3, 2003). State trial courts have thus far ruled that municipal separate storm sewer system (MS4) permits issued under delegated federal authority can

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impose restrictions on flow where changes in flow impair the beneficial uses of surface waters (Beckman, 2007). EPA should consider more formally clarifying that significant, transient increases in flow in urban watersheds serve as a legally valid proxy for the loading of pollutants. This clarification will allow regulators to address the problems of stormwater in more diverse ways that include attention to water volume as well as to the concentration of individual pollutants.

Stormwater Discharge Program

By 1987, Congress became concerned about the significant role that stormwater played in contributing to water pollution, and it commanded EPA to regulate a number of enumerated stormwater discharges more rigorously. Specifically, Section 402(p), introduced in the 1987 Amendments to the CWA, directs EPA to regulate some of the largest stormwater discharges—those that occur at industrial facilities and municipal storm sewers from larger cities and other significant sources (like large construction sites)—by requiring permits and promulgating discharge standards that require the equivalent of the best available technology [42 U.S.C. § 1342(p)(3)]. Effectively, then, Congress grafted larger stormwater discharges onto the existing NPDES program that was governing discharges from manufacturing and sewage treatment plants.

Upon passage of Section 402(p), EPA divided the promulgation of its stormwater program into two phases that encompass increasingly smaller discharges. The first phase, finalized in 1990, regulates stormwater discharges from ten types of industrial operations (this includes the entire manufacturing sector), construction occurring on five or more acres, and medium or large storm sewers in areas that serve 100,000 or more people [40 C.F.R. § 122.26(a)(3)(1990); 40 C.F.R. § 122.26 (b)(14) (1990)]. The second phase, finalized in 1995, includes smaller municipal storm sewer systems and smaller construction sites (down to one acre) [60 Fed. Reg. 40,230 (Aug. 7, 1995) (codified at 40 C.F.R. Parts 122, 124 (1995)]. If these covered sources fail to apply for a permit, they are in violation of the CWA.

Because stormwater is more variable and site specific with regard to its quality and quantity than wastewater, EPA found it necessary to diverge in two important ways from the existing NPDES program governing discharges from industries and sewage treatment plants. First, stormwater discharge limits are not federally specified in advance as they are with discharges from manufacturing plants. Even though Congress directed EPA to require stormwater sources to install the equivalent of the best available technology or "best management practices," EPA concluded that the choice of these best management practices (referred to in this report as stormwater control measures or SCMs) would need to be source specific. As a result, although EPA provides constraints on the choices available, it generally leaves stormwater sources with responsibility for

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developing a stormwater pollution prevention plan and the state with the authority to approve, amend, or reject these plans (EPA, 2006, p. 15).

Second, because of the great variability in the nature of stormwater flow, some sources are not required to monitor the pollutants in their stormwater discharges. Even when monitoring is required, there is generally a great deal of flexibility for regulated parties to self-monitor as compared with the monitoring requirements applied to industrial waste effluent (not stormwater from industries). More specifically, for a small subset of stormwater sources such as Phase I MS4s, some monitoring of effluent during a select number of storms at a select number of outfalls is required (EPA, 1996a, p. VIII-1). A slightly larger number of identified stormwater dischargers, primarily industrial, are only required to collect grab samples four times during the year and visually sample and report on them (so-called benchmark monitoring). The remaining stormwater sources are not required to monitor their effluent at all (EPA, 1996a). States and localities may still demand more stringent controls and rigorous stormwater monitoring, particularly in areas undergoing a Total Maximum Daily Load (TMDL) assessment, as discussed below. Yet, even for degraded waters subject to TMDLs, any added monitoring that might be required will be limited only to the pollutants that cause the degraded condition [40 C.F.R. §§ 420.32-420.36 (2004)].

Water Quality Management

Since technology-based regulatory requirements imposed on both stormwater and more traditional types of discharges are not tied to the conditions of the receiving water—that is, they require sources only to do their technological best to eliminate pollution—basic federal effluent limits are not always adequate to protect water quality. In response to this gap in protection, Congress has developed a number of programs to ensure that waters are not degraded below minimal federal and state goals [e.g., 33 U.S.C. §§ 1288, 1313(e), 1329, 1314(l)]. Among these, the TMDL program involves the most rigorous effort to control both point and nonpoint sources to ensure that water quality goals are met [33 U.S.C. § 1313(d)].

Under the TMDL program, states are required to list waterbodies not meeting water quality standards and to determine, for each degraded waterbody, the "total maximum daily load" of the problematic pollutant that can be allowed without violating the applicable water quality standard. The state then determines what types of additional pollutant loading reductions are needed, considering not only point sources but also nonpoint sources. It then promulgates controls on these sources to ensure further reductions to achieve applicable water quality goals.

The TMDL process has four separate components. The first two components are already required of the states through other sections of the CWA: (1) identify beneficial uses for all waters in the state and (2) set water quality stan-

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dards that correlate with these various uses. The TMDL program adds two components by requiring that states then (3) identify segments where water quality goals have not been met for one or more pollutants and (4) develop a plan that will ensure added reductions are made by point and/or nonpoint sources to meet water quality goals in the future. Each of these is discussed below.

Beneficial Uses. States are required to conduct the equivalent of "zoning" by identifying, for each water segment in the state, a beneficial use, which consists of ensuring that the waters are fit for either recreation, drinking water, aquatic life, or agricultural, industrial, and other purposes [33 U.S.C. § 1313(c)(2)(A)]. All states have derived "narrative definitions" to define the beneficial uses of waterbodies that are components of all water quality standard programs. Many of these narrative criteria are conceptual in nature and tend to define general aspects of the beneficial uses. For categories such as *aquatic life uses*, most states have a single metric for differentiating uses by type of stream (e.g., coldwater vs. warmwater fisheries). In general, the desired biological characteristics of the waterbody are not well defined in the description of the beneficial use. Some states, such as Ohio, have added important details to their beneficial uses by developing tiered aquatic life uses that recognize a strong gradient of anthropogenic background disturbance that controls whether a waterbody can attain a certain water quality and biological functioning (see Box 2-1; Yoder and Rankin, 1998). Any aquatic life use tier less stringent than the CWA interim goal of "swimmable–fishable" requires a Use Attainability Analysis to support a finding that restoration is not currently feasible and recovery is not likely in a reasonable period of time. This analysis and proposed designation must undergo public comment and review and are always considered temporary in nature. More importantly, typically one or more tiers above the operative interim goal of "swimmable–fishable" are provided. This method typically will protect the highest attainable uses in a state more effectively than having only single uses.

The concept of tiered beneficial uses and use attainability is especially important with regard to urban stormwater because of the potential irreversibility of anthropogenic development and the substantial costs that might be incurred in attempting to repair degraded urban watersheds to "swimmable–fishable" or higher status. Indeed, it is important to consider what public benefits and costs might occur for different designated uses. For example, large public benefits (in terms of aesthetics and safety) might be gained from initial improvements in an urban stream (e.g., restoring base flow) that achieve modest aquatic use and protect secondary human contact. However, achieving designated uses associated with primary human contact or exceptional aquatic habitat may be much more costly, such that the perceived incremental public gains may be much lower than the costs that must be expended to achieve that more ambitious designation.

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BOX 2-1
Ohio's Tiered Aquatic Life Uses

"Designated" or "beneficial" uses for waterbodies are an important aspect of the CWA because they are the explicit water quality goals or endpoints set for each water or class of waters. Ohio was one of the first states to implement tiered aquatic life uses (TALUs) in 1978 as part of its water quality standards (WQS). Most states have a single aquatic life use for a class of waters based on narrative biological criteria (e.g., warmwater or cold-water fisheries) although many states now collect data that would allow identification of multiple tiers of condition. EPA has recognized the management advantages inherent to tiered aquatic life uses and has developed a technical document on how to develop the scientific basis that would allow States to implement tiered uses (EPA, 2005a; Davies and Jackson, 2006).

Ohio's TALUs reflect the mosaic of natural features across Ohio and over 200 years of human changes to the natural landscape. Widespread information on Ohio's natural history (e.g., Trautman's 1957 *Fishes of Ohio*) provided strong evidence that the potential fauna of streams was not uniform, but varied geographically. Based on this knowledge, Ohio developed a more protective aquatic life use tier to protect streams of high biological diversity that harbored unique assemblages of rare or sensitive aquatic species (e.g., fish, mussels, invertebrates). In its WQS in 1978, Ohio established a narrative Exceptional Warmwater Habitat (EWH) aquatic life use to supplement its more widespread general or "Warmwater Habitat" aquatic life use (WWH) (Yoder and Rankin, 1995).

The CWA permits states to assign aquatic life uses that do not meet the baseline swimmable-fishable goals of the CWA under specific circumstances after conducting a Use Attainability Analysis (UAA), which documents that higher CWA aquatic life use goals (e.g., WWH and EWH in Ohio) are not feasibly attainable. These alternate aquatic life uses are always considered temporary in case land use changes or technology changes to make restoration feasible. The accrual of more than ten years of biological assessment data by the late 1980s and extensive habitat and stressor data provided a key link between the stressors that limited attainment of a higher aquatic life use in certain areas and reaches of Ohio streams. This assessment formed the basis for several "modified" (physical) warmwater uses for Ohio waters and a "limited" use (limited resource water, LRW) for mostly small ephemeral or highly artificial waters (Yoder and Rankin, 1995). Table 2-2 summarizes the biological and physical characteristics of Ohio TALUs and the management consequences of these uses. Channelization typically maintained by county or municipal drainage and flood control efforts, particularly where such changes have been extensive, are the predominant cause of Modified and Limited aquatic life uses. Extensive channel modification in urban watersheds has led to some modified warmwater habitat (MWH) and LRW uses in urban areas. There has been discussion of developing specific "urban" aquatic life uses; however the complexity of multiple stressors and the need to find a clear link between the sources limiting aquatic life and feasible remediation is just now being addressed in urban settings (Barbour et al., 2006).

The TALUs in Ohio (EWH→LRW) reflect a gradient of landscape and direct physical changes, largely related to changes to instream habitat and associated hydrological features. Aquatic life uses and the classification strata based on ecoregion and stream size (headwater, wadeable, and boatable streams) provide the template for the biocriteria expectations for Ohio streams (see Box 2-2). Identification of the appropriate tiers for streams and UAA are a routine part of watershed monitoring in Ohio and are based on biological, habitat, and other supporting data. Any recommendations for changes in aquatic life uses are subject to public comment when the Ohio WQS are changed.

Ohio's water quality standards contain specific listings by stream or stream reach with notations about the appropriate aquatic life use as well as other applicable uses (e.g., recreation). Much of the impact of tiered uses on regulated entities or watershed management

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TABLE 2-2 Key features associated with tiered aquatic life uses in the Ohio WQS. SOURCE: EPA (2005a), Appendix B.

Aquatic Life Use	Key Attributes	Why a Waterbody Would Be Designated	Practical Impacts (compared to a baseline of WWH)
Warmwater Habitat (WWH)	Balanced assemblages of fish/invertebrates comparable to least impacted *regional* reference condition	Either supports biota consistent with numeric biocriteria for that ecoregion **or** exhibits the habitat potential to support recovery of the aquatic fauna	Baseline regulatory requirements consistent with the CWA "fishable" and "protection & propagation" goals; criteria consistent with U.S. EPA guidance with State/regional modifications as appropriate
Exceptional Warmwater Habitat (EWH)	Unique and/or diverse assemblages; comparable to upper quartile of *statewide* reference condition	Attainment of the EWH biocriteria demonstrated by both organism groups	More stringent criteria for D.O., temperature, ammonia, and nutrient targets; more stringent restrictions on dissolved metals translators; restrictions on nationwide dredge & fill permits; may result in more stringent wastewater treatment requirements
Coldwater Habitat (CWH)	Sustained presence of Salmonid or non-salmonid coldwater aquatic organisms; bonafide trout fishery	Bioassessment reveals coldwater species as defined by Ohio EPA (1987); put-and-take trout fishery managed by Ohio DNR	Same as above except that common metals criteria are more stringent; may result in more stringent wastewater treatment requirements
Modified Warmwater Habitat (MWH)	Warmwater assemblage dominated by species tolerant of low D.O., excessive nutrients, siltation, and/or habitat modifications	Impairment of the WWH biocriteria; existence and/or maintenance of hydrological modifications that cannot be reversed or abated to attain the WWH biocriteria; a use attainability analysis is required	Less stringent criteria for D.O., ammonia, and nutrient targets; less restrictive applications of dissolved metals translators; Nationwide permits apply without restrictions or exception; may result in less restrictive wastewater treatment requirements
Limited Resource Waters (LRW)	Highly degraded assemblages dominated exclusively by tolerant species; *should not* reflect acutely toxic conditions	Extensive physical and hydrological modifications that cannot be reversed and which preclude attainment of higher uses; a use attainability analysis is required	Chemical criteria are based on the prevention of acutely lethal conditions; may result in less restrictive wastewater treatment requirements

efforts arises from the tiered chemical and stressor criteria associated with each TALU. Criteria for compounds such as ammonia and dissolved oxygen vary with aquatic life use (see Table 2-2). Furthermore, application of management actions in Ohio, ranging from assigning antidegradation tiers, awarding funding for wastewater infrastructure and other projects, to issuing CWA Section 401/404 permits, are influence by the TALU and the biological assemblages present.

Ohio has been expanding its use of tiered uses by proposing tiered uses for wetlands (*http://www.epa.state.oh.us/dsw/rules/draft_1-53_feb06.pdf*) and developing new aquatic life uses for very small (primary headwater, PHW) streams. Both of these water types have a strong intersection with urban construction and stormwater practices. In Ohio this is especially so because the proposed mitigation standards for steams and wetlands are linked to TALUs (Ohio EPA, 2007).

Davies and Jackson (2006) present a good summary of the Maine rationale for TALUs: "(1) identifying and preserving the highest quality resources, (2) more accurately depicting existing conditions, (3) setting realistic and attainable management goals, (4) preserving incremental improvements, and (5) triggering management action when conditions decline" (Davies et al., 1999). Appendices A and B of EPA (2005a) provide more detailed information about the TALUs in Maine and Ohio, respectively.

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Water Quality Criteria. Once a state has created a list of beneficial uses for its waters, water quality criteria are then determined that correspond with these uses. These criteria can target chemical, biological, or physical parameters, and they can be either numeric or narrative.

In response to the acute chemical water pollution that existed when the CWA was written, the primary focus of water quality criteria was the control of toxic and conventional pollutants from wastewater treatment plants. EPA developed water quality criteria for a wide range of conventional pollutants and began working on criteria for a list of priority pollutants. These were generally in the form of numeric criteria that are then used by states to set their standards for the range of waterbody types that exist in that state. While states do not have to adopt EPA water quality criteria, they must have a scientific basis for setting their own criteria. In practice, however, states have promulgated numerical water quality standards that can vary by as much as 1,000-fold for the same contaminant but are still considered justified by the available science [e.g., the water quality criteria for dioxin—*Natural Resources Defense Council, Inc. vs. EPA*, 16 F.3d 1395, 1398, 1403-05 (4th Cir. 1993)].

The gradual abatement of point source impairments and increased focus on ambient monitoring and nonpoint source pollutants has led to a gradual, albeit inconsistent, shift by states toward (1) biological and intensive watershed monitoring and (2) consideration of stressors that are not typical point source pollutants including nutrients, bedded sediments, and habitat loss. For these parameters, many states have developed narrative criteria (e.g., "nutrients levels that will not result in noxious algal populations"), but these can be subjective and hard to enforce.

The use of biological criteria (biocriteria) has gained in popularity because traditional water quality monitoring is now perceived as insufficient to answer questions about the wide range of impairments caused by activities other than wastewater point sources, including stormwater (GAO, 2000). As described in Box 2-2, Ohio has defined biocriteria in its water quality standards based on multimetric indices from reference sites that quantify the baseline expectations for each tier of aquatic life use.

Antidegradation. The antidegradation provision of the water quality standards deals with waters that already achieve or exceed baseline water quality criteria for a given designated use. Antidegradation provisions must be considered before any regulated activity can be authorized that may result in a lowering of water quality which includes biological criteria. These provisions protect the existing beneficial uses of a water and only allow a lowering of water quality (but never lower than the baseline criteria associated with the beneficial use) where necessary to support important social and economic development. It essentially asks the question: is the discharge or activity necessary? States with refined designated uses and biological criteria have used these programs to their advantage to craft scientifically sound, protective, yet flexible antidegradation rules (see Ohio and Maine). Antidegradation is not a replacement for tiered

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BOX 2-2
Ohio's Biocriteria

After it implemented tiered aquatic life uses in 1978, Ohio developed numeric biocriteria in 1990 (Ohio WQS; Ohio Administrative Code 3745-1) as part of its WQS. Since designated uses were formulated and described in ecological terms, Ohio felt that it was natural that the criteria should be assessed on an ecological basis (Yoder, 1978). Subsequent to the establishment of the EWH tier in its WQS, Ohio expanded its biological monitoring efforts to include both macroinvertebrates and fish (Yoder and Rankin, 1995) and established consistent and robust monitoring methodologies that have been maintained to the present. This core of consistently collected data has allowed the application of analytical tools, including multimetric indices such as the Index of Biotic Integrity (IBI), the Invertebrate Community Index (ICI), and other multivariate tools. The development of aquatic ecoregions (Omernik, 1987, 1995; Gallant et al., 1989), a practical definition of biological integrity (Karr and Dudley, 1981), multimetric assessment tools (Karr, 1981; Karr et al., 1986), and reference site concepts (Hughes et al., 1986) provided the basis for developing Ohio's ecoregion-based numeric criteria.

Successful application of biocriteria in Ohio was dependent on the ability to accurately classify aquatic ecosystem changes based on primarily natural abiotic features of the environment. Ohio's reference sites, on which the biocriteria are based, reflect spatial differences that were partially explained by aquatic ecoregions and stream size. Biological indices were calibrated and stratified on this basis to arrive at biological criteria that present minimally acceptable baseline ecological index scores (e.g., IBI, ICI). Ohio biocriteria stratified by ecoregion aquatic life use and stream size are depicted in Figure 2-1.

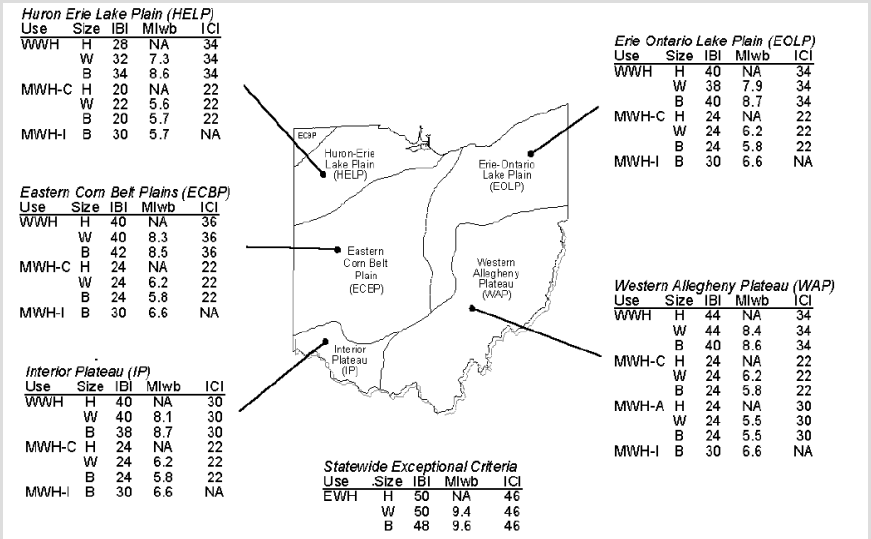

FIGURE 2-1 Numeric biological criteria adopted by Ohio EPA in 1990, using three biological indices [IBI, ICI, and the Modified Index of well-being (Mlwb), which is used to assessed fish assemblages] and showing stratification by stream size, ecoregion, and designated use (warmwater habitat, WWH; modified warmwater habitat-channelized, MWH-C; modified warmwater habitat-impounded, MWH-I; and exceptional warmwater habitat, EWH). SOURCE: EPA (2006, Appendix B). The basis for the Ohio biocriteria and sampling methods is found in Ohio EPA (1987, 1989a,b), DeShon (1995), and Yoder and Rankin (1995).

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uses, which provide a permanent floor against lowering water quality protection. Tiered beneficial uses and refined antidegradation rules can have substantial influence on stormwater programs because they influence the goals and levels of protection assigned to each waterbody.

Monitoring Programs to Identify Degraded Segments. Monitoring strategies by the states generally follow the regulatory efforts of EPA and seek to identify those waterbodies where water quality standards are not being met. Much of the initial ambient monitoring (i.e., monitoring of receiving waterbodies) was chemical based and focused on documenting changes in pollutant concentrations and exceedances of water quality criteria. Biological monitoring techniques have a long history of use as indicators of water quality impacts. However, it was not until such tools became more widespread—initially in states like Maine, North Carolina, and Ohio—that the extent of stormwater and other stressor effects on waterbodies became better understood. The biological response to common nonpoint stressors has driven the consideration of new water quality criteria (e.g., for nutrients, bedded sediments) that were not major considerations under an effluent-dominated paradigm of water management.

In parallel with the increase in biocriteria has been the development of biological monitoring to measure beneficial use attainment. Integrated biological surveys have revealed impairments of waterbodies that go beyond those caused by typical point sources (EPA, 1996b; Barbour et al., 1999a). The substantial increase in biological assemblage monitoring during the 1980s was enhanced by the development of more standard methods (Davis, 1995; Barbour et al., 1999a,b; Klemm et al., 2003) along with conceptual advances in the development of assessment tools (Karr, 1981; Karr and Chu, 1999). Development of improved classification tools (e.g., ecoregions, stream types), the reference site concept (Stoddard et al., 2006), and analytical approaches including multivariate (e.g., discriminant analysis) and multimetric indices such as IBI and ICI (see Box 2-3; Karr et al., 1986; DeShon, 1995) resulted in biological criteria being developed for several states. Biological monitoring approaches are becoming a widespread tool for assessing attainment of aquatic life use designation goals inherent to state water quality standards. Development of biocriteria represents a maturation of the use of biological data and provides institutional advantages for states in addressing pollutants without numeric criteria (e.g., nutrients) and non-chemical stressors such as habitat (Yoder and Rankin, 1998).

Setting Loads and Restricting Loading. Section 303d of the CWA requires that states compare existing water quality data with water quality standards set by the states, territories, and tribes. For those waters found to be in violation of their water quality standards, Section 303d requires that the state develop a TMDL. Currently, approximately 20,000 of monitored U.S. waters are in non-attainment of water quality standards, as evidenced by not meeting at least one specific narrative or numeric physical, chemical, or biological criterion, and thus require the development of a TMDL.

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BOX 2-3
Commonly Used Biological Assessment Indices

Much of the initial work using biological data to assess the effects of pollution on inland streams and rivers was a response to Chicago's routing of sewage effluents into the Illinois River in the late 1800s. Early research focused on the use of indicator species, singly or in aggregate, and how they changed along gradients of effluent concentrations (Davis, 1990, 1995). In the 1950s Ruth Patrick used biological data to assess rivers by observing longitudinal changes in taxonomic groups, and later in the 1950s and 1960s "diversity indices" (e.g., Shannon-Wiener index, Shannon and Weaver, 1949) were used to assess aquatic communities (Washington, 1984; Davis 1990, 1995). These indices were various mathematical constructs that measured attributes such as richness and evenness of species abundance in samples and are still widely used today in ecological studies. Similarity indices are another approach that is used to compare biological assemblages between sites. There are a wide multitude of such indices (e.g., Bray-Curtis, Jaccard) and all use various mathematical constructs to examine species in common and absent between samples.

Biotic indices are generally of more recent origin (1970s to the present). Hilsenhoff (1987, 1988) assigned organic pollution tolerances to macroinvertebrate taxa and then combined these ratings in a biotic index that is still widely used for macroinvertebrates. Karr (1981) developed the Index of Biotic Integrity (IBI), a "multimetric" index that is composed of a series of 12 metrics of a Midwest stream fish community. This approach has been widely adopted and adapted to many types of waterbodies (streams, lakes, rivers, estuaries, wetlands, the Great Lakes, etc.) and organism groups and is probably the most widely used biotic index approach in the United States. Examples include the periphyton IBI (PIBI; Hill et al., 2000) for algal communities, the Invertebrate Community Index (ICI; DeShon, 1995) and benthic IBI (B-IBI, Kerans and Karr, 1994) for macroinvertebrates, a benthic IBI for estuaries (B-IBI; Weisberg et al., 1997), and a vegetative IBI for wetlands (VIBI-E; Mack, 2007).

Various multivariate statistical approaches have also been used to assess aquatic assemblages, often concurrently with multimetric indices. Maine, for example, uses a discriminant analysis that assesses stream stations by comparison to reference sites (Davies and Tsomides, 1997). Predictive modeling approaches, incorporating both biotic and environmental variables, have been widely used in Great Britain and Europe (River Invertebrate Prediction and Classification System, RIVPACS; Wright et al., 1993), Australia (AUSRIVAS; Simpson and Norris, 2000), and more recently in the United States by Hawkins et al. (2000).

All of these approaches now have a wide scientific literature supporting their use and application. EPA (2002a) reports that most states have a biomonitoring program with at least one organism group to assess key waters in their states, although the level of implementation and sophistication varies by state. For example, only four states have numeric biocriteria in their state water quality standards, although 11 more are developing such biocriteria based on one or more of the above monitoring approaches (EPA, 2002a). The key to implementation of any of these approaches is to set appropriate goals for waters that can be accurately measured and then to use this type of information to identify limiting stressors (e.g., EPA Stressor Identification Process; EPA, 2000a).

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The TMDL process includes an enforceable pollution control plan for degraded waters based on a quantification of the loading of pollutants and an understanding of problem sources within the watershed [33 U.S.C. § 1313(d)(1)(C)]. Both point and nonpoint sources of the problematic pollutants, including runoff from agriculture, are typically considered and their contributions to the problem are assessed. A plan is then developed that may require these sources to reduce their loading to a level (the TMDL) that ensures that the water will ultimately meet its designated use. Most of the TMDL requirements have been developed through regulation. Additional effluent limits for point sources discharging into segments subject to TMDLs are incorporated into the NPDES permit.

Total Maximum Daily Load Program and Stormwater

The new emphasis on TMDLs and the revelation that impacts are primarily from diffuse sources has increased the attention given to stormwater. If a TMDL assigns waste load allocations to stormwater discharges, these must be incorporated as effluent limitations into stormwater permits. In addition, the TMDL program provides a new opportunity for states to regulate stormwater sources more vigorously. In degraded waterbodies, effluent reductions for point sources are not limited by what is economically feasible but instead include requirements that will ensure that the continued degradation of the receiving water is abated. If a permitted stormwater source is contributing pollutants to a degraded waterbody and the state believes that further reductions in pollution from that source are needed, then more stringent discharge limitations are required. For example, in *City of Arcadia vs. State Water Resources Control Board* [135 Cal. App. 4th 1392 (Ca. Ct. App. 2006)], the court held in part that California's zero trash requirements for municipal storm drains, resulting from state TMDLs, were not inconsistent with TMDL requirements or the CWA. Thus, the maximum-extent-practicable standard for MS4s, as well as other technology-based requirements for other stormwater permittees, are a floor, not a ceiling, for permit requirements when receiving waters are impaired (Beckman, 2007). Finally, since the TMDL program expects the states to regulate any source—point or nonpoint—that it considers problematic, any source of stormwater is fair game, regardless of whether it is listed in Section 402p, and regardless of whether it is a "point source." Nonpoint source runoff from agricultural and silvicultural operations is in fact a common target for TMDL-driven restrictions [see, e.g., *Pronsolino vs. Nastri*, 291 F.3d 1123, 1130 (9th Cir. 2002), upholding restrictions on nonpoint sources, such as logging, compelled by State's TMDLs)].

Despite the potential for positive interaction between stormwater regulation and the TMDL program, there appears to be little activity occurring at the stormwater–TMDL interface. This is partly because the TMDL program itself has been slow in developing. In 2000, the National Wildlife Federation applied 36 criteria to the 50 states' water quality programs and concluded that 75 per-

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cent of the states had failed to develop meaningful TMDL programs (National Wildlife Federation, 2000, pp. 1–2). The General Accounting Office (GAO, 1989) identified the lack of implementation of TMDLs as a major impediment to attaining the goals of the CWA, which led to a spate of lawsuits filed by environmental groups to reverse this pattern. The result was numerous settlements with ambitious deadlines for issuing TMDLs.

Commentators blame the delays in these TMDL programs on inadequate ambient monitoring data and on the technical and political challenges of causally linking individual sources to problems of impairment. In a 2001 report, for example, the National Research Council (NRC) noted that unjustified and poorly supported water quality standards, a lack of monitoring, uncertainty in the relevant models, and a failure to use biocriteria to assess beneficial uses directly all contributed to the delays in states' abilities to bring their waters into attainment through the TMDL program (NRC, 2001). Each of these facets is not only technically complicated but also expensive. The cost of undertaking a rigorous TMDL program in a single state has been estimated to be about $4 billion per state, assuming that each state has 100 watersheds in need of TMDLs (Houck, 1999, p. 10476).

As a result, the technical demands of the TMDL program make for a particularly bad fit with the technical impediments already present in monitoring and managing stormwater. As mentioned earlier, the pollutant loadings in stormwater effluent vary dramatically over time and stormwater is notoriously difficult to monitor for pollutants. It is thus difficult to understand how much of a pollutant a stormwater point source contributes to a degraded waterbody, much less determine how best to reduce that loading so that the waterbody will meet its TMDL. As long as the focus in these TMDLs remains on pollutants rather than flow (a point raised earlier that will be considered again), the technical challenges of incorporating stormwater sources in a water quality-based regulatory program are substantial. Without considerable resources for modeling and monitoring, the regulator has insufficient tools to link stormwater contributions to water quality impairments.

These substantial challenges in linking stormwater sources back to TMDLs are reflected by the limited number of reports and guidance documents on the subject. In one recent report, for example, EPA provides 17 case studies in which states and EPA regions incorporated stormwater control measures into TMDL plans, but it is not at all clear from this report that these efforts are widespread or indicative of greater statewide activity (EPA, 2007a). Indeed, it almost appears that these case studies represent the universe of efforts to link TMDLs and stormwater management together. The committee's statement of task also appears to underscore, albeit implicitly, EPA's difficulty in making scientific connections between the TMDL and stormwater programs. This challenge is returned to in Chapter 6, which suggests some ways that the two can be joined together more creatively.

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Other Statutory Authorities that Control Stormwater

Although the CWA is by far the most direct statutory authority regulating stormwater discharges, there are other federal regulatory authorities that could lead to added regulation of at least some stormwater sources of pollution.

Critical Resources

If there is evidence that stormwater flows or pollutants are adversely impacting either endangered species habitat or sensitive drinking water sources, federal law may impose more stringent regulatory restrictions on these activities. Under the Endangered Species Act, stormwater that jeopardizes the continued existence of endangered species may need to be reduced to the point that it no longer threatens the endangered or threatened populations in measurable ways, especially if the stormwater discharge results from the activity of a federal agency [16 U.S.C. §§ 1536(a), 1538(a)].

Under the Safe Drinking Water Act, a surface water supply of drinking water must conduct periodic "sanitary surveys" to ensure the quality of the supply (see 40 C.F.R. § 142.16). During the course of these surveys, significant stormwater contributions to pollution may be discovered that are out of compliance or not regulated under the Clean Water Act because they are outside of an MS4 area. Such a discovery could lead to more rigorous regulation of stormwater discharges. For a groundwater source that supplies 50 percent or more of the drinking water for an area and for which there is no reasonably available alternative source, the aquifer can be designated as a "Sole Source Aquifer" and receive greater protection under the Safe Drinking Water Act [42 U.S.C. § 300(h)-3(e)]. Stormwater sources that result from federally funded projects are also more closely monitored to ensure they do not cause significant contamination to these sole source aquifers.

Some particularly sensitive water supplies are covered by both programs. The Edwards Aquifer underlying parts of Austin and San Antonio, Texas, for example, is identified as a "Sole Source Aquifer." There are also several endangered species of fish and salamander in that same area. As a result, both the Safe Drinking Water Act and the Endangered Species Act demand more rigorous stormwater management programs to protect this delicate watershed.

Stormwater is also regulated indirectly by floodplain control requirements promulgated by the Federal Emergency Management Agency (FEMA). In order for a community to participate in the FEMA National Flood Insurance Program, it must fulfill a number of requirements, including ensuring that projects will not increase flood heights, including flood levels adjacent to the project site [see, e.g., 44 C.F.R. § 60.3(d)].

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Contaminated Sites

Continuous discharges of contaminated stormwater and other urban pollutants (particularly through combined sewer overflows) have led to highly contaminated submerged sediments in many urban bays and rivers throughout the United States. In several cases where the sediment contamination was perceived as presenting a risk to human health or has led to substantial natural resource damages, claims have been filed under the federal hazardous waste cleanup statute commonly known as Superfund (42 U.S.C. § 9601 et seq.). This liability under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) technically applies to any area—whether submerged or not—as long as there is a "release or a threat of release of a hazardous substance" and the hazardous substances have accumulated in such a way as to lead to the "incurrence of response [cleanup] costs" or to "natural resource damages" [42 U.S.C. §9607(a)]. Although only a few municipalities and sewer systems have been sued, Superfund liability is theoretically of concern for possibly a much larger number of cities or even industries whose stormwater contains hazardous substances and when at least some of the discharges were either in violation of a permit or unpermitted. The National Oceanic and Atmospheric Administration brought suit against the City of Seattle and the Municipality of Metropolitan Seattle alleging natural resource damages to Elliott Bay resulting from pollution in stormwater and combined sewer overflows; the case was settled in 1991 (*United States vs. City of Seattle*, No. C90-395WD, *http://www.gc.noaa.gov/natural-office1.html*). While some of the elements for liability remain unresolved by the courts, such as whether some or all of the discharges are exempted under the "federally permitted release" defense of CERCLA [42 U.S.C. § 9601(10)(H)], which exempts surface water discharges that are covered by a general or NPDES permit from liability, the prospect of potential liability is still present.

Diversion of Stormwater Underground or into Wetlands

In some areas, stormwater is eliminated by discharging it into wetlands. If done through pipes or other types of point sources, these activities require a permit under the CWA. Localities or other sources that attempt to dispense with their stormwater discharges in this fashion must thus first acquire an NPDES permit.

Even without a direct discharge into wetlands, stormwater can indirectly enter wetland systems and substantially impair their functioning. In a review of more than 50 studies, the Center for Watershed Protection found that increased urbanization and development increased the amount of stormwater to wetlands, which in turn "led to increased ponding, greater water level fluctuation and/or hydrologic drought in urban wetlands" (Wright et al., 2006). They found that, in

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some cases, the ability of the wetlands to naturally remove pollutants became overwhelmed by pollutant loadings from stormwater.

An even more common method of controlling stormwater is to discharge it underground. Technically, these subsurface discharges of stormwater, including dry wells, bored wells, and infiltration galleries, are considered by EPA to be infiltration or "Class V" wells, which require a permit under the CWA as long as they are in proximity to an underground source of drinking water (40 C.F.R. Parts 144, 146). While EPA's definition excludes surface impoundments and excavated trenches lined with stone (provided they do not include subsurface fluid distribution systems or amount to "improved sinkholes" that involve the man-made modification of a naturally occurring karst depression for the purpose of stormwater control), most other types of subsurface drainage systems are covered regardless of the volume discharged (40 C.F.R. § 144.81(4)).

Given EPA's recent description of SCMs considered to be Class V injection wells (EPA, 2008), most SCMs that rely on infiltration are exempted. For example, if an infiltration trench is wider than it is deep, it is exempted from the Class V well regulations. Residential septic systems are also exempted [see 40 C.F.R. §§ 144.1(g)(1)(ii) and (2)(iii)]. However, those that involve deeper dry wells or infiltration galleries appear to require Class V well permits under the Safe Drinking Water Act. Because the use of these SCMs is likely to involve expensive compliance requirements, dischargers may steer away from them.

Air Contaminants

Air pollutants from vehicular exhaust and industrial sources that precipitate on roads and parking lots can also be collected in stormwater and increase pollutant loading (see Chapter 3 discussion of atmospheric deposition). While the Clean Air Act regulates these sources of air contamination, it does not eliminate them. Stormwater that is contaminated with air pollutants may consist of both "legal" releases of air pollutants, as well as "illegal" releases emitted in violation of a permit, although the distinction between the two groups of pollutants is effectively impossible to make in practice.

Pesticides and Other Chemical Products Applied to Land and Road Surfaces

EPA regulates the licensing of pesticides as well as chemicals and chemical mixtures, although its actual authority to take action, such as restricting product use or requiring labeling, varies according to the statute and whether the product is new or existing. Although EPA technically is allowed to consider the extent to which a chemical is accumulating in stormwater in determining whether additional restrictions of the chemical are needed, EPA is not aware of any instances in its Toxic Substances Control Act (TSCA) chemical regulatory decision-

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making in which it actually used this authority to advance water quality protection (Jenny Molloy, EPA, personal communication, March 13, 2008).

In its pesticide registration program, EPA does routinely consider a pesticide's potential for adverse aquatic effects from stormwater runoff in determining whether the pesticide constitutes an unreasonable risk (Bill Jordan, EPA, personal communication, March 14, 2008). EPA has imposed use restrictions on a number of individual pesticides, such as prohibiting aerial applications, requiring buffer strips, or reducing application amounts. Presumably states and localities are tasked with primary enforcement responsibility for most of these use restrictions. EPA has also required a surface water monitoring program as a condition of the re-registration for atrazine and continues to evaluate available surface water and groundwater data to assess pesticide risks (Bill Jordan, EPA, personal communication, March 14, 2008).

EPA STORMWATER PROGRAM

Stormwater is defined in federal regulations as "storm water runoff, snow melt runoff, and surface runoff and drainage" [40 CFR §122.26(b)(13)]. EPA intended that the term describe runoff from precipitation-related events and not include any type of non-stormwater discharge (55 Fed. Reg. 47995). A brief discussion of the evolution of the EPA's stormwater program is followed by an explanation of the permitting mechanisms and the various ways in which the program has been implemented by the states. As shown in Figure 2-2, the entire NPDES program has grown by almost an order of magnitude over the past 35 years in terms of the number of regulated entities, which explains the reliance of the program on general rather than individual permits. Both phases of the stormwater program have brought a large number of new entities under regulation.

Historical Background

States like Florida, Washington, Maryland, Wisconsin, and Vermont and some local municipalities such as Austin, Texas, Portland, Oregon, and Bellevue, Washington, preceded the EPA in implementing programs to mitigate the adverse impacts of stormwater quality and quantity on surface waters. The State of Florida, after a period of experimentation in the late 1970s, adopted a rule that required a state permit for all new stormwater discharges and for modifications to existing discharges if flows or pollutants increased (Florida Administrative Code, Chapter 17-25, 1982). The City of Bellevue, WA, established a municipal utility in 1974 to manage stormwater for water quality, hydrologic balance, and flood management purposes using an interconnected system of natural areas and existing drainage features.

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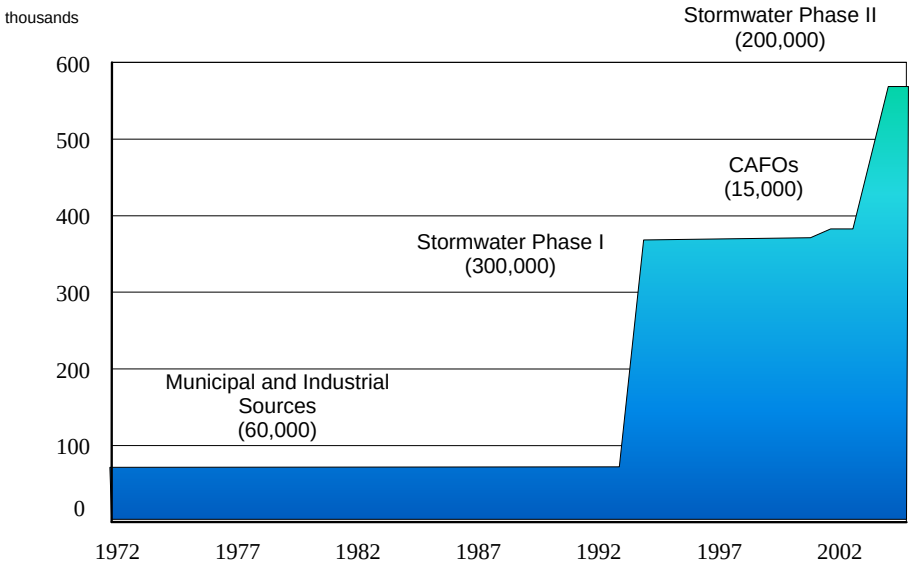

FIGURE 2-2 The number of permittees under the NPDES program of the Clean Water Act from 1972 to the present. Note that concentrated Animal Feeding Operations (CAFOs) are not considered in this report. SOURCE: Courtesy of Linda Boornazian, EPA.

EPA first considered regulating stormwater in 1973. At that time, it exempted from NPDES permit coverage conveyances carrying stormwater runoff not contaminated by industrial or commercial activity, unless the discharge was determined by the Administrator to be a significant contributor of pollutants to surface waters (38 Fed. Reg. 13530, May 22, 1973). EPA reasoned that while these stormwater conveyances were point sources, they were not suitable for end-of-pipe, technology-based controls because of the intermittent, variable, and less predictable nature of stormwater discharges. Stormwater pollution would be better managed at the local agency level through nonpoint source controls such as practices that prevent pollutants from entering the runoff. Further, EPA justified its decision by noting that the enormous numbers of individual permits that the Agency would have to issue would be administratively burdensome and divert resources from addressing industrial process wastewater and municipal sewage discharges, which presented more identifiable problems.

The Natural Resources Defense Council (NRDC) successfully challenged the EPA's selective exemption of stormwater point sources from the NPDES regulatory permitting scheme in federal court [*NRDC vs. Train*, 396 F.Supp. 1393 (D.D.C. 1975), *aff'd NRDC vs. Costle* 568 F.2d. 1369 (D.C. Cir. 1977)]. The court ruled that EPA did not have the authority to exempt point source discharges from the NPDES permit program, but recognized the Agency's discretion to use reasonable procedures to manage the administrative burden and to

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define what constitutes a stormwater point source. Consequently, EPA issued a rule establishing a comprehensive permit program for all stormwater discharges (except rural runoff) including municipal separate storm sewer systems (MS4s), which were to be issued "general" or area permits after a period of study (41 Fed. Reg. 11307, March 18, 1976). Individual permits were required for stormwater discharges from industrial or commercial activity, or where the stormwater discharge was designated by the permitting authority to be a significant contributor of pollutants. Comprehensive revisions to the NPDES regulations were published next, retaining the broad definition of stormwater discharges subject to the NPDES permit program and requiring permit application requirements similar to those for industrial wastewater discharges, including testing for an extended list of pollutants (44 Fed. Reg. 32854, June 7, 1979; 45 Fed. Reg. 33290, May 19, 1980).

The new NPDES regulations resulted in lawsuits filed in federal courts by a number of major trade associations, member companies, and environmental groups challenging several aspects of the NPDES program, including the stormwater provisions. The cases were consolidated in the D.C. Circuit Court of Appeals, and EPA reached a settlement with the industry petitioners on July 7, 1982, agreeing to propose changes to the stormwater regulations to balance environmental concerns with the practical limitations of issuing individual NPDES permits and limited resources. The Agency significantly narrowed the definition of stormwater point sources to conveyances contaminated by process wastes, raw materials, toxics, hazardous pollutants, or oil and grease, and it reduced application requirements by dividing stormwater discharges into two groups based on their potential for significant pollution problems (47 Fed. Reg. 52073, November 18, 1982). EPA issued a final rule retaining the broad coverage of stormwater point sources, and a two-tiered classification to administratively regulate these stormwater discharges (49 Fed. Reg. 37998, September 26, 1984).

The rule generated considerably controversy; trade associations and industry contended that application deadlines would be impossible to meet and that the sampling requirements were excessive, while the environmental community expressed a concern that additional changes or delays would exacerbate the Agency's failure to regulate sources of stormwater pollution. On the basis of the post-promulgation comments received, EPA determined that it was necessary to obtain additional data on stormwater discharges to assess their significance, and it conducted meetings with industry groups, who indicated an interest in providing representative data on the quality of stormwater discharges of their membership. The Agency determined that the submission of representative data was the most practical and efficient means of determining appropriate permit terms and conditions, as well as priorities for the multitude of stormwater point source discharges that needed to be permitted (50 Fed. Reg. 32548, August 12, 1985).

In the mean time, the U.S. House of Representatives and the Senate both passed bills to amend the CWA in mid-1985. The separate bills were reconciled in Conference Committee, and on February 4, 1987, Congress passed the Water

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Quality Act (WQA), which specifically addressed stormwater discharges. The WQA added Section 402(p) to the CWA, which requires stormwater permits to be issued prior to October 1992 for (i) municipal stormwater discharges from large and medium municipalities based on the 1990 census; (ii) discharges associated with industrial activity; and (iii) a stormwater discharge that the Administrator determines contributes to the violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. MS4s were required to reduce pollutants in stormwater discharges to the "maximum extent practicable" (MEP). Industrial and construction stormwater discharges must meet the best conventional technology (BCT) standard for conventional pollutants and the best available technology economically achievable (BAT) standard for toxic pollutants. EPA and the NPDES-delegated states were given the flexibility to issue municipal stormwater permits on a system-wide or jurisdiction-wide basis. In addition, the WQA amended Section 402(l)(2) of the CWA to not require a permit for stormwater discharges from mining and oil and gas operations if the stormwater discharge is not contaminated by contact, and it amended Section 502(14) of the CWA to exclude agricultural stormwater discharges from the definition of point source.

These regulations had been informed by the National Urban Runoff Program, conducted from 1978 to 1983 to characterize the water quality of stormwater runoff from light industrial, commercial, and residential areas (Athayde et al., 1983). The majority of samples collected were analyzed for eight conventional pollutants and three heavy metals, and a subset was analyzed for 120 priority pollutants. The study indicated that on an annual loading basis, some of the conventional pollutants were greater than the pollutant loadings resulting from municipal wastewater treatment plants. In addition, the study found that a significant number of samples exceeded EPA's water quality criteria for freshwater.

The Federal Highway Administration conducted studies over a ten-year period ending in 1990 to characterize the water quality of stormwater runoff from roadways (Driscoll et al., 1990). A total of 993 individual stormwater events at 31 highway sites in 11 states were monitored for eight conventional pollutants and three heavy metals. In addition, a subset of samples was analyzed for certain other conventional pollutant parameters. The studies found that urban highways had significantly higher pollutant concentrations and loads than non-urban highway sites. Also, sites in relatively dry semi-arid regions had higher concentrations of many pollutants than sites in humid regions.

Final Stormwater Regulations

EPA issued final regulations in 1990 establishing a process for stormwater permit application, the required components of municipal stormwater management plans, and a permitting strategy for stormwater discharges associated with industrial activities (55 Fed. Reg. 222, 47992, November 16, 1990). Stormwater

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discharges associated with industrial activity that discharge to MS4s were required to obtain separate individual or general NPDES permits. Nevertheless, EPA recognized that medium and large MS4s had a significant role to play in source identification and the development of pollution controls for industry, and thus municipalities were obligated to require the implementation of controls under local government authority for stormwater discharges associated with industrial activity in their stormwater management program. The final regulations also established minimum sampling requirements during permit application for medium and large MS4s (serving a population based on the 1990 census of 100,000 to 250,000, and 250,000 or more, respectively). MS4s were required to submit a two-part application over two years with the first part describing the existing program and resources and the second part providing representative stormwater quality discharge data and a description of a proposed stormwater management program, after which individual MS4 NPDES permits would be issued for medium and large MS4s.

In addition, the regulations identified ten industry groups and construction activity disturbing land area five acres or greater as being subject to stormwater NPDES permits. These industries were classified as either heavy industry or light industry where industrial activities are exposed to stormwater, based on the Office of Management and Budget Standard Industrial Classifications (SIC). The main industrial sectors subject to the stormwater program are shown in Table 2-3 and include 11 regulatory categories: (i) facilities with effluent limitations, (ii) manufacturing, (iii) mineral, metal, oil and gas, (iv) hazardous waste treatment, storage, or disposal facilities, (v) landfills, (vi) recycling facilities, (vii) steam electric plants, (viii) transportation facilities, (ix) treatment works, (x) construction activity, and (xi) light industrial activity.

The second phase of final stormwater regulations promulgated on December 8, 1999 (64 Fed. Reg. 68722) required small MS4s to obtain permit coverage for stormwater discharges no later than March 10, 2003. A small MS4 is defined as an MS4 not already covered by an MS4 permit as a medium or large MS4, or is located in "urbanized areas" as defined by the Bureau of the Census (unless waived by the NPDES permitting authority), or is designated by the NPDES permitting authority on a case-by-case basis if situated outside of urbanized areas. Further, the regulations lowered the construction activities regulatory threshold for permit coverage for stormwater discharges from five acres to one acre.

To give an idea of the administrative burden associated with the stormwater program and the different types of permits, Table 2-4 shows the number of regulated entities in the Los Angeles region that fall under either individual or general permit categories. Industrial and construction greatly outweigh municipal permittees, and stormwater permittees are vastly more numerous that traditional wastewater permittees.

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TABLE 2-3 Sectors of Industrial Activity Covered by the EPA Stormwater Program

Category (see page 69)	**Sector**	**SIC Major Group**	**Activity Represented**
(i)	A	24	Timber products
(ii)	B	26	Paper and allied products
(ii)	C	28 and 39	Chemical and allied products
(i), (ii)	D	29	Asphalt paving and roofing materials and lubricants
(i) (ii)	E	32	Glass, clay, cement, concrete, and gypsum products
(i) (iii)	F	33	Primary metals
(i), (iii)	G	10	Metal mining (ore mining and dressing)
(i), (iii)	H	12	Coal mines and coal mining-related facilities
(i), (iii)	I	13	Oil and gas refining
(i), (iii)	J	14	Mineral mining and dressing
(iv)	K	HZ	Hazardous waste, treatment, storage, and disposal
(v)	L	LF	Landfills, land application sites, and open dumps
(vi)	M	50	Automobile salvage yards
(vii)	N	50	Scrap recycling facilities
(vii)	O	SE	Steam electric generating facilities
(viii)	P	40, 41, 42, 43, 51	Land transportation and warehousing
(viii)	Q	44	Water transportation
(viii)	R	37	Ship and boat building or repairing yards
(viii)	S	45	Air transportation
(ix)	T	TW	Treatment works
(xi)	U	20, 21	Food and kindred products
(xi)	V	22, 23, 31	Textile mills, apparel, and other fabric product manufacturing, leather and leather products
(xi)	W	24, 25	Furniture and fixtures
(xi)	X	27	Printing and publishing
(xi)	Y	30, 39, 34	Rubber, miscellaneous plastic products, and miscellaneous manufacturing industries
(xi)	AB	35, 37	Transportation equipment, industrial or commercial machinery
(xi)	AC	35, 36, 38	Electronic, electrical, photographic, and optical goods
(x)			Construction activity
	AD		Non-classified facilities designated by Administrator under 40 CFR §122.26(g)(1)(l)

SOURCE: 65 Fed. Reg. 64804, October 30, 2000.

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TABLE 2-4 Number of NPDES Wastewater and Stormwater Entities Regulated by the CalEPA, Los Angeles Regional Water Board, as of May 2007

Waste Type	Individual Permittees	General Permittees
Wastewater and Non-stormwater Industry	103	574
Combined Wastewater and Stormwater	23	0
Stormwater (pre-1990)	45	0
Industrial Stormwater (post-1990)	0	2990
Construction Stormwater (post-1990)	0	2551
Municipal Stormwater (post-1990)	100	0
Total	271	6215

Municipal Permits

States with delegated NPDES permit authority (all except Alaska, Arizona, Idaho, Massachusetts, New Hampshire, and New Mexico) issued the first large and medium MS4 permits beginning in 1990, some of which are presently in their fourth permit term. These MS4 permits require large and medium municipalities to implement programmatic control measures (the six minimum measures) in the areas of (1) public education and outreach, (2) public participation and involvement, (3) illicit discharge detection and elimination, (4) construction site runoff control, (5) post-construction runoff control, and (6) pollution prevention and good housekeeping—all to reduce the discharge of pollutants in stormwater to the *maximum extent practicable*. Efforts to meet the six minimum measures are documented in a stormwater management plan. Non-stormwater discharges to the MS4 are prohibited unless separately permitted under the NPDES, except for certain authorized non-stormwater discharges, such as landscape irrigation runoff, which are deemed innocuous nuisance flows and not a source of pollutants. MS4 permits generally require analytic monitoring of pollutants in stormwater discharges for all Phase I medium and large MS4s from a subset of their outfalls that are 36 inches or greater in diameter or drain 50 acres or more. These data, at the discretion of the permitting authority, may be compared with water quality standards and considered (by default) to be effluent limitations, which refer to any restriction, including schedules of compliance, established by a state or the Administrator pursuant to CWA Section 304(b) on quantities, rates, and concentrations of chemical, physical, biological, and other constituents discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean (40 CFR §401.11). A future exceedance of an effluent limitation constitutes a permit violation. However, permitting authorities have so far not taken this approach to interpreting MS4 stormwater discharge data.

The Phase I stormwater regulations require medium and large MS4s to inspect "high-risk" industrial facilities and construction sites within their jurisdictions. Certain industrial facilities and construction sites of a minimum acreage are also subject to separate EPA/state permitting under the industrial and con-

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struction general permits (see below). While EPA envisioned a partnership with municipalities on these inspections in its Phase I Rule Making, it provided no federal funding to build these partnerships. Both industry and municipalities have argued that the dual inspection responsibilities are duplicative and redundant. Municipalities have further contended that the inspection of Phase I industrial facilities and construction sites are solely an EPA/state obligation, although state and federal courts have ruled otherwise. In the committee's experience, many MS4s do not oversee or regulate industries within their boundaries.

As part of the Phase II program, small MS4s are covered under general permits and are required to implement a stormwater management program to meet the six minimum measures mentioned above. Unlike with Phase I, Phase II MS4 stormwater discharge monitoring was made discretionary, and inspection of industrial facilities within the boundary of a Phase II MS4 is not required.

Industrial Permits

EPA issued the first nationwide multi-sector industrial stormwater general permit (MSGP) on September 29, 1995 (60 Fed. Reg. 50804), which was reissued on October 30, 2000 (65 Fed. Reg. 64746). A proposed new MSGP was released for public comment in 2005 (EPA, 2005b). The proposed MSGP requires that industrial facility operators prepare a stormwater pollution prevention plan (similar to an MS4's stormwater management plan) that documents the SCMs that will be implemented to reduce pollutants in stormwater discharges. They must achieve technology-based requirements using BAT or BCT or water quality-based effluent limits, which is the same requirement as for process wastewater permits.

All industrial sectors covered under the MSGP must conduct visual monitoring four times a year. The visual monitoring is performed by collecting a grab sample within the first hour of stormwater discharge and observing its characteristics qualitatively. A subset of MSGP industrial categories is required to perform analytical monitoring for benchmark pollutant parameters four times in Year 2 of permit coverage and again in Year 4 if benchmarks were exceeded in Year 2. The benchmark pollutant parameters, listed in Table 2-5, were selected based on the sampling data included with group permit applications submitted after the EPA issued its stormwater regulations in 1990. To comply with the benchmark monitoring requirements, a grab sample must be collected within the first hour of stormwater discharge after a rainfall event of 0.1 inch or greater and with an interceding dry period of at least 72 hours. A benchmark exceedance is not a permit violation, but rather is meant to trigger the facility operator to investigate SCMs and make necessary improvements.

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TABLE 2-5 Industry Sectors and Sub-Sectors Subject to Benchmark Monitoring

MSGP Sector	**Industry Sub-sector**	**Required Parameters for Benchmark Monitoring**
C	Industry organic chemicals Plastics, synthetic resins, etc. Soaps, detergents, cosmetics, perfumes Agricultural chemicals	Al, Fe, nitrate and nitrite N Zn Zn, nitrate and nitrite N Pb, Fe, Zn, P, nitrate and nitrite N
D	Asphalt paving and roofing materials	TSS
E	Clay products Concrete products	Al TSS and Fe
F	Steel works, blast furnaces, rolling and finishing mills Iron and steel foundries Non-ferrous rolling and drawing Non-ferrous foundries (casting)	Al, Zn Al, Cu, Fe, Zn, TSS Cu, Zn Cu, Zn
G	Copper ore mining and dressing	COD, TSS, nitrate and nitrite N
H	Coal mines and coal mining related facilities	TSS
J	Dimension stone, crushed stone, and non-metallic minerals (except fuels) Sand and gravel mining	TSS, Al, Fe Nitrate and nitrite N, TSS
K	Hazardous waste treatment, storage, or disposal	NH_3, Mg, COD, Ar, Cd, CN, Pb, Hg, Se, Ag
L	Landfills, land application sites, and open dumps	Fe, TSS
M	Automobile salvage yards	TSS, Al, Fe, Pb
N	Scrap recycling	Cu, Al, Fe, Pb, Zn, TSS, COD
O	Steam electric generating facilities	Fe
Q	Water transportation facilities	Al, Fe, Pb, Zn
S	Airports with deicing activities	BOD, COD, NH_3, pH
U	Grain mill products Fats and oils	TSS BOD, COD, nitrate and nitrite N, TSS
Y	Rubber products	Zn
AA	Fabricated metal products except coating Fabricated metal coating and engraving	Fe, Al, Zn, nitrate and nitrite N Zn, nitrate and nitrite N

NOTE: BOD, biological oxygen demand; COD, chemical oxygen demand; TSS, total suspended solids.
SOURCE: 65 Fed. Reg. 64817, October 30, 2000.

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EPA had already established technology-based effluent limitations for stormwater discharges for eight subcategories of industrial discharges prior to 1987, namely, for cement manufacturing, feedlots, fertilizer manufacturing, petroleum refining, phosphate manufacturing, steam electric, coal mining, and ore mining and dressing (see Table 2-6). Most of these facilities were covered under individual permits prior to 1987 and are generally required to stay covered under individual stormwater permits. Facilities in these sub-categories that had not been issued a stormwater discharge permit prior to 1992 are allowed to be covered under the MSGP, but they still have analytical monitoring requirements that must be compared to effluent limitation guidelines. An exceedance of the effluent limitation constitutes a permit violation.

TABLE 2-6 Select Stormwater Effluent Limitation Guidelines for Illustrative Purposes

Discharges	**Design Storm**	**Pollutant Parameters**	**Effluent Limitations (max per day)**
Phosphate Fertilizer Manufacturing Runoff (40 C.F.R. 418)	Not specified	Total P Fluoride	105 mg/L 75 mg/L
Petroleum Refining (40 C.F.R. 419)	Not specified	O&G TOC BOD5 COD Phenols Cr Hex Cr pH	15 mg/L 110 mg/L 48 kg/1000 m^3 flow 360 mg/1000 m^3 flow 0.35 mg/1000 m^3 flow 0.73 mg/1000 m^3 flow 0.062 mg/1000 m^3 flow 6–9
Asphalt Paving and Roofing Emulsion Products Runoff (40 C.F.R. 443)	Not specified	TSS O&G pH	0.023 kg/m^3 0.015 kg/m^3 6.0–9.0
Cement Manufacturing Material Storage Piles Runoff (40 C.F.R. 411)	10 yr, 24 hour	TSS pH	50 mg/L 6.0–9.0
Coal Mining (40 C.F.R. 434 Subpart B)	1 yr, 24 hour	Fe Mn TSS pH	7.0 mg/L 4 mg/L 70 mg/L 6.0–9.0
Steam Electric Power Generating (40 C.F.R. 423)	10 yr, 24 hour	TSS pH PCBs	50 mg/L 6.0–9.0 No discharge

NOTE: BOD5, biological oxygen demand; COD, chemical oxygen demand; O&G, oil and grease; PCBs, polychlorinated biphenyls; TOC, total organic carbon; TSS, total suspended solids. SOURCE: 40 C.F.R.

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At the issuance of the Final Storm Water Rule in 1990, EPA envisioned the use of a mix of general permits and individual permits to better manage the administrative burden associated with permitting thousands of industrial stormwater point sources. In its original permitting strategy for industrial stormwater discharges, EPA articulated a four-tier strategy with the nationwide general permits: Tier 1 was baseline permitting, Tier 2 would incorporate watershed permits, Tier 3 would be industry category-specific permitting, and Tier 4 would encompass facility-specific individual permits. In reality, individual permits, which would allow for the crafting of permit conditions to be better structured to the specific industrial facility based on its higher potential risk to water quality, and could include adequate monitoring for purposes of compliance and enforcement, have been sparsely used. Similarly, neither the watershed permitting strategy nor the industry category-specific permitting strategy has found favor in the absence of better federal guidance and funding.

Industrial stormwater general permits are issued by the State NPDES Permitting Authority in NPDES-delegated states, and may be in the form a single statewide permit covering thousands of industrial permittees or sector-specific stormwater general permits covering less than a hundred facilities. EPA Regions issue the MSGP in states without NPDES-delegated authority and for facilities on Native Indian and Tribal Lands. EPA's nationwide 2000 MSGP presently covers 4,102 facilities.

Construction Permits

EPA issued the first nationwide construction stormwater general permit (CGP) in February 1998 (63 Fed. Reg. 7858). The permits are valid for five-year terms. The most recent CGP was issued in 2005 (68 Fed. Reg. 39087), and the EPA in 2008 administratively continued the CGP until the end of 2009, when it is expected to have developed effluent guidelines for construction activity (73 Fed. Reg. 40338). The EPA is presently under court order to develop effluent limitation guidelines for stormwater discharges from the construction and land development industry. The construction general permit requires the implementation of stormwater pollution prevention plans to prevent erosion, control sediment in stormwater discharges, and manage construction waste materials. Operators of the construction activity are required to perform visual inspections regularly, but no sampling of stormwater discharge during rainfall events is required. As with the industrial and municipal permittees, an exceedance of an effluent limitation incorporated in a permit would be a violation of the CWA and is subject to penalties.

EPA's CGP covers construction activity in areas where EPA is the permitting authority, including Indian lands, Puerto Rico, the District of Columbia, Massachusetts, New Hampshire, New Mexico, Idaho, Arizona, and Alaska. All other states have been delegated the authority to issue NPDES permits, and

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these states issue CGPs based on the EPA model but with subtle variations. For example the California and Georgia CGPs include monitoring requirements for construction sites discharging to sediment-impaired waterbodies. Wisconsin requires weekly inspections and an inspection within 24 hours of a rain event of 0.5 inches or greater. Georgia imposes discharge limits of an increase of no more than 10 Nephelometric Turbidity Units (NTU) above background in trout streams and no more than 25 NTU above background in other types of streams.

Permit Creation, Administration, and Requirements

For individual permits, the entity seeking coverage submits an application and one permit is issued. The conditions of the permit are based on an analysis of information provided in a rather lengthy permit application by the facility operator about the facility and the discharge. Generally, it takes six to 18 months for the permittee to compile the application information and for the permitting authority to finalize the permit. Individual permits are common for medium and large MS4s (Phase I), small MS4s in a few states (Phase II), and a few industrial activities.

General permits, on the other hand, are issued by the permitting authority, and interested parties then submit an Notice of Intent (NOI) to be covered. This mechanism is used where large numbers of dischargers require permit coverage, such as construction activities, most industrial activities, and most small MS4s (Phase II). The permit must identify the area of coverage, the sources covered, and the process for obtaining coverage. Once the permit is issued, a permittee may submit a NOI and receive coverage either immediately or within a very short time frame (e.g., 30 days).

All permits contain "effluent limitations" or "effluent guidelines," adherence to which is required of the permittee. However, the terms (which are synonymous) are agonizingly broad and encompass (1) meeting numeric pollutant limits in the discharge, (2) using certain SCMs, and (3) meeting certain design or performance standards. Effluent limitations may be expressed as SCMs when numeric limits are infeasible or for stormwater discharges where monitoring data are insufficient to carry out the purposes and intent of the CWA [122.44(k)]. If EPA has promulgated numerical "effluent guidelines" for existing and new stormwater sources under CWA Sections 301, 304, or 306, then the permits must incorporate the "effluent guidelines" as permit limits.

Effluent limitations can be either technology-based or water quality-based requirements. Technology-based requirements establish pollutant limits for discharges on what the best pollution control technology installed for that industry would normally accomplish. Water-quality based requirements, by contrast, look to the receiving waters to determine the level of pollution reduction needed for individual sources. There are national technology-based standards available for many categories of point sources, including many industrial sectors and municipal wastewater treatment plants. In the absence of national standards, tech-

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nology-based requirements are developed on a case-by-case basis using best professional judgment. In general, BAT is the standard for toxic and non-conventional pollutants, while BCT is the standard for conventional pollutants. Water quality-based effluent limitations are required where technology-based limits are found to be insufficient to achieve applicable water quality standards, including restoring impaired waters, preventing impairments, and protecting high-quality waters. Limitations must control all pollutants or pollutant parameters that are or may be discharged at a level which will *cause, have reasonable potential to cause, or contribute to* an excursion above any applicable water quality standard. To distinguish between technology-based and water quality-based effluent limits, consider that a permittee is required to meet a numeric pollutant limit in their stormwater discharge. A technology-based limit would be based on studies of effluent concentrations coming from that technology, while a water quality-based limit would be based on some assessment of the impact of the discharge on a nearby receiving water (with the applicable water quality standard being the most conservative choice).

EPA is presently writing stormwater "effluent guidelines" for airport deicing operations and construction/development activity, with an estimated final action date of December 2009.

Permits Prior to 1990

A limited number of individual stormwater permits (perhaps in the low thousands) were first issued prior to 1990, the period before EPA promulgated regulations specific to stormwater discharges, and before EPA first received the authority to issue general NPDES permits. These individual NPDES permits for industrial stormwater discharges, like traditional individual wastewater NPDES permits, incorporate numerical effluent limits and they impose discharge monitoring requirements to demonstrate compliance. These facilities were selected for permitting before 1990, presumably because of the risk they presented to causing or contributing to the exceedance of water quality standards.

Do Permittees Have to Meet Water Quality Standards in their Effluent?

It is unclear as to whether municipal, industrial, and construction stormwater discharges must meet water quality standards. Furthermore, even if such discharges were required to meet water quality standards, the absence of monitoring found within the permits means that enforcement of the requirement would be difficult at best. Nonetheless, some sources suggest that, with the exception of Phase II MS4 discharges, EPA's intent is that stormwater discharges comply with water quality standards, especially where a TMDL is in place.

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First, the EPA Office of General Counsel issued a memorandum in 1991 stating that municipal stormwater permits must require that MS4s reduce stormwater pollutant discharges to the maximum extent practicable and must also comply with water quality standards. Recognizing the complexity of stormwater, EPA's 1996 Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits (61 Fed. Reg. 43761) stated that stormwater permits should use SCMs in first-term stormwater permits and expanded or better-tailored SCMs in subsequent term permits to provide for the attainment of water quality standards. However, where adequate information existed to develop more specific conditions or limitations to meet water quality standards, these conditions or limitations are to be incorporated into stormwater permits as necessary and appropriate.

As permitting authorities began to develop TMDL waste load allocations to address impaired receiving waters, and waste load allocations were assigned to stormwater discharges, EPA issued a TMDL Stormwater Policy. It stated that stormwater permits must include permit conditions consistent with the assumptions and requirements of available waste load allocations (EPA, 2002b). Since waste load allocations derive directly from water quality standards, this could be interpreted as saying that stormwater discharges must meet water quality standards. However, EPA expected that most water quality-based effluent limitations for NPDES-regulated stormwater discharges that implement TMDL waste load allocations would be expressed as SCMs, and that numeric limits would be used only in rare instances. This is understandable, given that storm events are dynamic and variable and it would be expensive to monitor all storm events and discharge points, particularly for MS4s, to demonstrate compliance with a waste load allocation expressed as a numeric effluent limitation. Effluent limitations expressed as SCMs appear to be the best interim approach to demonstrate compliance with TMDLs, provided that these SCMs are reasonably expected to satisfy the waste load allocation in the TMDL. As part of the TMDL, the NPDES permit must also specify the monitoring necessary to determine compliance with effluent limitations. Where effluent limits are specified as SCMs, the permit should specify the monitoring necessary to assess if the load reductions expected from SCM implementation are achieved (e.g., SCM performance data).

Implementation of the Stormwater Program by States and Municipalities

NPDES-delegated states and Indian Tribes generally utilize the CGP and the MSGP as model templates for adopting their respective general permits to regulate stormwater discharges associated with industrial activity, including construction, within their jurisdictions. Nevertheless, some variations exist. For example, the California CGP requires sampling of stormwater at construction sites that discharge to surface waters that are listed as being impaired for sediment. Connecticut's MSGP regulates stormwater discharges associated with

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commercial activity, in addition to industrial activity. With respect to the municipal permits, the variability with which the stormwater program is implemented reflects the flexibility inherent in the MEP standard. In the absence of a definite description of MEP or nationwide effluent guidelines issued by EPA, states and municipalities have not been very rigorous in determining what constitutes an adequate level of compliance. This self-defined compliance threshold has been translated into a wide range of efforts at program implementation.

A number of MS4 programs have been leaders in some areas of program implementation. For example, Prince George's County, Maryland, was a pioneer in implementing low impact development (LID) techniques. Notable efforts have been made by states and municipalities in the Pacific Northwest, such as Oregon and Washington. California and Florida also are in the forefront of implementing comprehensive and progressive stormwater programs.

Greater implementation is evident in states that had state stormwater regulations in place prior to the advent of the national stormwater program (GAO, 2007). Some states issued early MS4 permits (e.g., California, Florida, Washington, and Wisconsin) prior to the promulgation of the national stormwater program, while a number of MS4s (e.g., Austin, Texas,; Santa Monica, California; and Bellevue, Washington) were already implementing comprehensive stormwater management programs. In addition, some MS4s conducted individual stormwater management activities, such as street-sweeping, household hazardous waste collection, construction site plan review, and inspections, prior to the national stormwater program. These areas are more likely than areas without a stormwater program that predated the EPA program to be successfully meeting the requirements of the current program.

One of the obvious differences is the level of interest and effort exercised by coastal communities or communities in close proximity to a water resource that have immediate access to the beneficial uses of those resources but also have an immediate view of the impacts of polluted runoff. That interest may contrast with the less active posture of upstream or further inland communities that may not be as sensitive and willing to implement more stringent stormwater programs. A recent report has found that programs with more specific permit requirements generally result in more comprehensive and progressive stormwater management programs (TetraTech, 2006a). The report concluded that permittees should be required to develop measurable goals based on the desired outcomes of the stormwater program. Furthermore, additional stormwater permit requirements can be expected as more TMDLs are developed and wasteload allocations must be translated into permit conditions.

GAO Report on Current Status of Implementation

In 2007, the GAO issued a report to determine the impact of EPA's Stormwater Program on communities (GAO, 2007). Some of the relevant findings are

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that urban stormwater runoff continues to be a major contributor to the nation's degraded waters and that stormwater program implementation has been slow for both Phase I and Phase II communities, with almost 11 percent of all communities not yet permitted as of fall 2006. Litigation, among other reasons, delayed the issuance of some permits for years after the application deadlines. As a result, almost all Phase II and some Phase I communities are still in the early stages of program implementation although deadlines for permit applications were years ago—16 years for Phase I and six years for Phase II. EPA has acknowledged that it does not currently have a system in place to measure the success of the Phase I program on a national scale (EPA, 2000b). Therefore, it is reasonable to conclude that the level of implementation of the stormwater program ranges widely, from municipalities having completed a third-term permit (such as Los Angeles County MS4 permit) to municipalities not yet covered by a Phase II MS4 permit.

The GAO report also indicates that communities' inconsistent reporting of activities makes it difficult to evaluate program implementation nationwide. Based on the report's findings it seems that little auditing activity has been performed to gauge the status of implementation and effectiveness in achieving water quality improvements. Most often cited is the effort by EPA's Region 9 and the State of California auditors that recently discovered, among other things, that some MS4s (1) had not developed stormwater management plans, (2) were not properly performing an adequate number of inspections to enforce their stormwater ordinances, and (3) were lax in implementing SCMs at publicly owned construction sites. They also found that some MS4s were not adequately controlling stormwater runoff at municipally owned and operated facilities, such as maintenance yards. In response to these findings, EPA issued in January 2007 an MS4 Program Evaluation Guidance document (EPA, 2007b).

In the absence of a nationwide perspective of the implementation of the stormwater program, it is hard to make a determination about the program's success. There are communities and states that seem to have made great strides in implementing progressive stormwater programs, but it also seems that overall many programs are still in the early stages of implementation, while a number of communities are still waiting to obtain coverage under the MS4 permits. In addition, it appears that there is no national uniform system of tracking success or cost data. All these unknowns make it very difficult to formulate any definite statements about how successful the implementation of the program is on a national perspective.

Committee Survey

In order to get a better understanding of how the stormwater program is implemented by the states, during 2007 the committee conducted two surveys asking states about their monitoring requirements, compliance determination, and other facts for each program (municipal, industrial, and construction). For the

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larger survey, 18 states representing all ten EPA regions responded to the survey. Both surveys and all responses are found in Appendix C.

As expected, the responding states reported that Phase I MS4s are required to sample their stormwater discharges for pollutants, although the frequency of sampling and the number of pollutants being sampled tended to vary. No state reported requiring Phase II MS4s to sample stormwater discharges. Monitoring requirements for industrial stormwater varied by state from none in Minnesota, Nebraska, and Maine to benchmark monitoring required under the MSGP in Virginia, New York, and Wyoming. California, Connecticut, and Washington require all industrial facilities to monitor for select chemical pollutants. Connecticut, additionally, requires sampling for aquatic toxicity. Most of the responding states do not require construction sites to do much more than visual monitoring periodically and after rain events. Georgia and Washington require construction sites to monitor for parameters such as turbidity and pH. California and Oregon require sampling when the discharge is to a waterbody impaired by sediment.

As mentioned previously, Phase I MS4s (but not Phase II MS4s) are required to address industrial dischargers within their boundaries. There was considerable variability regarding the survey questions of whether MS4s can conduct inspections of industrial facilities and what industries are considered high risk. In all of the responding states except Virginia, the responders think that MS4s have the authority to inspect industries within their boundaries, although the extent to which this is done is not clear and, in the committee's experience, is quite rare. Many of the responding states have not identified "high-risk" facilities and targeted them for compliance scrutiny, although certain categories were felt to be problematic by the state employee responding to the survey, such as metal foundries, auto salvage yards, metal recyclers, cement plants, and saw mills. In California and Washington, however, some of the Phase I MS4 permits have identified high-risk facilities for the municipal permittee to inspect.

Georgia, Maine, Minnesota, Nevada, New York, Vermont, and Washington have State Guidance Manuals for MS4 implementation, while in California a coalition of municipalities and the California Department of Transportation have developed MS4 guidance manuals. The rest of the responding states rely on general guidance provided by the EPA. State guidance manuals for the implementation of the industrial stormwater program were less common than guidance manuals for construction activity, with only California and Washington having such guidance manuals. In contrast, except for Nebraska and Oklahoma, statewide guidance manuals for erosion and sediment control were available. This may have resulted from the fact that many states had laws in place that required erosion and sediment control practices during land development, timber harvesting, and agricultural farming that predated the EPA stormwater regulations.

In an attempt to determine the level of oversight that a state provides for industrial and construction operations, the survey asked whether and to whom

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stormwater pollution prevention plans (SWPPPs) are submitted. Most of the responding states require the stormwater pollution prevention plans that industrial facilities prepare to be retained at the facility and produced when requested by the state. Only Oregon, Vermont, Washington, and Hawaii required industrial SWPPPs to be submitted to the state when seeking coverage under the MSGP. The practice for the submittal of construction SWPPPs was similar, except that some states required that SWPPPs for large construction projects be submitted to the state.

Compliance with the MS4 permit in the responding States is mainly determined through the evaluation of annual reports and program audits, although no indication was given of the frequency of audits. Regulators in Maine have monthly meetings with municipalities. The responding states evaluate compliance with the MSGP by reviewing annual monitoring reports and conducting inspections of industrial facilities. Connecticut characterized its industrial inspections as "regular," Maine inspects industrial facilities twice per five-year permit cycle, while Vermont performs visual inspections four times a year. No other responding states specified the frequency of inspections. Inspections and reviews of the SWPPPs constitute the main ways for responding states to determine the compliance of sites and facilities covered under the CGP.

With respect to the extent of actual compliance, few states have such information, partly because it has not routinely been collected and analyzed. West Virginia has found that, of the 871 permitted industrial facilities in the state, 576 were delinquent in submitting the results of their benchmark monitoring. Several case studies of compliance rates for municipal, industrial, and construction sites in Southern California are presented in Box 2-4. The data suggest that compliance in all three groups is poor, particularly for industrial sites. This may be partly explained by the preponderance of small businesses covered by the MSGP, whose operators may have financial difficulty in committing funds to SCMs, or lack a recognition and knowledge of the stormwater program and its requirements.

Another aspect of compliance is the extent to which industrial facilities have identified themselves and applied for coverage under the state MSGP. Six states responded to the committee's survey about that topic; only two of the six (California and Vermont) have made efforts to determine the numbers of non-filers of an NOI to be covered by the MSGP. In both cases, the efforts, which involved mailings, telephone calls, and file review, found that the number of non-filing facilities that should be subject to the MSGP was substantial (see Box 2-5 for California's data). Duke and Augustenborg (2006) studied this level of compliance (whether industries are filing an NOI for permit coverage) and found incomplete compliance that is variable among states and urbanized areas. Texas and Oklahoma had higher levels of permit coverage than California or Florida.

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BOX 2-4
Compliance with Stormwater Permits in Southern California

Construction General Permits

In order to determine the compliance of construction sites with the general stormwater permit, data were collected and analyzed from three sources: (1) an audit performed in June 2004 of the development construction program of five cities that are permittees in the Los Angeles County MS4 permit (about 44 sites), (2) an audit performed in February 2002 of the development construction program (among others) of five Ventura County MS4 permittees (about 32 sites), and (3) a review and inspection of 24 large construction sites (50 acres or greater of disturbed land). These sites accounted for about 5 percent of all construction sites in the region at the time, and they represent both small and large construction sites. The most common violations on construction sites were paper violations, such as incomplete SWPPPs and a lack of record keeping. Forty (40) percent of the sites had some type of paper deficiency. A close second is the absence of erosion and/or sediment control, observed on 30 percent of the sites. SOURCE: TetraTech (2002, 2006b,c).

Industrial Multi-Sector General Permit

For industrial sites, information was obtained from the following sources: (1) a review of SCM inspections performed in February 2005 which consisted of 38 sites in the transportation sector; (2) a review of inspections and non-filer identification information in the plastics sector performed in 2007, which consisted of about 100 permitted sites among a large number of non-filer sites; and (3) a review of 13 area airport inspections and 55 port tenant inspections at the ports of Los Angeles and Long Beach. The sites are about 6 percent of the total number of permittees covered by California's MSGP and represent some of the major regulated industrial sectors. The most common violations observed at industrial sites were the lack of implementation of SCMs such as overhead cover, secondary containment and/or spill control. Sixty (60) percent of the sites had poor housekeeping problems. This was followed by incomplete stormwater pollution prevention plans (40 percent). (SOURCE: E. Solomon, California EPA, Los Angeles Regional Water Board, personal communication, 2008).

In another study, the California Water Boards with the assistance of an EPA contractor conducted inspections of 1,848 industrial stormwater permittees (21 percent of permitted facilities) between 2001 and 2005 (TetraTech, 2006d). Seventy-one (71) percent of the industrial facilities inspected were not in compliance with the MSGP and 18 percent were identified as a threat to water quality. Fifty-six (56) percent of facilities that collected one or more water quality samples reported an exceedance of a benchmark. Facility follow-up inspections indicated that field presence of the California Water Boards inspectors improved facility compliance with the MSGP.

Municipal Permits

An audit similar to the TetraTech study described above was conducted for 84 Phase I and Phase II MS4s in California during the same period (TetraTech, 2006e). The audits found that municipal maintenance facilities were often deficient in implementing SCMs, MS4 permittees did not obtain adequate legal authority to implement the program, they were not inspecting industrial facilities and construction sites or were inspecting them inadequately, and they were unable to evaluate program effectiveness in improving water quality. Overall, the audits found that programs with more specific permit requirements

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BOX 2-4 Continued

generally resulted in more comprehensive and progressive stormwater management programs. For example, the Los Angeles or San Diego MS4 permits enumerate in detail the permit tasks such as the frequency of inspection, the types of facilities, and the SCMs to be inspected that permittees must perform in implementing their stormwater program. The auditors concluded that the specificity of the provisions enabled the permitting authorities to enforce the MS4 permits and improve the quality of MS4 discharges.

Compliance with Industrial Permits within MS4s

The EPA and the California EPA Los Angeles Regional Water Board conducted a limited audit of the inspection program requirements of the Los Angeles County MS4 Permit and the City of Long Beach MS4 Permit in conjunction with industrial facilities covered under the MSGP within the Ports of Los Angeles and Long Beach (EPA, 2007c). The Port of Long Beach is covered under a single NOI for its 53 tenant facilities that discharge stormwater associated with industrial activity, while 137 industrial facilities within the Port of Los Angeles file independent NOIs. At the Port of Los Angeles, of the 23 facilities that were inspected, 30 percent were judged to pose a significant threat to water quality, 43 percent were determined to have some violations with regard to implementation of SCMs or paperwork requirements, and 26 percent appeared to be in compliance with the MSGP. At the Port of Long Beach, of the 21 tenant facilities that were inspected, 14 percent were judged to pose a significant threat to water quality, 52 percent were determined to have some deficiencies with regard to implementation of SCMs or paperwork requirements, and 33 percent appeared to be in full compliance with general permit requirements. The Port of Long Beach had a more comprehensive stormwater monitoring program which indicated that several pollutant parameters were above EPA benchmark values. Communication between the MS4 departments and the ports in both programs appeared deficient. The EPA issued 20 compliance orders for violations of the MSGP, but it did not pursue any action against the MS4s overseeing the industries because it was outside the scope of the EPA audit.

LOCAL CODES AND ORDINANCES THAT AFFECT STORMWATER MANAGEMENT

Zoning and building standards, codes, and ordinances have been the basis for city building in the United States for almost a century. They define how to build to protect the health, safety, and welfare of the public, and to establish a predictable, although often lengthy and cumbersome, process for ensuring that built improvements become a well-integrated part of the larger urban environment. Review processes can be as simple as a walk-through in a local building department for a minor house remodeling project. In other cases, extended rezoning processes for larger projects can require several years of planning; multiple public meetings; multiple reviews by city, state, and federal agencies; and specialized studies to determine impacts on the natural environment and water, sewer, and transportation systems.

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BOX 2-5
Searching for Non-Filers Under the Industrial MSGP in Southern California

The California Water Boards conducted an industrial non-filer identification study between 1995 and 1998 (CA SWB, 1999). The study had three components: (1) to develop a mechanism to identify facilities subject to the industrial stormwater general permit that had not filed an NOI, which involved a comparison of commercially available and agency databases with that maintained by the California Water Boards; (2) to communicate with operators of these facilities to inform them of their responsibility to comply, which was done using post-mail, telephone calls, and filed verification; and (3) to refer responses to the communication efforts to the Water Boards for any appropriate follow-up.

About 9 percent of the potential non-filers submitted an NOI after the initial mail contact. About 52 percent of facilities indicated that they were exempt. About 37 percent failed to respond and 16 percent of mailed packages were returned unopened. A follow-up on facilities that claimed they were exempt indicated that 16 percent of them indeed needed to comply. Similarly 33 percent of facilities that failed to respond were determined as needing to file NOIs. The study suggested that only half of facilities considered heavy industrial had filed NOIs through the first five years of the program (Duke and Shaver, 1999).

The California EPA Los Angeles Regional Water Board and the City of Los Angeles conducted a study in the City of Los Angeles between January 1998 and June 2000 to identify non-filers and evaluate compliance by door-to-door visits in industrially zoned areas of the city (Swamikannu et al., 2001). The field investigations covered industrial zones totaling about 4.2 square miles, or about 22 percent of the area in the City of Los Angeles zoned for industrial land use. A total of 1,103 of suspected non-filer facilities were subject to detailed on-site facility investigation. Ninety-three (93) were determined to have already have submitted NOIs, and 436 were determined not to be subject to the industrial stormwater general permit. The site visits identified 223 potential non-filers, or industrial facilities where site-visit evidence suggested the facilities probably needed to comply with relevant regulations but that had not filed NOIs or recognized their duty to comply at the time of the visit. Of the facilities identified as potential non-filers, 202 were identified during detailed on-site investigations, or 18 percent of facilities inspected with that methodology; and 21 were identified during the less-detailed non-filer assessment visits, or 6 percent of the 379 facilities inspected with that methodology. In total, 295 of the 1,103 facilities visited under the project (about 27 percent) were known or suspected to be required to file NOIs under the permit, including 93 facilities that had previously filed NOIs and 202 facilities identified as probably required to file NOIs based on visual evidence of industrial activities exposed to stormwater. Thus, prior to the project, only 31 percent of all facilities in the project area needing to comply had submitted an NOI.

There is an overlapping and conflicting maze of codes, regulations, ordinances, and standards that have a profound influence on the ability to implement stormwater control measures, although they can be loosely categorized into three areas. Land-use zoning is the first type of control. Zoning, which was developed in response to unsanitary and unhealthy living conditions in 19th-century cities, prescribes permitted land uses, building heights, setbacks, and the arrangement of different types of land uses on a given site. Zoning often requires improvements that enhance the aesthetic and functional qualities of communities. For example, ordinances prescribing landscaping, minimum parking requirements, paving types, and related requirements have been developed to

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improve the livability of cities. These ordinances have a significant impact on both how stormwater affects waterbodies and on attempts to mitigate its impacts.

The second category involves the design and construction of buildings. National and international building codes and standards, such as the International Building Code, and Uniform Plumbing, Electrical, and Fire Codes, for example, allow local governments to establish minimum requirements for building construction. Because these controls primarily affect building construction, they have less effect on stormwater discharges than zoning.

The third category includes engineering and infrastructure standards and practices that govern the design and maintenance of the public realm—streets, roads, utilities rights-of-way, and urban waterways. Roadway design standards and emergency access requirements have resulted in contemporary cities that are 30 percent or more pavement, just to accommodate the movement and storage of vehicles in the public right-of-way. The standards for the construction of deep utilities—water and sewer lines that are typically located underneath streets—are often the reason that streets are wider than necessary to safely carry traffic.

Over time, these codes, standards, and practices have become more complex, and they may no longer support the latest innovations in planning practices. The past 10 to 20 years have seen a number of innovations in zoning and related building standards. Mixed-use, mixed-density communities that incorporate traditional patterns of community development (often described as "New Urbanism"), low impact development (LID), and transit-oriented development are examples of building patterns that challenge traditional zoning and city design standards. With the exception of LID, proposed new patterns of development and regulations connected with their implementation rarely incorporate specific guidelines for innovations in stormwater management, other than to have general references to environmental responsibility, ecological restoration, and natural area protection.

The following sections describe in more detail the codes, ordinances, and standards that affect stormwater and our ability to control it, and alternative approaches to developing new standards and practices that support and encourage effective stormwater management.

Zoning

The primary, traditional purpose of zoning has been to segregate land uses thought to be incompatible. In practice, zoning is used as a permitting system to prevent new development from harming existing residents or businesses. Zoning is commonly controlled by local governments such as counties or cities, though the specifics of the zoning regime are determined primarily by state planning laws (see Box 2-6 for a discussion of land use acts in Oregon and Washington).

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BOX 2-6
Growth Management in the Pacific Northwest

In Oregon, the 1973 Legislative Assembly enacted the Oregon Land Use Act, which recognized that the uncoordinated use of lands threatens orderly development of the environment, the health, safety, order, convenience, prosperity and welfare of the people of Oregon. The state required all of Oregon's 214 cities and 36 counties to adopt comprehensive plans and land-use regulations. It specified planning concerns that had to be addressed, set statewide standards that local plans and ordinances had to meet, and established a review process to ensure that those standards were met. Aims of the program are to conserve farm land, forest land, coastal resources, and other important natural resources; encourage-efficient development; coordinate the planning activities of local governments and state and federal agencies; enhance the state's economy; and reduce the public costs that result from poorly planned development. Setting urban growth boundaries is a major mechanism for implementing the act.

The Washington State Legislature followed in 1990 with the Growth Management Act (GMA), adopted on grounds similar to Oregon's act. The GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans, and implementing them through capital investments and development regulations. Similar again to Oregon, rather than centralize planning and decision-making at the state level, the GMA established state goals, set deadlines for compliance, offered direction on how to prepare local comprehensive plans and regulations, and set forth requirements for early and continuous public participation. Urban growth areas (UGAs) are those areas, designated by counties pursuant to the GMA, "within which urban growth shall be encouraged and outside of which growth can occur only if it is not urban in nature." Within these UGAs, growth is encouraged and supported with adequate facilities. Areas outside of the UGAs are reserved for primarily rural and resource uses. Urban growth areas are to be based on population forecasts made by counties, which are required to have a 20-year supply of land for future residential development inside the boundary—a time frame also pertaining in the Oregon system. In both states urban growth boundaries are reconsidered and sometimes adjusted to meet this criterion.

It is important to note that the growth management efforts in the two states have no direct relationship to stormwater management. Rather, the laws control development density, which has implications for how stormwater should be managed (see discussion in Chapter 5). The local jurisdictions in Washington have reacted in different ways to link growth management and stormwater management. For example, the King County, Washington, stormwater code requires drainage review to evaluate and deal with stormwater impacts for development that adds 2,000 square feet or more of impervious surface or clears more than 7,000 square feet. For rural residential lots outside the UGA, the impervious threshold is reduced to 500 square feet.

Sources:
http://bluebook.state.or.us/state/executive/Land_Conservation/land_conservation_history.htm
http://www.oregonmetro.gov/index.cfm/go/by.web/id=277
http://www.gmhb.wa.gov/gma/ and *http://www.mrsc.org/Subjects/Planning/compfaqs.aspx*

Zoning involves regulation of the kinds of activities that will be acceptable on particular lots (such as open space, residential, agricultural, commercial or industrial), the densities at which those activities can be performed (from low-density housing such as single-family homes to high-density housing such as high-rise apartment buildings), the height of buildings, the amount of space

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structures may occupy, the location of a building on the lot (setbacks), the proportions of the types of space on a lot (for example, how much landscaped space and how much paved space), and how much parking must be provided. Thus, zoning can have a significant impact on the amount of impervious area in a development and on what constitutes allowable stormwater management.

As an example, local parking ordinances are often found within zoning that govern the size, number, and surface material of parking spaces, as well as the overall geometry of the parking lot as a whole. The parking demand requirements are tied to particular land uses and zoning categories, and can create needless impervious cover. Most local parking codes are overly generous and have few, if any, provisions to treat stormwater at the source (Wells, 1995). For example, in a co-housing project under construction in Fresno, California, current city codes require 27-foot-long parking spaces. The developer, in an effort to reduce construction costs, requested that the length of spaces be reduced to 24 feet. The city agreed to the smaller spaces if the developer would sign an indemnity clause guaranteeing that the local government would not be sued in case of an accident (Wenz, 2008).

Similarly, landscaping ordinances apply to certain commercial and institutional zoning categories and specify that a fixed percentage of site area be devoted to landscaping, screening, or similar setbacks. These codes may require as much as 5 to 10 percent of the site area to be landscaped, but seldom reference opportunities to capture and store runoff at the source, despite the fact that the area devoted to landscaping is often large enough to meet some or all of their stormwater treatment needs.

Zoning codes have evolved over the years as urban planning theory has changed, legal constraints have fluctuated, and political priorities have shifted. The various approaches to zoning can be divided into four broad categories: Euclidean, performance, planned unit development, and form-based.

Euclidean Zoning

Named for the type of zoning code adopted in the town of Euclid, Ohio, Euclidean zoning codes are by far the most prevalent in the United States, used extensively in small towns and large cities alike. Euclidean zoning is characterized by the segregation of land uses into specified geographic districts and dimensional standards stipulating limitations on the magnitude of development activity that is allowed to take place on lots within each type of district. Typical land-use districts in Euclidean zoning are residential (single- or multi-family), commercial, and industrial. Uses within each district are usually heavily prescribed to exclude other types of uses (for example, residential districts typically disallow commercial or industrial uses). Some “accessory” or “conditional” uses may be allowed in order to accommodate the needs of the primary uses. Dimensional standards apply to any structures built on lots within each zoning district and typically take the form of setbacks, height limits,

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minimum lot sizes, lot coverage limits, and other limitations on the building envelope.

Although traditional Euclidean zoning does not include any significant requirements for stormwater drainage, there is no reason that it could not. Modern Euclidean ordinances include a broad list of "development standards" that address topics like signage, lighting, steep slopes, and other topics, and that list could be expanded to included stormwater standards for private development.

Euclidean zoning is used almost universally across the country (with rare exceptions) because of its relative effectiveness, ease of implementation (one set of explicit, prescriptive rules), long-established legal precedent, and familiarity to planners and design professionals. However, Euclidean zoning has received heavy criticism for its unnecessary separation of land uses, its lack of flexibility, and its institutionalization of now-outdated planning theory. . In response, variances and other methods have been used to modify Euclidean zoning so that it is better adapted to localized conditions and existing patterns of development. The sections below briefly describe a range of innovations in local zoning regulations that have potential for incorporating stormwater controls into existing regulations.

Incentive Zoning. Incentive zoning systems are typically an add-on to Euclidean zoning systems. First implemented in Chicago and New York City in 1961, incentive zoning is intended to provide a reward-based system to encourage development that meets established urban development goals. Typically, a base level of prescriptive limitations on development will be established and an extensive list of incentive criteria with an associated reward scale will be established for developers to adopt at their discretion. Common examples include floor-area-ratio bonuses for affordable housing provided on-site and height-limit bonuses for the inclusion of public amenities on-site.

With incentive zoning, developers are awarded additional development capacity in exchange for a public benefit, such as a provision for low- or moderate-income housing, or an amenity, such as additional open space. Incentive zoning is often used in more highly urbanized areas. Consideration for water quality treatment and innovative SCMs fits well within the incentive zoning model. For example, redevelopment sites in urbanized areas are often required to incorporate stormwater control measures into developments to minimize impacts on aging, undersized stormwater systems in that area, and to meet new water quality requirements. An incentive could be to allow greater building height, and therefore higher density, than under existing zoning, freeing up land area for SCMs that could also serve as a passive park area. Another example would be to allow a higher density on the site and to require not an on-site system but a cash payment to the governing entity to provide for consolidated stormwater management and treatment. Off-site consolidated systems, discussed more extensively in Chapter 5, may require creation of a localized main-

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tenance district or an increase in stormwater maintenance fees to offset long-term maintenance costs.

Incentive zoning could be used to preserve natural areas or stream corridors as part of a watershed enhancement strategy. For example, transferrable development rights (TDR) could be used in the context of the urban or semi-urban interface with rural lands. Many of the formal TDR programs in Colorado (such as Fruita/Mesa County and Aspen/Pitkin) involve cities or counties seeking to preserve sensitive areas in the county, or outlying areas of the city, including the floodplain, in exchange for urban-level density on a more appropriate site (David D. Smith, Garfield & Hecht P.C., personal communication, 2008).

Incentive zoning allows for a high degree of flexibility, but it can be complex to administer. The more a proposed development takes advantage of incentive criteria, the more closely it has to be reviewed on a discretionary basis. The initial creation of the incentive structure can also be challenging and often requires extensive ongoing revision to maintain balance between incentive magnitude and value given to developers.

Performance Zoning

Performance zoning uses performance-based or goal-oriented criteria to establish review parameters for proposed development projects in any area of a municipality. At its heart, performance zoning deemphasizes the specific land uses, minimum setbacks, and maximum heights applicable to a development site and instead requires that the development meet certain performance standards (usually related to noise, glare, traffic generation, or visibility). Performance zoning sometimes utilizes a "points-based" system whereby a property developer can apply credits toward meeting established zoning goals through selecting from a menu of compliance options (some examples include mitigation of environmental impacts, providing public amenities, and building affordable housing units). Additional discretionary criteria may also be established as part of the review process.

The appeal of performance zoning lies in its high level of flexibility, rationality, transparency, and accountability. Because performance zoning is grounded in specific and in many cases quantifiable goals, it better accommodates market principles and private property rights with environmental protection. However, performance zoning can be extremely difficult to implement and can require a high level of discretionary activity on the part of the supervising authority. City staff must often be trained to use specialized equipment to measure the performance of the development, and sometimes those impacts cannot be measured until the building is completed and the activity operating, by which time it may be difficult and expensive to modify a building that turns out not to meet the required performance standards. Because stormwater performance is measurable (especially the amounts of water retained/detained and rates and amounts of water discharge), stormwater

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regulations could be integrated into a performance zoning system. As with other topics, however, it might be time-consuming or require special equipment to measure compliance (particularly before the building is built).

Planned Unit Development (Including Cluster Development and Conservation Design)

A planned unit development (PUD) is generally a large area of land under unified control that is planned and developed as a whole through a single development operation or series of development phases, in accord with a master plan. In California, these are known as Specific Plans. More specialized forms of PUDs include clustered subdivisions where density limitations apply to the development site as a whole but provide flexibility in the lot size, setback, and other standards that apply to individual house lots. These PUDs provide considerable flexibility in locating building sites and associated roads and utilities, allowing them to be concentrated in parts of the site, with the remaining land use for agriculture, recreation, preservation of sensitive areas, or other open-space purposes.

PUDs are typically, although not exclusively, found in new development areas and have significant open space and park areas that are often 25 percent or more of the total land area. This large amount of open space provides considerable opportunity for the use of consolidated, multifunctional stormwater controls.

Form-Based Zoning

Form-based zoning relies on rules applied to development sites according to both prescriptive and potentially discretionary criteria. These criteria are typically dependent on lot size, location, proximity, and other various site- and use-specific characteristics. Form-based codes offer considerably more flexibility in building uses than do Euclidean codes, but, as they are comparatively new, may be more challenging to create. When form-based codes do not contain appropriate illustrations and diagrams, they are criticized as being difficult to interpret.

One example of a recently adopted code with form-based features is the Land Development Code adopted by Louisville, Kentucky, in 2003. This zoning code creates “form districts” for Louisville Metro. Each form district intends to recognize that some areas of the city are more suburban in nature, while others are more urban. Building setbacks, heights, and design features vary according to the form district. As an example, in a “traditional neighborhood” form district, a maximum setback might be 15 feet from the property line, while in a suburban “neighborhood” there may be no maximum

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setback. Narrower setbacks allow increased density, requiring less land area for the same number of housing units and resulting in a smaller development footprint.

In rural and suburban areas, form-based codes can often reinforce the "open" character of development by preserving open site areas, which could be used for on-site stormwater management. In denser, urban areas, however, some form-based ordinances favor shorter, more pedestrian-scale buildings that cover more of the site than taller buildings of the same square footage, on the basis that keeping activity closer to the ground and enclosing street frontages results in a better pedestrian environment and urban form. One result of this preference is that there may be less of the site left potentially available for on-site stormwater detention or infiltration. Integrating stormwater management considerations into form-based codes may require a cash payment system where the developer contributes to financing of a district or regional stormwater treatment facility because on-site solutions are not available.

Building Codes

Building codes define minimum standards for the construction of virtually all types and scales of structures. With a few exceptions, building codes have limited direct impact on stormwater management. The main example is where structural and geotechnical design standards, which stem from the need to protect buildings and infrastructure from water damage, discourage or prohibit the potential infiltration of water adjacent to building foundations. Such standards can make it difficult to use landscape-based SCMs, such as porous pavement, bioinfiltration, and extended detention. There is a need to examine and redefine structural and geotechnical "standards of care" that ensure the structural integrity of buildings and other infrastructure like buried utilities, in order for landscaped areas adjacent to structures to be utilized more effectively for SCMs. For example, a developer building a mixed-use, medium-density infill development in Denver intended to incorporate innovative approaches to stormwater management by infiltrating stormwater in a number of areas around the site. The standard of care for the geotechnical design of building foundations typically requires that positive drainage be maintained a minimum of 5 feet from the building edge. The geotechnical engineer required, when informed that water might be infiltrated in the area of the building and without further study, that the minimum distance to an infiltration area must be at least to 20 feet from the building, greatly limiting the potential for using the building landscape areas as SCMs. The City of Los Angeles is in the process of updating its Building Code, but it is not clear if it will be sufficiently comprehensive to address the use of some LID practices, such as on-site infiltration. The 2002 Building Code now in effect is written to require the builder to convey water away from the building using concrete or some other "non-erosive device."

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Engineering and Infrastructure Standards and Practices

Engineering standards and practices for public rights-of-way complement building and zoning codes which control development on private property. Engineering standards and practices typically describe requirements for public utilities such as stormwater and wastewater, roadways, and related basic services. For example, there are standards for parking and roadway design that typically describe the specific type of roadway and parking surfacing requirements. Regulations and standards often require minimum gradients for surface drainage, site grading, and drainage pipe size, all of which play an important role in how stormwater is transported. There are also often landscape planting requirements, including the requirement to mound landscape areas to screen cars, which can preclude the opportunity to incorporate SCMs into landscape areas.

Unless right-of-way improvements are constructed as part of the subdivision process by private developers, improvements in the right-of-way are typically provided for by city government and public agencies. Because engineering standards are often based on decades of refinement and have evolved regionally and nationally, they are difficult to change. For example, street widths are determined more by the ability to maneuver emergency equipment and to accommodate water and sewer easements than the need for adequate lane widths for vehicles. Street lane-width requirements might be as narrow as 11 feet for each travel lane, resulting in a street width of 22 to 24 feet. This could accommodate emergency vehicle access, which typically can require a minimum of 20 feet of unobstructed street. However, because most streets also include potable water distribution lines and easement requirements for the lines, which are a minimum of 30 feet in width, this results in a minimum roadway width of 30 feet.

Local drainage codes govern the disposal of stormwater and essentially dictate the nature and capacity of the stormwater infrastructure from the roof to the floodplain. Like many codes, they were developed over time to address problems such as basement flooding, nuisance drainage problems, maintenance of floodplain boundaries, and protection of infrastructure such as bridges and sewers from storm damage. Local drainage codes, many of which predate the EPA's stormwater program, often involve peak discharge control requirements for a series of design storm events ranging from the 2-year storm up to the 100-year event. Traditional drainage codes can often conflict with effective approaches to reducing runoff volume or removing pollutants from stormwater. Examples of such codes include requirements for positive drainage, directly connected roof leaders, curbs and gutters, lined channels, storm-drain inlets, and large-diameter storm-drain pipes discharging to a downstream detention or flood control basins.

Often, standards have been tested through legal precedent, and case law has developed around certain standards of care, which can further deter innovation. Changes in design standards could result in unknown legal exposure and liabil-

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ity. Specific types of equipment, maintenance protocols and procedures, and extensive training further discourage changes in established standards and procedures.

Innovations in Codes and Regulations to Promote Better Stormwater Management

A number of innovations have been developed in the previously described zoning, building codes, and infrastructure and engineering standards that make them more amenable to stormwater management. These are described in detail below.

Separate Ordinances for New and Infill Development

Redevelopment of existing urban areas is almost universally more difficult and expensive than Greenfield development because of the deconstruction costs of the former, higher costs of designing around existing infrastructure, upgrading existing infrastructure, and higher costs and risks associated with assuming liability of pre-existing problems (contamination, etc). Redevelopment often occurs in areas of medium to high levels of impervious surface (e.g., downtown areas). Such severely space-limited areas with high land costs drive up stormwater management costs. Consequently, holding developers of such areas to the same stormwater standard as for Greenfield developments creates a financial disincentive for redevelopment. Without careful application, stormwater requirements may discourage needed redevelopment in existing urban areas. This would be unfortunate because redevelopment can take pressure off of the development of lands at the urban fringe, it can accommodate growth without introducing new impervious surfaces, and it can bring improvements in stormwater management to areas that had previously had none.

Stormwater planning can include the development of separate ordinances for infill and new developments. Wisconsin has administrative rules that establish specific requirements for stormwater management based on whether the site is new development, redevelopment, or infill. Requirements for new development include reducing total suspended solids (TSS) by 80 percent, maintaining the pre-development peak discharge for the 2-year, 24-hour storm, infiltrating 90 percent of the pre-development infiltration volume for residential areas, and infiltrating 60 percent of the pre-development infiltration volume for non-residential areas. Redevelopment varies from new development only in that the TSS requirement is less at 40 percent reduction. Requirements for existing developed areas in incorporated cities, villages, and towns do not include peak flow reduction or infiltration performance standards, but the municipalities must achieve a 40 percent reduction in their TSS load by 2013. Other requirements unique to developed areas include public education activities, proper application

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of nutrients on municipality property, and elimination of illicit discharges (*www.dnr.state.wi.us/org/water/wm/nps/stormwater/post-constr/*). Chapter 5 makes recommendations for the specific types of SCMs that should be used for new, low-density residential development as opposed to redevelopment of existing urban and industrial areas.

Integrated Stormwater Management and Growth Policies

In the city of San Jose, California, an approach was taken to link water quality and development policies that emphasized higher density in-fill development and performance-based approaches to achieving water quality goals. The city's approach encourages stormwater practices such as minimizing impervious surface and incorporating swales as the preferred means of conveyance and treatment. In urbanized areas, the policy then goes on to define criteria to determine the practicability of meeting numeric sizing requirements for stormwater control measures, and identifies Equivalent Alternative Compliance Measures for cases where on-site controls are impractical. Equivalent Measures can include regional stormwater treatment and other specific projects that "count" as SCMs, including certain affordable and senior housing projects, significant redevelopment within the urban core, and Brownfield projects. This is similar to in lieu fee programs that are sometimes implemented by municipalities to provide additional regulated parties with compliance options (see discussion in Chapter 6).

This approach is a breakthrough in terms of measuring environmental performance, which is now focused only on what happens within the boundaries of a site for a project. This myopic view tends to allow many environmentally unfriendly projects that encourage sprawl and expand the city's boundaries to qualify as "low impact," while more intense projects on a small footprint appear to have a much higher impact because they cover so much of the site. San Jose brought several other layers of review, including location in the watershed (close to other uses or not) as a means of estimating performance. A PowerPoint presentation describing their approach in greater detail is linked here (*http://www.cmcgc.com/media/handouts/260126/THR-PDF/040-Ketchum.PDF*, Lisa Nisenson, Nisenson Consulting, LLC, personal communication, May 8, 2007).

Unified Development Codes

A unified development code (UDC) consolidates development-related regulations into a single code that represents a more consistent, logical, integrated, and efficient means of controlling development. UDCs integrate zoning and subdivision regulations, simplifying development controls that are often con-

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flicting, confusing, and that require multiple layers of review and administration. UDC development standards may include circulation standards that address how vehicles and pedestrians move, including provision for adequate emergency access. Utility standards are described for water distribution and sewage collection, and necessary utility easements are prescribed. Because of the integrated nature of the code, efficiencies in requirements for right-of-way can reduce street widths or the reduction in setbacks, for example, resulting in more compact development.

Design Review Incentives to Speed Permitting

A number of incentives have been put in place to promote innovative stormwater control measures in cities such as Portland and Chicago, where environmental concerns have been identified as a key goal for development and redevelopment. Practices such as the waiver or reduction of development fees, preferential treatment and review and approval of innovative plans, reduction in stormwater fees, and related incentives encourage the use of innovative stormwater practices. In Chicago, the Green Permit Program initiated in April 2005 has proven attractive to many developers as it speeds up the permitting process. Under the Green Permit Program, a green building adviser reviews design plans under an aggressive schedule long before a permit application is submitted. There is one point of contact with intimate knowledge about the project to help speed up the permit process. Projects going through the Green Permit Program receive benefits based on their "level of green." Tier I commercial projects are designed to be Leadership in Energy and Environmental Design (LEED) certified (see Box 2-7). Tier II projects must obtain LEED silver rating. At this level, outside consultant review fees, which range from $5,000 to $50,000, are waived. Tier III projects must earn LEED gold. The goal for a Tier III project is to issue a permit in three weeks for a small project such as a 12-unit condo building. Thus, there is both time and money saved. Private developers are interested in the time savings because they can pay less interest on their construction loans by completing the building faster. By the end of 2005, 19 green permits were issued. The program's director estimated that about 50 would be issued in 2006, which exceeds the city's goal of 40.

In Portland, Oregon, the city's Green Building Program is considering instituting a new High-Performance Green Building Policy. Along with goals for reducing global warming pollution, it proposes (1) waiving development fees if goals are exceeded by specified percentages and (2) eligibility for cash rewards and qualification for state and federal financial incentives and tax credits if even higher goals are achieved. Developers can earn credits by incorporating enhanced stormwater management and water conservation features into their projects, including the use of green roofs (Wenz, 2008).

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BOX 2-7
Innovative Building Codes

An increased interest in energy conservation and more environmentally friendly building practices in general has led to various methods by which buildings can be evaluated for environmentally friendly construction, in addition to conventional code compliance. The most popular system in the United States is the Leadership in Energy and Environmental Design (LEED) system developed in 2000.

The LEED Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. The U.S. Green Building Council is a 501(c)(3) nonprofit organization that certifies sustainable businesses, homes, hospitals, schools, and neighborhoods.

The LEED system encourages progressive stormwater management practices as part of its rating system. The LEED system has identified specific criteria, with points assigned to each of the criteria, to assess the success of stormwater strategies. Generally, the criteria are based on LID principles and practices and relate directly to the *Better Site Design Handbook* of the Center for Watershed Protection (CWP, 1998). The system identifies eight categories by which building sites and site-planning practices are evaluated. Of the 69 points possible to achieve the highest LEED rating, 16 points are directly related to innovative site design and stormwater management practices. Six of the eight criteria describing sound site-planning practices relate directly to good stormwater practices, including the following:

- Erosion and sediment control;
- Site selection to protect farmland, wetlands, and watercourses;
- Site design to encourage denser infill development to protect Greenfield sites;
- Limitations on site disturbance;
- Specific requirements for the management of stormwater rate and quantity; and
- Specific requirements for the treatment of stormwater for TSS and phosphorous removal.

The LEED rating system has been criticized because it focuses on individual buildings in building sites. A new category, LEED neighborhood development, was developed in response to consider the interrelationship of buildings and building sites and connections to existing urban infrastructure. The category is currently in pilot testing. Evaluation criteria related directly to stormwater include:

- All requirements of the original site design criteria,
- A reduced requirement for parking based on access to transit and reduced auto use, and
- Site planning that emphasizes compact development.

There are parallel challenges in the realm of community development and city building that tend to discourage innovative stormwater management policies and practices. Building codes and zoning have evolved to reflect the complex relationship of legal, political, and social processes and frequently do not promote or allow the most innovative stormwater management. Engineering standards and practices that guide the development of roads and utilities present equal and possibly greater challenges, in that legal and technical precedents and

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large investments in public equipment and infrastructure present even more intractable reasons to resist change.

The difficulty of implementing stormwater control measures cannot be attributed to an individual code, standard, or regulation. It is important to unravel the complexities of codes, regulations, ordinances, and standards and practices that discourage innovative stormwater management and target the particular element (or multiple elements) that is a barrier to innovation. Elements that are barriers might not have been considered previously. For example, roadway design is controlled more by access for emergency equipment and utilities rights-of-way than by the need for wide travel lanes; it is the fire marshal and the water department that should be the focus of attention, rather than the transportation engineer.

LIMITATIONS OF THE FEDERAL STORMWATER PROGRAM

The regulation of stormwater discharges seems an inevitable next step to the CWA's objective of "restoring the nation's waters," and EPA's stormwater program is still evolving. Yet, in its current configuration EPA's approach seems inadequate to overcome the unique challenges of stormwater and therefore runs the risk of only being partly effective in meeting its goals. A number of regulatory, institutional, and societal obstacles continue to hamper stormwater management in the United States, as described below.

The Poor Fit Between the Clean Water Act's Regulatory Approach and the Realities of Stormwater Management

Controlling stormwater discharges with the CWA introduces a number of obstacles to effective stormwater regulation. Unlike traditional industrial effluent, stormwater introduces not only contaminants but also surges in volume that degrade receiving waterbodies; yet the statute appears focused primarily on the "discharge" of "pollutants." Moreover, unlike traditional effluent streams from manufacturing processes, the pollutant loadings in stormwater vary substantially over time, making effluent monitoring and the development of enforceable control requirements considerably more challenging. Traditional use of end-of-pipe control technologies and automated effluent monitors used for industrial effluent do not work for the episodic and variable loading of pollutants in stormwater unless they account for these eccentricities by adjustments such as flow-weighted measurements. Finally, at the root of the stormwater problem is increasingly intensive land use. Yet the CWA contains little authority for regulators to directly limit land development, even though the discharges that result from these developments increase stormwater loading at a predictably rapid pace. The CWA thus expects regulators to reduce stormwater loadings, but gives them incomplete tools for effectuating this goal.

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A more straightforward way to regulate stormwater contributions to waterbody impairment would be to use flow or a surrogate, like impervious cover, as a measure of stormwater loading (such as in the Barberry Creek TMDL [Maine DEP, 2003, pp. 16–20] or the Eagle Brook TMDL [Connecticut DEP, 2007, pp. 8–10]). Flow from individual stormwater sources is easier to monitor, model, and even approximate as compared to calculating the loadings of individual contaminants in stormwater effluent. Efforts to reduce stormwater flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality. Flow provides an inexpensive, convenient, and realistic means of tracking stormwater contributions to surface waters. Congress itself recently underscored the usefulness of flow as a measure for aquatic impairments by requiring that all future developments involving a federal facility with a footprint larger than 5,000 square feet ensure that the development achieves predevelopment hydrology to the maximum extent technically feasible "with regard to the temperature, rate, volume, and duration of flow" (Energy Independence and Security Act of 2007, § 438). Several EPA regions have also used flow in modeling stormwater inputs for TMDL purposes (EPA, 2007a, Potash Brook TMDL, pp. 12–13).

Permitting and Enforcement

For industrial wastewater discharged directly from industrial operations (rather than indirectly through stormwater), the CWA requirements are relatively straightforward. In these traditional cases, EPA essentially identifies an average manufacturer within a category of industry, like iron and steel manufacturers engaged in coke-making, and then quantifies the pollutant concentrations that would result in the effluent if the industry installed the best available pollution control technology. EPA promulgates these effluent standards as national, mandatory limits (e.g., see Table 2-7).

TABLE 2-7 Effluent Limits for Best Available Technology Requirements for By-product Coke-making in Iron and Steel Manufacturing

Regulated Parameter	Maximum Daily[1]	Maximum Monthly Average[1]
Ammonia-N	0.00293	0.00202
Benzo(a)pyrene	0.0000110	0.00000612
Cyanide	0.00297	0.00208
Naphthalene	0.0000111	0.00000616
Phenols (4AAP)	0.0000381	0.000238

[1]pounds per thousand pound of product.
SOURCE: 40 C.F.R. § 420.13(a).

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By contrast, the uncertainties and variability surrounding both the nature of the stormwater discharges and the capabilities of various pollution controls for any given industrial site, construction site, or municipal storm sewer make it much more difficult to set precise numeric limits in advance for stormwater sources. The quantity and quality of stormwater are quite variable over time and vary substantially from one property to another. Natural causes of variation in the pollutant loads in stormwater runoff include the topography of a site, the soil conditions, and of course, the nature of storm flows in intensity, frequency, and volume. In addition, the manner in which the facility stores and uses materials, the amount of impervious cover, and sometimes even what materials the facility uses can vary and affect pollutant loads in runoff from one site to another. Together, these sources of variability, particularly the natural features, make it much more difficult to identify or predict a meaningful "average" pollutant load of stormwater runoff from a facility. As a result, EPA generally leaves it to the regulated facilities, with limited oversight from regulators, to identify the appropriate SCMs for a site. Unfortunately, this deferential approach makes the permit requirements vulnerable to significant ambiguities and difficult to enforce, as discussed below for each permit type.

Municipal Stormwater Permits. MS4 permits are difficult to enforce because the permit requirements have not yet been translated into standardized procedures to establish end-of-pipe numerical effluent limits for MS4 stormwater discharges. CWA Section 402(p) requires that pollutants in stormwater discharges from the MS4 be reduced to the maximum extent practicable and comply with water quality standards (when so required by the permitting authority). However, neither EPA nor NPDES-delegated states have yet expressed these criteria for compliance in numerical form.

The EPA has not yet defined MEP in an objective manner that could lead to convergence of MS4 programs to reduce stormwater pollution. Thus, at present MS4 permittees have no more guidance on the level of effort expected other than what is stated in the CWA:

> [S]hall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practice, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants. [CWA Section 402(p)(3)(B)(iii)]

A legal opinion issued by the California Water Board's Office of Chief Counsel in 1993 stated that MEP would be met if MS4 permittees implemented technically feasible SCMs, considering costs, public acceptance, effectiveness, and regulatory compliance (Memorandum from Elizabeth Miller Jennings, Office of Chief Counsel, to Archie Matthews, Division of Water Quality, California Water Board, February 11, 1993). In its promulgation of the Phase II Rule in 1999, the EPA described MEP as a flexible site-specific standard, stating that:

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> The pollutant reductions that represent MEP may be different for each [MS4 Permittee] given the unique local hydrological and geological concerns that may exist and the differing possible pollutant control strategies. (64 Fed. Reg. 68722, 68754)

As matters stand today, MS4 programs are free to choose from the EPA's menu of SCMs, with MEP being left to the discretionary judgment of the implementing municipality. Similarly, there are no clear criteria to be met for industrial facilities that discharge to MS4s in order for the MS4s to comply with MEP. The lack of federal guidance for MS4s is understandable. A stormwater expert panel convened by the California EPA State Water Board in 2006 (CA SWB, 2006) concluded that it was not yet feasible to establish strictly enforceable end-of-pipe numeric effluent limits for MS4 discharges. The principal reasons cited were (1) the lack of a design storm (because in any year there are few storms sufficiently large in volume and/or intensity to exceed the design volume capacity or flow rates of most treatment SCMs) and (2) the high variability of stormwater quality influenced by factors such as antecedent dry periods, extent of connected impervious area, geographic location, and land use.

Industrial and Construction Stormwater Permits. The industrial and construction stormwater programs suffer from the same kind of deficiencies as the municipal stormwater program. These stormwater discharges are not bound by the MEP criterion, but they are required to comply with either technology-based or, less often, water quality-based effluent limitations. In selecting SCMs to comply with these limitations, the industrial discharger or construction operator similarly selects from a menu of options devised by the EPA or, in some cases, the states or localities for their particular facility (EPA, 2006, p. 15). For example, the regulated party will generally identify structural SCMs, such as fences and impoundments that minimize runoff, and describe how they will be installed. The SWPPP must also include nonstructural SCMs, like good housekeeping practices, that require the discharger to minimize the opportunity for pollutants to be exposed to stormwater. The SWPPP and the accompanying SCMs constitute the compliance requirements for the stormwater discharger and are essentially analogous to the numeric effluent limits listed for industrial effluents in the Code of Federal Regulations.

This set of requirements leaves considerable discretion to regulated parties in several important ways. First, the regulations require the discharger to evaluate the site for problematic pollutants; but where the regulated party does not have specific knowledge or data, they need only offer "estimates" and "predictions" of the types of pollutants that might be present at the site (EPA, 1996a, pp. IV-3, V-3). With the exception of visible features, the deferential site investigation requirements allow regulated parties to describe site conditions in ways that may effectively escape accountability unless there is a vigorous regulatory presence.

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Second, dischargers enjoy considerable discretion in drafting the SWPPP (EPA, 1996a, p. IV-3). Despite EPA's instructions to consider a laundry list of considerations that will help the facility settle on the most effective plan (EPA, 2006, p. 20), rational operators may take advantage of the wiggle room and develop ambiguous requirements that leave them with considerable discretion in determining whether they are in compliance (EPA, 2006, pp. 15, 20, 132). Indeed, the federal regulations do little to prevent regulated parties from devising requirements that maximize their discretion. Instead, EPA describes many of the permit requirements in general terms. For example, in its industrial stormwater permit program the EPA commands the regulated party to "implement any additional SCMs that are economically reasonable and appropriate in light of current industry practice, and are necessary to eliminate or reduce pollutants in . . . stormwater discharges" (EPA, 2006, p. 23).

EPA's program provides few rewards or incentives for dischargers to go beyond the federal minimum and embrace rigorous or innovative SCMs. In fact, if the regulated party invests resources to measure pollutant loads on their property, they are creating a paper trail that puts them at risk of greater regulation. Under the EPA's regulations, a regulated party "must provide a summary of existing stormwater discharge sampling data previously taken at [its] facility," but if there are no data or sampling efforts, then the facility is off the hook (EPA, 2006, p. 20). Quantitative measures can thus be incriminating, particularly in a regulatory setting where the regulator is willing to settle for estimates.

Dilemma of Self-Monitoring

Unlike the wastewater program where there are relatively rigid self-monitoring requirements for the end-of-pipe effluent, self-monitoring is much more difficult to prescribe for stormwater discharges, which are variable over time and space. [For example, *compare* 33 U.S.C. § 1342(a)(2)-(b)(2) (2000) (outlining requirements for compliance under NPDES) *with* EPA, 2006, p. 26 (outlining requirements for self-compliance under EPA regulations.)] EPA's middle ground, in response to these challenges, requires self-monitoring of select chemicals in stormwater for only a subset of regulated parties—Phase I MS4 permittees and a limited number of industrial facilities (see Table 2-8, EPA, 2006, pp. 93-94). Yet even for these more rigid monitoring requirements, the discharger enjoys some discretion in sampling. The EPA's sampling guidelines do prescribe regular intervals for sampling but ultimately must defer to the discharger insofar as requiring only that the samples should be taken within 30 minutes after the storm begins, and only if it is the first storm in three days (EPA, 2006, p. 33).

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TABLE 2-8 Effluent Monitoring Requirements for Various Dischargers of Stormwater

Source Category	**Type of Effluent Monitoring Required by EPA**
Phase I MS4	Municipality must develop a monitoring plan that provides for representative data collection. This requires the municipality, at the very least, to select at least 5 to 10 of its most representative outfalls for regular sampling and sample for selected conventional pollutants and heavy metals in its effluent.
Phase II MS4	None
Small subset of highest risk industries, like hazardous waste landfills	Must conduct compliance monitoring as specified in effluent guidelines and ensure compliance with these effluent limits. Must also conduct visual monitoring and benchmark monitoring.
Larger subset of higher risk industrial dischargers	Benchmark monitoring: Must conduct analytic monitoring to determine whether effluent exceeds numeric benchmark values; compliance with the numeric values is not required, however. Must also conduct visual monitoring.
Remaining set of industry except construction	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.
Construction (larger than 5 acres)	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.
Construction (between 1 and 5 acres)	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.

Note: State regulators can and sometimes do require more—see Appendix C.

Moreover, while the monitoring itself is mandatory, the legal consequences of an exceedance of a numerical limit vary and may be quite limited. For a small number of identified industries, exceedances of effluent limits established by EPA are considered permit violations (65 Fed. Reg. 64766). For the other high-risk industries subject to benchmark monitoring requirements (see Table 2-5), the analytical limits do not lead to violations per se, but only serve to "flag" the discharger that it should consider amending its SWPPP to address the problematic pollutant (EPA, 2006, pp. 10, 30, 34). Although municipalities are required to do more extensive sampling of stormwater runoff and enjoy less sampling discretion, even municipalities are allowed to select what they believe are their most representative outfalls for purposes of monitoring pollutant loads (EPA, 1996a. p. VIII-1).

A large subset of dischargers—the remaining industrial dischargers and construction sites—are subject to much more limited monitoring requirements. They are not required to sample contaminant levels, but instead are required only to conduct a visual inspection of a grab sample of their stormwater runoff on a quarterly basis and describe the visual appearance of the sample in a document that is kept on file at the site (EPA, 2006, p. 28). Certainly a visual sample is better than nothing, but the requirement allows the discharger not only some discretion in determining how and when to take the sample (explained below), but also discretion in how to describe the sample.

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A final set of regulated parties, the Phase II MS4s, are not required to perform any quantitative monitoring of runoff to test the effectiveness of SCMs (EPA, 1996a, p. 3).

Making matters worse, in some states there appear to be limited regulatory resources to verify compliance with many of these permit requirements. Thus, even though monitoring plans are subject to review and approval by permitting agencies, there may be insufficient resources to support this level of oversight. As shown in Appendix C, the total number of staff associated with state stormwater programs is usually just a handful, except in cases of larger states (California and Georgia) or those where there is a longer history of stormwater management (Washington and Minnesota). In its survey of state stormwater programs, the committee asked states how they tracked sources' compliance with the stormwater permits. For the 18 states responding to the questionnaire, review of (1) monitoring data, (2) annual reports, and (3) SWPPP as well as onsite inspections were the primary mechanisms. However, several states indicated that they conduct an inspection only after receiving complaints. West Virginia tracked whether industrial facilities submitted their required samples and followed up with a letter if they failed to comply, but in 2006 it found that over 65 percent of the dischargers were delinquent in their sampling. Although the states were not asked in the survey to estimate the overall compliance rate, Ohio admitted that at least for construction, "the general sense is that no site is 100 percent in compliance with the Construction General Permit" (see Appendix C).

Even where considerable regulatory resources are dedicated to ensuring that dischargers are in compliance, it is not clear how well regulators can independently assess compliance with the permit requirements. For example, some of the permits will require "good housekeeping" practices that should take place daily at the facility. Whether or how well these practices are followed cannot be assessed during a single inspection. While a particularly non-compliant facility might be apparent from a brief visual inspection, a facility that is mildly sloppy**,** or at least has periods during which it is not careful**,** can escape detection on one of these pre-announced audits. Facilities also know best the pollutants they generate and how or whether those pollutants might make contact with stormwater. Inspectors might be able to notice some of these problems, but because they do not have the same level of information about the operations of the facility, they can be expected to miss some problems.

Identifying Potentially Regulatable Parties

Evidence suggests that a sizable percentage of industrial and construction stormwater dischargers are also failing to self-identify themselves to regulators, and hence these unreported dischargers remain both unpermitted and unregulated (GAO, 2005; Duke and Augustenborg, 2006). In contrast to industrial pipes that carry wastes from factories out to receiving waters, the physical pres-

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ence of stormwater dischargers may be less visible or obvious. Thus, particularly for some industries and construction, if a stormwater discharger does not apply for a permit, the probability of detecting it is quite low.

In Maine, less than 20 percent of the stormwater dischargers that fall within the regulatory jurisdiction of the federal stormwater program actually applied for permits before 2005—more than a decade after the federal regulations were promulgated (Richardson, 2005). Yet there is no record of enforcement action taken by Maine against the unpermitted dischargers during that interim period. Indeed, in the one enforcement action brought by citizens in Maine for an unpermitted discharge, the discharger claimed ignorance of the stormwater program. In Washington, the State Department of Ecology speculates that between 10 and 25 percent of all businesses that should be covered by the federal stormwater permit program are actually permitted (McClure, 2004). In a four-state study, Duke and Augustenborg (2006) found a higher percentage of stormwater dischargers—between 50 and 80 percent—had applied for permits by 2004, but they concluded that this was still "highly incomplete" compliance for an established permit program.

In 2007, the committee sent a short survey to each state stormwater program inquiring as to whether and how they tracked non-filing stormwater dischargers, but only six states replied to the questions and only two of the six states had any methods for tracking non-filers or conducting outreach to encourage all covered parties to apply for permits (see Appendix C). While the low response rate cannot be read to mean that the states do not take the stormwater program seriously, the responses that were received lend some support to the possibility that there is substantial noncompliance at the filing stage.

In response to this problem of unpermitted discharges, the EPA appears to be targeting enforcement against stormwater dischargers that do not have permits. In several cases, the EPA pursued regulated industries that failed to apply for stormwater permits (EPA Region 9, 2005; Kaufman et al., 2005). The EPA has also brought enforcement actions against at least three construction companies for failing to apply for a stormwater permit for their construction runoff (EPA Region 1, 2004). Such enforcement actions help to make the stormwater program more visible and give the appearance of a higher probability of enforcement associated with non-compliance. Nevertheless, the non-intuitive features of needing a permit to discharge stormwater, coupled with a rational perception of a low probability of being caught, likely encourage some dischargers to fail to enter the regulatory system.

Absence of Regulatory Prioritization

Many states have been overwhelmed with the sheer numbers of permittees, particularly industry and construction sites, and lack a prioritization strategy to identify high-risk sources in particular need of rigorous and enforceable permit

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conditions. For example, in California major facilities like the Los Angeles International Airport and the Los Angeles and Long Beach ports are covered under California's MSGP along with a half-acre metal plating facility in El Segundo—all subject to the same level of compliance scrutiny even after nearly two decades of implementation! Similarly, a multiphase, 20-year, thousand-acre residential development such as Newhall Land Development in North Los Angeles County is covered by the same California CGP as a one-acre residential home construction project in West Los Angeles, and subject to the same level of compliance scrutiny. The lack of an EPA strategy to identify and address high-risk industrial facilities and construction sites (i.e., those that pose the greatest risk of discharging polluted stormwater) remains an enormous deficiency. Phase I MS4s, for example, are left to their own devices to determine how to identify the most significant contributors to their stormwater systems (Duke, 2007).

Limited Public Participation

Public participation is more limited in the stormwater program in comparison to the wastewater permit program, providing less citizen-based oversight over stormwater discharges. Typically, during the issuance of an individual NPDES permit (for either wastewater or stormwater) the public has a chance to comment and review the draft permit requirements that are specifically prescribed for a certain site and discharge. While the same is true about the public participation during the adoption of a general stormwater permit, those general permits contain only the framework of the requirements and the menu of conditions, but do not prescribe specific requirements. Instead, it is up to the permittee to tailor the compliance to the specific conditions of the site in the form of a SWPPP. However, at this phase neither the public nor the regulators have access to the site-specific plan developed by the permittee to comply with the obligations of the permit. In the case of general permits, then, the discharger has enormous flexibility in designing its compliance activities.

Citizens also encounter difficulties in enforcing stormwater permit requirements. Citizens have managed to sue facilities for unpermitted stormwater discharges: this is a straightforward process because citizens need only verify that the facility should be covered and lacks a permit (Richardson, 2005). Overseeing facility compliance with stormwater permit requirements is a different story, however, and citizens are stymied at this stage of ensuring facility compliance. Citizens can access a facility's SWPPP, but only if they request the plan from the facility in writing (EPA, 2006, p. 25). Moreover, the facility is given the authority to make a determination—apparently without regulator oversight—of whether the plan contains confidential business information and thus cannot be disclosed to citizens (EPA, 2006, p. 26). But, even if the facility sends the plan to the citizens, it will be nearly impossible for them to independently assess whether the facility is in compliance unless the citizens station telescopes,

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conduct air surveillance of the site, or are allowed to access the facility's records of its own self-inspections. Moreover, to the extent that the stormwater outfalls are on the facility's property**,** citizens might not be able to conduct their own sampling without trespassing.

Not surprisingly, significant progress has nevertheless been made in reducing stormwater pollution when stormwater becomes a visible public issue. This increased visibility is often accomplished with the help of local environmental advocacy groups who call attention to the endangered species, tourism, or drinking water supplies that are jeopardized by stormwater contamination. Box 2-8 describes two cases of active public participation in the management of stormwater.

BOX 2-8
Citizen Involvement/Education in Stormwater Regulations

The federal Clean Water Act, under Section 505, authorizes citizen groups to bring an action in U.S. or state courts if the EPA or a state fails to enforce water quality regulations. Unsurprisingly, the few areas nationally where stormwater quality has become a visible public issue and significant progress has been made in reducing stormwater pollution have prominent local environmental advocacy groups actively involved.

Heal the Bay, Santa Monica, California. In Southern California, Santa Monica-based Heal the Bay has utilized research, education, community action, public advocacy, and political activism to improve the quality of stormwater discharges from MS4s in Southern California. Heal the Bay operates an aquarium to educate the public, conducts stream teams to survey local streams, posts a beach report card on the web to inform swimmers on beach quality, appears before the California Water Boards to comment on NPDES stormwater permits, and works with lawmakers to sponsor legislative bills that protect water quality.

In 1998, the organization helped co-author legislation to notify the public when shoreline water samples show that water may be unsafe for swimming. California regulations (AB411) require local health agencies (county or city) to monitor water quality at beaches that are adjacent to a flowing storm drain and have 50,000 visitors annually (from April 1 to October 31). At a minimum, these beaches are tested on a weekly basis for three specific bacteria indicators: total coliform, fecal coliform, and *enterococcus*. Local health officials are required to post or close the beach, with warning signs, if state standards for bacterial indicators are exceeded. The monitoring data collected are available to the public.

In order to better inform and engage the public, Heal the Bay has followed up with a web-based Weekly Beach Report Card (*http://healthebay.org/brc/statemap.asp*) and the release of an Annual California Beach Report Card assigning an "A" to "F" letter grade to more than 500 beaches throughout the state based on their levels of bacterial pollution. Heal the Bay's Annual Beach Report Card is a comprehensive evaluation of California coastal water quality based on daily and weekly samples gathered at beaches from Humboldt County to the Mexican border. A poor grade means beachgoers face a higher risk of contracting illnesses such as stomach flu, ear infections, upper respiratory infections, and skin rashes than swimmers at cleaner beaches.

Heal the Bay was instrumental in passing Proposition O in the City of Los Angeles which sets aside half a billion dollars to improve the quality of stormwater discharges. In the 2007 term of the California Legislature, the organization has sponsored five legislative bills to address marine debris, including plastic litter transported in stormwater runoff, that

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Box 2-8 Continued

foul global surface waters (*Currents*, Vol. 21, No. 2, p.8, 2007). Heal the Bay also coordinates its actions and partners with other regional and national environmental organizations, such as the WaterKeepers and the NRDC, in advancing water quality protection nationally.

Save Our Springs, Austin, Texas. Citizen groups have played a very influential role in the development of a rigorous stormwater control program in the City of Austin, Texas. Catalyzed in 1990 by a proposal for extensive development that threatened the fragile Barton Springs area, a citizens group named Save Our Springs Legal Defense Fund (later renamed Save our Springs Alliance) formed to oppose the development. It orchestrated an infamous all-night council meeting, with 800 citizens registering in opposition to the proposed development and ultimately led to the City Council's rejection of the 4,000-acre proposal and the formulation of a "no degradation" policy for the Barton Creek watershed. The nonprofit later sponsored the Save Our Springs Ordinance, a citizen initiative supported by 30,000 signatures, which passed by a 2 to 1 margin in 1992 to further strengthen protection of the area. The Save Our Springs Ordinance limits impervious cover in the Barton Springs watershed to a maximum of between 15 and 25 percent, depending on the location of the development in relation to the recharge and contributing zones. The ordinance also mandates that stormwater runoff be as clean after development as before. The ordinance was subject to a number of legal challenges, all of which were successfully defended by the nonprofit in a string of court battles.

Since its initial formation in 1990, the Save Our Springs Alliance has continued to serve a vital role in educating the community about watershed protection and organizing citizens to oppose development that threatens Barton Springs. The organization has also been instrumental in working with a variety of government and nonprofit organizations to set aside large areas of parkland and open spaces within the watershed. Other citizen groups, like the Save Barton Creek Association, also play a very active, complementary role to the Save Our Springs Alliance in protecting the watershed. These other nonprofits are sometimes allied and sometimes diverge to take more moderate stances to development proposals. The resulting constellation of citizen groups, citizen outreach, and community participation is very high in the Austin area and has unquestionably led to a much more informed citizenry and a more rigorous watershed protection program than would exist without such grassroots leadership.

Accounting for Future Land Use

One of the challenges of managing stormwater from urban watersheds thus involves anticipating and channeling future urban growth. Currently, the CWA does little to anticipate and control for future sources of stormwater pollution in urban watersheds. Permits are issued individually on a technology-based basis, allowing for uncontrolled cumulative increases in pollutant and volume loads over time as individual sources grow in number. The TMDL process in theory requires states to account for future growth by requiring a "margin of safety" in loading projections. However, it is not clear how frequently future growth is included in individual TMDLs or how vigorous the growth calculations are (for example, see EPA [2007a, pp. 12, 37], mentioning considerations of future land use as a consideration in stormwater related TMDLs for only a few—Potash Brook and the lower Cuyahoga River—of the 17 TMDLs described in the report). In any event, as already noted a TMDL is generally triggered only after

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waters have been impaired, which does nothing to anticipate and channel land development before waters become degraded.

The fact that stormwater regulation and land-use regulation are largely decoupled in the federal regulatory system is understandable given the CWA's industrial and municipal wastewater focus and concerns about federalism, but this limited approach is not a credible approach to stormwater management in the future. Federal incentives must be developed to encourage states and municipalities to channel growth in a way that acknowledges, estimates, and minimizes stormwater problems.

Picking up the Slack at the Municipal and State Level

Because it involves land use, any stormwater discharge program strikes at a target that is traditionally within the province of state and even more likely local government regulation. Indeed, it is possible that part of the reason for the EPA's loosely structured permit program is its concern about intruding on the province of state and local governments, particularly given their superior expertise in regulating land-use practices through zoning, codes, and ordinances.

In theory, it is perfectly plausible that some state and local governments will step into the void and overcome some of the problems that afflict the federal stormwater discharge program. If local or state governments required mandatory monitoring or more rigorous and less ambiguous SCMs, they would make considerable progress in developing a more successful stormwater control program. In fact, some states and localities have instituted programs that take these steps. For example, Oregon has established its own benchmarks based on industrial stormwater monitoring data, and it uses the benchmark exceedances to deny industries coverage under Oregon's MSGP. In such cases, the facility operator must file for an individual stormwater discharge NPDES permit. Some municipalities are also engaging in these problems, such as the City of Austin and its ban on coal tar sealants.

Despite these bursts of activity, most state and local governments have not taken the initiative to fill the gaps in the EPA's federal program (see Tucker [2005] for some exceptions). Because they involve some expense, stormwater discharge requirements can increase resident taxes, anger businesses, and strain already busy regulatory staff. Moreover, if the benefits of stormwater controls are not going to materialize in waters close to or of value to the community instituting the controls, then the costs of the program from the locality's standpoint are likely to outweigh its benefits. Federal financial support for state and local stormwater programs is very limited (see section below). Until serious resources are allocated to match the seriousness and complexity of the problem and the magnitude of the caseload, it seems unlikely that states and local communities will step in to fill the gaps in EPA's program. These impediments help explain why there appear to be so many stormwater sources out of compliance

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with the stormwater discharge permit program as discussed above, at least in the few states that have gone on record.

Funding Constraints

Without a doubt, the biggest challenge for states, regions, and municipalities is having adequate fiscal resources dedicated to implement the stormwater program. Box 2-9 highlights the costs of the program for the State of Wisconsin, which has been traditionally strong in stormwater management. Phase I regulations require that a brief description of the annual proposed budget for the following year be included in each annual report, but this requirement has been dispensed with entirely for Phase II.

Ever since the promulgation of the stormwater amendments to the CWA and the issuance of the stormwater regulations, the discharger community pointed out that this statutory requirement had the flavor of an unfunded mandate. Unlike the initial CWA that provided significant funding for research, design, and construction of wastewater treatment plants, the stormwater amendments did not provide any funding to support the implementation of the requirements by the municipal operators. The lack of a meaningful level of investment in addressing the more complex and technologically challenging problem of cleaning up stormwater has left states and municipalities in the difficult position of scrambling for financial support in an era of multiple infrastructure funding challenges.

While a number of communities have passed stormwater fees linked to water quality as described below, a significant number of communities still do not have that financial resource. Municipalities that have not formed utility districts or imposed user fees have had to rely on general funds, where stormwater permit compliance must compete with public safety, fire protection, and public libraries. This circumstance explains why elected local government officials have been reluctant to embrace the stormwater program. Stormwater quality management is often not regarded as a municipal service, unlike flood control or wastewater conveyance and treatment. A concerted effort will need to be made by all stakeholders to make the practical and legal case that stormwater quality management is truly another municipal service like trash collection, wastewater treatment, flood control, etc. Even in states that do collect fees to finance stormwater permit programs, the programs appear underfunded relative to other types of water pollution initiatives. Table 2-10 shows the water quality budget of the California EPA, Los Angeles Regional Water Board. The amount of money per regulated entity (see Table 2-4) dedicated to the stormwater program pales in comparison to the wastewater portion of the NPDES program, and it has

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BOX 2-9
Preliminary Cost Estimates for Complying with Stormwater Discharge Permits in Wisconsin

The Wisconsin Department of Natural Resources (WDNR) was delegated authority under the CWA to administer the stormwater permit program under Chapter NR 216. There are 75 municipalities regulated under individual MS4 permits and 141 MS4s regulated under a general permit for a total of 216 municipalities with stormwater discharge permits.

As part of the "pollution prevention" minimum measure the municipalities are required to achieve compliance with the developed urban area performance standards in Chapter NR 151.13. By March 10, 2008, municipalities subject to a municipal stormwater permit under NR 216 must reduce their annual TSS loads by 20 percent. These same permitted municipalities are required to achieve an annual TSS load reduction of 40 percent by March 10, 2013. The reduction in TSS is compared to no controls, and any existing SCMs will be given credit toward achieving the 20 or 40 percent. As part of their compliance with NR151.13 developed area performance standards, the municipalities are preparing stormwater plans describing how they will achieve the 20 and 40 percent TSS reduction. They are required to use an urban runoff model, such as WinSLAMM or P8, to do the pollutant load analysis.

As the permitted municipalities comply with the six minimum control measures and submit the stormwater plans for their developed area urban areas, the WDNR is learning how much it is going to cost to achieve the requirements in the stormwater discharge permits. Some cities have already been submitting annual reports that include the cost of the six minimum measures. Nine of the permitted municipalities in the southeast part of Wisconsin have been submitting their annual reports for at least four years. The average population of these nine communities is 17,700 with a range of about 6,000 to 65,000. The average cost of the six minimum measures in 2007 for the nine municipalities is $162,900 with a range of $11,600 to $479,000. These costs have not changed significantly from year to year. The average per capita cost is $9 with a range of $1 to $16 per person. Street cleaning and catch basin cleaning (Figures 2-3 and 2-4) cost are included in the cost for the pollution prevention measure, and most of the cities were probably incurring costs for these two activities before the issuing of the permit. On average the street cleaning and catch basin cleaning represent about 40 percent of the annual cost for the six minimum measures. These two activities will help the cities achieve the 20 and 40 percent TSS performance standards for developed urban areas.

Information is available on the preliminary cost of achieving the 40 percent TSS performance standard for selected cities in Wisconsin. The costs were prepared for 15 municipalities by Earth Tech Inc. in Madison, Wisconsin. Areas of the municipality developed after October 2004 are not included in the TSS load analysis. At this point in the preparation of the stormwater plans the costs are just capital cost estimates done at the planning level (Table 2-9). Because the municipalities receive credit for their existing practices, these capital costs represent the additional practices needed to achieve the annual 40 percent TSS reduction. The costs per capita appear to decline for cities with a population over 50,000. All of the costs in Table 2-9 will increase when other costs, such as maintenance and land cost, are included.

For most of the 15 municipalities, the capital costs are for retrofitting dry ponds with permanent pools, installing new wet detention ponds, and improved street cleaning capabilities. Because of their lower cost, the regional type practices have received more attention in the stormwater plans than the source area practices, such as proprietary devices and biofilters. Municipalities with a higher percentage of newer areas will usually have lower cost because the newer developments tend to have stormwater control measures designed to achieve a high level of TSS control, such as wet detention ponds. Older parts of a municipality are usually limited to practices with a lower TSS reduction, such as street cleaning and catch basin cleaning. Of course, retrofitting older areas with higher efficiency practices is expensive,

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BOX 2-9 Continued

and the cost can go higher than expected when unexpected site limitations occur, such as the presence of underground utilities.

Over the next five years all of the 15 municipalities must budget the costs in Table 2-9. It is not clear yet how much of a burden these costs represent to the taxpayers in each municipality. All the permits will be reviewed for compliance with the performance standards in 2013.

TABLE 2-9 Planning-Level Capital Cost Estimate to Meet 40 Percent TSS Reduction

Population	Number of Cities	Average Cost ($)	Minimum Cost ($)	Maximum Cost ($)	Avg. Cost per Capita per Year over 5 Years ($)
5,000 to 10,000	5	1,380,000	425,000	2,800,000	34
10,000 to 50,000	6	4,600,00	2,700,00	9,200,000	35
50,000 to 100,000	4	9,200,000	7,000,000	12,500,000	26

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FIGURE 2-3 Catch basin cleaning. SOURCE: Robert Pitt, University of Alabama.



FIGURE 2-4 Street cleaning. SOURCE: Courtesy of the U.S. Geological Survey.

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TABLE 2-10 Comparison of Fiscal Year (FY) 02–03 Budget with FY 06–07 Budget for Water Quality Programs at the California EPA, Los Angeles Regional Water Board

Program	Funding Source	2002–2003	2006–2007
NPDES[1]	Federal	$2.8 million	$2.6 million
Stormwater	State	$2.3 million	$2.1 million
TMDLs	Federal	$1.47 million	$1.38 million
Spills, Leaks, Investigation Cleanup	State	$1.32 million	$2.87 million
Underground Storage Tanks	State	$2.78 million	$2.74 million
Non-Chapter 15 (Septics)	State	$0.93 million	$0.93 million
Water Quality Planning	Federal	$0.2 million	$0.21 million
Well Investigation	State	$1.36 million	$0.36 million
Water Quality Certification	Federal	$0.2 million	$0.23 million
Total		$17.1 million	$15.82 million

[1]The NPDES row is entirely wastewater funding, as there is no federal money for implementing the stormwater program. Note that the stormwater program in the table is entirely state funded.

declined over time. Furthermore, of the more than $5 billion dollars in low-interest loans provided in 2006 for investments in water quality improvements, 96 percent of that total funding went to wastewater treatment (EPA, 2007d).

There are a number of potential methods that agencies can use to collect stormwater quality management fees, as described more extensively in Chapter 5. A number of states now levy permit fees, with some permits costing in excess of $10,000, to help defray the costs of implementation and enforcement of their stormwater programs. The State of Colorado, for example, has developed an elaborate fee structure for separate types of general permits for industry and construction, as well as MS4s (see *http://www.cdphe.state.co.us/wq/permitsunit/stormwater/StormwaterFees.pdf*). The ability of a state agency to collect fees generally must first be authorized by the state legislatures (see, e.g., Revised Code of Washington 90.48.465, providing the state agency with the authority to "collect expenses for issuing and administering each class of permits"). The lack of state legislative authorization may limit some state agencies from creating such programs on their own. In fact, in those states where fees cannot be levied against permittees, the stormwater programs appear to be both underfinanced and understaffed. Some municipalities have even experienced political backlash because of the absence of a strong state or federal program requiring them to engage in rigorous stormwater management (see Box 2-10).

Stormwater Management Expertise

Historically, engineering curriculum dealt with stormwater management by focusing on the flood control aspects, with little attention given to the water quality aspects. Thus, there has been a significant gap in knowledge and a lack

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BOX 2-10
A City's Ability to Pay for Stormwater, Water, and Sewage Utility Fees

With the implementation of the stormwater permit program of the CWA, stormwater utilities are becoming more common as a way to jointly address regional stormwater quality and drainage issues. One such program is the Jefferson County, Alabama, Storm Water Management Authority (SWMA), formed in 1997 under state legislation that enables local governments to pool their resources in a regional stormwater authority to meet regulations required by the CWA. Jefferson County, the City of Birmingham, and 22 other regional municipalities in Jefferson, part of Shelby and part of St. Clair counties, Alabama, were required to comply with CWA regulations. The act gave the stormwater program the ability to develop a funding mechanism for the program and to form a Public Corporation.

Over the years, SWMA has been responsible for many activities. One of their first goals was to develop a comprehensive GIS database to map outfalls, land uses, stormwater practices, and many other features that were required as part of the permit program. Another major activity conducted by SWMA was the collection of water samples from about 150 sites in the authority's jurisdiction, both during wet and dry weather. SWMA also inspects approximately 4,000 outfalls during dry weather to check for inappropriate connections to the storm drainage system. SWMA coordinates public volunteer efforts with local environmental groups, including the Alabama Water Watch, the Alabama River Alliance, the Black Warrior Riverkeeper, and the Cahaba River Society. SWMA also inspects businesses and industries (including construction sites) within their jurisdictions that are not permitted by the Alabama Department of Environmental Management (ADEM). SWMA does not enforce rules or issue fines, although it can report violators to the state. In its most famous case, it reported McWane Inc. for pollution that led to investigations by the state and the federal government, and ultimately a trial and criminal convictions.

The Birmingham News (Bouma, 2007) reported that from 1997 to 2005, SWMA's responsibilities under the CWA increased substantially, although their fees did not rise. In late 2005, SWMA proposed that member cities increase their stormwater charges from $5 a year to $12 a year per household for residences and from $15 to $36 per year for businesses. At that point, the Business Alliance for Responsible Development (BARD), a group of large businesses, utilities, mining interests, developers and landowners, began to argue that the group was financially irresponsible, and its attorneys convinced member cities that they could save money by withdrawing from SWMA. Even though SWMA withdrew its fee increase request, many local municipalities have pulled out of SWMA, significantly reducing the agency's budget and ability to conduct comprehensive monitoring and reporting. BARD claims the pollution control programs of the ADEM are sufficient. In their countersuit, several environmental groups maintain that ADEM has failed to adequately protect the state's waters because the agency is underfunded, understaffed, and ineffective at enforcement. Much of the Cahaba and Black Warrior River systems within Jefferson County have such poor water quality that they frequently violate water quality standards (*http://www.southernenvironment.org*). SWMA has been significantly impaired in its ability to monitor and report water quality violations with the withdrawal of many of its original member municipalities and the associated reduced budget.

At the same time, the sewer bill for a family of four in the region is expected to be about $63 per month in 2008. Domestic water rates have also increased, up to about $32 per month (*The Birmingham News*, Barnett Wright, December 30, 2007). Domestic water rates have increased in recent years in attempts to upgrade infrastructure in response to widespread and long-lasting droughts and to cover rising fuel costs. It is ironic that stormwater management agency fees are very small compared to these other urban water agency fees per household by orders of magnitude. The $12 per year stormwater fee was used to justify the dismantling of an agency that was doing its job and identifying CWA violators. In order to bring some reasonableness to the stormwater management situation and expected fees, it may be possible for the EPA to re-examine its guidelines of 2 percent of the household income for sewer fees to reflect other components of the urban water system, and to ensure adequate enforcement of existing regulations, especially by underfunded state environmental agencies.

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of qualified personnel. In areas where SCMs are just beginning to be introduced, many municipalities, industrial operators, and construction site operators are not prepared to address water quality issues; the problem is especially difficult for smaller municipalities and operators. The profession and academia are moving to correct this shortfall. Professional associations such as the Water Environment Federation (WEF) and the American Society for Civil Engineers (ASCE) are co-authoring an update of the WEF/ASCE Manual of Practice "Design of Urban Runoff Controls" that integrates quality and quantity, after years of issuing separate manuals of design and operation for the water quality and water quantity elements of stormwater management.

The split between water quantity and quality is evident in municipal efforts that have focused primarily on flood control issues and design of appropriate appurtenances tailored for this purpose. As discussed earlier, most municipal codes specify practices to collect and move water away as fast as possible from urbanized areas. Very little focus has been put on practices to mitigate the quality of the stormwater runoff. This is especially true in urbanized areas with separate municipal storm sewer systems. Even the designation "sewer" is borrowed from the sanitary sewer conveyance system terminology. In arid or semiarid areas, these flood control systems have been maximally engineered such that river beds have become concrete channels. A typical example is the Los Angeles River, which most of the year resembles an empty freeway. This analysis does not intend to minimize the engineering feat of designing a robust and reliable flood control system. For example, during the unusually wet 2005 season in Southern California, the Los Angeles area did not have any major flooding incidents. However, based on recent studies (Stein and Ackerman, 2007) up to 80 percent of the annual metals loading from six watersheds in the Los Angeles area was transported by stormwater events.

Because of the historical lack of focus on stormwater quality, municipal departments in general are not designed to address the issue of pollution in urban runoff. Just recently and due to the stormwater regulations, cities have been adding personnel and creating new sections to deal with the issue. However, because of the complexities of the task, many duties are spread among various municipal departments, and more often than not coordination is still lacking. Perhaps most problematic is the fact that the local governmental entities in charge of stormwater management are often different from those that oversee land-use planning and regulation. This disconnect between land-use planning and stormwater management is especially true for large cities. It is not unusual for program responsibilities to be compartmentalized, with industrial aspects of the program handled by one group, construction by another, and planning and public education by other distinct units. Smaller cities may have one person handling all aspects of the program assisted by a consulting firm. While coordination may be ensured, the task can be overwhelming for a single staff person.

Beyond water quality issues, training to better understand the importance of volume control and the role of LID has not yet reached many practitioners.

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Many established practices and industry standards in the fields of civil, geotechnical, and structural engineering were developed prior to the introduction of the current group of SCMs and can unnecessarily limit their use. Indeed, certain SCMs such as porous landscape detention, extended detention, and vegetated swales require special knowledge about soils and appropriate plant communities to ensure their longevity and ease of maintenance.

Supplementing the Clean Water Act with Other Federal Authorities that Can Control Stormwater Pollutants at the Source

EPA does have other supplemental authorities that are capable of making significant progress in reducing or even eliminating some of the problematic stormwater pollutants at the national level. Under both the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the TSCA, for example, EPA could restrict some of the most problematic pollutants at their source by requiring labels that alert consumers to the deleterious water quality impacts caused by widely marketed chemical products, restricting their use, or even banning them. This source-based regulation bypasses the need of individual dischargers or governments to be concerned with reducing the individual contaminants in stormwater.

The City of Austin's encounter with coal tar-based asphalt sealants provides an illustration of the types of products contributing toxins to stormwater discharges that could be far better controlled at the production or marketing stage. Through detective work, the City of Austin learned that coal tar-based asphalt sealants leach high levels of polycyclic aromatic hydrocarbons (PAHs) into surface waters (Mahler et al., 2005; Van Metre et al., 2006). The city discovered this because the PAHs were found in sediments in Barton Springs, which were in turn leading to the decline of the endangered Barton Creek salamander (Richardson, 2006). By tracing upstream, the city was able to find the culprit—a parking lot at the top of the hill that was recently sealed with coal tar sealant and produced very high PAH readings. Further tests revealed that coal tar sealants typically leach very high levels of PAHs, but other types of asphalt sealants that are not created from coal tar are much less toxic to the environment and are no more expensive than the coal tar-based sealants (City of Austin, 2004). As a result of its findings, the City of Austin banned the use of coal tar-based asphalt sealants. Several retailers, including Lowes and Home Depot followed the city's lead and refused to carry coal tar sealants. Dane County in the State of Wisconsin has now also banned coal tar sealants[1].

[1] See, e.g., Coal Tar-based pavement sealants studied, Science Daily, February 12, 2007, available at *http://www.sciencedaily.com/upi/index.php?feed=Science&article=UPI-1-20070212-10255500-bc-us-sealants.xml*; Matthew DeFour, Dane County bans Sealants with Coal Tar, Wisconsin State Journal, April 6, 2007, available at *http://www.madison.com/wsj/home/local/index.php?ntid=128156&ntpid=5.*

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For reasons that appear to inure to the perceived impotency of TSCA and the enormous burdens of restricting chemicals under that statute, EPA declined to take regulatory action under TSCA against coal tar sealants (Letter from Brent Fewell, Acting Assisting Administrator, U.S. EPA, to Senator Jeffords, October 16, 2006, p. 3). Yet, it had authority to consider whether this particular chemical mixture presents an "unreasonable risk" to health and the environment, particularly in comparison to a substitute product that is available at the same or even lower price [15 U.S.C. § 2605(a); *Corrosion Proof Fittings vs. EPA*, 947 F.2d 1201 (5th Cir. 1991)]. Indeed, if EPA had undertaken such an assessment, it might have even discovered that the coal tar sealants are not as inferior as Austin and others have concluded; alternatively it could reveal that these sealants do present an "unreasonable risk" since there are substantial risks from the sealant without corresponding benefits, given the availability of a less risky substitute.

A similar situation holds for other ubiquitous stormwater pollutants, such as the zinc in tires, roof shingles, and downspouts; the copper in brake pads; heavy metals in fertilizers; creosote- and chromated copper arsenate (CCA)-treated wood; and de-icers, including road salt. Each of these sources may be contributing toxins to stormwater in environmentally damaging amounts, and each of these products might have less deleterious and equally cost-effective substitutes available, yet EPA and other federal agencies seem not to be undertaking any analysis of these possibilities. The EPA's phase-out of lead in gasoline in the 1970s, which led to measurable declines in the concentrations of lead in stormwater by the mid-1980s (see Figure 2-5), may provide a model of the type of gradual regulatory ban EPA could use to reduce contaminants in products that are non-essential.

Some states are taking more aggressive forms of product regulation. For example, in the mid-1990s, numerous scientific studies conducted in California by stormwater programs, wastewater treatment plants, the University of California, California Water Boards, the U.S. Geological Survey, and EPA showed widespread toxicity in local creeks, stormwater runoff, and wastewater treatment plant effluent from pesticide residues, particularly diazinon and chlopyrifos (which are commonly used organophosphate pesticides available in hundreds of consumer products) (Kuivila and Foe, 1995; MacCoy et al., 1995). As a result, the California Water Boards and EPA listed many waters in urban areas of California as being impaired in accordance with CWA Section 303(d). Many cities and counties were required to implement expensive programs to control the pollution under the MS4 NPDES permits to restore the designated beneficial uses of pesticide-impaired waters. Figure 2-6 shows the results of one such action—a ban on diazinon.

In sum, even though there are a number of sources of pollutants—from roof tiles to asphalt sealants to de-icers to brake linings—that could be regulated more restrictively at the product and market stage, EPA currently provides little meaningful regulatory oversight of these sources with regard to their contri-

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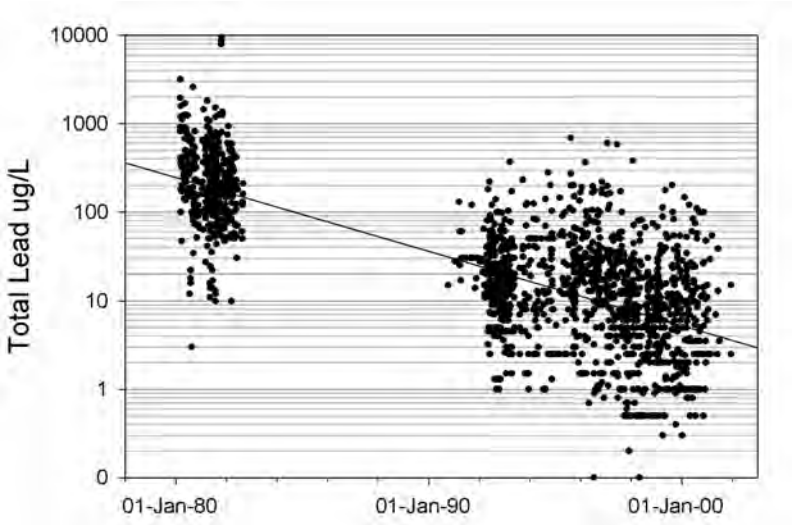

FIGURE 2-5 Trend of lead concentrations in stormwater in EPA rain zone 2 from 1980 to 2001. Although the range of lead concentrations for any narrow range of years is quite large, there is a significant and obvious trend in concentration for these 20 years. SOURCE: National Stormwater Quality Database (version 3).

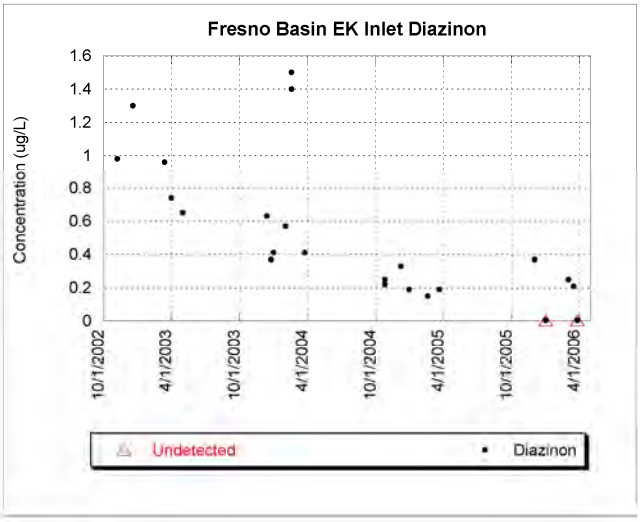

FIGURE 2-6 Trend of the organophosphate pesticide diazinon in MS4 discharges that flow into a stormwater basin in Fresno County, California, following a ban on the pesticide. The figure shows the significant drop in the diazinon concentration in just four years to levels where it is no longer toxic to freshwater aquatic life. EPA prohibited the retail sale of diazinon for crack and crevice and virtually all indoor uses after December 31, 2002, and non-agriculture outdoor use was phased out by December 31, 2004. Restricted use for agricultural purposes is still allowed. SOURCE: Reprinted, with permission, from Brosseau (2007). Copyright 2006 by Fresno Metropolitan Flood Control District.

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bution to stormwater pollution. The EPA's authority to prioritize and target products that increase pollutants in runoff, both for added testing and regulation, seems clear from the broad language of TSCA [15 U.S.C. § 2605(a)]. The underutilization of this national authority to regulate environmentally deleterious stormwater pollutants thus seems to be a remediable shortcoming of EPA's current stormwater regulatory program.

CONCLUSIONS AND RECOMMENDATIONS

In an ideal world, stormwater discharges would be regulated through direct controls on land use, strict limits on both the quantity and quality of stormwater runoff into surface waters, and rigorous monitoring of adjacent waterbodies to ensure that they are not degraded by stormwater discharges. Future land-use development would be controlled to prevent increases in stormwater discharges from predevelopment conditions, and impervious cover and volumetric restrictions would serve as a reliable proxy for stormwater loading from many of these developments. Large construction and industrial areas with significant amounts of impervious cover would face strict regulatory standards and monitoring requirements for their stormwater discharges. Products and other sources that contribute significant pollutants through stormwater—like de-icing materials, urban fertilizers and pesticides, and vehicular exhaust—would be regulated at a national level to ensure that the most environmentally benign materials are used when they are likely to end up in surface waters.

In the United States, the regulation of stormwater looks quite different from this idealized vision. Since the primary federal statute—the CWA—is concerned with limiting pollutants into surface waters, the volume of discharges are secondary and are generally not regulated at all. Moreover, given the CWA's focus on regulating pollutants, there are few if any incentives to anticipate or limit intensive future land uses that generate large quantities of stormwater. Most stormwater discharges are regulated instead on an individualized basis with the demand that existing point sources of stormwater pollutants implement SCMs, without accounting for the cumulative contributions of multiple sources in the same watershed. Moreover, since individual stormwater discharges vary with terrain, rainfall, and use of the land, the restrictions governing regulated parties are generally site-specific, leaving a great deal of discretion to the dischargers themselves in developing SWPPPs and self-monitoring to ensure compliance. While states and local governments are free to pick up the large slack left by the federal program, there are effectively no resources and very limited infrastructure with which to address the technical and costly challenges faced by the control of stormwater. These problems are exacerbated by the fact that land use and stormwater management responsibilities within local governments are frequently decoupled. The following conclusions and recommendations are made.

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EPA's current approach to regulating stormwater is unlikely to produce an accurate or complete picture of the extent of the problem, nor is it likely to adequately control stormwater's contribution to waterbody impairment. The lack of rigorous end-of-pipe monitoring, coupled with EPA's failure to use flow or alternative measures for regulating stormwater, make it difficult for EPA to develop enforceable requirements for stormwater dischargers. Instead, under EPA's program, the stormwater permits leave a great deal of discretion to the regulated community to set their own standards and self-monitor.

Implementation of the federal program has also been incomplete. Current statistics on the states' implementation of the stormwater program, discharger compliance with stormwater requirements, and the ability of states and EPA to incorporate stormwater permits with TMDLs are uniformly discouraging. Radical changes to the current regulatory program (see Chapter 6) appear necessary to provide meaningful regulation of stormwater dischargers in the future.

Future land development and its potential increases in stormwater must be considered and addressed in a stormwater regulatory program. The NPDES permit program governing stormwater discharges does not provide for explicit consideration of future land use. Although the TMDL program expects states to account for future growth in calculating loadings, even these more limited requirements for degraded waters may not always be implemented in a rigorous way. In the future, EPA stormwater programs should include more direct and explicit consideration of future land developments. For example, stormwater permit programs could be predicated on rigorous projections of future growth and changes in impervious cover within an MS4. Regulators could also be encouraged to use incentives to lessen the impact of land development (e.g., by reducing needless impervious cover within future developments).

Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. These analogs for the traditional focus on the "discharge" of "pollutants" have great potential as a federal stormwater management tool because they provide specific and measurable targets, while at the same time they focus regulators on water degradation resulting from the increased volume as well as increased pollutant loadings in stormwater runoff. Without these more easily measured parameters for evaluating the contribution of various stormwater sources, regulators will continue to struggle with enormously expensive and potentially technically impossible attempts to determine the pollutant loading from individual dischargers or will rely too heavily on unaudited and largely ineffective self-reporting, self-policing, and paperwork enforcement.

Local building and zoning codes, and engineering standards and practices that guide the development of roads and utilities, frequently do not promote or allow the most innovative stormwater management. Fortu-

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nately, a variety of regulatory innovations—from more flexible and thoughtful zoning to using design review incentives to guide building codes to having separate ordinances for new versus infill development can be used to encourage more effective stormwater management. These are particularly important to promoting redevelopment in existing urban areas, which reduces the creation of new impervious areas and takes pressure off of the development of lands at the urban fringe (i.e., reduces sprawl).

EPA should provide more robust regulatory guidelines for state and local government efforts to regulate stormwater discharges. There are a number of ambiguities in the current federal stormwater program that complicate the ability of state and local governments to rigorously implement the program. EPA should issue clarifying guidance on several key areas. Among the areas most in need of additional federal direction are the identification of industrial dischargers that constitute the highest risk with regard to stormwater pollution and the types of permit requirements that should apply to these high-risk sources. EPA should also issue more detailed guidance on how state and local governments might prioritize monitoring and enforcement of the numerous and diverse stormwater sources within their purview. Finally, EPA should issue guidance on how stormwater permits could be drafted to produce more easily enforced requirements that enable oversight and enforcement not only by government officials, but also by citizens. Further detail is found in Chapter 6.

EPA should engage in much more vigilant regulatory oversight in the national licensing of products that contribute significantly to stormwater pollution. De-icing chemicals, materials used in brake linings, motor fuels, asphalt sealants, fertilizers, and a variety of other products should be examined for their potential contamination of stormwater. Currently, EPA does not apparently utilize its existing licensing authority to regulate these products in a way that minimizes their contribution to stormwater contamination. States can also enact restrictions on or tax the application of pesticides or even ban particular pesticides or other particularly toxic products. Austin, for example, has banned the use of coal-tar sealants within city boundaries. States and localities have also experimented with alternatives to road salt that are less environmentally toxic. These local efforts are important and could ultimately help motivate broader scale, federal restrictions on particular products.

The federal government should provide more financial support to state and local efforts to regulate stormwater. State and local governments do not have adequate financial support to implement the stormwater program in a rigorous way. At the very least, Congress should provide states with financial support for engaging in more meaningful regulation of stormwater discharges. EPA should also reassess its allocation of funds within the NPDES program. The agency has traditionally directed funds to focus on the reissuance of NPDES

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wastewater permits, while the present need is to advance the NPDES stormwater program because NPDES stormwater permittees outnumber wastewater permittees more than five fold, and the contribution of diffuse sources of pollution to degradation of the nation's waterbodies continues to increase.

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3
Hydrologic, Geomorphic, and Biological Effects of Urbanization on Watersheds

A watershed is defined as the contributing drainage area connected to an outlet or waterbody of interest, for example a stream or river reach, lake, reservoir, or estuary. Watershed structure and composition include both naturally formed and constructed drainage networks, and both undisturbed areas and human dominated landscape elements. Therefore, the watershed is a natural geographic unit to address the cumulative impacts of urban stormwater. Urbanization has affected change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a built drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed can experience radically different flow regimes than they did prior to urbanization. This altered hydrology, when combined with the introduction of pollutant sources that accompany urbanization (such as people, domesticated animals, industries, etc.), has led to water quality degradation of many urban streams.

This chapter first discusses the typical land-use and land-cover composition of urbanized watersheds. This is followed by a description of changes to the hydrologic and geomorphic framework of the watershed that result from urbanization, including altered runoff, streamflow mass transport, and stream-channel stability. The chapter then discusses the characteristics of stormwater runoff, including its quantity and quality from different land covers, as well as the characteristics of dry weather runoff. Finally, the effects of urbanization on aquatic ecosystems and human health are explored.

LAND-USE CHANGES

Land use has been described as the human modification of the natural environment into the built environment, such as fields, pastures, and settlements. Important characteristics of different land uses are the modified surface characteristics of the land and the activities that take place within that land use. From a stormwater viewpoint, land uses are usually differentiated by building density and comprised of residential, commercial, industrial, institutional, recreational, and open-space land uses, among others. Each of these land uses usually has distinct activities taking place within it that affect runoff quality. In addition, each land use is comprised of various amounts of surface land cover, such as roofs, roads, parking areas, and landscaped areas. The amount and type of each cover also affect the quality and quantity of runoff from urban areas. Changes in land use and in the land covers within the land uses associated with develop-

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ment and redevelopment are therefore important considerations when studying local receiving water problems, the sources of these problems within the watershed, and the stormwater control opportunities.

Land-Use Definitions

Although there can be many classifications of residential land use, a crude and common categorization is to differentiate by density. High-density residential land use refers to urban single-family housing at a density of greater than 6 units per acre, including the house, driveway, yards, sidewalks, and streets. Medium density is between 2 and 6 units per acre, while low density refers to areas where the density is 0.7 to 2 units per acre. Another significant residential land use is multiple-family housing for three or more families and from one to three stories in height. These units may be adjoined up-and-down, side-by-side, or front-and-rear.

There are a variety of commercial land uses common in the United States. The strip commercial area includes those buildings for which the primary function is the sale of goods or services. This category includes some institutional lands found in commercial strips, such as post offices, court houses, and fire and police stations. This category does not include warehouses or buildings used for the manufacture of goods. Shopping centers are another common commercial area and have the unique distinction that the related parking lot that surrounds the buildings is at least 2.5 times the area of the building roof area. Office parks are a land use on which non-retail business takes place. The buildings are usually multi-storied and surrounded by larger areas of lawn and other landscaping. Finally, downtown central business districts are highly impervious areas of commercial and institutional land use.

Industrial areas can be differentiated by the intensity of the industry. For example, “manufacturing industrial” is a land use that encompasses those buildings and premises that are devoted to the manufacture of products, with many of the operations conducted outside, such as power plants, steel mills, and cement plants. Institutional areas include a variety of buildings, for example schools, churches, and hospitals and other medical facilities that provide patient overnight care.

Roads constitute a very important land use in terms of pollutant contributions. The “freeway” land use includes limited-access highways and the interchange areas, including any vegetated rights-of-ways. Finally, there are a variety of open-space categories, such as cemeteries, parks, and undeveloped land. Parks include outdoor recreational areas such as municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas. Undeveloped lands are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, transformer stations, radio and TV transmission areas, water towers, and railroad rights-of-way.

The preceding land-use descriptions are the traditional categories that make

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up the vast majority of the land in U.S. cities. However, there are emerging categories of land use, such as those espoused under the term New Urbanism, which combine several area types (such as commercial and high-density residential areas). Although land use can be broadly and generally categorized, local variations can be extremely important such that locally available land-use data and definitions should always be used. For example, local planning agencies typically do not separate the medium-density residential areas into subcategories. However, this may be necessary to represent different development trends that have occurred with time, and to represent newly emerging types of land uses for an area. Box 3-1 discusses the subtle influence that tree canopy could have on the residential land-use classification.

Trends in Urbanization

Researchers at Columbia University (de Sherbinin, 2002) state that 83 percent of the Earth's land surface has been affected by human settlements and activities, with the urbanized areas comprising about 4 percent of the total land use of the world. Urban areas are expanding world-wide, especially in developing countries. The United Nations Population Division estimates suggest that the

BOX 3-1
The Role of Tree Cover in Residential Land Use

Figure 3-1 shows two medium-density residential neighborhoods, one older and one newer. Tree canopy is obviously different in each case, and it may have an effect on seasonal organic debris in an area and possibly on nutrient loads (although nutrient discharges appear to be more related to homeowner fertilizer applications). Increased tree canopy cover also has a theoretical benefit in reducing runoff quantities due to increased interception losses. In both cases, however, monitoring data to quantify these benefits are sparse. Xiao (1998) examined the effect urban tree cover had on the rainfall volume striking the ground in Sacramento, California. The results indicated that the type of tree or type of canopy cover affected the amount of rainfall reduction measured during a rain event, such that large broad-leafed evergreens and conifers reduced the rainfall that reached the ground by 36 percent, while medium-sized conifers and deciduous trees reduced the rainfall by 18 percent. Cochran (2008) compared the volume and intensity of rain that reached the ground in an open area (no canopy cover) versus two areas with intact canopy covers in Shelby County, Alabama, over a year. The sites were sufficiently close to each other to assume that the rainfall characteristics were the same in terms of the intensity and the variation of intensity and volume during the storm. Rainfall "throughfall" was reduced by about 13.5 percent during the spring and summer months when heavily wooded cover existed. The rainfall characteristics at the leafless tree sites (winter deciduous trees) were not significantly different from the parking lot control sites. In many locations around the county, very high winds are associated with severe storms, significantly decreasing the interception losses. Of course, mature trees are known to provide other benefits in urban areas, including shading to counteract stormwater temperature increases and massive root systems that help restore beneficial soil structure conditions. Additional research is needed to quantify the benefits of urban trees through a comprehensive monitoring program.

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BOX 3-1 Continued



FIGURE 3-1 Two medium-density residential areas (no alleys); the area below is older. SOURCE: Robert Pitt, University of Alabama.

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world's population will become mostly urbanized by 2010, whereas only 37 percent of the world's population was urbanized in 1970. De Sherbinin (2002) concludes that although the extent of urban areas is not large when compared with other land uses (such as agriculture or forestry) their environmental impact is significant. Population densities in the cities are large, and their political, cultural, and economic influence is great. Most industrial activity is also located near cities. The influence of urban areas extends beyond their boundaries due to the need for large amounts of land for food and energy production, to generate raw materials for industry, for building water supplies, for obtaining other resources such as construction materials, and for recreational areas. One study estimated that the cities of Baltic Europe require from 500 to more than 1,000 times the urbanized land area (in the form of forests, agricultural, marine, and wetland areas) to supply their resources and to provide for waste disposal (de Sherbinin, 2002).

Currently, considerable effort is being spent investigating land-use changes world-wide and in the United States in support of global climate change research. The U.S. Geological Survey (USGS, 1999) has prepared many research reports describing these changes; Figure 3-2 shows the results for one study in the Chicago and Milwaukee areas, and Figure 3-3 shows the results for a study in the Chesapeake Bay area. These maps graphically show the dramatic rate of change in land use in these areas. The very large growth in urban areas during the 20 years between 1975 and 1995 is especially astonishing. By 1995, Milwaukee and Chicago's urbanized areas more than doubled in size from prior years. Even more rapid growth has occurred in the Washington, D.C.–Baltimore area.

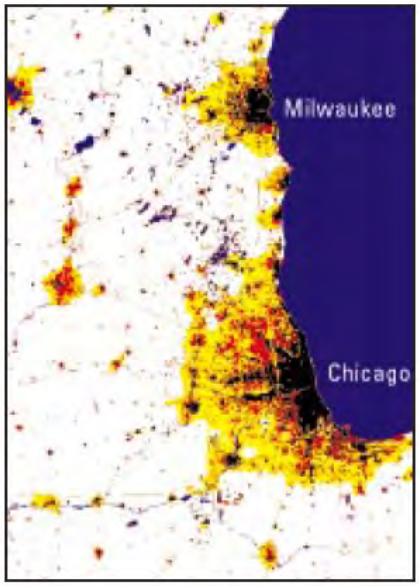

FIGURE 3-2 The extent of urban land in Chicago and Milwaukee in 1955 (black), 1975 (medium gray), and 1995 (light gray). SOURCE: USGS (1999).

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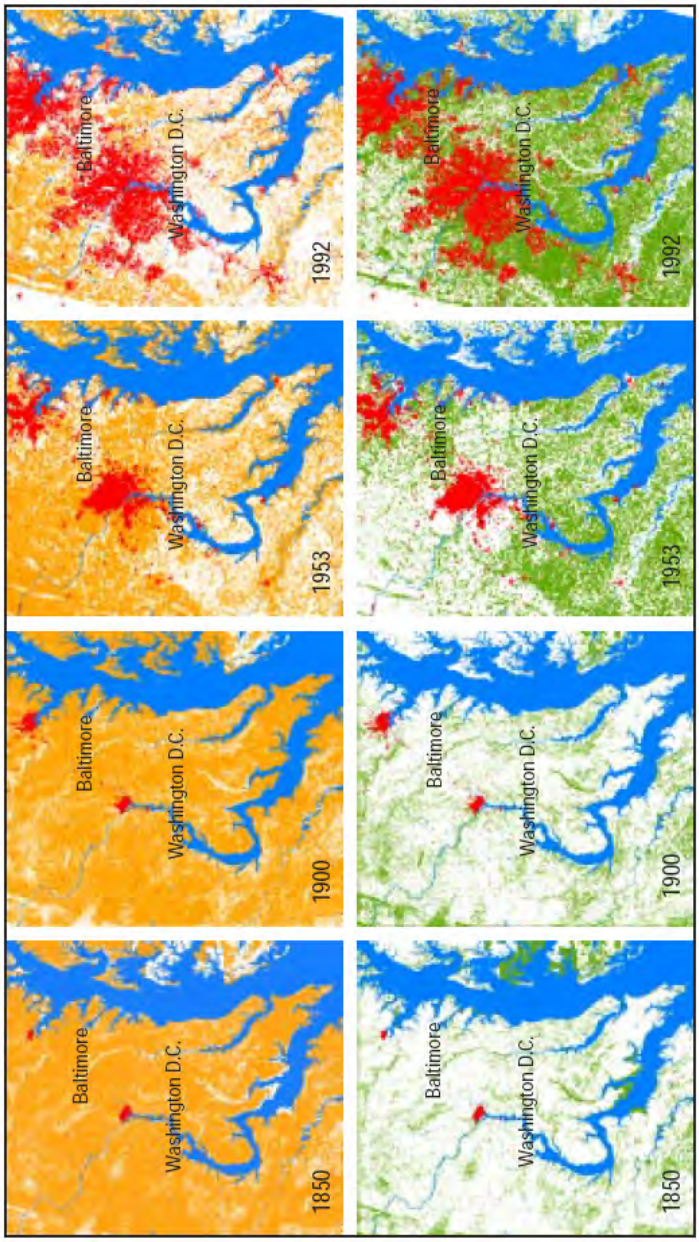

FIGURE 3-3 This series of maps compares changes in urban, agricultural, and forested lands in the Patuxent River watershed over the past 140 years. The top series shows the extent of urban areas (black) along with agriculture (gray), which was at its peak in the mid- to late 1800s. The bottom series show that urban (black) and forested land (gray) have increased since 1900. SOURCE: USGS (1999).

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Many different metrics can be used to measure the rate of urbanization in the United States, including the number of housing starts and permits and the level of new U.S. development. The latter is tracked by the U.S. Department of Agriculture's (USDA) National Resources Inventory (USDA, 2000). The inventory, conducted every five years, covers all non-federal lands in the United States, which is 75 percent of the U.S. total land area. The inventory uses land-use information from about 800,000 statistically selected locations. From 1992 to 1997, about 2.2 million acres per year were converted from non-developed to developed status. According to the USDA (2000), the per capita developed land use (acres per person, a classical measure of urban sprawl) has increased in the United States between the years of 1982 and 1997 from about 0.43 to about 0.49 acres per person. The smallest amount of developed land used per person was for New York and Hawaii (0.15 acres), while the largest land consumption rate was for North Dakota, at about 10 times greater. Surprisingly, Los Angeles is the densest urban area in the country at 0.11 acres per person. The amount of urban sprawl is also directly proportionate to the population growth. According to Beck et al. (2003):

> In the 16 cities that grew in population by 10 percent or less between 1970 and 1990 (but whose population did not decline), developed area expanded 38 percent—more than in cities that declined in population but considerably less than in the cities where population increased more dramatically. Cities that grew in population by between 10 and 30 percent sprawled 54 percent on average. Cities that grew between 31 and 50 percent sprawled 72 percent on average. Cities that grew in population by more than 50 percent sprawled on average 112 percent. These findings confirm the common sense, but often unacknowledged proposition, that there is a strong positive relationship between sprawl and population growth.

In most areas, the per capita use of developed land has increased, along with the population growth. However, even some cities that had no population growth or had negative growth, such as Detroit, still had large amounts of sprawl (increased amounts of developed land used per person), but usually much less than cities that had large population growth. Los Angeles actually had an 8 percent decreased rate of land consumption per resident during this period, but the city still experienced tremendous growth in land area due to its very large population growth. The additional 3.1 million residents in the Los Angeles area during this time resulted in the development of almost an additional 400 square miles.

Land-Cover Characteristics in Urban Areas

As an area urbanizes, the land cover changes from pre-existing rural sur-

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faces, such as agricultural fields or forests, to a combination of different surface types. In municipal areas, land cover can be separated into various common categories—pictured and described in Box 3-2—that include roofs, roads, parking areas, storage areas, other paved areas, and landscaped or undeveloped areas.

Most attention is given to impervious cover, which can be easily quantified for different types of land development. Given the many types of land cover described in Box 3-2, impervious cover is composed of two principal components: building rooftops and the transportation system (roads, driveways, and parking lots). Compacted soils and unpaved parking areas and driveways also have "impervious" characteristics in that they severely hinder the infiltration of water, although they are not composed of pavement or roofing material. In terms of total impervious area, the transportation component often exceeds the rooftop component (Schueler, 1994). For example, in Olympia, Washington, where 11 residential multifamily and commercial areas were analyzed in detail, the areas associated with transportation-related uses comprised 63 to 70 percent of the total impervious cover (Wells, 1995). A significant portion of these impervious areas—mainly parking lots, driveways, and road shoulders—experience only minimal traffic activity. Most retail parking lots are sized to accommodate peak parking usage, which occurs only occasionally during the peak holiday shopping season, leaving most of the area unused for a majority of the time. On the other hand, many business and school parking areas are used to their full capacity nearly every work day and during the school year. Other differences at parking areas relate to the turnover of parking during the day. Parked vehicles in business and school lots are mostly stationary throughout the work and school hours. The lighter traffic in these areas results in less vehicle-associated pollutant deposition and less surface wear in comparison to the greater parking turnover and larger traffic volumes in retail areas (Brattebo and Booth, 2003).

As described in Box 1-1, impervious cover is broken down into two main categories: directly connected impervious areas (or effective impervious area) and non-directly connected (disconnected) impervious areas (Sutherland, 2000; Gregory et al., 2005) (although it is recognized that these two states are end-members of a range of conditions). Directly connected impervious area includes impervious surfaces which drain directly to the sealed drainage system without flowing appreciable distances over pervious surfaces (usually a flow length of less than 5 to 20 feet over pervious surfaces, depending on soil and slope characteristics and the amount of runoff). Those areas are the most important component of stormwater runoff quantity and quality problems. Approximately 80 percent of directly connected impervious areas are associated with vehicle use such as streets, driveways, and parking (Heaney, 2000).

Values of imperviousness can vary significantly according to the method used to estimate the impervious cover. In a detailed analysis of urban imperviousness in Boulder, Colorado, Lee and Heaney (2003) found that hydrologic modeling of the study area resulted in large variations (265 percent difference)

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BOX 3-2
Land Cover in Urban Areas

For any given land use, there is a range of land covers that are typical. Common land covers are described below, along with some indication of their contribution to stormwater runoff and their pollutant-generating ability.

Roofs. These are usually either flat or pitched, as both have significantly different runoff responses. Flat roofs can have about 5 to 10 mm of detention storage while pitched roofs have very little detention storage. Roofing materials are also usually quite different for these types of roofs, further affecting runoff quality. In addition, roof flashing and roof gutters may be major sources of heavy metals if made of galvanized metal or copper. Directly connected roofs have their roof drains efficiently connected to the drainage system, such as direct connections to the storm drainage itself or draining to driveways that lead to the drainage system. These directly connected roofs have much more of their runoff waters reaching the receiving waters than do partially connected roofs, which drain to pervious areas.



A directly connected roof drain



A disconnected roof drain (drains to pervious area)

Parking Areas. These can be asphalt or concrete paved (impervious surface) or unpaved (traditionally considered a pervious surface) and are either directly connected or drain to adjacent pervious areas. Areas that have rapid turnover of parked cars throughout the day likely have greater levels of contamination due to the frequent starting of the vehicles, an expected major source of pavement pollutants. Unpaved parking areas actually should be considered impervious surfaces, as the compacted surface does not allow any infiltration of runoff. Besides automobile activity in the parking areas, other associated activities contribute to contamination. For example, parked cars in disrepair awaiting service can contribute to parking area runoff contamination. In addition, maintenance of the pavement surface, such as coal-tar seal coating, can be significant sources of polycyclic aromatic hydrocarbons (PAHs) to the runoff.

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BOX 3-2 Continued



Paved parking area with frequent automobile movement



Contamination of paved parking areas due to commercial activities

Storage Areas. These can also be paved, unpaved, directly connected, or drained to pervious areas. As with parking areas, unpaved storage areas should not be considered pervious surfaces because the compacted material effectively hinders infiltration. Detention storage runoff losses from unpaved storage areas can be significant. In storage areas (especially in commercial and industrial land uses), activities in the area can have significant effects on runoff quality.



Contaminated paved storage area at vehicle junk yard



Heavy equipment storage area on concrete surface

Streets. Streets in municipal areas are usually paved and directly connected to the storm drainage system. In municipal areas, streets constitute a significant percentage of all impervious surfaces and runoff flows. Features that affect the quality of runoff from streets include the varying amounts of traffic on different roads and the amount and type of roadside vegetation. Large seasonal phosphorus loads can occur from residential roads in heavily wooded areas, for example.

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Wide arterial street with little roadside vegetation (left) and narrow residential street with substantial vegetation (top, right)

Other Paved Areas. Other paved areas in municipal regions include driveways, playgrounds, and sidewalks. Depending on their slopes and local grading, these areas may drain directly to the drainage system or to adjacent pervious areas. In most cases, the runoff from these areas contributes little to the overall runoff for an area, and the runoff quality is of relatively better quality than from the other "hard" surfaces.

Landscaped and Turf Areas. Although these are some of the only true pervious surfaces in municipal areas, disturbed urban soils can be severely compacted, with much more reduced infiltration rates than are assumed for undisturbed regional soils. Besides the usually greater than expected quantities of runoff of pervious surfaces in urban areas, they can also contribute high concentrations of various pollutants. In areas with high rain intensities, erosion of sediment can be high from pervious areas, resulting in much higher concentrations of total suspended solids (TSS) than from paved areas. Also, landscaping chemicals, including fertilizers and pesticides, can be transported from landscaped urban areas. Undeveloped woods in urban areas can have close to natural runoff conditions, but many parks and other open-space areas usually have degraded runoff compared to natural conditions. Turf grass has unique characteristics compared to other landscaped areas in that the soil structure is usually more severely degraded compared to natural conditions. The normally shallower root systems are not as effective in restoring compacted soils and they can remain compacted due to some activities (pathways, parked cars, playing fields, etc.) that do not occur on areas planted with shrubs and trees.

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BOX 3-2 Continued



Soil erosion from turf areas with fine-grained soils during periods of high rain intensities

Undeveloped Areas. Undeveloped areas in otherwise urban locations differ from natural areas. In many situations, they can be previously disturbed (cleared and graded) areas that have not been sold or developed. They may be overgrown with various local vegetation types that thrive in disturbed locations. In other situations, undeveloped areas may be small segments of natural areas that have not been disturbed or revegetated. In this case, their stormwater characteristics may approach natural conditions but still be degraded due to adjacent activities and atmospheric deposition.

SOURCE: Pitt and Voorhees (1995, 2002). Photographs courtesy of Robert Pitt, University of Alabama.

in the calculations of peak discharge when impervious surface areas were determined using different methods. They concluded that the main focus should be on effective impervious area (EIA) when examining the effects of urbanization on stormwater quantity and quality.

Runoff from disconnected impervious areas can be spread over pervious surfaces as sheet flow and given the opportunity to infiltrate before reaching the drainage system. Therefore, there can be a substantial reduction in the runoff volume and a delay in the remaining runoff entering the storm drainage collection system, depending on the soil infiltration rate, the depth of the flow, and the

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available flow length. Examples of disconnected impervious surfaces are rooftops that discharge into lawns, streets with swales, and parking lots with runoff directed to adjacent open space or swales. From a hydrologic point of view, road-related imperviousness usually exerts a larger impact than rooftop-related imperviousness, because roadways are usually directly connected whereas roofs can be disconnected (Schueler, 1994).

Methods for Determining Land Use and Land Cover

Historically, land-use and land-cover information was acquired by a combination of field measurements and aerial photographic analyses—methods that required intensive interpretation and cross validation to guarantee that the analyst's interpretations were reliable (Goetz et al., 2003). Figure 3-4 is an example of a high-resolution panchromatic aerial photograph that was taken from an airplane in Toronto and used for measurements of urban surfaces (Pitt and McLean, 1986). Most recently, satellite images have become available at high spatial resolution for many areas (<1 to 5 m resolution) and have the advantage of digital multi-spectral information more complete than even that provided by digital orthophotographs. Minnesota has one of the longest records (over 20 years) of continuously recorded statistics on land cover and impervious surfaces derived from satellite images—information which has been incorporated into the



FIGURE 3-4 Example of a high-resolution panchromatic aerial photograph of an industrial area used for measurements of urban surfaces. SOURCE: Pitt and McLean (1986).

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Minnesota Statewide Conservation and Preservation Plan. Some of the remaining problems to be overcome with satellite imagery include difficulties in obtaining consistent sequential acquisition dates, intensive computer processing time requirements, and large computer storage space requirements to store massive amounts of image information.

The recommended approach for conducting a survey of land uses and development characteristics (land cover and activities) for an area is to use both aerial photography and site surveys. Aerial photography has improved greatly in recent years, but it is still not suitable for obtaining all the information needed for developing a comprehensive stormwater management plan. Initially, aerial photos should be used to identify the locations and extents of the various land uses in the study area. Neighborhoods representing homogenous land uses should then be identified for site surveys. Usually, about 10 to 15 neighborhoods for each land use are sufficient for a community being studied (Burton and Pitt, 2002). After the field surveys are conducted, the aerials are again used to measure the actual areas associated with land surface cover. This information can be used with field survey data to separate the surfaces into the appropriate categories for analyses and modeling.

Box 3-3 presents a detailed study of land cover for several land uses in the southern United States using satellite imagery and ground surveys (Bochis, 2007; Bochis et al., 2008). The results presented here have been found to be broadly similar to other areas studied in the United States, although few studies have been as detailed, and there are likely to be regional differences.

The general conclusion of many land-use and land-cover studies is that in urban areas, the amount of impervious surfaces has increased since the early years of the 20th century because of the tendency toward increased automobile use and bigger houses, which is associated with an increase in the facilities necessary to accommodate them (wider streets, more parking lots, and garages). As shown in later sections of this report, the construction of impervious surfaces leads to multiple impacts on stream systems. Therefore, future development plans and water resource protection programs should consider reducing impervious cover in the potential expansion of communities. Wells (1995), Booth (2000), Stone (2004), and Gregory et al. (2005) show that reducing the size and dimensions of residential parcels, promoting cluster developments (clustered medium-density residential areas in conjunction with open space, instead of large tracts of low-density areas), building taller buildings, reducing the residential street width (local access streets), narrowing the width and/or building one-side sidewalks, reducing the size of paved parking areas to reflect the average parking needs instead of peak needs, and using permeable pavement for intermittent/overflow parking can reduce the traditional impervious cover in communities by 10 to 50 percent. Many of these benefits can also be met by paying better attention to how the pavement and roof areas are connected to the drainage system. Impervious surfaces that are “disconnected” by allowing their drainage water to flow to adjacent landscaped areas can result in reduced runoff quantities.

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BOX 3-3
Land Use and Land Cover for the Little Shades Creek Watershed

Data collected by Bochis-Micu and Pitt (2005) and Bochis (2007) for the Little Shades Creek watershed near Birmingham, Alabama, were acquired using IKONOS satellite imagery (provided by the Jefferson County Storm Water Management Authority) as an alternative to classical aerial photography to map the characteristics of the land uses in the monitored watershed areas, supplemented with verified ground truth surveys. IKONOS is the first commercially owned satellite that provides 1-m-resolution panchromatic image data and 4-m multi-spectral imagery (Goetz et al., 2003).

This project was conducted to evaluate the effects of variable site conditions associated with each land-use category. About 12 homogeneous neighborhoods were investigated in each of the 16 major land uses in this 2,500-hectare watershed. Detailed land-cover measurements were made using a variety of techniques, as listed above, including field surveys for small details that were not visible with remote sensing tools (such as roof drain connectiveness, pavement texture, and landscaping maintenance practices). Each of these individual neighborhoods was individually modeled to investigate the resultant variability in runoff volume and pollutant discharges. These were statistically evaluated to determine if the land-use categories properly stratified these data by explaining significant fractions of the variability. Bochis-Micu and Pitt (2005) and Bochis (2007) concluded that land-use categories were an appropriate surrogate that can be used to describe the observed combinations of land surfaces. However, proper stormwater modeling should examine the specific land surfaces in each land-use category in order to better understand the likely sources of the pollutants and the effectiveness of candidate stormwater control measures (SCMs).

This watershed has an overall impervious cover of about 35 percent, of which about 25 percent is directly connected to the drainage system. Table 3-1 shows the average land covers for each of the surveyed land uses, along with the major source areas in each of the directly connected and disconnected impervious and pervious surface categories. The impervious covers include streets, driveways, parking, playgrounds, roofs, walkways, and storage areas. The directly connected areas are indicated as “connected” or “draining to impervious” and do not include the pervious area or the impervious areas that drain to pervious areas. As expected, the land uses with the least impervious cover are open space (vacant land, cemeteries, golf courses) and low-density residential, and the land uses with the largest impervious covers are commercial areas, followed by industrial areas. For a typical high-density residential land use in this region (having 15 or more units per hectare), the major land cover was found to be landscaped areas, subdivided into front- and backyard categories, while 25 percent of this land-use area is covered by impervious surfaces broken down into three major subcategories: roofs, streets, and driveways. The subareas making up each land use show expected trends, with roofs and streets being the predominant directly connected impervious covers in residential areas, and parking and storage areas also being important in commercial and industrial areas.

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BOX 3-3 Continued

TABLE 3-1 Little Shades Creek Watershed Land Cover Information (percent and the predominant land cover)

Land Use	Directly Connected Impervious Cover (%)	Disconnected Impervious Cover (%)	Pervious Cover (%)
High-Density Residential	14 (streets and roof)	10 (roofs)	76 (front and rear landscaping)
Medium-Density Residential (<1960 to 1980)	11 (streets and roofs)	8 (roofs)	81 (front and rear landscaping)
Medium-Density Residential (>1980)	14 (streets and roofs)	5 (roofs)	80 (front and rear landscaping)
Low-Density Residential	6 (streets)	4 (roofs)	89 (front and rear landscaping)
Apartments	21 (streets and parking)	22 (roofs)	58 (front and rear landscaping)
Multiple Families	28 (roofs, parking , and streets)	7 (roofs)	65 (front and rear landscaping)
Offices	59 (parking, streets, and roofs)	3 (parking)	39 (front and rear landscaping)
Shopping Centers	64 (parking, roofs, and streets)	4 (roofs)	31 (front landscaping)
Schools	16 (roofs and parking)	20 (playground)	64 (front and rear landscaping, large turf)
Churches	53 (parking and streets)	7 (parking)	40 (front landscaping)
Industrial	39 (storage, parking, and streets)	18 (storage and roofs)	44 (front and rear landscaping)
Parks	32 (streets and parking)	33 (playground)	34 (large turf and undeveloped)
Cemeteries	7 (streets)	15 (parking)	78 (large turf)
Golf Courses	2 (streets)	4 (roofs)	95 (large turf)
Vacant	5 (streets)	1 (driveways)	94 (undeveloped and large turf)

SOURCE: Bochis-Micu and Pitt (2005) and Bochis (2007). Reprinted, with permission, from Bochis (2007). Copyright 2007 by Celina Bochis.

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HYDROLOGIC AND GEOMORPHIC CHANGES

The watershed provides an organizing framework for the management of stormwater because it determines the natural patterns of water flow as well as the constituent sediment, nutrient, and pollutant loads. In undeveloped watersheds, hillslope hydrologic flow-path systems co-evolve with microclimate, soils, and vegetation to form topographic patterns within which ecosystems are spatially arranged and adjusted to the long-term patterns of water, energy, and nutrient availability. The landforms that comprise the watershed include the network patterns of streams, rivers, and their associated riparian zones and floodplains, as well as component freshwater lakes, reservoirs, wetlands, and estuaries.

This section starts with a discussion of precipitation measurement and characteristics before turning to the typical changes in hydrology and geomorphology of the watershed brought on by urbanization. In both the terrestrial and aquatic phases, retention and residence time of sediment and solutes decreases with increasing flow volume and velocity. This results in relatively high retention and low export of water and nutrients in undeveloped watersheds compared to decreasing retention and greater pollutant export in disturbed or developed systems.

The Storm in Stormwater

The magnitude and frequency of stormwater discharges are not just determined by rainfall. Instead, they are the combined product of storm and interstorm characteristics, land use, the natural and built drainage system, and any stormwater control measures (SCMs) that have been implemented. The total volume and peak discharge of runoff, as well as the mobilization and transport of pollutants, are dependent on all aspects of the storm magnitude, catchment antecedent moisture conditions, and the interstorm period. Therefore, information on the frequency distribution of storm events and properties is an important aspect of understanding the distribution of pollutant concentrations and loads in stormwater discharges. In northern climates, runoff production from precipitation can be significantly delayed by the accumulation, ripening, and melt of snowpacks, such that much of the annual load of certain pollutants may be mobilized in peak flow from snowmelt events. Therefore, measurement of precipitation and potential accumulation in both liquid and solid form is critical for stormwater assessment.

Precipitation Measurements

Any given storm is characterized by the storm's total rainfall (depth), its duration, and the average and peak intensity. A *storm hyetograph* depicts meas-

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ured precipitation depth (or intensity) at a precipitation gauge as a function of time; an example is shown in Figure 3-5. This figure illustrates the typical high degree of variability of precipitation over the total duration of a storm. In this example, the total storm depth is 50.9 mm, the duration is 19 hours, and the peak intensity is 0.56 mm/minute (peak depth of 2.79 mm divided by the measurement increment of 5 minutes). The average intensity is 0.045 mm/minute, quite a bit lower than the peak intensity, since the storm duration is punctuated by periods of low and no measurable precipitation.

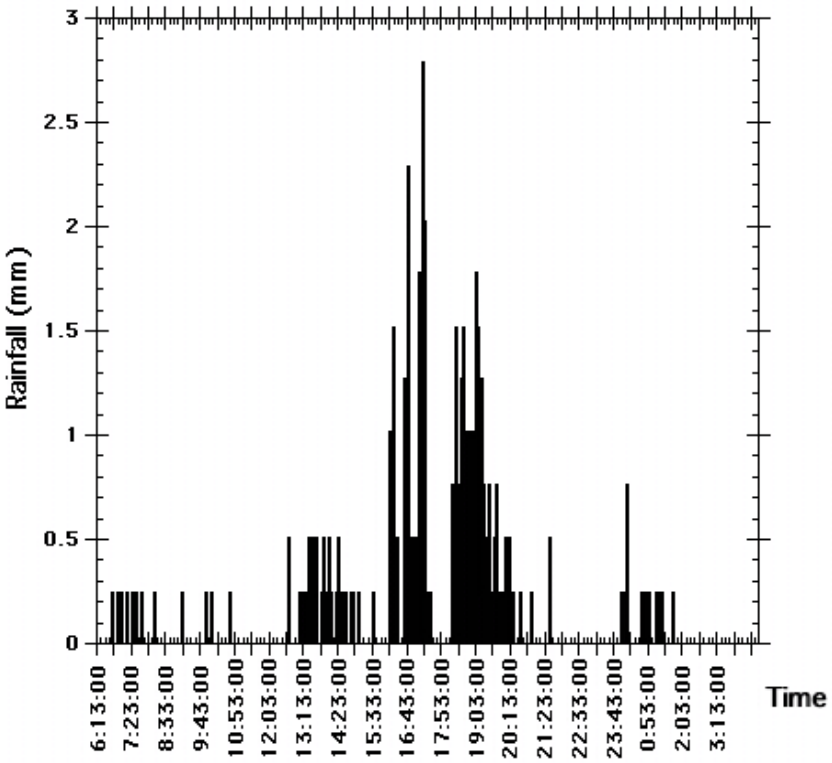

FIGURE 3-5 Example of a storm hyetograph at location RG2, September 20–21, 2001, Valley Creek watershed, Chester County, Pennsylvania. The time increment of measurement is 5 minutes, while the entire duration of this storm is about 16 hours.

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In addition to measurements of individual storm events, precipitation data are routinely collected for longer time periods and compiled and analyzed annually when trying to understand local rainfall patterns and their impact on baseflow, water quality, and infrastructure design. Figure 3-6 shows the rainfall during 2007 at both humid (Baltimore) and arid (Phoenix) locations. Especially apparent in the Baltimore data is the fact that the majority of storm events are less than 20 mm in depth.

Several networks of precipitation gauges are available in the United States; gauge data are available online from the National Climatic Data Center (NCDC) (*http://ncdc.nws.noaa.gov*). High-resolution precipitation data (i.e., with measurement intervals of an hour or less) are typically not recorded except at primary weather service meteorological stations, while daily precipitation records are more extensively collected and available through the Cooperative Weather Observer Program (*http://www.nws.noaa.gov/om/coop/*). This distinction is important to stormwater managers because most stormwater applications require short-duration measurements or model results (minutes to hours). Fortunately, a combination of precipitation gauges and precipitation radar estimates are available to estimate precipitation depth and duration, as well as additional methods to estimate snowfall and snowpack water equivalent depth and conditions. (A thorough description of precipitation measurement by radar is given by Krajewski and Smith [2001]). While most of the conterminous United States is covered by NEXRAD radar for estimation of high-temporal-resolution precipitation at current resolutions of ~4 km, the radar backscatter information requires calibration and correction with precipitation gauge data, and satellite estimates

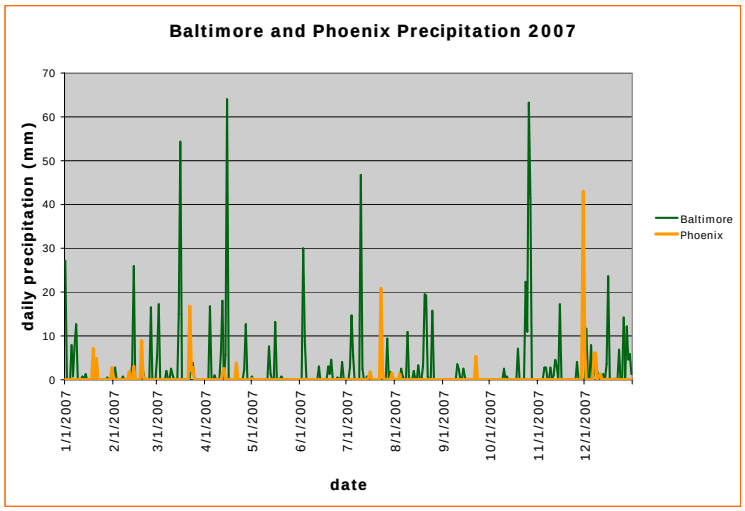

FIGURE 3-6 Daily precipitation totals for the Baltimore-Washington and Phoenix airports for 2007. SOURCE: Data from the National Weather Service.

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of precipitation are generally not sufficiently reliable for stormwater applications. It goes without saying that the measurement, quality assurance, and maintenance of long-term precipitation records are both vital and nontrivial to stormwater management.

Precipitation Statistics

The basic characterization of precipitation is by depth-duration-frequency curves, which describe the return period, recurrence interval, and exceedance probability (terms all denoting frequency) of different precipitation intensities (depths) over different durations. The methodology for determining the curves is described in Box 3-4. Precipitation durations of interest in stormwater management range from a few minutes (important for determining peak discharge from small urban drainage areas) to a year (where the interest is in the total annual volume of runoff production). As an example, one might be interested in the return period of the 1-inch, 1-hour event, or the 1-inch, 24-hour event; the latter would have a much shorter return period, because accumulating an inch of rain over a day is much more common than accumulating the same amount over just an hour.

BOX 3-4
Determining Depth-Duration-Frequency Curves

Depth-duration-frequency curves are developed from precipitation records using either annual maximum data series or annual exceedance data series. Annual maximum data series are calculated by extracting the annual maximum precipitation depths of a chosen duration from a record. In cases where there are only a few years of data available (less than 20 to 25 years), then an annual exceedance series (a type of "partial duration series") for each storm duration can be calculated, where N largest values from N years are chosen. An annual maximum series excludes other extreme values of record that may occur in the same year. For example, the second highest value on record at an observing station may occur in the same year as the highest value on record but will not be included in the annual maximum series. The design precipitation depths determined from the annual exceedance series can be adjusted to match those derived from an annual maximum series using empirical factors (Chow et al., 1988; NOAA Atlas data series, see *http://www.weather.gov/oh/hdsc/currentpf.htm*, e.g., Bonnin et al., 2006). Hydrologic frequency analysis is then applied the data series to determine desired return periods by fitting a probability distribution to the data to determine the return periods[1] of interest. The process is repeated for other chosen storm durations.

[1]Analysis of annual maximum series produces estimates of the average period between years when a particular value is exceeded ("average recurrence interval"). Analysis of partial duration (annual exceedance) series gives the average period between cases of a particular magnitude ("annual exceedance probability"). The two results are numerically similar at rarer average recurrence intervals but differ at shorter average recurrence intervals (below about 20 years). NOAA (e.g., Bonnin et al., 2006) notes that the use of the terminology "average recurrence interval" and "annual exceedance probability" typically reflects the analysis of the two different series, but that sometimes the term "average recurrence interval" is used as a general term for ease of reference.

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The National Weather Service has developed an online utility to estimate the return period for a range of depth–duration events for any place in the conterminous United States (*http://hdsc.nws.noaa.gov/hdsc/pfds/*). Figures 3-7 and 3-8 show examples of precipitation depth-duration-frequency curves for a humid location (Baltimore, Maryland) and an arid site (Phoenix, Arizona). As an illustration of the climatic influence on the depth-duration-frequency curves, the 2-year, 1-hour storm is associated with a depth of 1.2 inches of precipitation in Baltimore, whereas this same recurrence interval and duration are associated with a depth of only 0.6 inch of precipitation in Phoenix. Durations from 5 minutes to one day are shown because this is the range typically used in the design of stormwater management facilities. The shorter durations provide expected magnitude and frequency for brief but significant precipitation intensity peaks that can mobilize and transport large amounts of pollutants and erode soil, and they are used in high-resolution stormwater models. More commonly, however, stormwater regulations are written for 24-hour durations at 2-, 10-, 25-, 50-, or 100-year recurrence intervals.

Because storm magnitudes and frequencies vary by climatic region, it is reasonable to expect them to change during recurring climate events (e.g., El Niño) or over the long term by climate change. Alteration in convective precipitation by major urban centers has been documented for some time (Huff and Changnon, 1973). Some evidence exists that precipitation regimes are shifting systematically toward an increase in more intense rainfall events, which is consistent with modeled projections of global climate change increases in hydrologic extremes. Kunkel et al. (1999) analyzed precipitation data from 1,295 weather stations from 1931 to 1996 across the contiguous United States and found that storms with extreme levels of precipitation have increased in frequency. The analysis considered short-duration events (1, 3, and 7 days) of 1-year and 5-year return intervals. A linear trend analysis using Kendall's slope estimator statistic indicated that the overall trend in 7-day, 1-yr events for the conterminous United States is upward at a rate of about 3 percent per decade for 1931 to 1996; the upward trend in 7-day, 5-year events is about 4 percent per decade. These two time series are shown in Figure 3-9. An increased frequency of intense precipitation events will shift depth-frequency-duration curves for a given location, with a given return period being associated with a more intense event. Alternatively, the return period for a given intensity (or depth) of an event will be reduced if the event is occurring more frequently. In light of climate change, depth-duration-frequency curves will need to be updated regularly in order to ensure that stormwater management facilities are not underdesigned for an increasing intensity of precipitation. Additional implications of climate change for stormwater management are discussed in Box 3-5.

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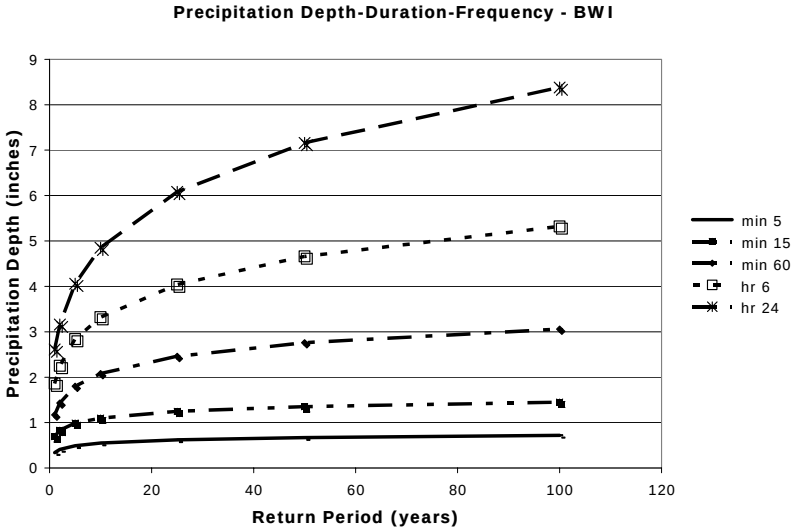

FIGURE 3-7 Depth-duration-frequency curves for Baltimore, Maryland. SOURCE: Data from the National Weather Service.

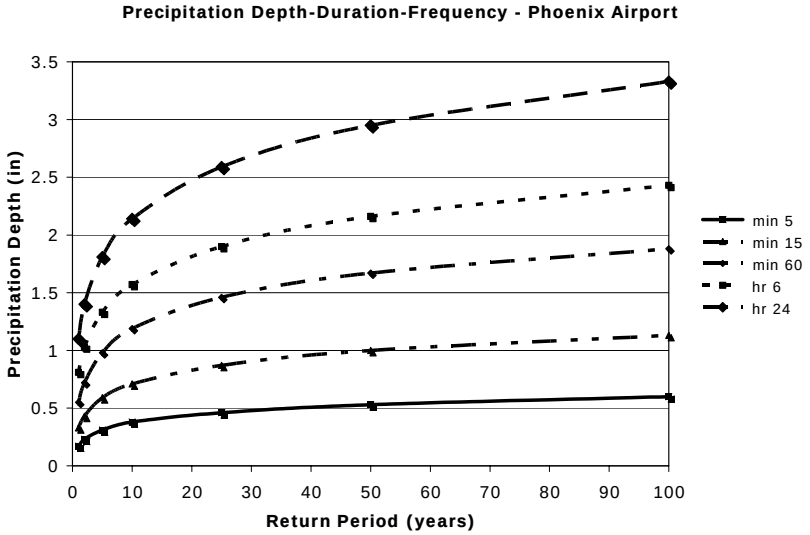

FIGURE 3-8 Depth-duration-frequency curves for Phoenix, Arizona. SOURCE: Data from the National Weather Service.

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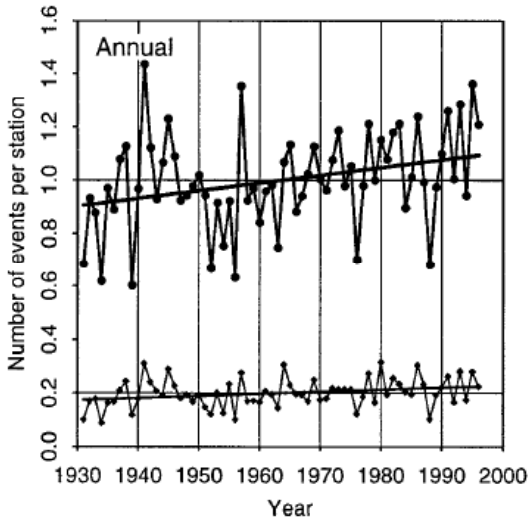

FIGURE 3-9 Nationally averaged annual U.S. time series of the number of precipitation events of 7-day duration exceeding 1-year (dots) and 5-year (diamonds) recurrence intervals. SOURCE: Reprinted, with permission, from Kunkel et al. (1999). Copyright 1999 by American Meteorological Society.

BOX 3-5
Climate Change and Stormwater Management

An ongoing report series issued by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research summarizes the evidence for climate change to date and expected impacts of climate change, including impacts on the water resources sector (*http://www.climatescience.gov/*). According to the Intergovernmental Panel on Climate Change (IPCC 2007), annual precipitation will likely increase in the northeastern United States and will likely decrease in the southwestern United States over the next 100 years. In the western United States, precipitation increases are projected during the winter, whereas decreases are projected for the summer. As temperatures warm, precipitation will increasingly fall as rain rather than snow, and snow season length and snow depth are very likely to decrease in most of the country. More extreme precipitation events are also projected, which, when coupled with an anticipated increase in rain-on-snow events, would contribute to more severe flooding due to increases in extreme stormwater runoff.

The predictions for increases in the intensity and frequency of extreme events have significant implications for future stormwater management. First, many of the design standards currently in use will need to be revised, since they are based on historical data. For example, depth-duration-frequency curves used for design storm data will need to be updated, because the magnitude of the design storms will change. Even with revised design standards, in light of future uncertainty, new SCMs will need to be designed conservatively to allow for additional storage that will be required for regions with predicted trends in increased precipitation. In addition, existing SCM designs based on old standards may prove to be undersized in the future. Implementation of a monitoring program to check existing SCM inflows against original design inflows may be prudent to aid in judging whether retrofit of existing facilities or additional stormwater infrastructure is needed.

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Design Storms

Given that only daily precipitation records are widely available, but short-duration data are required for stormwater analysis and prediction, *design storms* have been developed for the different regions of the United States by different state and federal resource agencies. A *design storm* is a specified temporal pattern of rainfall at a location, created using an overall storm duration and frequency relevant to the design problem at hand. Examples of design storms include the 24-hour, 100-year event for flood control and the 24-hour, 2-year event for channel protection. The magnitude of the design storm can be derived from data at a single gauge, or from synthesized regional data published by state or federal agencies. The simplest form of a design storm is a triangular hyetograph where the base is the duration and the height is adjusted so that the area under the curve equals the total precipitation. In instances where the hyetograph is to be used to estimate sequences of shorter duration intensities (i.e., minutes to a few hours) within larger duration events, depth-duration-frequency curve data can be used to synthesize a design storm hyetograph (see Chow et al., 1988). An example design storm for the 100-year storm event for St. Louis based on NOAA Atlas 14 depth-duration-frequency data is shown in Figure 3-10.

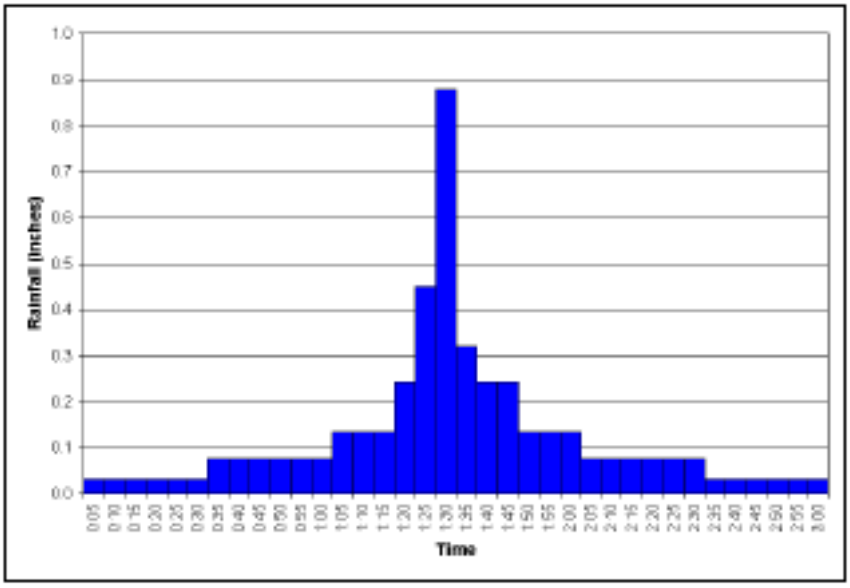

FIGURE 3-10 Hundred-year design storm for St. Louis based on NOAA Atlas 14 data. SOURCE: Hoblit et al. (2004) based on data from Bonnin et al. (2003).

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Conversion of Precipitation to Runoff

Dynamics of Watershed Flowpaths

Precipitation falling on the land surface is subject to evaporative loss to the atmosphere by vegetation canopy and leaf litter interception, evaporation directly from standing water on the surface and upper soil layers or impervious surfaces, and later transpiration through root uptake by vascular plants. Snowpack is also subject to sublimation (conversion of snow or ice directly to vapor), which results in the loss of a portion of the snow prior to melt. The rate of evaporative loss depends on local weather conditions (temperature, humidity, wind speed, solar radiation) and the rate and duration of precipitation. Precipitation (or snowmelt) in excess of interception and potential evaporative loss rates is then partitioned into infiltration and direct runoff.[1]

There is a gradation of flowpaths transporting water, sediment, and solutes through a watershed, ranging from rapid surface flowpaths through generally slower subsurface flowpaths. Residence times generally increase from surface to subsurface flowpaths, with rapid surface flow providing the major contribution to flood flow while subsurface flowpaths contribute to longer-term patterns of surface wetness. Watershed characteristics that influence the relative dominance of surface versus subsurface flowpaths include infiltration capacity as affected by land cover, soil properties, and macropores; subsurface structure or soil horizons with varying conductivity; antecedent soil moisture and groundwater levels; and the precipitation duration and intensity for a particular storm.

The distribution and activity of flowpaths result in changing patterns of soil moisture and groundwater depth, which result in patterns of soil properties, vegetation, and microbial communities. These ecosystem patterns, in turn, can have strong influences on the hydraulics of flow and biogeochemical transformations within the flowpaths, with important implications for sources, sinks, and transport of solutes and sediment in the watershed. Riparian areas, wetlands, and the benthos of streams and waterbodies are nodes of interaction between surface and groundwater flowpaths, yielding reactive environments in which "hot spots" of biogeochemical transformation develop (McClain et al., 2003). Thus, any alteration of surface and subsurface hydrologic flowpaths, for

[1] The term *runoff* is often used in two senses. For a given precipitation event, direct *storm runoff* refers to the rainfall (minus losses) that is shed by the landscape to a receiving waterbody. In an area of 100 percent imperviousness, the runoff nearly equals the rainfall (especially for larger storms). Over greater time and space scales, *surface water runoff* refers to streamflow passing through the outlet of a catchment, including base flow from groundwater that has entered the stream channel. The raw units of runoff in either case are volume per time, but the volumetric flowrate (discharge) is often divided by contributing area to express runoff in units of depth per time. In this way, unit runoff rates from various-sized watersheds can be compared to account for differences other than the contributing area.

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example due to urbanization, not only alters the properties of soil and vegetation canopy but also reforms the ecosystem distribution of biogeochemical transformations.

Runoff Measurements

Surface water runoff for a given area is measured by dividing the discharge at a given point in the stream channel by the contributing watershed area. The basic variables describing channel hydraulics include width, mean depth, slope, roughness, and velocity. Channel discharge is the product of width, depth, and velocity and is typically estimated by either directly measuring each of these three components, or by development of a rating curve of measured discharge as a function of water depth, or stage relative to a datum, of the channel that is more easily estimated by a staff gauge or pressure transducer. The establishment of a gauging station to measure discharge typically requires a stable cross section so that stage can be uniquely related to discharge. Maintenance of reliable, long-term gauge sites is expensive and requires periodic remeasurement to update rating curves, as well as to remove temporary obstructions that may raise stage relative to unobstructed conditions.

Most stream gauging in the United States is carried out by the USGS, and can be found on-line at *http://waterdata.usgs.gov/nwis*. Recent reviews of standard methods of stream gauging and the status of the USGS stream gauging network are given by the USGS (1998) and the National Research Council (NRC, 2004). A major concern is the overall decline in the number of active gauges, particularly long-term gauges, as well as the representativeness of the stream gauge network relative to the needs of stormwater permitting. For example, restored streams typically lack any gauged streamflow or water quality information prior to or following restoration. This makes it very difficult to assess both the potential for successful restoration and whether project goals are met.

Support of existing and development of new gauges is often in collaboration through a co-funding mechanism with other agencies. Municipal co-funding for stations in support of National Pollutant Discharge Elimination System (NPDES) permitting is common and has tended to shift the concentration of active gauges toward more urban areas. Note that the USGS river monitoring system was originally designed for resource inventory, and therefore did not originally sample many headwater streams, particularly intermittent and ephemeral channels that are typically most proximal to stormwater discharges. While this is beginning to change with municipal co-funding, headwater streams are still underrepresented in the National Water Information System relative to their ecological significance.

Reliable records for stream discharge are vital because the frequency distribution and temporal trends of flows must be known to evaluate long-term loading to waterbodies. Magnitude and frequency analysis of sediment and other

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stream constituent loads consists of a transport equation as a function of discharge, integrated over the discharge frequency distribution (e.g., Wolman and Miller, 1960). Different constituent loads have different forms of dependency on discharge, but are often nonlinear such that long-term or expected loads cannot be simply evaluated from mean flow conditions. Similar to precipitation, discharge levels often follow an Extreme Value distribution, dependent on climate, land use, and hydrogeology, but which is typically dampened compared to precipitation due to the memory effects of subsurface storage and flows (e.g., Winter, 2007).

Impacts of Urbanization on Runoff

Shift from Infiltration and Evapotranspiration to Surface Runoff

Replacement of vegetation with impervious or hardened surfaces affects the hydrologic budget—the quantity of water moving through each component of the hydrologic cycle—in a number of predictable ways. As the percent of the landscape that is paved over or compacted is increased, the land area available for infiltration of precipitation is reduced, and the amount of stormwater available for direct surface runoff becomes greater, leading to increased frequency and severity of flooding. Reduced infiltration of precipitation leads to reduced recharge of the groundwater reservoir; absent new sources of recharge, this can lead to reduction in base flow of streams (e.g., Simmons and Reynolds, 1982; Rose and Peters, 2001). Vegetation removal also results in a lower amount of evapotranspiration compared to undeveloped land. This can have particularly profound hydrologic effects in those regions of the country where a significant percent of precipitation is evapotranspirated, such as the arid Southwest (Ng and Miller, 1980). Figure 3-11 illustrates the changes to these components of the hydrologic budget as the percent of impervious area is increased.

It should be noted that the conversion in hydrology from infiltrated water to surface runoff following urbanization is not entirely straightforward in all cases. Leaking pressurized water supply pipes and sanitary sewers, subsurface discharge of septic system effluent (Burns et al., 2005), infiltration of stormwater from unlined detention ponds, and lawn irrigation can offset reduced infiltration of precipitation, such that stream baseflow levels may actually be increased, especially during low base flow months, when such effects would be most pronounced (Konrad and Booth, 2005; Meyer, 2005). Cracks in sealed surfaces can also provide concentrated points of infiltration (Sharp et al., 2006).

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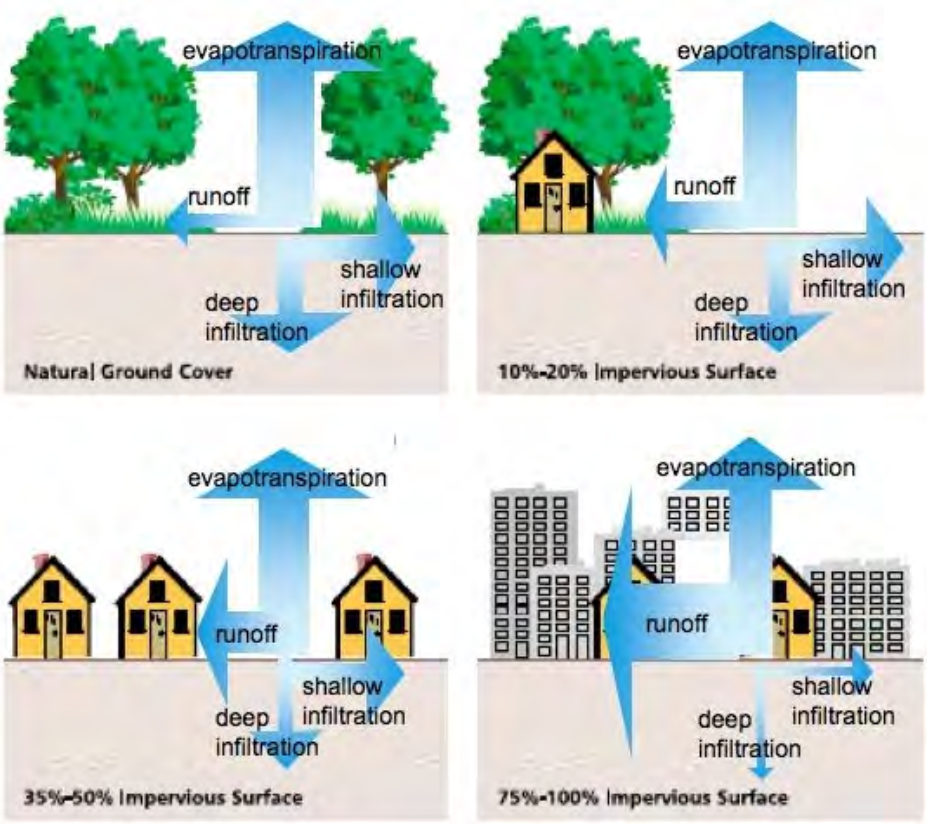

FIGURE 3-11 As land cover changes from vegetated and undeveloped (upper left) to developed with increased connected impervious surfaces (lower right), the partitioning of precipitation into other components of the hydrologic cycle is shifted. Evapotranspiration and shallow and deep infiltration are reduced, and surface runoff is increased. SOURCE: Adapted from the Federal Interagency Stream Restoration Working Group (FISRWG, 2000).

Relationship Between Imperviousness, Drainage Density, and Runoff

Excess runoff due to urbanization is a direct reflection of the land uses onto which the precipitation falls, as well as the presence of drainage systems that receive stormwater from many separate source areas before it enters receiving waters. Thus, a functional way of partitioning urban areas is by the nature of the impervious cover and by its connection to the drainage system, underlying the differentiation of total impervious area and effective impervious area discussed in Box 1-2.

As examples of how runoff changes with urbanization, Figure 3-12 shows

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daily stream flow values for a low-density suburban catchment and a high-density urban catchment in the Baltimore, Maryland area. The low-density site (Figure 3-12A) shows a strong seasonal signal and a marked decline in flow during an extreme drought in 2002. In contrast, the more densely urbanized catchment (Figure 3-12B) shows a much greater variability in flow that is dominated by impervious surface runoff, and a dampened response to the drought because natural groundwater flow is a much smaller component of the total discharge.

The percentage of time a discharge level is equaled or exceeded is displayed by flow duration curves, which show the cumulative frequency distributions of flows for a given duration. Examples for three catchments in the Baltimore area are given in Figure 3-13, showing the tendency for urban areas to produce high flows with much longer aggregate durations.

As another example of how runoff changes with imperviousness, a locally calibrated version of WinSLAMM was used to investigate the relationships between watershed and runoff characteristics for 125 individual neighborhoods in

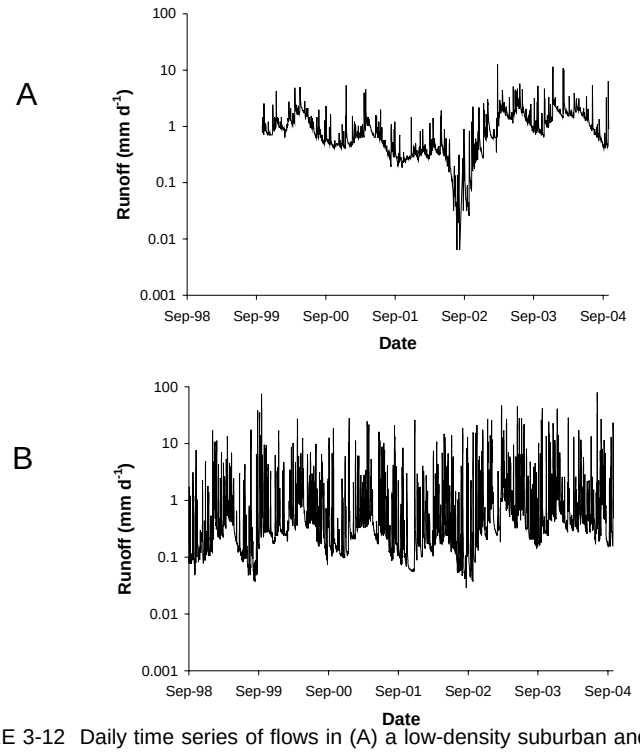

FIGURE 3-12 Daily time series of flows in (A) a low-density suburban and forested catchment (Baisman Run, *http://waterdata.usgs.gov/md/nwis/uv/?site_no=01583580*) and (B) a catchment dominated by medium- to high-density residential and commercial land uses (Dead Run, *http://waterdata.usgs.gov/md/nwis/uv/?site_no=01589330*). Both lie within the Piedmont physiographic province.

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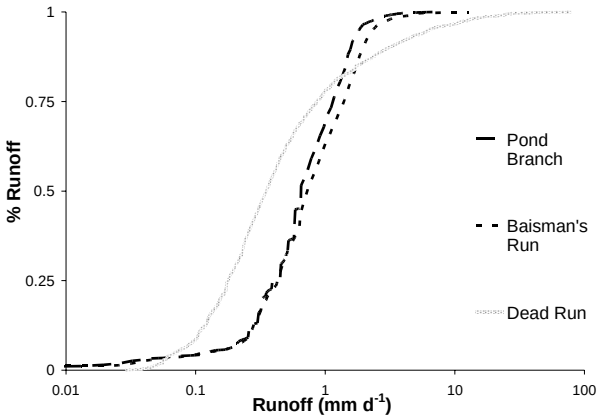

FIGURE 3-13 Flow duration curves for three watersheds with distinct land use in the Baltimore, Maryland area. Pond branch is a forested reference site, Baisman's Run is exurban, and Dead Run is urban. Urban areas have flashier runoff with greater frequency of low and high extreme flows.

Jefferson County, Alabama (Bochis-Micu and Pitt, 2005). Figure 3-14 shows the relationships between the directly connected impervious area values and the calculated volumetric runoff coefficient (R_v, which is the volumetric fraction of the rainfall that occurs as runoff), based on 43 years of local rain data. As expected, there is a strong relationship between these parameters for both sandy and clayey soil conditions. It is interesting to note that the R_v values are relatively constant until values of directly connected impervious cover of 10 to 15 percent are reached (at R_v values of about 0.07 for sandy soil areas and 0.16 for clayey soil areas)—the point where receiving water degradation typically has been observed to start (as discussed later in the chapter). The 25 to 30 percent directly connected impervious levels (where significant degradation is usually observed) is associated with R_v values of about 0.14 for sandy soil areas and 0.25 for clayey soil areas; this is where the curves start to greatly increase in slope.

Relationship Between Runoff and Rainfall Conditions

The runoff that results from various land uses also varies depending on rainfall conditions. For small rain depths, almost all the runoff originates solely from directly connected impervious areas, as disconnected areas have most of their flows infiltrated (Pitt, 1987). For larger storms, both directly connected

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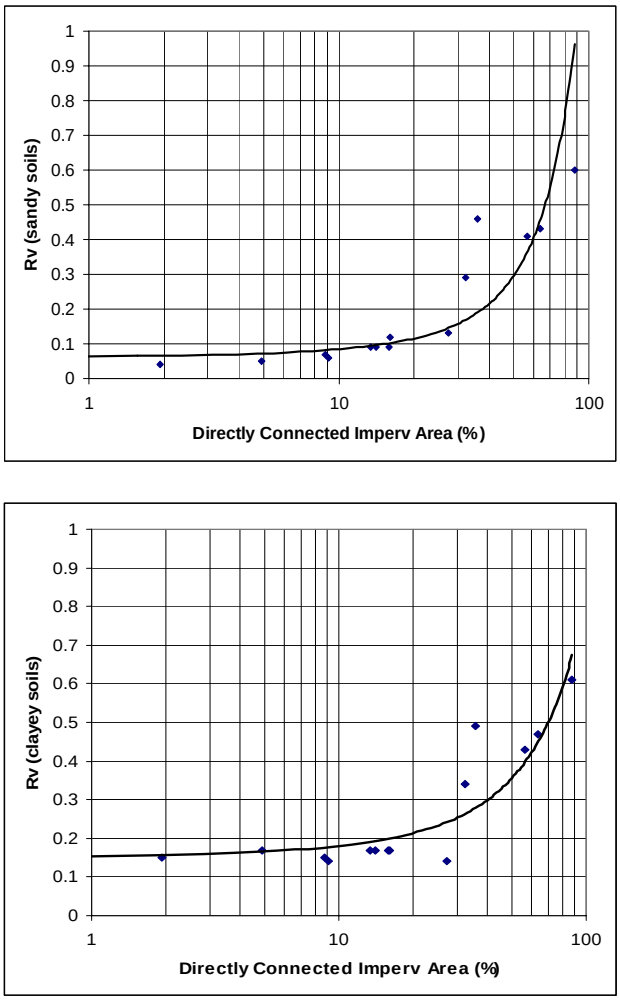

FIGURE 3-14 Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (R_v) for sandy soil (top) and clayey soil (bottom). SOURCE: Reprinted, with permission, from Bochis-Micu and Pitt (2005). Copyright 2005 by Water Environment Federation, Alexandria, Virginia.

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and disconnected impervious areas contribute runoff to the stormwater management system. For example, Figure 3-15 (created using WinSLAMM; Pitt and Voorhees, 1995) shows the relative runoff contributions for a large commercial/mall area in Hoover, Alabama, for different rains (Bochis, 2007). In this example, about 80 percent of the runoff originates from the parking areas for the smallest runoff-producing rains. This contribution decreases to about 55 percent at rain depths of about 0.5 inch (13 mm). This decrease in the importance of parking areas as a source of runoff volume is associated with an increase in runoff contributions from streets and directly connected roofs. In many areas, pervious areas are not hydrologically active until the rain depths are relatively large and are not significant runoff contributors until the rainfall exceeds about 25 mm for many land uses and soil conditions. However, compacted urban soils can greatly increase the flow contributions from pervious areas during smaller rains. Burges and others (1998), for example, found that more than 60 percent of the storm runoff in a suburban development in western Washington State originated from nominally "green" parts of the landscape, primarily lawns.

A further example illustrating the relationship between rainfall and runoff is given for Milwaukee, summarized in Box 3-6. The two curves of Figure 3-16 show a relationship between rainfall and runoff that is typical of urban areas. Very small storms (< 0.05 inch) produce no measurable runoff, owing to removal by interception storage and evaporation. Storms that deposit up to one inch of rainfall constitute about 90 percent of the storm events in this region, but these events produced only about 50 percent of the runoff. Very large events (greater than 3 inches of precipitation) are rare and destructive, accounting for only a few percent of the annual rainfall events.

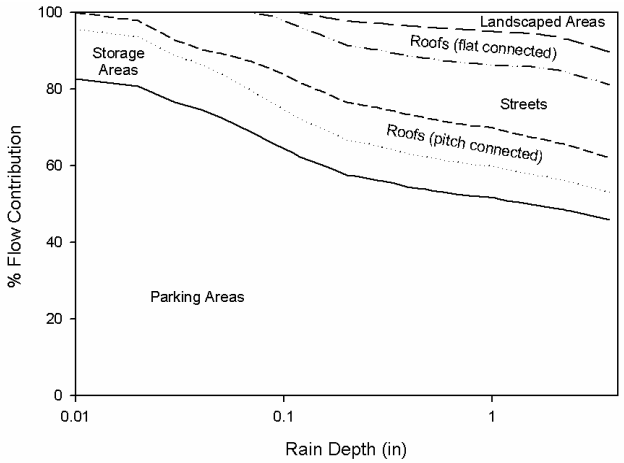

FIGURE 3-15 Surfaces contributing to runoff for a commercial/mall area. SOURCE: Reprinted, with permission, from Bochis (2007). Copyright 2007 by Celina Bochis.

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BOX 3-6
Example Rainfall and Runoff Distributions

Figure 3-16 is an example of rainfall and runoff observed at Milwaukee, Wisconsin (Bannerman et al., 1983), as monitored during the Nationwide Urban Runoff Program (NURP) (EPA, 1983). This observed distribution is interesting because of the unusually large rains that occurred twice during the monitoring program. These two major rains would be in the category of design storms for conventional drainage systems. These plots indicate that these very large events, in the year they occurred, caused a measureable fraction of the annual pollutant loads and runoff volume discharges, but smaller events were responsible for the vast majority of the discharges. In typical years, when these rare design events do not occur, their pro-rated contributions would be even smaller.

More than half of the runoff from this typical medium-density residential area was associated with rain events that were smaller than 0.75 inch. Two large storms (about 3 and 5 inches in depth), which are included in the figure, distort this figure because, on average, the Milwaukee area only expects one 3.5-inch storm about every five years, and 5-inch storms even less frequently. If these large rains did not occur, such as for most years, then the significance of the smaller rains would be even greater. The figure also shows the accumulated mass discharges of different pollutants (suspended solids, chemical oxygen demand [COD], phosphates, and lead) monitored during the Milwaukee NURP project. When these figures are compared, it is seen that the runoff and pollutant mass discharge distributions are very similar and that variations in the runoff volume are much more important than variations in pollutant concentrations (the mass divided by the runoff volume) for determining pollutant mass discharges.

These rainfall and runoff distributions for Milwaukee can thus be divided into four regions:

- **Less than 0.5 inch.** These rains account for most of the events, but little of the runoff volume, and they are therefore easiest to control. They produce much less pollutant mass discharge and probably have less receiving water effects than other rains. However, the runoff pollutant concentrations likely exceed regulatory standards for several categories of critical pollutants (bacteria and some total recoverable heavy metals). They also cause large numbers of overflow events in uncontrolled combined sewers. These rains are very common, occurring once or twice a week (accounting for about 60 percent of the total rainfall events and about 45 percent of the total runoff-generating events), but they only account for about 20 percent of the

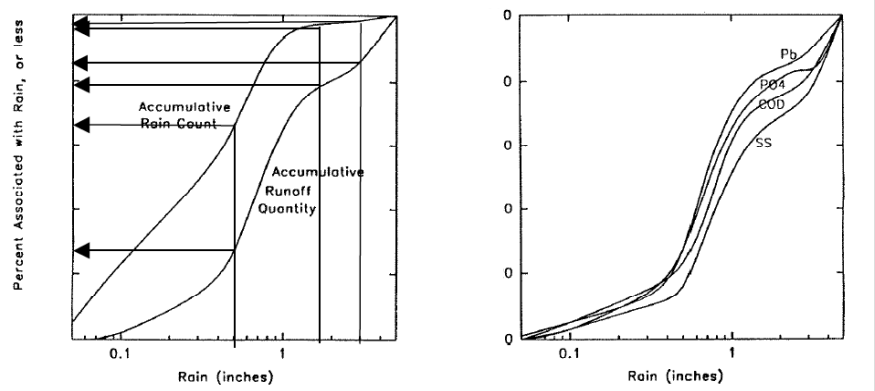

FIGURE 3-16 Milwaukee rainfall and runoff probability distributions, and pollutant mass discharge probability distributions (1981 to 1983). Rain count refers to the number of rain events. SOURCE: Data from Bannerman et al. (1983).

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BOX 3-6 Continued

annual runoff and pollutant discharges. Rains less than about 0.05 inch did not produce noticeable runoff.

- **0.5 to 1.5 inches**. These rains account for the majority of the runoff volume (about 50 percent of the annual volume for this Milwaukee example) and produce moderate to high flows. They account for about 35 percent of the annual rain events, and about 20 percent of the annual runoff events, by number. These rains occur on average about every two weeks from spring to fall and subject the receiving waters to frequent high pollutant loads and moderate to high flows.

- **1.5 to 3 inches**. These rains produce the most damaging flows from a habitat destruction standpoint and occur every several months (at least once or twice a year). These recurring high flows, which were historically associated with much less frequent rains, establish the energy gradient of the stream and cause unstable streambanks. Only about 2 percent of the rains are in this category, but they are responsible for about 10 percent of the annual runoff and pollutant discharges.

- Greater than **3 inches.** The rains in this category are included in design storms used for traditional drainage systems in Milwaukee, depending on the times of concentration and rain intensities. These rains occur only rarely (once every several years to once every several decades, or less frequently) and produce extremely large flows that greatly exceed the capacities of the storm drainage systems, causing extensive flooding. The monitoring period during the Milwaukee NURP was unusual in that two of these events occurred. Less than 2 percent of the rains were in this category (typically <<1 percent would be in this category), and they produced about 15 percent of the annual runoff quantity and pollutant discharges. However, when they do occur, substantial property and receiving water damage results (mostly associated with habitat destruction, sediment scouring, and the flushing of organisms great distances downstream and out of the system). The receiving water can conceivably recover naturally to pre-storm conditions within a few years. These storms, while very destructive, are sufficiently rare that the resulting environmental problems do not justify the massive controls that would be necessary to decrease their environmental effects.

Alteration of the Drainage Network

As shown in Figure 3-17, urbanization disrupts natural systems in ways that further complicate the hydrologic budget, beyond the imperviousness effects on runoff discussed earlier. As an area is urbanized, lower-order stream channels are typically re-routed or encased in pipes and paved over, resulting in a highly altered drainage pattern. The buried stream system is augmented by an extensive system of storm drains and pipes, providing enhanced drainage density (total lengths of pipes and channels divided by drainage area) compared to the natural system. Figure 3-18 shows how the drainage density of Baltimore today compares to the natural watershed before the modern stormwater system was fully developed. The artificial drainage system occupies a greater percentage of the landscape compared to natural conditions, permanently altering the terrestrial component of the hydrologic cycle.

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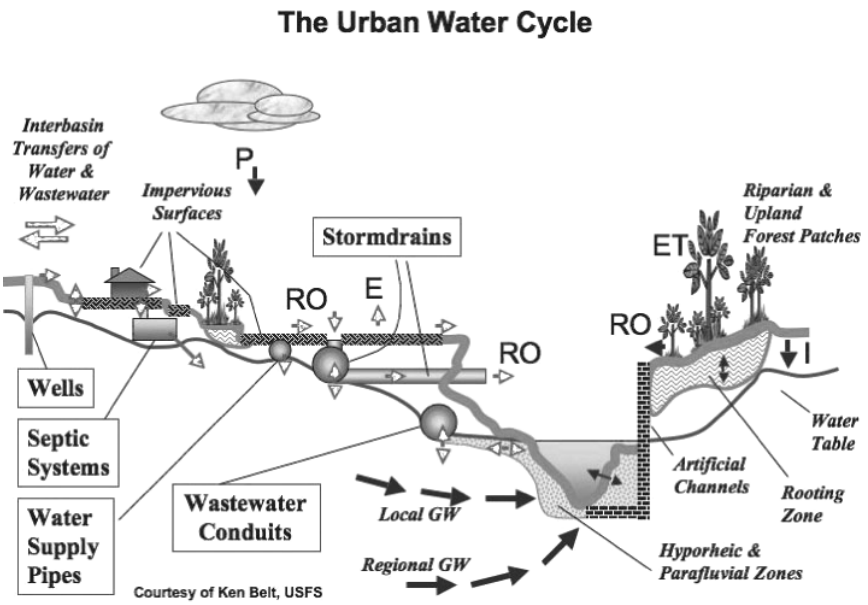

FIGURE 3-17 Alteration of the natural hydrologic cycle by the presence of piped systems. Black arrows represent the natural system; outlined arrows indicate short-circuiting due to piped systems. Note that several elements of the water cycle shown in this diagram are not considered in this report, such as septic systems, interbasin transfers of water and wastewater, and the influence of groundwater withdrawals. SOURCE: Courtesy of Kenneth Belt, USDA Forest Service, Baltimore, Maryland.

Flowpaths are altered in other ways by urban infrastructure. Buried stormwater and sewer pipes can act as infiltration galleries for groundwater, causing shortened groundwater flowpaths between groundwater reservoirs and stream systems. Natural surface water pathways are often interrupted or reversed, as shown by the blue lines in Figure 3-19 for a drainage system in Baltimore. Understanding how the system operates as a whole can often require knowledge of the history of construction conditions and field verification of the actual flow paths.

Large-scale infrastructure such as dams, ponds, and bridges can also have a major impact on stormwater flows. Figure 3-20 illustrates the interruption of the drainage network by bridges and culverts, even in places where there have been attempts to keep excessive development out of the riparian corridor. Simulations and post-flood mapping in areas around Baltimore have shown that bridge abutments such as those shown in Figure 3-20 can slow down channel floodwaters during storms. This is because water backs up behind bridges constructed

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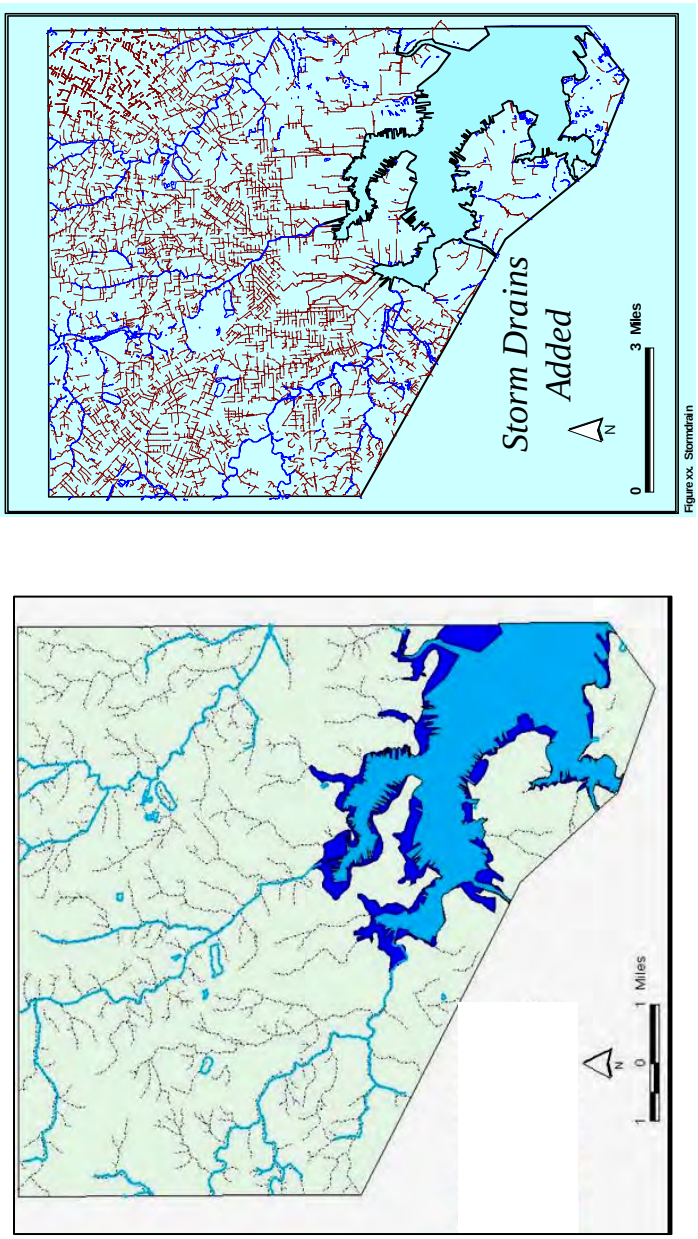

FIGURE 3-18 Baltimore City before and after development of its stormwater system. The left-hand panel shows first- and second-order streams lost to development. The right-hand panel shows the increase in drainage density resulting from construction of the modern storm-drain network. SOURCE: Courtesy of William Stack, Baltimore Department of Public Works.

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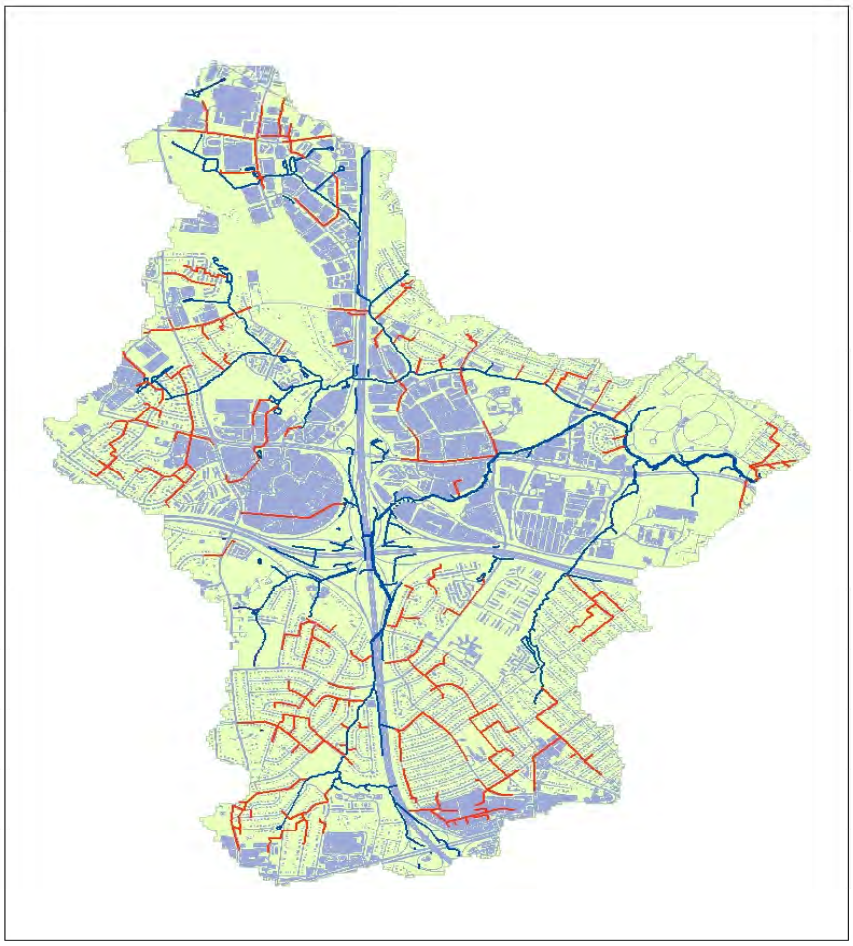

FIGURE 3-19 Dead Run drainage system, Baltimore, Maryland. Black lines indicate surface (daylighted) drainage; dark grey indicates the subsurface storm-drain system. The surface drainage system is highly disconnected. From the coverage it is difficult to impossible to discern the flow direction of some of the surface drainage components. SOURCE: Reprinted, with permission, from Meierdierks et al. (2004). Copyright 2004 by the American Geophysical Union.

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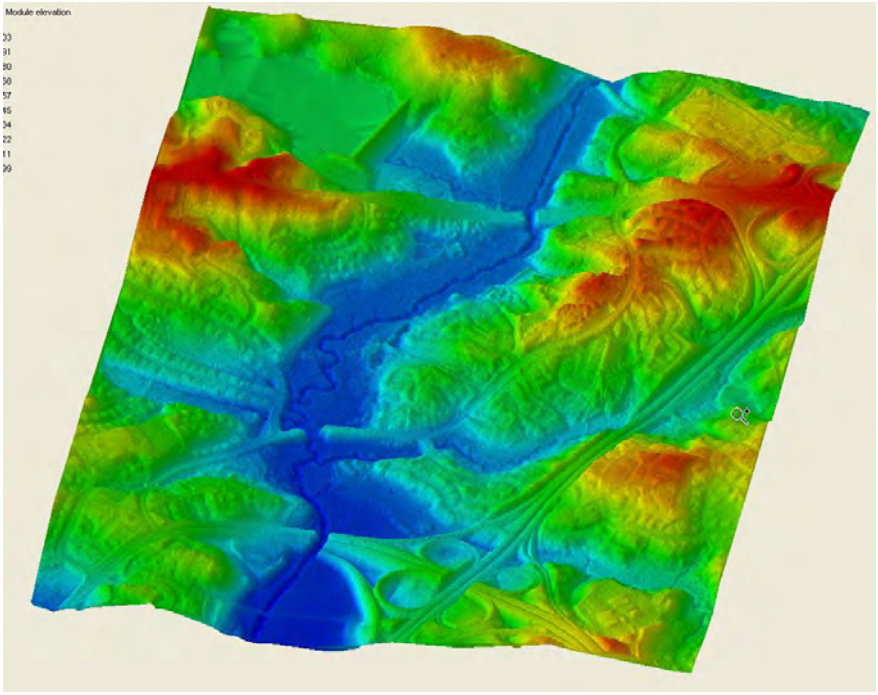

FIGURE 3-20 Shaded-relief lidar image of a portion of the Middle Patuxent River valley in Howard County, Maryland, showing the pervasive interruption of the drainage network by bridges and culverts, even in places where there is an attempt to keep excessive development out of the riparian corridor. SOURCE: Reprinted, with permission, from Miller, University of Maryland, Baltimore County. Copyright 2006 by Andrew J. Miller.

across the floodplain and spreads out over land surfaces and then flows back into channels as floodwaters subside. Although reducing the severity of downstream flooding, this phenomenon also interrupts the transport of sediment, leading to local zones of both enhanced deposition and downstream scour.

Alteration of Travel Times

The combination of impervious surface and altered drainage density provides significantly more rapid hydraulic pathways for stormwater to enter the nearest receiving waterbody compared to a natural landscape. This is illustrated quantitatively by Figure 3-21, which shows that the lag time—the difference in time between the center of mass of precipitation and the center of mass of the storm response hydrograph—is reduced for an urbanized landscape compared to a natural one.

The increase in surface runoff volumes and reduction in lag times between

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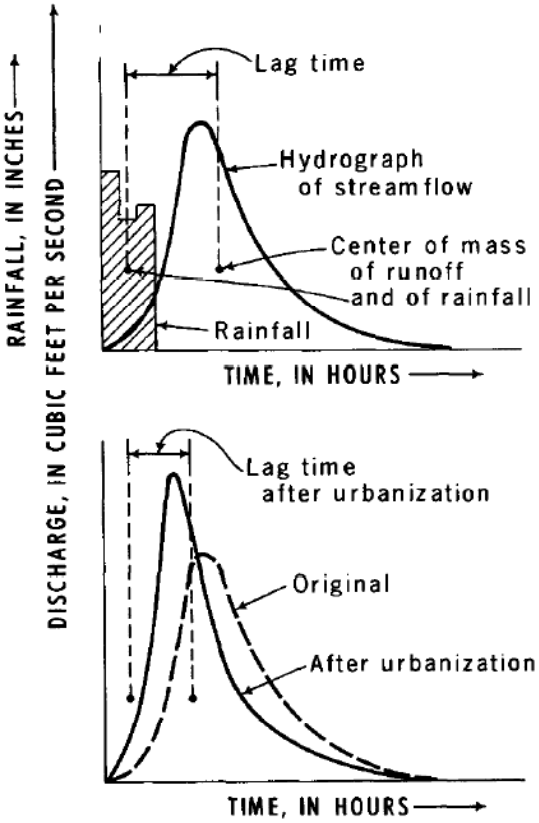

FIGURE 3-21 Illustration of the effect of urbanization on storm hydrograph lag time, the difference in time between the center of mass of rainfall and runoff response before and after urbanization. SOURCE: Leopold (1968).

precipitation and a waterbody's response give rise to greater velocities and volumetric discharges in receiving waters. Storm hydrographs in a developed setting peak earlier and higher than they do in undeveloped landscapes. This altered flow regime is of concern to property owners because upstream development can increase the probability of a flood-prone property being inundated. Properties in the floodplain and near stream channels are particularly susceptible to flooding from upstream development. Such increased flood risk is accompanied by associated potential property damages and costs of replacement or repair.

Various descriptors can be used to quantify the effects of urbanization on streamflow including flood frequency, flow duration, mean annual flood, discharge at bankfull stage, and frequency of bankfull stage. The "classic" view of

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urban-induced changes to runoff was presented by Leopold (1968), who provided several quantitative descriptors of the effects of urbanization on the mean annual flood. For example, Figure 3-22 shows the ratio of discharge before and after urbanization for the mean annual flood for a 1-square-mile area as a function of percentage of impervious area and percentage area served by a storm-drain system. This shows that for unsewered areas, increases from 0 to 100 percent impervious area will increase the peak discharge by a factor of 2.5. However, for 100 percent sewered areas, the ratio of peak discharges ranges from 1.7 to 8 for 0 to 100 percent impervious area. Clearly both impervious surfaces and the presence of a storm-drain system combine to increase discharge rates in receiving waters. Combining this information with regional flood frequency data, a discharge–frequency relationship can be developed that shows the expected discharge and recurrence interval for varying degrees of storm-drain coverage and impervious area coverage. An example is shown in Figure 3-23, using data from the Brandywine Creek watershed in Pennsylvania (Leopold, 1968). Bankfull flow for undeveloped conditions in general has a recurrence interval of about 1.5 years (which, in the particular case of the Brandywine, was 67 cubic feet per second); with 40 percent of the watershed area paved, this discharge would occur about three times as often.

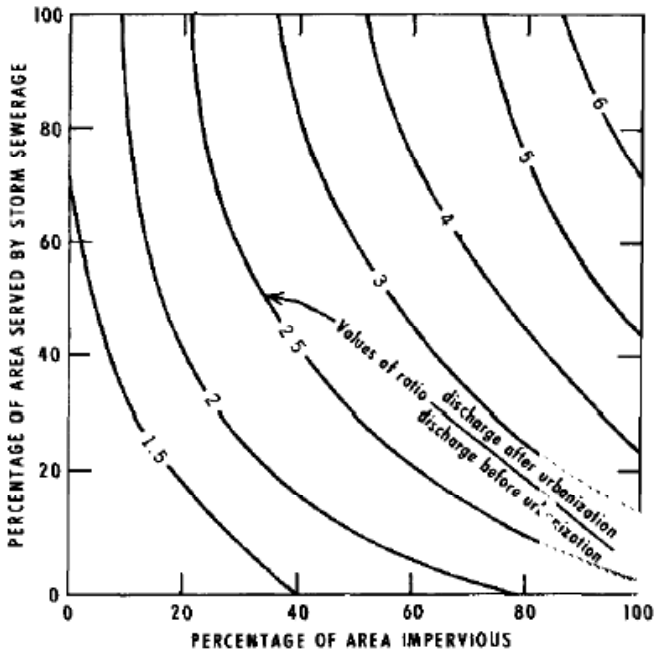

FIGURE 3-22 Ratio of peak discharge after urbanization to peak discharge before urbanization for the mean annual flood for a 1-square-mile drainage area, as a function of percent impervious surface and percent area drained by storm sewers. SOURCE: Leopold (1968).

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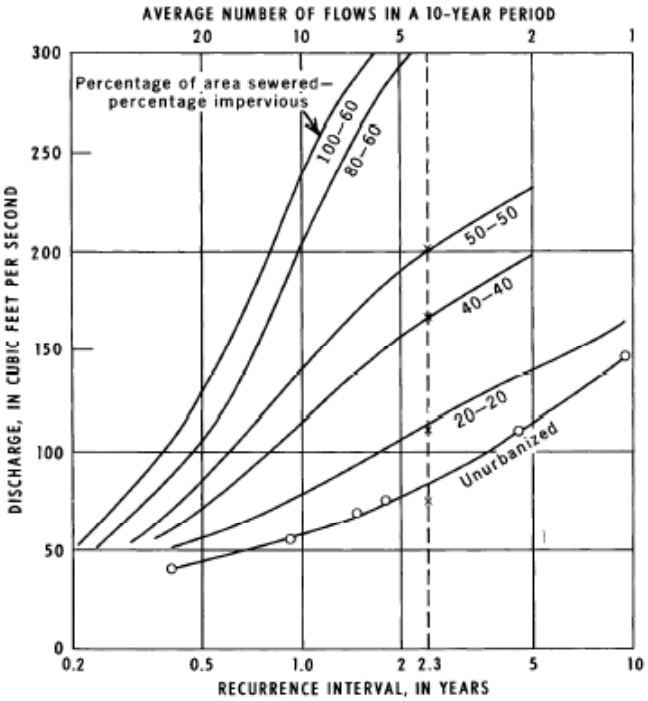

FIGURE 3-23 Flood frequency curves as a function of percent impervious area and percent of area serviced by storm sewers. The unurbanized data are from Brandywine Creek, Pennsylvania. SOURCE: Leopold (1968).

Over the past four decades since this first quantitative characterization of urban hydrology, a much greater variety of hydrologic changes resulting from urbanization has been recognized. Increases in peak discharge are certainly among those changes, and they will always gather attention because of their direct impact on human infrastructure and potential for more frequent and more severe flooding. The extended duration of flood flows, however, also affects natural channels because of the potential increase in erosion. Ecological effects of urban-altered flow regimes are even more diverse, because changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and even the season of the year in which high flows can occur all have significant ecological effects and can be dramatically altered by watershed urbanization (e.g., Rose and Peters, 2001; Konrad et al., 2005; Roy et al., 2005; Poff et al., 2006).

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The overarching conclusion of many studies is that the impact of urbanization on the hydrologic cycle is dramatic. Increased impervious area and drainage connectedness decreases stormwater travel times, increases flow rates and volumes, and increases the erosive potential of streams. The flooding caused by increased flows can be life-threatening and damaging to property. As described below, changes to the hydrologic flow regime also can have deleterious effects on the geomorphic form of stream channels and the stability of aquatic ecosystems. Although these impacts are commonly ignored in efforts to improve "water quality," they are inextricably linked to measured changes in water chemistry and must be part of any attempt to recover beneficial uses that have been lost to upstream urbanization.

Geomorphology

Watershed geomorphology is determined by the arrangement, interactions, and characteristics of component landforms, which include the stream-channel network, the interlocking network of ridges and drainage divides, and the set of hillslopes between the channel (or floodplain) and ridge. The stream and ridge systems define complementary networks, with the ridge (or drainage divide) network separating the drainage areas contributing to each reach in the stream network. At the hillslope scale, the ridges provide upper boundaries of all surface flowpaths which converge into the complementary stream reaches. A rich literature describes the topology and geometry of stream and ridge networks (e.g., Horton, 1945; Strahler, 1957, 1964; Shreve, 1966, 1967, 1969; Smart, 1968; Abrahams, 1984; Rodriguez-Iturbe et al., 1992).

Besides stream channels, a variety of other water features and landforms make up a watershed. Fresh waterbodies (ponds, lakes, and reservoirs) are typically embedded within the stream network, while wetlands may be either embedded within the stream network or separated and upslope from the channels. Estuaries represent the interface of the stream network with the open ocean. Additional fluvial and colluvial landforms include alluvial fans, landslide features, and a set of smaller features within or near the channels and floodplains including bar deposits, levees, and terraces. Each of these landforms are developed and maintained by the fluvial and gravitational transport and deposition of sediment, and are therefore potentially sensitive to disruption or alteration of flowpaths, hydrologic flow regimes, and sediment supply.

Stream Network Form and Ordering Methods

Most watersheds are fully convergent, with tributary streams combining to form progressively larger channels downstream. The manner is which streams from different source areas join to produce mainstreams strongly influences the propagation of stormwater discharge and pollutant concentrations, and the con-

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sequent level of ecological impairment in the aquatic ecosystem.

Methods for indexing the topologic position of individual reaches within the drainage network have been introduced by Horton (1945), Strahler (1957), Shreve (1966, 1967) and others. All stream topologic systems are dependent on the identification of first-order streams—the most upstream element of the network—and their lengths and drainage areas. Unfortunately, no universal standards exist to define where the stream head is located, or whether perennial, intermittent, and ephemeral channels should be considered in this determination. While this may seem like a trivial process, the identification and delineation of these sources effectively determines what lengths and sections of channels are defined to be *waterbodies* and, thus, the classification of all downstream waterbodies.

Nadeau and Rains (2007) have recently reviewed stream-channel delineation in the United States using standardized maps and hydrographic datasets to better relate climate to the extent of perennial, intermittent, and ephemeral channel types. Because this may influence the set of stream channels that are regulated by the Clean Water Act (CWA), it is the subject of current legal arguments in courts up to and including the Supreme Court (e.g., *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 [2001], *John A. Rapanos et al. vs. United States* [U.S., No. 04-1034, 2005]). In addition to the stream-channel network, additional features (discussed below) that are embedded in or isolated from the delineated stream network (lakes, ponds, and wetlands) are subject to regulation under the CWA based on their proximity or interaction with the defined stream and river network. Therefore, definition of the extent and degree of connectivity of the nation's stream network, with an emphasis on the headwater region, is a critical determinant of the set of waterbodies that are regulated for stormwater permitting (Nadeau and Rains, 2007).

Stream Reach Geomorphology

Within the channel network, stream reaches typically follow a regular pattern of changes in downstream channel form. Hydraulic geometry equations, first introduced by Leopold and Maddock (1953), describe the gross geomorphic adjustment of the channel (in terms of average channel depth and width) to the flow regime and sometimes the sediment supply. Within this general pattern of larger flows producing larger channels, variations in channel form are evident, particularly the continuum among straight, meandering, or braided patterns. These forms are dependent on the spatial and temporal patterns of discharge, sediment supply, transport capacity, and roughness elements.

Most natural channels have high width-to-depth ratios and complexity of channel form compared with engineered channels. Meanders are ubiquitous self-forming features in channels, created as accelerated flow around the outside of the meander entrains and transports more sediment, producing greater flow depths and eroding the bank, while decelerated flow on the inside of the mean-

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der results in deposition and the formation of lower water depth and bank gradients. These channels typically show small-scale alternation between larger cross sections with lower velocities and defining pools, and smaller cross sections with higher velocity flow in riffles. Braided streams form repeated subdivision and reconvergence of the channel in multiple threads, with reduced specific discharge compared to a single channel. Natural obstructions including woody debris, boulders, and other large (relative to channel dimensions) features all contribute to hydraulic and habitat heterogeneity. The complexity of these channel patterns contributes to hydraulic roughness, further dissipating stream energy by increasing the effective wetted perimeter of the channel through a valley and deflecting flow between banks.

Embedded Standing Waterbodies

Standing waterbodies include natural, constructed, or modified ponds and lakes and are characterized by low or near-zero lateral velocity. They can be thought of as extensions of pools within the drainage network, although there is no clear threshold at which a pool can be defined as a pond or lake. When they are embedded within the channel network, they are characterized with much greater cross-sectional area (width x depth), lower surface water slopes (approaching flat), and lower velocities than a stream reach of similar length. Therefore, standing waterbodies function as depositional zones, have higher residence times, and provide significant storage of water, sediment, nutrients, and other pollutants within the stream network.

Riparian Zone

The riparian area is a transitional zone between the active channel and the uplands, and between surface water and groundwater. The area typically has shallower groundwater levels and higher soil moisture than the surrounding uplands, and it may support wetlands or other vegetation communities that require higher soil moisture. Riparian zones provide important ecosystem functions and services, such as reducing peak flood flows, transforming bioavailable nutrients into organic matter, and providing critical habitat.

In humid landscapes, a functioning riparian area commonly is an area where shallow groundwater forms discharge seeps, either directly to the surface and then to the stream channel or through subsurface flowpaths to the stream channel. The potential for high moisture and organic material content provides an environment conducive to anaerobic microbial activity, which can provide effective sinks for inorganic nitrogen by denitrification, reducing nitrate loading to the stream channel. However, the width of the effective riparian zone depends on local topographic gradients, hydrogeology, and the channel geomorphology (Lowrance et al., 1997). In steeply incised channels and valleys, or areas with

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deeper flowpaths, the riparian zone may be narrow and relatively well drained.

Under more arid conditions with lower groundwater levels, riparian areas may be the only areas within the watershed with sufficient moisture levels to support significant vegetation canopy cover, even though saturation conditions may occur only infrequently. Subsurface flowpaths may be oriented most commonly from the channel to the bed and banks, forming the major source of recharge to this zone from periodic flooding. In monsoonal climates in the U.S. southwest, runoff generated in mountainous areas or from storm activity may recharge riparian aquifers well downstream from the storm or snowmelt activity. Channelization that reduces this channel-to-riparian recharge may significantly impair riparian and floodplain ecosystems that provide critical habitat and other ecosystem services (NRC, 2002).

Floodplains

The presence and distribution of alluvial depositional zones, including floodplains, is dependent on the distribution and balance of upstream sediment sources and sediment transport capacity, the temporal and spatial variability of discharge, and any geological structural controls on valley gradient. Lateral migration of streams contributes to the development of floodplains as the outer bank of the migrating channel erodes sediment and deposition occurs on the opposite bank. This leads to channels that are closely coupled to their floodplains, with frequent overbank flow and deposition, backwater deposits, wetlands, abandoned channels, and other floodplain features. During major events, overbank flooding and deposition adds sediment, nutrients, and contaminants to the floodplain surface, and may significantly rework preexisting deposits and drainage patterns. Constructional landforms typical of urbanized watersheds, such as levees, tend to disconnect streams from their floodplains.

Changes in Geomorphology from Urbanization

Changes to channel morphology are among the most common and readily visible effects of urban development on natural stream systems (Booth and Henshaw, 2001). The actions of deforestation, channelization, and paving of the uplands can produce tremendous changes in the delivery of water and sediment into the channel network. In channel reaches that are alluvial, the responses are commonly rapid and often dramatic. Channels widen and deepen, and in some cases may incise many meters below the original level of their beds. Alternatively, channels may fill with sediment derived from farther upstream to produce a braided form where a single-thread channel previously existed.

The clearest single determinant of urban channel change is the alteration of the hydrologic response of an urban watershed, notably the increase in streamflow discharges. Increases in runoff mobilize sediment both on the land surface

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and within the stream channel. Because transport capacity increases nonlinearly with flow velocity (Vogel et al., 2003), much greater transport will occur in higher flow events. However, the low frequency of these events may result in decreasing cumulative sediment transport during the highest flows, as described by standard magnitude and frequency analysis (Wolman and Miller, 1960), such that the maximum time-integrated sediment transport occurs at moderate flows (e.g., bankfull stage in streams in the eastern United States).

If the increase in sediment transport caused by the shift in the runoff regime is not matched by the sediment supply, channel bed entrenchment and bank erosion and collapse lead to a deeper, wider channel form. Increases in channel dimensions caused by increased discharges have been observed in numerous studies, including Hammer (1972), Hollis and Luckett (1976), Morisawa and LaFlure (1982), Neller (1988), Whitlow and Gregory (1989), Moscrip and Montgomery (1997), and Booth and Jackson (1997). MacRae (1997), reporting on other studies, found that channel cross-sectional areas began to enlarge after about 20 to 25 percent of the watershed was developed, commonly corresponding to about 5 percent impervious cover. When the watersheds were completely developed, the channel enlargements were about 5 to 7 times the original cross-sectional areas. Channel widening can occur for several decades before a new equilibrium is established between the new cross-section and the new discharges.

Construction results in a large—but normally temporary—increase in sediment load to aquatic systems (e.g., Wolman and Schick, 1967). Indeed, erosion and sediment transport rates can reach up to more than 200 Mg/ha/yr on construction sites, which is well in excess of typical rates from agricultural land (e.g., Wolman and Schick, 1967; Dunne and Leopold, 1978); rates from undisturbed and well-vegetated catchments are negligible (e.g., <<1 Mg/ha/yr). The increased sediment loads from construction exert an opposing tendency to channel erosion and probably explain much of the channel narrowing or shallowing that is sometimes reported (e.g., Leopold, 1973; Nanson and Young, 1981; Ebisemiju, 1989; Odemerho, 1992).

Additional sediment is commonly introduced into the channel network by the erosion of the streambank and bed itself. Indeed, this source can become the largest single fraction of the sediment load in an urbanizing watershed (Trimble, 1997). For example, Nelson and Booth (2002) reported on sediment sources in the Issaquah Creek watershed, an urbanizing, mixed-use watershed in the Pacific Northwest. Human activity in the watershed, particularly urban development, has caused an increase of nearly 50 percent in the annual sediment yield, now estimated to be 44 tons/km^2/yr^1. The main sources of sediment in the watershed are landslides (50 percent), channel-bank erosion (20 percent), and stormwater discharges (15 percent).

The higher flow volumes and peak discharge caused by urbanization also tend to preferentially remove fine-grained sediment, leaving a lag of coarser bed material (armoring) or removing alluvial material entirely and eroding into the geologic substrate (Figure 3-24). The geomorphic outcome of these changes is a

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FIGURE 3-24 Example of an urban stream that has eroded entirely through its alluvium to expose the underlying consolidated geologic stratum below (Thornton Creek, Seattle, Washington). SOURCE: Derek Booth, Stillwater Sciences, Inc.

mix of erosional enlargement of some stream reaches, significant sedimentation in others, and potential head-ward downcutting of tributaries as discharge levels from small catchments increase. The collective effects of these processes have been described by Walsh et al. (2005) as "Urban Stream Syndrome," which includes not only the visible alteration of the physical form of the channel but also the consequent deterioration of stream biogeochemical function and aquatic trophic structures.

Other changes also accompany these geomorphic changes. Episodic inundation of the floodplain during floods may be reduced in magnitude and frequency, depending on the increases in peak flow relative to the deepening and resultant increase in flow capacity of the channel. Where deeply entrenched, this channel morphology will lower the groundwater level adjacent to the channel. The effectiveness of riparian areas in filtering or removing solutes is thus reduced because subsurface water may reach the channel only by flowpaths now well below the organic-rich upper soil horizons. Removal of fine-grained stream-bottom sediment, or erosion down to bedrock, may substantially lower the exchange of stream water with the surrounding groundwater of the hyporheic zone.

In addition to these indirect effects on the physical form of the stream channel, urbanization also commonly modifies streams directly to improve drainage, applying channel straightening and lining to reduce friction, increase flow capacity, and stabilize channel position (Figure 3-25). The enlarged and often

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FIGURE 3-25 Example of a channelized urban stream for maximized flood conveyance and geomorphic stability (Los Angeles River, California). SOURCE: Robert Pitt, University of Alabama.

lined and straightened stream-channel cross section reduces the complexity of the bed and the contact between the stream and floodplain, and increases transport efficiency of sediment and solutes to receiving waterbodies. Enhanced sedimentation of receiving waterbodies, in turn, reduces water clarity, decreases depth, and buries the benthic environment.

POLLUTANT LOADING IN STORMWATER

Hydrologic flowpaths influence the production of particulate and dissolved substances on the land surface during storms, as well as their delivery to the stream-channel network. Natural watersheds typically develop a sequence of ecosystem types along hydrologic flowpaths that utilize available limiting resources, thereby reducing their export farther downslope or downstream, such that in-stream concentrations of these nutrients are low. As a watershed shifts from having mostly natural pervious surfaces to having heavily disturbed soils, new impervious surfaces, and activities characteristic of urbanization, the runoff quality shifts from relatively lower to higher concentrations of pollutants. Anthropogenic activities that can increase runoff pollutant concentrations in urban watersheds include application of chemicals for fertilization and pest control; leaching and corrosion of pollutants from exposed materials; exhaust emissions,

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leaks from, and wear of vehicles; atmospheric deposition of pollutants; and inappropriate discharges of wastes.

Most lands in the United States that have been developed were originally grasslands, prairies, or forest. About 40 percent of today's developed land went through an agricultural phase (cropland or pastureland) before becoming urbanized, while more than half of today's developed land area has been a direct conversion of natural covers (USDA, 2000). Agricultural land can produce stormwater runoff with high pollutant concentrations via soil erosion, the introduction of chemicals (fertilizers, pesticides, and herbicides), animal operations that are major sources of bacteria in runoff, and forestry operations. Indeed, urban stormwater may actually have slightly lower pollutant concentrations than other nonpoint sources of pollution, especially for sediment and nutrients. The key difference is that urban watersheds produce a much larger annual volume of runoff waters, such that the mass of pollutants discharged is often greater following urbanization. Some of the complex land-use–pollutant loading relationships are evident in Box 3-7, which shows the measured annual mass loads of nitrogen and phosphorus in four small watersheds of different land use monitored as part of the Baltimore Long-Term Ecological Research program. Depending on the nutrient and the year, the agricultural and urban watersheds had a higher nutrient export rate than the forested subwatershed.

Table 3-3 summarizes the comparative importance of urban land-use types in generating pollutants of concerns that can impact receiving waters (Burton and Pitt, 2002). This summary is highly qualitative and may vary depending on the site-specific conditions, regional climate, activities being conducted in each land use, and development characteristics. It should be noted that the rankings in Table 3-3 are relative to one another and classified on a per-unit-area basis. Furthermore, this table shows the parameters for each land-use category, such that the effects for a community at large would be dependent on the areas of each land use shown. Thus, although residential land use is shown to be a relatively smaller source of many pollutants, it is the largest fraction of land use in most communities, typically making it the largest stormwater source on a mass pollutant discharge basis. Similarly, freeway, industrial, and commercial areas can be very significant sources of many stormwater problems, and their discharge significance is usually much greater than their land area indicates. Construction sites are usually the overwhelming source of sediment in urban areas, even though they make up very small areas of most communities. A later table (Table 3-4) presents observed stormwater discharge concentrations for selected constituents for different land uses.

The following section describes stormwater characteristics associated with urbanized conditions. At any given time, parts of an urban area will be under construction, which is the source of large sediment losses, flow path disruptions, increased runoff quantities, and some chemical contamination. Depending on the time frame of development, increased stormwater pollutant discharges associated with construction activities may last for several years until land covers are stabilized. After construction has been completed, the characteristics of urban

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BOX 3-7
Comparison of Nitrogen and Phosphorus Export from Watersheds with Different Land Uses

Land use is a significant influence on nutrient export as controlled by impervious area, sanitary infrastructure, fertilizer application, and other determinants of input, retention, and stormwater transport. Tables 3-2A and 3-2B compare dissolved nitrate, total nitrogen, phosphate, and total phosphorus loads exported from forest catchments with catchments in different developed land uses studied by the Baltimore Ecosystem Study (Groffman et al., 2004). Loads were computed with the Fluxmaster system (Schwarz et al., 2006) from weekly samples taken at outlet gauges. In these sites in Baltimore County, the forested catchment, Pond Branch, has nitrogen loads one to two orders of magnitude lower than the developed catchments. Baisman Run, with one-third of the catchment in low-density, septic-served suburban land use, has nitrogen export exceeding Dead Run, an older, dense urban catchment. In this case, nutrient load does not follow the direct variation of impervious area because of the switch to septic systems and greater fertilizer use in lower density areas. However, Figure 3-26 shows that as impervious area increases, a much greater proportion of the total nitrogen load is discharged in less frequent, higher runoff events (Shields et al., 2008), reducing the potential to decrease loads by on-site SCMs. Total phosphorus loads were similarly as low (0.05–0.6 kg P/ha/yr) as nitrogen in the Pond Branch catchment (forest) over the 2000–2004 time period, and one to two orders of magnitude lower compared to agricultural and residential catchments.

It should be noted that specific areal loading rates, even in undeveloped catchments, can vary significantly depending on rates of atmospheric deposition, disturbance, and climate conditions. The hydrologic connectivity of nonpoint pollutant source areas to receiving waterbodies is also a critical control on loading in developed catchments (Nadeau and Rains, 2007) and is dependent on both properties of the pollutant as well as the catchment hydrology. For example, total nitrogen was high in both the agricultural and low-density suburban sites. Total phosphorus, on the other hand, was high in the Baltimore Ecosystem Study agricultural catchment, but close to the concentration of the forest site in the low-density suburban site serviced by septic systems. This is because septic systems tend to retain phosphorus, while septic wastewater nitrogen is typically nitrified in the unsaturated zone below a spreading field and efficiently transported in the groundwater to nearby streams.

TABLE 3-2A Dissolved Nitrate and Total Nitrogen Export Rates from Forest and Developed Land-Use Catchments in the Baltimore Ecosystem Study

Catchment	Land Use	Nitrate (kg N/ha/yr)			Total N (kg N/ha/yr)		
		2000	2001	2002	2000	2001	2002
Pond Branch	Forest	0.11	0.08	0.04	0.47	0.37	0.17
McDonogh	Agriculture	17.6	12.9	4.3	20.5	14.5	4.5
Baisman Run	Mixed Forest and Suburban	7.2	3.8	1.5	8.2	4.2	1.7
Dead Run	Urban	3.0	2.9	2.9	5.6	5.3	4.2

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TABLE 3-2B Dissolved Phosphate and Total Phosphorus Export Rates from Forest and Developed Land-Use Catchments in the Baltimore Ecosystem Study

Catchment	Land Use	Phosphate (kg P/ha/yr)			Total P (kg P/ha/yr)		
		2000	2001	2002	2000	2001	2002
Pond Branch	Forest	0.009	0.007	0.003	0.02	0.014	0.006
McDonogh	Agriculture	0.12	0.080	0.022	0.22	0.14	0.043
Baisman Run	Mixed Forest and Suburban	0.009	0.005	0.002	0.02	0.011	0.004
Dead Run	Urban	0.039	0.037	0.03	0.10	0.10	0.08

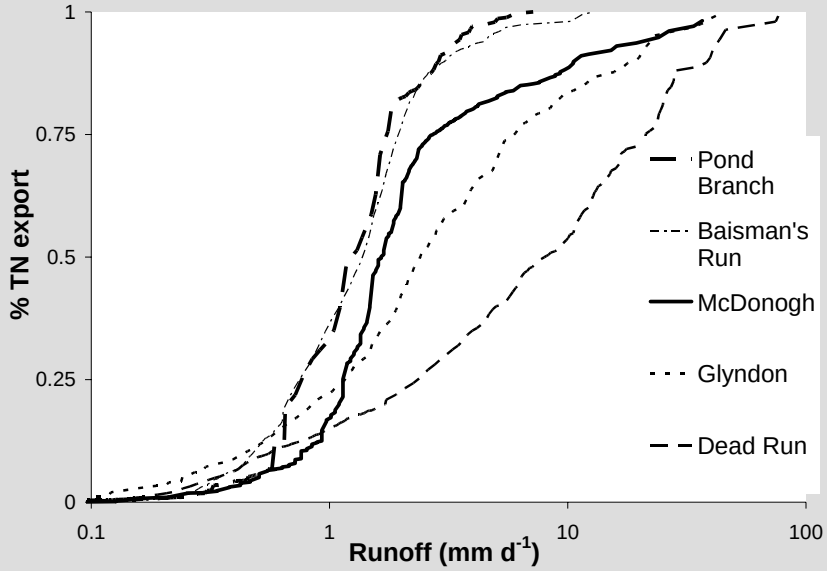

FIGURE 3-26 Cumulative transport of total nitrogen at increasing flow levels from catchments in Baltimore City and County including dominantly forest (Pond Branch), low-density development on septic systems and forest (Baisman Run), agricultural (McDonogh), medium-density suburban development on separate sewers (Glyndon), and higher-density residential, commercial, and highway land cover (Dead Run). SOURCE: Reprinted, with permission, from Shields et al. (2008). Copyright 2008 by the American Geophysical Union.

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TABLE 3-3 Relative Sources of Parameters of Concern for Different Land Uses in Urban Areas

Problem Parameter	Residential	Commercial	Industrial	Freeway	Construction
High flow rates (energy)	Low	High	Moderate	High	Moderate
Large runoff volumes	Low	High	Moderate	High	Moderate
Debris (floatables and gross solids)	High	High	Low	Moderate	High
Sediment	Low	Moderate	Low	Low	Very high
Inappropriate discharges (mostly sewage and cleaning wastes)	Moderate	High	Moderate	Low	Low
Microorganisms	High	Moderate	Moderate	Low	Low
Toxicants (heavy metals/organics)	Low	Moderate	High	High	Moderate
Nutrients (eutrophication)	Moderate	Moderate	Low	Low	Moderate
Organic debris (SOD and DO)	High	Low	Low	Low	Moderate
Heat (elevated water temperature)	Moderate	High	Moderate	High	Low

NOTE: SOD, sediment oxygen demand; DO, dissolved oxygen.
SOURCE: Summarized from Burton and Pitt (2002), Pitt et al. (2008), and CWP and Pitt (2008).

runoff are controlled largely by the increase in volume and the washoff of pollutants from impervious surfaces. Stormwater in this phase is associated with increases in discharges of most pollutants, but with less sediment washoff than from construction and likely less sediment and nutrient discharges compared to any pre-urbanization agricultural operations (although increased channel erosion may increase the mass of sediment delivered in this phase; Pitt et al., 2007). A third significant urban land use is industrial activity. As described later, industrial site stormwater discharges are highly variable, but often greater than other land uses.

Construction Site Erosion Characteristics

Problems associated with construction site runoff have been known for many years. More than 25 years ago, Willett (1980) estimated that approximately 5 billion tons of sediment reached U.S. surface waters annually, of which 30 percent was generated by natural processes and 70 percent by human activities. Half of this 70 percent was attributed to eroding croplands. Although construction occurred on only about 0.007 percent of U.S. land in the 1970s, it ac-

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counted for approximately 10 percent of the sediment load to all U.S. surface waters and equaled the combined sediment contributions of forestry, mining, industrial, and commercial land uses (Willett, 1980).

Construction accounts for a much greater proportion of the sediment load in urban areas than it does in the nation as a whole. This is because construction sites have extremely high erosion rates and because urban construction sites are efficiently drained by stormwater drainage systems installed early during the construction activities. Construction site erosion losses vary greatly throughout the nation, depending on local rain, soil, topographic, and management conditions. As an example, the Birmingham, Alabama, area may have some of the highest erosion rates in the United States because of its combination of very high-energy rains, moderately to severely erosive soils, and steep slopes (Pitt et al., 2007). The typically high erosion rates mean that even a small construction project may have a significant detrimental effect on local waterbodies.

Extensive evaluations of urban construction site runoff problems have been conducted in Wisconsin for many years. Data from the highly urbanized Menomonee River watershed in southeastern Wisconsin indicate that construction sites have much greater potentials for generating sediment and phosphorus than do other land uses (Chesters et al., 1979). For example, construction sites can generate approximately 8 times more sediment and 18 times more phosphorus than industrial sites (the land use that contributes the second highest amount of these pollutants) and 25 times more sediment and phosphorus than row crops. In fact, construction sites contributed more sediment and phosphorus to the Menomonee River than any other land use, although in 1979, construction comprised only 3.3 percent of the watershed's total land area. During this early study, construction sites were found to contribute about 50 percent of the suspended sediment and total phosphorus loading at the river mouth (Novotny and Chesters, 1981).

Similar conclusions were reported by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in a 1978 modeling study of the relative pollutant contributions of 17 categories of point and nonpoint pollution sources to 14 watersheds in the southeast Wisconsin regional planning area (SEWRPC, 1978). This study revealed construction as the first or second largest contributor of sediment and phosphorus in 12 of the 14 watersheds. Although construction occupied only 2 percent of the region's total land area in 1978, it contributed approximately 36 percent of the sediment and 28 percent of the total phosphorus load to inland waters, making construction the region's second largest source of these two pollutants. The largest source of sediment was estimated to be cropland; livestock operations were estimated to be the largest source of phosphorus. By comparison, cropland comprised 72 percent of the region's land area and contributed about 45 percent of the sediment and only 11 percent of the phosphorus to regional watersheds. When looking at the Milwaukee River watershed as a whole, construction is a major sediment contributor, even though the amount of land under active construction is very low. Construction areas were estimated to contribute about 53 percent of the total sediment discharged by the

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Milwaukee River in 1985 (total sediment load of 12,500 lb/yr), while croplands contributed 25 percent, streambank erosion contributed 13 percent, and urban runoff contributed 8 percent.

Line and White (2007) recently investigated runoff characteristics from two similar drainage areas in the Piedmont region of North Carolina. One of the drainage areas was being developed as part of a large residential subdivision during the course of the study, while the other remained forested or in agricultural fields. Runoff volume was 68 percent greater for the developing compared with the undeveloped area, and baseflow as a percentage of overall discharge was approximately zero compared with 25 percent for the undeveloped area. Overall annual export of sediment was 95 percent greater for the developing area, while export of nitrogen and phosphorus forms was 66 to 88 percent greater for the developing area.

The biological stream impact of construction site runoff can be severe. For example, Hunt and Grow (2001) describe a field study conducted to determine the impact to a stream from a poorly controlled construction site, with impact being measured via fish electroshocking and using the Qualitative Habitat Evaluation Index. The 33-acre construction site consisted of severely eroded silt and clay loam subsoil and was located within the Turkey Creek drainage, Scioto County, Ohio. The number of fish species declined (from 26 to 19) and the number of fish found decreased (from 525 to 230) when comparing upstream unimpacted reaches to areas below the heavily eroding site. The Index of Biotic Integrity and the Modified Index of Well-Being, common fisheries indexes for stream quality, were reduced from 46 to 32 and 8.3 to 6.3, respectively. Upstream of the area of impact, Turkey Creek had the highest water quality designation available, but fell to the lowest water quality designation in the area of the construction activity. Water quality sampling conducted at upstream and downstream sites verified that the decline in fish diversity was not due to chemical affects alone.

Municipal Stormwater Characteristics

The suite of stormwater pollutants generated by municipal areas is expected to be much more diverse than construction sites because of the greater variety of land uses and pollutant source areas found within a typical city. Many studies have investigated stormwater quality, with the U.S. Environmental Protection Agency's (EPA's) NURP (EPA, 1983) being the best known and earliest effort to collect and summarize these data. Unfortunately, NURP was limited in that it did not represent all areas of the United States or all important land uses. More recently, the National Stormwater Quality Database (NSQD) (CWP and Pitt, 2008; Pitt et al., 2008 for version 3) has been compiling data from the EPA's NPDES stormwater permit program for larger Phase I municipal separate storm sewer system (MS4) communities. As a condition of their Phase I permits, municipalities were required to establish a monitoring program to characterize their local stormwater quality for their most important land uses discharging to the

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MS4. Although only a few samples from a few locations were required to be monitored each year in each community, the many years of sampling and large number of communities has produced a database containing runoff quality information for nearly 8,000 individual storm events over a wide range of urban land uses. The NSQD makes it possible to statistically compare runoff from different land uses for different areas of the country.

A number of land uses are represented in MS4 permits and also the database, including industrial stormwater discharges to an MS4. However, there is no separate compilation of quantitative mass emissions from specific industrial stormwater sources that may have been collected under industrial permit monitoring efforts. The observations in the NSQD were all obtained at outfall locations and do not include snowmelt or construction erosion sources. The most recent version of the NSQD contains stormwater data from about one-fourth of the total number of communities that participated in the Phase I NPDES stormwater permit monitoring activities. The database is located at *http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml*.

Table 3-4 is a summary of *some* of the stormwater data included in NSQD version 3, while Figure 3-27 shows selected plots of these data. The table describes the total number of observations, the percentage of observations above the detection limits, the median, and coefficients of variation for a few of the major constituents for residential, commercial, industrial, institutional, freeway, and open-space land-use categories, although relatively few data are available for institutional and open-space areas. It should be noted that even if there are significant differences in the median concentrations by the land uses, the range of the concentrations within single land uses can still be quite large. Furthermore, plots like Figure 3-27 do not capture the large variability in data points observed at an individual site.

There are many factors that can be considered when examining the quality of stormwater, including land use, geographical region, and season. The following is a narrative summary of the entire database and may not reflect information in Table 3-4 and Figure 3-29, which show only subsets of the data. First, statistical analyses of variance on the NSQD found significant differences among land-use categories for all of the conventional constituents, except for dissolved oxygen. (Turbidity, total solids, total coliforms, and total *E. coli* did not have enough samples in each group to evaluate land-use differences.) Freeway sites were found to be significant sources of several pollutants. For example, the highest TSS, COD, and oil and grease concentrations (but not necessarily the highest *median* concentrations) were reported for freeways. The median ammonia concentration in freeway stormwater is almost three times the median concentration observed in residential and open-space land uses, while freeways have the lowest orthophosphate and nitrite–nitrate concentrations—half of the concentration levels that were observed in industrial land uses.

In almost all cases the median metal concentrations at the industrial areas were about three times the median concentrations observed in open-space and residential areas. The highest lead and zinc concentrations (but not necessarily

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TABLE 3-4 Summary of Selected Stormwater Quality Data Included in NSQD, Version 3.0

	TSS (mg/L)	COD (mg/L)	Fecal Coliform (mpn/100 mL)	Nitrogen, Total Kjeldahl (mg/L)	Phosphorus, Total (mg/L)	Cu, Total (µg/L)	Pb, Total (µg/L)	Zn, Total (µg/L)
All Areas Combined (8,139)								
Coefficient of variation (COV)	2.2	1.1	5.0	1.2	2.8	2.1	2.0	3.3
Median	62.0	53.0	4300	1.3	0.2	15.0	14.0	80.0
Number of samples	6780	5070	2154	6156	7425	5165	4694	6184
% samples above detection	99	99	91	97	97	88	78	98
All Residential Areas Combined (2,586)								
COV	2.0	1.0	5.7	1.2	1.6	1.9	2.1	3.3
Median	59.0	50.0	4200	1.2	0.3	12.0	6.0	70.0
Number of samples	2167	1473	505	2026	2286	1640	1279	1912
% samples above detection	99	99	89	98	98	88	77	97
All Commercial Areas Combined (916)								
COV	1.7	1.0	3.0	0.8	1.2	1.4	1.7	1.4
Median	55.0	63.0	3000	1.3	0.2	17.9	15.0	110.0
Number of samples	843	640	270	726	920	753	605	839
% samples above detection	97	98	89	98	95	85	79	99
All Industrial Areas Combined (719)								
COV	1.7	1.3	6.1	1.1	1.4	2.1	2.0	1.7
Median	73.0	59.0	2850	1.4	0.2	19.0	20.0	156.2
Number of samples	594	474	317	560	605	536	550	596
% samples above detection	98	98	94	97	95	86	76	99

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All Freeway Areas Combined (680)									
COV	2.6	1.0	2.7	1.2	5.2	2.2	1.1	1.4	
Median	53.0	64.0	2000	1.7	0.3	17.8	49.0	100.0	
Number of samples	360	439	67	430	585	340	355	587	
% samples above detection	100	100	100	99	99	99	99	99	
All Institutional Areas Combined (24)									
COV	1.1	1.0	0.4	0.6	0.9	0.6	1.0	0.9	
Median	18.0	37.5	3400	1.1	0.2	21.5	8.6	198.0	
Number of samples	23	22	3	22	23	21	21	22	
% samples above detection	96	91	100	91	96	57	86	100	
All Open -Space Areas Combined (79)									
COV	1.8	0.6	1.2	1.2	1.5	0.4	0.9	0.8	
Median	10.5	21.3	2300	0.4	0.0	9.0	48.0	57.0	
Number of samples	72	12	7	50	77	15	10	16	
% samples above detection	97	83	100	96	97	47	20	50	

NOTE: The complete database is located at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml. SOURCE: National Stormwater Quality Database.

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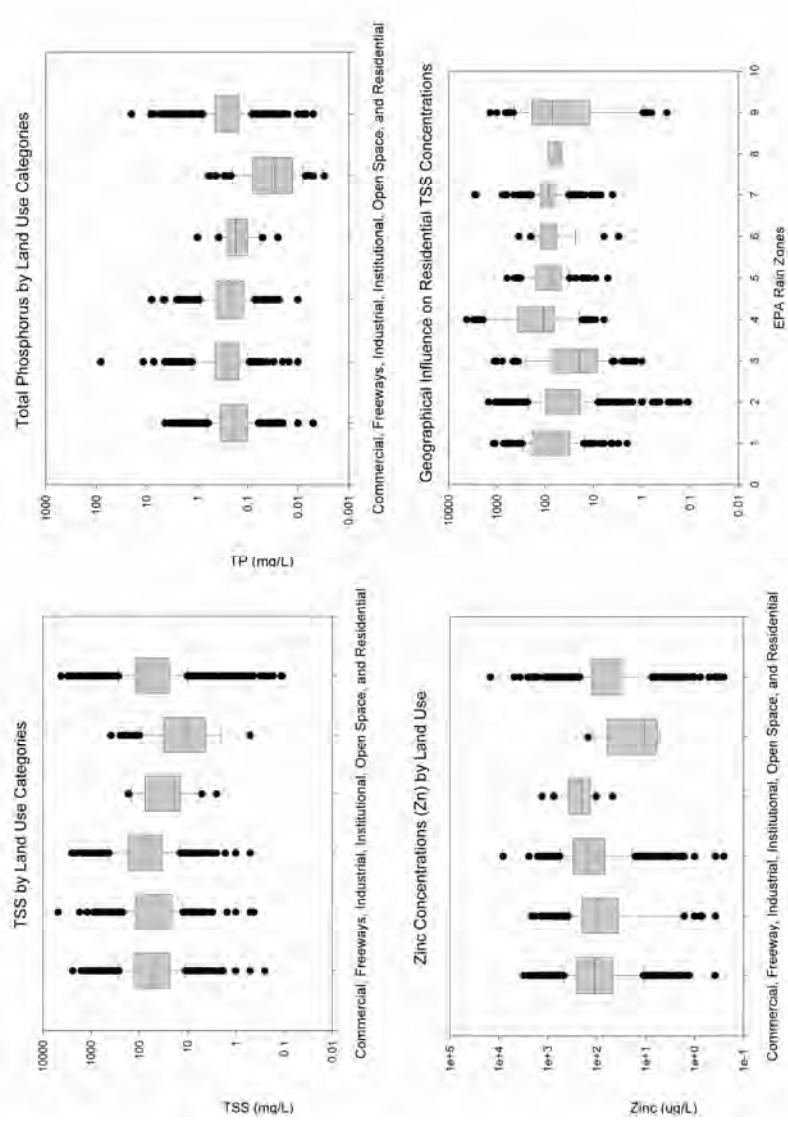

FIGURE 3-27 Grouped box and whisker plots of data from the NSQD. The median values are indicated with the horizontal line in the center of the box, while the ends of the box represent the 25th and 75th percentile values. The whickers extend to the 5th and 95th percentile values, and values outside of these extremes are indicated with separate dots. These groups were statistically analyzed and were found to have at least one group that is significantly different from the other groups. The ranges of the values in each group are large, but a very large number of data points is available for each group. The grouping of the data into these categories helps explain much of the total variability observed, and the large number of samples in each category allows suitable statistical tests to be made. Many detailed analyses are presented at the NSQD website (Maestre and Pitt, 2005).

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the highest *median* concentrations) were found in industrial land uses. Lower concentrations of TDS, five-day biological oxygen demand (BOD_5), and fecal coliforms were observed in industrial land-use areas. By contrast, the highest concentrations of dissolved and total phosphorus were associated with residential land uses. Fecal coliform concentrations are also relatively high for residential and mixed residential land uses. Open-space land-use areas show consistently low concentrations for the constituents examined. There was no significant difference noted for total nitrogen among any of the land uses monitored.

In terms of regional differences, significantly higher concentrations of TSS, BOD_5, COD, total phosphorus, total copper, and total zinc were observed in arid and semi-arid regions compared to more humid regions. In contrast, fecal coliforms and total dissolved solids were found to be higher in the upper Midwest. More detailed discussions of land use and regional differences in stormwater quality can be found in Maestre et al. (2004) and Maestre and Pitt (2005, 2006). In addition to the information presented above, numerous researchers have conducted source area monitoring to characterize sheet flows originating from urban surfaces (such as roofs, parking lots, streets, landscaped areas, storage areas, and loading docks). The reader is referred to Pitt et al. (2005a,b,c) for much of this information.

Industrial Stormwater Characteristics

The NSQD, described earlier, has shown that industrial-area stormwater has higher concentrations of most pollutants compared to other land uses, although the variability is high. MS4 monitoring activities are usually conducted at outfalls of drainage systems containing many individual industrial activities, so discharge characteristics for specific industrial types are rarely available. This discussion provides some additional information concerning industrial stormwater beyond that included in the previous discussion of municipal stormwater. In general, there is a profound lack of data on industrial stormwater compared to municipal stormwater, and a correspondingly greater uncertainty about industrial stormwater characteristics.

The first comprehensive monitoring of an industrial area that included stormwater, dry weather base flows, and snowmelt runoff was conducted in selected Humber River catchments in Ontario (Pitt and McLean, 1986). Table 3-5 shows the annual mass discharges from the monitored industrial area in North York, along with ratios of these annual discharges compared to discharges from a mixed commercial and residential area in Etobicoke. The mass discharges of heavy metals, total phosphorus, and COD from industrial stormwater are three to six times that of the mixed residential and commercial areas.

Hotspots of contamination on industrial sites are a specific concern. Stormwater runoff from "hotspots" may contain loadings of hydrocarbons, trace metals, nutrients, pathogens and/or other toxicants that are greater than the loadings of "normal" runoff. Examples of these hotspots include airport de-icing

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TABLE 3-5 Annual Storm Drainage Mass Discharges from Toronto-Area Industrial Land Use

Measured Parameter	Units	Annual Mass Discharges from Industrial Drainage Area	Stormwater Annual Discharge Ratio (Industrial Compared to Residential and Commercial Mixed Area)
Runoff volume	m^3/hr/yr	6,580	1.6
total solids	kg/ha/yr	6,190	2.8
total phosphorus	kg/ha/yr	4,320	4.5
TKN	g/ha/yr	16,500	1.2
COD	kg/ha/yr	662	3.3
Cu	g/ha/yr	416	4.0
Pb	g/ha/yr	595	4.2
Zn	g/ha/yr	1,700	5.8

SOURCE: Pitt and McLean (1986).

facilities, auto recyclers/junkyards, commercial garden nurseries, parking lots, vehicle fueling and maintenance stations, bus or truck (fleet) storage areas, industrial rooftops, marinas, outdoor transfer facilities, public works storage areas, and vehicle and equipment washing/steam cleaning facilities (Bannerman et al., 1993; Pitt et al., 1995; Claytor and Schueler, 1996).

The elevated concentrations and mass discharges found in stormwater at industrial sites are associated with both the activities that occur and the materials used in industrial areas, as discussed in the sections that follow.

Effects of Roofing Materials on Stormwater Quality

The extensive rooftops of industrial areas can be a significant pollutant source area. A summary of the literature on roof-top runoff quality, including both roof surfaces and underlying materials used as subbases (such as treated wood), is presented in Table 3-6. Good (1993) found that dissolved metals' concentrations and toxicity remained high in roof runoff samples, especially from rusty galvanized metal roofs during both first flush and several hours after a rain has started, indicating that metal leaching continued throughout the events and for many years. During pilot-scale tests of roof panels exposed to rains over a two-year period, Clark et al. (2008) found that copper roof runoff concentrations for newly treated wood panels exceeded 5 mg/L (a very high value compared to median NSQD stormwater concentrations of about 10 to 40 µg/L for different land uses) for the first nine months of exposure. These results indicated that copper continued to be released from these wood products at levels high enough to exceed aquatic life criteria for long periods after installation, and were not simply due to excess surface coating washing off in the first few storms after installation.

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TABLE 3-6 Roof Runoff Analysis—A Literature Summary

Roof Type	Location	Water Quality Parameter								Reference
		Cu (µg/L)	Zn (µg/L)	Pb (µg/L)	Cd (µg/L)	As (µg/L)	pH	NH_4^+ (mg/L)	NO_3^- (mg/L)	
Polyester Tile Flat gravel	Duebendorf, Switzerland	6817 1905 140	2076 360 36	510 172 22	3.1 2.1 0.2					Boller (1997)
Plywood w/ roof paper/tar Rusty galvanized metal Old metal w/Al paint Flat tar surface w/fibrous reflective Al paint New anodized Al	Washington	$166^T/128^D$ $20^T/2^D$ $11^T/7^D$ $25^T/14^D$ $16^T/7^D$	$877^T/909^D$ $12200^T/1190^D$ $1980^T/1610^D$ $297^T/257^D$ $101^T/82^D$	$11^T/<5^D$ $302^T/35^D$ $10^T/<5^D$ $10^T/5^D$ $15^T/<5^D$			4.3 5.9 4.8 4.1 5.9			Good (1993)
Zinc - galvanized Fe	Dunedin City, New Zealand	560 µg/g	5901 µg/g	670 µg/g						Brown & Peake (2006)
Fe-Zn sheets Concrete slate tiles Asbestos cement sheets Aluminum sheets	Ile-Ife, Nigeria						6.77 7.45 7.09 6.68	0.06 0.05 0.06 0.05	1.52 3.34 2.26 6.18	Ademiyi and Olabanji (2005)
Cu panels	Munich, Germany	200–11100					6.7–7.0			Athanasiadis et al. (2006)
Galvanized metals (primarily Galvalume®)	Seattle, WA	10–1400	420–14700	ND						Tobiason (2004)
CCA wood Untreated wood	Florida					1200–1800 2–3				Khan et al. (2006)

Note: D, dissolved; T, total; ND, not detected.
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Traditional unpainted or uncoated hot-dip galvanized steel roof surfaces can also produce very high zinc concentrations. For example, pilot-scale tests by Clark et al. (2008) indicated that zinc roof runoff concentrations were 5 to 30 mg/L throughout the first two years of monitoring of a traditional galvanized metal panel. These are very high values compared to median stormwater values reported in the NSQD of 60 to 300 µg/L for different land uses. Factory-painted aluminum–zinc alloy panels had runoff zinc levels less than 250 µg/L, which were closer to the reported NSQD median values. The authors concluded that traditional galvanized metal roofing contributed the greatest concentrations of many metals and nutrients. In addition, they found that pressure-treated and waterproofed wood contributed substantial copper loads. The potential for nutrient release exists in many of the materials tested (possibly as a result of phosphate washes and binders used in the material's preparation or due to natural degradation).

Other researchers have investigated the effects of industrial rooftop runoff on receiving waters and biota. Bailey et al. (1999) investigated the toxicity to juvenile rainbow trout of runoff from British Columbia sawmills and found that much of the toxicity may have been a result of divalent cations on the industrial site, especially zinc from galvanized roofs.

Effects of Pavement and Pavement Maintenance on Stormwater Quality

Pavement surfaces can also have a strong influence on stormwater runoff quality. For example, concrete is often mixed with industrial waste sludges as a way of disposing of the wastes. However, this can lead to stormwater discharges high in toxic compounds, either due to the additives themselves or due to the mobilization of compounds via the additives. Salaita and Tate (1998) showed that high levels of aluminum, iron, calcium, magnesium, silicon, and sodium were seen in the cement-waste samples. A variety of sands, including waste sands, have been suggested as potential additives to cement and for use as fill in roadway construction. Wiebusch et al. (1998) tested brick sands and found that the higher the concentration of alkaline and alkaline earth metals in the samples, the more easily the heavy metals were released. Pitt et al. (1995) also found that concrete yard runoff had the highest toxicity (using Microtox screening methods) observed from many source areas, likely due to the elevated pH (about 11) from the lime dust washing off from the site.

The components of asphalt have been investigated by Rogge et al. (1997), who found that the majority of the elutable organic mass that could be identified consisted of *n*-alkanes (73 percent), carboxylic acids such as *n*-alkanoic acids (17 percent), and benzoic acids. PAHs and thiaarenes were 7.9 percent of the identifiable mass. In addition, heterocyclic aromatic hydrocarbons containing sulfur (S-PAH), such as dibenzothiophene, were identified at concentration lev-

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els similar to that of phenanthrene. S-PAHs are potentially mutagenic (similar to other PAHs), but due to their slightly increased polarity, they are more soluble in water and more prone to aquatic bioaccumulation.

In addition to the bitumens and asphalts, other compounds are added to paving (and asphaltic roofing) materials. Chemical modifiers are used both to increase the temperature range at which asphalts can be used and to prevent stripping of the asphalt from the binder. A variety of fillers may also be used in asphalt pavement mixtures. The long-term environmental effects of these chemicals in asphalts are unknown. Reclaimed asphalt pavements have also been proposed for use as fill materials for roadways. Brantley and Townsend (1999) performed a series of leaching tests and analyzed the leachate for a variety of organics and heavy metals. Only lead from asphalt pavements reclaimed from older roadways was found to be elevated in the leachate.

Stormwater quality from asphalt-paved surfaces seems to vary with time. Fish kills have been reported when rains occur shortly after asphalt has been installed in parking areas near ponds or streams (Anonymous, 2000; Perez-Rivas, 2000; Kline, 2002). It is expected that these effects are associated with losses of the more volatile and toxic hydrocarbons that are present on new surfaces. It is likely that the concentrations of these materials in runoff decrease as the pavement ages. Toxicity tests conducted on pavements several years old have not indicated any significant detrimental effects, except for those associated with activities conducted on the surface (such as maintenance and storage of heavy equipment; Pitt et al., 1995, 1999). However, pavement maintenance used to "renew" the asphalt surfaces has been shown to cause significant problems, which are summarized below.

A significant source of PAHs in the Austin, Texas, area (and likely elsewhere) has been identified as coal-tar sealants commonly used to "restore" asphalt parking lots and storage areas. Mahler et al. (2005) found that small particles of sealcoat that flake off due to abrasion by vehicle tires have PAH concentrations about 65 times higher than for particles washed off parking lots that are not seal coated. Unsealed parking lots receive PAHs from the same urban sources as do sealed parking lots (e.g., tire particles, leaking motor oil, vehicle exhaust, and atmospheric fallout), and yet the average yield of PAHs from the sealed parking lots was found to be 50 times greater than that from the control lots. The authors concluded that sealed parking lots could be the dominant source of PAHs in watersheds that have seal-coated surfaces, such as many industrial, commercial, and residential areas. Consequently, the City of Austin has restricted the use of parking lot coal-tar sealants, as have several Wisconsin communities.

Stored Materials Exposed to Rain

Although roofing and pavement materials make up a large fraction of the total surface covers and can have significant effects on stormwater quality, leaching of rain through stored materials may also be a significant pollutant

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source at industrial sites. Exposed metals in scrap yards can result in very high concentrations of heavy metals. For example, Table 3-7 summarizes data from three metals recycling facilities/scrap yards in Wisconsin and shows the large fraction of metals that are either dissolved in the runoff or associated with very fine particulate matter. For most of these metals, their greatest abundance is associated with the small particles (<20 μm in diameter), and relatively little is associated with the filterable fraction. These metals concentrations (especially zinc, copper, and lead) are also very high compared to that of most outfall industrial stormwater.

OTHER SOURCES OF URBAN RUNOFF DISCHARGES

Wet weather stormwater discharges from separate storm sewer outfalls are not the only discharges entering receiving waters from these systems. Dry weather flows, snowmelt, and atmospheric deposition all contribute to the pollutant loading of urban areas to receiving waters, and for some compounds may be the largest contributor. Many structural SCMs, especially those that rely on sedimentation or filtration, have been designed to function primarily with stormwater and are not nearly as effective for dry weather discharges, snowmelt, or atmospheric deposition because these nontraditional sources vary considerably in key characteristics, such as the flow rate and volume to be treated, sediment concentrsations and particle size distribution, major competing ions, association of pollutants with particulates of different sizes, and temperature. Information on the treatability of stormwater vs. snowmelt and other nontraditional sources of urban runoff can be found in Pitt and McLean (1986), Pitt et al. (1995), Johnson et al. (2003), and Morquecho (2005).

TABLE 3-7 Metal Concentration Ranges Observed in Scrapyard Runoff

Particle Size	Iron (mg/L)	Aluminum (mg/L)	Zinc (mg/L)
Total	20 – 810	15 – 70	1.6 – 8
< 63 μm diameter	22 – 767	15 – 58	1.5 – 7.6
< 38 μm diameter	21 – 705	15 – 58	1.4 – 7.4
< 20 μm diameter	15 – 534	12 – 50	1.1 – 7.2
< 0.45 μm diameter (filterable fraction)	0.1 – 38	0.1 – 5	0.1 – 6.7
	Copper (mg/L)	**Lead (mg/L)**	**Chromium (mg/L)**
Total	1.1 – 3.8	0.6 – 1.7	0.1 – 1.9
< 63 μm diameter	1.1 – 3.6	0.1 – 1.6	0.1 – 1.6
< 38 μm diameter	1.1 – 3.3	0.1 – 1.6	0.1 – 1.4
< 20 μm diameter	1.0 – 2.8	0.1 – 1.6	0.1 – 1.2
< 0.45 μm diameter (filterable fraction)	0.1 – 0.3	0.1 – 0.3	0.1 – 0.3

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Dry Weather Flows

At many stormwater outfalls, discharges occur during dry weather. These may be associated with discharges from leaking sanitary sewer and drinking water distribution systems, industrial wastewaters, irrigation return flows, or natural spring water entering the system (Figures 3-28 to 3-33). Possibly 25 percent of all separate stormwater outfalls have water flowing in them during dry weather, and as much as 10 percent are grossly contaminated with raw sewage, industrial wastewaters, and so forth (Pitt et al., 1993). These flow contributions can be significant on an annual mass basis, even though the flow rates are relatively small, because they have long duration. This is particularly true in arid areas, where dry weather discharges can occur daily. For example, despite the fact that rain is scarce from May to September in Southern California, an estimated 40 to 90 million liters of discharge flow per day into Santa Monica Bay through approximately 70 stormwater outlets that empty onto or across beaches (LAC DPW, 1985; SMBRP, 1994), such that the contribution of dry weather flow to the total volume of runoff into the bay is about 30 percent (NRC, 1984). Furthermore, in the nearby Ballona Creek watershed, dry weather discharges of trace metals were found to comprise from 8 to 42 percent of the total annual loading (McPherson et al., 2002). Stein and Tiefenthaler (2003) further found that the highest loadings of metals and bacteria in this watershed discharging during dry weather can be attributed to a few specific stormwater drains.

In many cases, stormwater managers tend to overlook the contribution of dry weather discharges, although the EPA's NPDES Stormwater Permit program requires municipalities to conduct stormwater outfall surveys to identify, and then correct, inappropriate discharges into separate storm sewer systems. The role of inappropriate discharges in the NPDES Stormwater Permit program, the developed and tested program to identify and quantify their discharges, and an extensive review of these programs throughout the United States can be found in the recently updated report prepared for the EPA (CWP and Pitt, 2004).



FIGURE 3-28 Washing of vehicle engine and allowing runoff to enter storm drainage system. SOURCE: Robert Pitt, University of Alabama.

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FIGURE 3-29 Contamination of storm drainage with inappropriate disposal of oil. SOURCE: Courtesy of the Center for Watershed Protection.



FIGURE 3-30 Dry weather flows from Toronto industrial area outfall. SOURCE: Pitt and McLean (1986).

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FIGURE 3-31 Sewage from clogged system overflowing into storm drainage system. SOURCE: Robert Pitt, University of Alabama.



FIGURE 3-32 Failing sanitary sewer, causing upwelling of sewage through soil, and draining to gutter and then to storm drainage system. SOURCE: Robert Pitt, University of Alabama.

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FIGURE 3-33 Dye tests to confirm improper sanitary sewage connection to storm drainage system. SOURCE: Robert Pitt, University of Alabama.

Snowmelt

In northern areas, snowmelt runoff can be a significant contributor to the annual discharges from urban areas through the storm drainage system (see Figure 3-34). In locations having long and harsh winters, with little snowmelt until the spring, pollutants can accumulate and be trapped in the snowpack all winter until the major thaw when the contaminants are transported in short-duration events to the outfalls (Jokela, 1990). The sources of the contaminants accumulating in snowpack depend on the location, but they usually include emissions from nearby motor vehicles and heating equipment and industrial activity in the neighborhood. Dry deposition of sulfur dioxide from industrial and power plant smokestacks affects snow packs over a wider area and has frequently been studied because of its role in the acid deposition process (Cadle, 1991). Pollutants are also directly deposited on the snowpack. The sources of directly deposited pollutants include debris from deteriorated roadways, vehicles depositing petroleum products and metals, and roadway maintenance crews applying salt and anti-skid grit (Oberts, 1994). Urban snowmelt, like rain runoff, washes some material off streets, roofs, parking and industrial storage lots, and drainage gutters. However, snowmelt runoff usually has much less energy than striking rain and heavy flowing stormwater. Novotny et al. (1986) found that urban soil ero-

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sion is reduced or eliminated during winter snow-cover conditions. However, erosion of bare ground at construction sites in the spring due to snowmelt can still be very high (Figure 3-35).



FIGURE 3-34 Snowmelt photos. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.



FIGURE 3-35 Construction site in early spring after snowmelt showing extensive sediment transport. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.

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Sources of Contaminants in Snowmelt

Several mechanisms can bring about contamination of snow and snowmelt waters. Initially, air pollutants can be incorporated into snowflakes as they form and fall to the ground. After it falls to the ground and accumulates, the snow can become further contaminated by dry atmospheric deposition, deposition of nearby lost fugitive dust materials (usually blown onto snow packs near roads by passing vehicles), and wash off of particulates from the exposed ground surfaces as it melts and flows to the drainage system.

Snowflakes can remove particulates and gases from the air by in-cloud or below-cloud capture. In-cloud capture of pollutants can occur during snowflake formation as super-cooled cloud water condenses on particles and aerosols that act as cloud condensation nuclei. This is known as nucleation scavenging and is a major pathway for air pollution to be incorporated into snow. Particles and gases may also be scavenged as snowflakes fall to the ground. Gases can also be absorbed as snow falls. Snowflakes are more effective below-cloud scavengers than raindrops because they are bigger and fall slower. Barrie (1991) reports that large snowflakes capture particles in the 0.2- to 0.4-μm-diameter range, not by impaction but by filtering the air that moves through the snow flakes as they fall to the ground.

Most of the contamination of snow in urban areas likely occurs after it lands on the ground. Table 3-8 shows the flow-weighted mean concentrations of pollutants found in undisturbed falling snow compared to snow found in urban snow cover (Bennett et al., 1981). Pitt and McLean (1986) also measured snowpack contamination as a function of distance from a heavily traveled road passing through a park. The contaminants in the snow were at much greater concentrations near the road (the major source of blown contamination on the snow) than farther away. (The pollutant levels in the fresh fallen snow are generally a small fraction of the levels in the snow collected from urban study areas.) Pierstorff and Bishop (1980) also analyzed freshly fallen snow and compared the quality to snow stored at a snow dump site. They concluded that "pollutant levels at the dump site are the result of environmental input occurring after the snow falls." Some pollutants in snowmelt have almost no atmospheric

TABLE 3-8 Comparison of Flow-Weighted Pollutant Concentration Means of Snow Samples from Boulder, Colorado

	Fresh Fallen	High Density Land Use	Low Density Land Use
COD	10	402	54
TS	86	2000	165
SS	16	545	4.5
TKN	0.19	2.69	2
NO_3	0.15	0	0
P	—	0.66	0.017
Pb	—	0.95	—

Note: The units are mg/L. SOURCE: Reprinted, with permission, from Bennett et al. (1981). Copyright 1981 by Water Pollution Control Federation.

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sources. For example, Oliver et al. (1974) found negligible amounts of chlorides in samples of snow from rooftops, indicating that the high chloride level found in the snowmelt runoff water comes almost entirely from surface sources (i.e., road salting). Similar roadside snowpack observations along city park roads by Pitt and McLean (1986) also indicated the strong association of road salt with snowpack chloride levels.

Runoff and Pollutant Loading from Snowmelt

Snowmelt events can exhibit a first flush, in which there are higher concentrations of contaminants at the beginning compared to the total event averaged concentration. The enrichment of the first portion of a snowmelt event by soluble pollutants may be due to snowpack density changes, where water percolation and melt/freeze events that occur in the snowpack cause soluble pollutants to be flushed from throughout the snowpack to concentrate at the bottom of the pack (Colbeck, 1981). This concentrated layer leaves the snowpack as a highly concentrated pulse, as snow melts from the bottom due to warmth from the ground (Oberts, 1994).

When it rains on snow, heavy pollutant loads can be produced because both soluble and particulate pollutants are melted from the snowpack simultaneously. Also, the large volume of melt plus rain can wash off pollutants that have accumulated on various surfaces such as roads, parking lots, roofs, and saturated soil surfaces. The intensity of runoff from a rain-on-snow event can be greater than a summer thunderstorm because the ground is saturated or frozen and the rapidly melting snowpack provides added runoff volume (Oberts, 1994).

Figure 3-36 compares the runoff volumes associated with snowmelts alone to those associated with snowmelts mixed with rain from monitoring at an industrial area in Toronto (Pitt and McLean, 1986). Rain with snowmelt contributes over 80 percent of the total cold-weather event runoff volume.

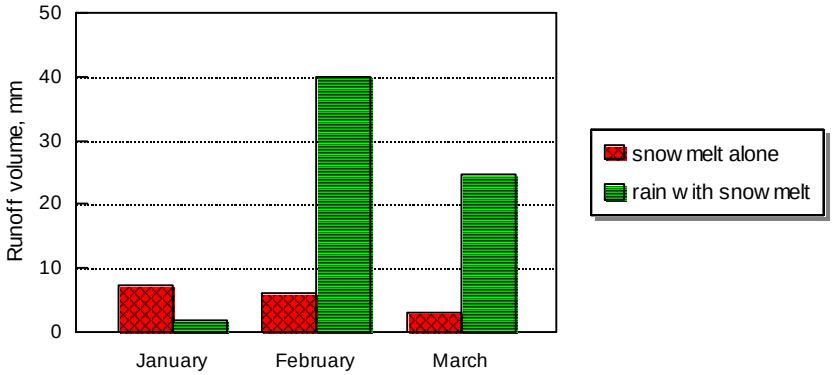

FIGURE 3-36 Runoff volumes for snowmelt events alone and when rain falls on melting snow packs (Toronto industrial area). SOURCE: Pitt and McLean (1986).

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Whether pollutant loadings are higher or lower for snowmelt than for rainfall depends on the particular pollutant and its seasonal prevalence in the environment. For example, the high concentrations of dissolved solids found in snowmelt are usually caused by high chloride concentrations that stem from the amount of de-icing salt used. Figure 3-37 is a plot of the chloride concentrations in the influent to the Monroe Street detention pond in Madison, Wisconsin. Chloride levels are negligible in the non-winter months but increase dramatically when road salting begins in the fall, and remain high through the snow melting period, even extending another month or so after the snowpack in the area has melted. Bennett et al. (1981) found that suspended solids and COD loadings for snowmelt runoff were about one-half of those for rainfall. Nutrients were much lower for snowmelt, while the loadings for lead were about the same for both forms of precipitation. Oberts (1994) reports that much of the annual pollutant yields from event flows in Minneapolis is accounted for by end-of-winter major melts. End-of-winter melts yielded 8 to 20 percent of the total phosphorous and total lead annual load in Minnesota. Small midwinter melts accounted for less than 5 percent of the total loads. Box 3-8 shows mass pollutant discharges for a study site in Toronto and emphasizes the significance of snowmelt discharges on the total annual storm drainage discharges.

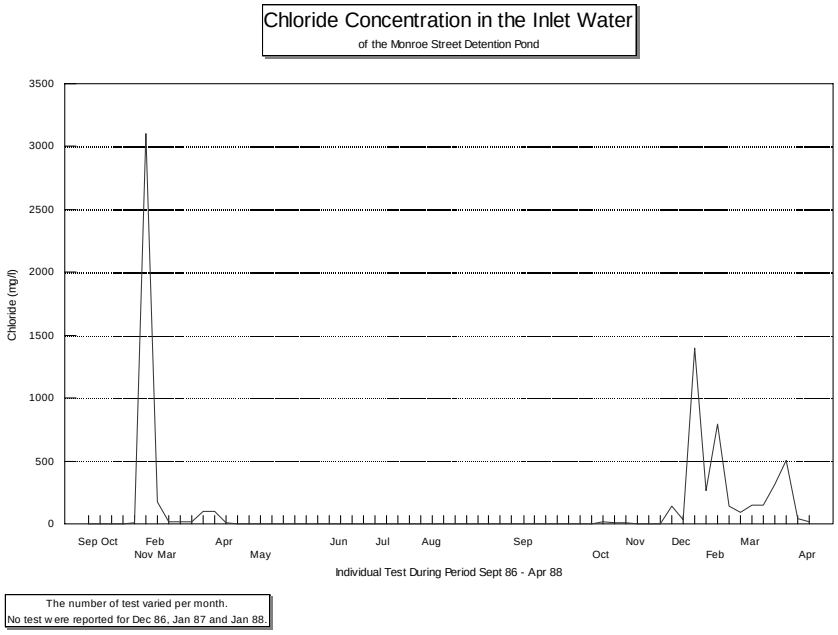

FIGURE 3-37 Monroe Street detention pond chloride concentration of influent (1986–1988). SOURCE: House et al. (1993).

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BOX 3-8
The Contribution of Dry Weather Discharges and Snowmelt to Overall Runoff in Toronto, Ontario

An extensive analysis of all types of stormwater flow—for both dry and wet weather—was conducted in Toronto in the mid-1980s (Pitt and McLean, 1986). The Toronto Area Watershed Management Strategy study included comprehensive monitoring in a residential/commercial area and an industrial area for summer stormwater, warm season dry weather flows, snowmelt, and cold season dry weather flows. In addition to the outfall monitoring, detailed source area sheet flow monitoring was also conducted during rain and snowmelt events to determine the relative magnitude of pollutant sources. Particulate accumulation and wash-off tests were also conducted for a variety of streets in order to better determine their role in contaminant contributions.

Tables 3-9 and 3-10 summarize Toronto residential/commercial and industrial urban runoff median concentrations during both warm and cold weather, respectively. These tables show the relative volumes and concentrations of wet weather and dry weather flows coming from the different land uses. The bacteria densities during cold weather are substantially less than during warm weather, but are still relatively high; similar findings were noted during the NURP studies (EPA, 1983). However, chloride concentrations and dissolved solids are much higher during cold weather. Early spring stormwater events also contain high dissolved solids concentrations. Cold weather runoff accounted for more than half of the heavy metal discharges in the residential/commercial area, while warm weather discharges of zinc were much greater than the cold weather discharges for the industrial area. Warm weather flows were also the predominant sources of phosphorus for the industrial area.

One of the interesting observations is that, at these monitoring locations, warm weather stormwater runoff only contributed about 20 to 30 percent of the total annual flows being discharged from the separate stormwater outfalls. The magnitudes of the base flows were especially surprising, as these monitoring locations were research sites to investigate stormwater processes and were carefully investigated to ensure that they did not have significant inappropriate discharges before they were selected for the monitoring programs.

In comparing runoff from the industrial and residential catchments, Pitt and McLean (1986) observed that concentrations of most constituents in runoff from the industrial watershed were typically greater than the concentrations of the same constituents in the residential runoff. The only constituents with a unit-area yield that were lower in the industrial area were chlorides and total dissolved solids, which was attributed to the use of road deicing salts in residential areas. Annual yields of several constituents (total solids, total dissolved solids, chlorides, ammonia nitrogen, and phenolics) were dominated by cold weather flows, irrespective of the land use.

A comparison of the Toronto sheet flow data from the different land-use areas indicated that the highest concentrations of lead and zinc were found in samples collected from paved areas and roads during both rain runoff and snowmelt (Pitt and McLean, 1986). Fecal coliform values were significantly higher on sidewalks and on, or near, roads during snowmelt sampling, likely because these areas are where dogs would be walked in winter conditions. In warm weather, dog walking would be less concentrated into these areas. The concentrations for total solids from grass or bare open areas were reduced dramatically during snowmelt compared to rain runoff, an indication of the reduced erosion and the

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BOX 3-8 Continued

poor delivery of particulate pollutants during snowmelt periods. Cold weather sheet flow median concentrations of particulate solids for the grass and open areas (80 mg/L) were much less than the TSS concentrations observed during warm weather runoff (250 mg/L) for these same areas. Snowmelt total solids concentrations also increased in areas located near roads due to the influence of road salting on dissolved solids concentrations. In the residential areas, streets were the most significant source of snowmelt solids, while yards and open areas were the major sources of nutrients. Parking and storage areas contrib-

TABLE 3-9 Median Pollutant Concentrations Observed at Toronto Outfalls during Warm Weather[1]

Measured Parameter	Baseflow		Stormwater	
	Residential	*Industrial*	*Residential*	*Industrial*
Stormwater volume (m^3/ha/season)	—	—	950	1500
Baseflow volume (m^3/ha/season)	1700	2100	—	—
Total residue	979	554	256	371
Total dissolved solids	973	454	230	208
Suspended solids	<5	43	22	117
Chlorides	281	78	34	17
Total phosphorus	0.09	0.73	0.28	0.75
Phosphates	<0.06	0.12	0.02	0.16
Total Kjeldahl nitrogen (organic N plus NH_3)	0.9	2.4	2.5	2.0
Ammonia nitrogen	<0.1	<0.1	<0.1	<0.1
Chemical oxygen demand	22	108	55	106
Fecal coliform bacteria (#/100 mL)	33,000	7,000	40,000	49,000
Fecal strep. bacteria (#/100 mL)	2,300	8,800	20,000	39,000
Pseudomonas aeruginosa bacteria (#/100 mL)	2,900	2,380	2,700	11,000
Cadmium	<0.01	<0.01	<0.01	<0.01
Chromium	<0.06	0.42	<0.06	0.32
Copper	0.02	0.05	0.03	0.06
Lead	<0.04	<0.04	<0.06	0.08
Zinc	0.04	0.18	0.06	0.19
Phenolics (μg/L)	<1.5	2.0	1.2	5.1
α-BHC (ng/L)	17	<1	1	3.5
γ-BHC (lindane) (ng/L)	5	<2	<1	<1
Chlordane (ng/L)	4	<2	<2	<2
Dieldrin (ng/L)	4	<5	<2	<2
Pentachlorophenol (ng/L)	280	50	70	705

[1]Values are in mg/L unless otherwise indicated. Warm weather samples were obtained during the late spring, summer, and early fall months when the air temperatures were above freezing and no snow was present.
SOURCE: Pitt and McLean (1986).

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uted the most snowmelt pollutants in the industrial area. An analysis of snow samples taken along a transect of a snowpack adjacent to an industrial road showed that the pollutant levels decreased as a function of distance from the roadway. At distances greater than 3 to 5 meters from the edge of the snowpack, the concentrations were relatively constant. Novotny et al. (1986) sampled along a transect of a snowpack by a freeway in Milwaukee. They also found that the concentration of constituents decreased as the distance from the road increased. Most of the measured constituents, including total solids and lead, were at or near background levels at 30 meters or more from the road.

TABLE 3-10 Median Pollutant Concentrations Observed at Toronto Outfalls during Cold Weather[1]

	Baseflow		**Snowmelt**	
Measured Parameter	*Residential*	*Industrial*	*Residential*	*Industrial*
Stormwater volume (m^3/ha/season)	—	—	1800	830
Base flow volume (m^3/ha/season)	1100	660	—	—
Total residue	2230	1080	1580	1340
Total dissolved solids	2210	1020	1530	1240
Suspended solids	21	50	30	95
Chlorides	1080	470	660	620
Total phosphorus	0.18	0.34	0.23	0.50
Phosphates	<0.05	<0.02	<0.06	0.14
Total Kjeldahl nitrogen (organic N plus NH_3)	1.4	2.0	1.7	2.5
Ammonia nitrogen	<0.1	<0.1	0.2	0.4
Chemical oxygen demand	48	68	40	94
Fecal coliform bacteria (#/100 mL)	9800	400	2320	300
Fecal strep bacteria (#/100 mL)	1400	2400	1900	2500
Pseudomonas aeruginosa bacteria (#/100 mL)	85	55	20	30
Cadmium	<0.01	<0.01	<0.01	0.01
Chromium	<0.01	0.24	<0.01	0.35
Copper	0.02	0.04	0.04	0.07
Lead	<0.06	<0.04	0.09	0.08
Zinc	0.07	0.15	0.12	0.31
Phenolics (mg/L)	2.0	7.3	2.5	15
α-BHC (ng/L)	NA	3	4	5
γ-BHC (lindane) (ng/L)	NA	NA	2	1
Chlordane (ng/L)	NA	NA	11	2
Dieldrin (ng/L)	NA	NA	2	NA
Pentachlorophenol (ng/L)	NA	NA	NA	40

[1]Values are in mg/L unless otherwise indicated. Cold weather samples were obtained during the winter months when the air temperatures were commonly below freezing. Snowmelt samples were obtained during snowmelt episodes and when rain fell on snow.
NA, not analyzed
SOURCE: Pitt and McLean (1986).

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Atmospheric Deposition

The atmosphere contains a diverse array of contaminants, including metals (e.g., copper, chromium, lead, mercury, zinc), nutrients (nitrogen, phosphorus), and organic compounds (e.g., PAHs, polychlorinated biphenyls, pesticides). These contaminants are introduced to the atmosphere by a variety of sources, including local point sources (e.g., power plant stacks) and mobile sources (e.g., motor vehicles), local fugitive emissions (e.g., street dust and wind-eroded materials), and transport from non-local areas. These emissions, composed of gases, small particles (aerosols), and larger particles, become entrained in the atmosphere and subject to a complex series of physical and chemical reactions (Schueler, 1983).

Atmospheric contaminants are deposited on land and water in two ways—termed wet deposition and dry deposition. Wet deposition (or wetfall) involves the sorption and condensation of pollutants to water drops and snowflakes followed by deposition with precipitation. This mechanism dominates the deposition of gases and aerosol particles. Dry deposition (or dryfall) is the direct transfer of contaminants to land or water by gravity (particles) or by diffusion (vapor and particles). Dry deposition occurs when atmospheric turbulence is not sufficient to counteract the tendency of particles to fall out at a rate governed, but not exclusively determined, by gravity (Schueler, 1983).

As atmospheric contaminants deposit, they can exert an influence on stormwater in several ways. Contaminants deposited by wetfall are directly conveyed to stormwater while those in dryfall can be washed off the land surface. For both processes, the atmospheric load of contaminants is strongly influenced by-characteristics such as the amount of impervious surface, the magnitude and proximity of emission sources, wind speed and direction, and precipitation magnitude and frequency (Schueler, 1983). Deposition rates can depend on the type of contaminant and can be site-specific. The relationships between atmospheric deposition and stormwater quality are, however, not well understood and difficult to determine. Following are a few illustrative examples.

Southern California

Several studies have addressed atmospheric deposition in Southern California (e.g., Lu et al., 2003; Harris and Davidson, 2005; Stolzenbach et al., 2007). Stolzenbach et al. and Lu et al. conclude the following *for this region:*

- the major source of contaminants to the atmosphere in this region is associated with resuspended dust, primarily from roads,
- contaminants in resuspended dust may reflect historical as well as current sources and distant as well as local sources,
- atmospheric loadings to the receiving water are primarily the result of chronic daily dry deposition of large particles greater than 10 μm in size on the

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watershed rather than directly on a waterbody,

- significant spatial variability occurs in trace metal mass loadings and deposition fluxes, particularly along transportation corridors along the coast and the mountain slopes of the airshed,
- significant diurnal and seasonal variations occur in the deposition of trace metals, and
- atmospheric deposition of metals is a significant component of contaminant loading to waterbodies in the region relative to other point and nonpoint sources.

Harris and Davidson (2005) have reported that traditional sources of lead to the south coast air basin of California accounted for less than 15 percent of the lead exiting the basin each year. They resolve this difference by considering that lead particles deposited during the years of leaded gasoline use are resuspended as airborne lead at this time, some decades after their original deposition. This result indicates that lead levels in the soil will remain elevated for decades and that resuspension of this lead will remain a major source of atmospheric lead well into the future.

Sabin et al. (2005) assessed the contribution of trace metals (chromium, copper, lead, nickel, and zinc) from atmospheric deposition to stormwater runoff in a small impervious urban catchment in the Los Angeles area. Dry deposition contributed 90 percent or more of the total deposition inside the catchment, indicating the dominance of dry deposition in semi-arid regions such as Los Angeles. Deposition potentially accounted for from 57 to 90 percent of the total trace metals in stormwater in the study area, demonstrating that atmospheric deposition can be an important source of trace metals in stormwater near urban centers.

San Francisco

Dissolved copper is toxic to phytoplankton, the base of the aquatic food chain. Copper and other metals are released in small quantities when drivers depress their brakes. The Brake Pad Partnership (*http://www.suscon.org/brakepad/index/asp*) has conducted studies to determine how much copper is released as wear debris, and how it travels through the air and streets to surface waters. A comprehensive and complex model of copper loads to and of transport and reactions in San Francisco Bay was developed (Yee and Franz, 2005). Objectives were to provide daily loadings of flow, TSS, and copper to the bay and to estimate the relative contribution of brake pad wear debris to copper in the bay. The modeling results (Rosselot, 2006a) indicated that an estimated 47,000 kg of copper was released to the atmosphere in the Bay Area in 2003. Of this amount, 17,000 kg Cu/yr was dry-deposited in subwatersheds; 3,200 kg Cu/yr was wet-deposited in subwatersheds; 1,200 kg Cu/yr was dry-deposited directly to bay waters; and 1,300 kg Cu/yr was wet-deposited directly to bay waters. The remaining 24,000 kg Cu/yr remained airborne until it left the Bay

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Area. The contribution of copper from brake pads to the bay is estimated to range from 10 to 35 percent of the total copper input, with the best estimate being 23 percent (Rosselot, 2006a,b).

Washington, D.C., Metropolitan Area

Schueler (1983) investigated the atmospheric deposition of several contaminants in Washington, D.C., and its surrounding areas in the early 1980s. The contaminants assessed included trace metals (cadmium, copper, iron, lead, nickel, and zinc), nutrients (nitrogen and phosphorus), solids, and organics as measured collectively by BOD and COD. Dryfall solids loading increased progressively from rural to urban sites. A similar trend was observed for total phosphorus, total nitrogen, and trace metal dry deposition rates. Wet deposition rates exhibited few consistent regional patterns.

The relative importance of wet and dry deposition varied considerably with each contaminant and each site. For example, most of the nitrogen was supplied by wet deposition while most of the phosphorus was delivered via dry deposition. If a contaminant is deposited primarily by wet deposition, it is likely that a major fraction of it will be rapidly entrained in urban runoff.

Atmospheric sources were estimated to contribute from 70 to 95 percent of the total nitrogen load to urban runoff and 20 to 35 percent of the total phosphorus load. Overall, atmospheric deposition appeared to be a moderate source of pollutants in urban runoff. However, with the exception of nitrogen, atmospheric deposition was not the major source.

Average annual atmospheric deposition rates suggested a general trend toward greater deposition rates from rural to suburban to urban sites. This pattern was most pronounced for dry deposition. Wet deposition was the most important deposition mechanism for total nitrogen, nitrate, organic nitrogen, COD, copper, and zinc. Dry deposition was most important for most soil-related constituents, such as total solids, iron, lead, total phosphorus, and orthophosphate.

Measurements of rainfall pH showed median values between 4.0 and 4.1 at all stations and during all seasons. Increased mobilization of trace metals from urban surfaces caused by acid rain was noted at several monitoring sites.

***

Relationships between atmospheric deposition rates and the quality of urban stormwater are complex and cannot be generalized regionally or temporally. Site-specific measurements or reliable estimates of (1) contaminant sources, (2) atmospheric particle size and contaminant concentrations, (3) deposition rates and mechanisms, (4) land surface characteristics, (5) local and regional hydrology and meteorology, and (6) contaminant concentrations in stormwater are needed to assess management decisions to improve stormwater quality. Transportation is a major source of metals (lead in gasoline, zinc in tires, copper in

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brake pads). The results of the modeling of copper in San Francisco and its watershed demonstrate the feasibility of modeling the impact of a source, in this case copper input by atmospheric deposition, on water quality in a receiving waterbody.

BIOLOGICAL RESPONSES TO URBANIZATION

As discussed in Chapter 1, the biological integrity of aquatic ecosystems is influenced by five major categories of environmental stressors: (1) chemical, (2) hydrologic, (3) physical (e.g., habitat), (4) biological (e.g., disease, alien species), and (5) energy-related factors (e.g., nutrient dynamics). Recent studies on biological assemblages in urban or urbanizing waters have begun to examine how stormwater stressors limit biological potential along various urban gradients (Horner et al., 2003; Carter and Fend, 2005; Meador et al., 2005; Barbour et al., 2008; Purcell et al., 2009). Advances in biological monitoring and assessment over the past two decades have enabled much of this research. Today, many states and tribes use biological data to directly measure their aquatic life beneficial uses and have developed numeric biocriteria that are institutionalized in their water quality standards. Most of these approaches compare biology and stressors to suites of reference sites (Hughes, 1995; Stoddard et al., 2006), which can vary from near-pristine areas to agricultural landscapes. While this section focuses on streams because of the wealth of data, similar work is being performed on other waterbody types such as wetlands (Mack and Micacchion, 2007) and estuaries, both of which are susceptible to stormwater pollutants such as metals because of their depositional nature (Morrisey et al., 2000).

Aquatic life beneficial uses are based on achieving aquatic *potential* given feasible restorative actions. Because such potential may vary substantially across a region depending on land use and other factors, some states have adopted tiered aquatic life uses (see Box 2-1). The potential of many urban streams is likely to be something less than "biological integrity" (the ultimate goal of the CWA) or even "fishable–swimmable" goals, which are the interim goals of the CWA. Indeed, there is a near-universal, negative association between biological assemblages in streams and increasing urbanization, to the extent that it has been termed the "Urban Stream Syndrome" (Walsh et al., 2005). Recent investigations that have quantified the responses of macroinvertebrates and other biological assemblages along multiple measures of urban/stormwater stressors have discussed how best to set aquatic life goals for urban streams (Booth and Jackson, 1997; Bernhardt and Palmer, 2007). One of the most important contributions to this debate has been the development of the Biological Condition Gradient (BCG) concept by EPA. The BCG is an attempt to anchor and standardize interpretations of biological conditions and to unify biological monitoring results across the United States in order to advance the use of tiered aquatic life beneficial uses. This section summarizes the characteristic biological responses to urban gradients, within the framework of the BCG, and it re-

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views evidence of biological responses within the aforementioned five major categories of environmental stressors.

Biological Condition Gradient

The BCG framework is an ecological model of how structural and functional components of biological assemblages change along gradients of increasing stressors of many kinds (Davies and Jackson, 2006). Ecological systems have some common general attributes related to their structure and function that form the basis for how biological organisms respond to stressors in the environment. Over the past 20 years, development of biological indicators nationwide has taken advantage of these repeatable biological responses to stress; however, state benchmarks often have varied substantially, even between adjacent states. To gain consistency, the EPA convened a national workgroup of EPA Regions, States, and Tribes to develop the BCG—a standardized, nationally applicable model that defines important attributes of biological assemblages and describes how these attributes change along a gradient of increasing stress from pristine environments to severely impaired conditions (Figure 3-38; Davies and Jackson, 2006). The goals of this work were to improve national consistency in the rating and application of biological assessment tools for all types of waterbodies and to provide a baseline for the development of tiered aquatic life uses.

To date, the BCG has been applied to assemblages including aquatic macroinvertebrates, fish, Unionid mussels, and algae in streams, but it could be applied to any organism group in any type of waterbody. The BCG is derived by applying a suite of ten ecological attributes that allows biological condition to be interpreted independently of assessment method (Table 3-11; Davies and Jackson, 2006). The first five attributes focus on taxa sensitivity, an important component of tools such as multimetric indices (e.g., the Index of Biotic Integrity [IBI], the Invertebrate Community Index [ICI]; see Box 2-3) used in the United States and Europe. Many indicator taxa have been widely studied, and, for groups such as fish, historical data often exist. Most states have established lists of tolerant and intolerant species as part of their use of biological indices (Simon and Lyons, 1995). The relatively large literature on species population and distribution changes in response to stressors and landscape condition offers insight into the mechanisms for population shifts, some of which are summarized in this section.

The first two attributes of the BCG relate to those streams that are closest to natural or pristine, with most taxa "as naturally occur." Attribute 1 and 2 taxa are the most sensitive species that typically disappear with even minor stress. Table 3-12 lists some example attribute 1 taxa for four different regions of the United States. Attribute 3 reflects more ubiquitous, but still sensitive, species that can provide information as human influence on the landscape becomes more obvious, but is not yet severe. Attributes 5 and 6 are taxa that increase in abundance and distribution with increasing stress. The organism condition at-

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The Biological Condition Gradient: Biological Response to Increasing Levels of Stress

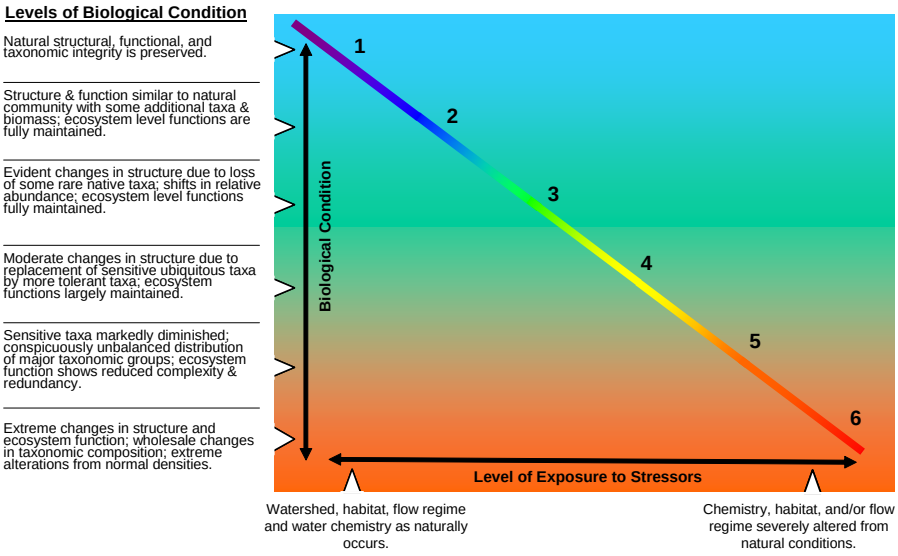

FIGURE 3-38 The Biological Condition Gradient (BCG) and summaries of biological condition along tiers of this gradient. SOURCE: Modified from Davies and Jackson (2006) by EPA.

TABLE 3-11 Ecological attributes that comprise the basis for the BCG

1. Historically documented, sensitive, long-lived or regionally endemic taxa
2. Sensitive-rare taxa
3. Sensitive-ubiquitous taxa
4. Taxa of intermediate tolerance
5. Tolerant taxa
6. Non-native or introduced taxa
7. Organism condition
8. Ecosystem functions
9. Spatial and temporal extent of detrimental effects
10. Ecosystem connectance

SOURCE: EPA (2005).

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TABLE 3-12 Example of Taxa that *Might Serve* as Attribute 1: "Historically Documented, Sensitive, Long-Lived, Regionally Endemic Taxa for Streams in Four Regions of the United States"

State and Taxon	Taxa Representative of Attribute I
Maine	
Mollusks	brook floater (*Alasmodonta varicosa*), triangle floater (*Alasmodonta undulata*), yellow lampmussel (*Lampsilis cariosa*)
Fishes	brook stickleback (*Culaea inconstans*), swamp darter (*Etheostoma fusiforme*)
Washington	
Fishes	steelhead (*Oncorhynchus mykiss*)
Amphibians	spotted frog (*Rana pretiosa*)
Arizona	
Mollusks	spring snails (*Pyrgulopsis* spp.)
Fishes	Gila trout (*Oncorhynchus gilae*), Apache trout (*Oncorhynchus apache*), cutthroat trout (endemic strains) (*Oncorhynchus clarki*)
Amphibians	Chihuahua leopard frog (*Rana chiricahuensis*)
Kansas	
Mollusks†	hickorynut (*Obovaria olivaria*), black sandshell (*Ligumia recta*), ponderous campeloma (*Campeloma crassulum*)
Fishes	Arkansas River shiner (*Notropis girardi*), Topeka shiner (*Notropis topeka*), Arkansas darter (*Etheostoma cragini*), Neosho madtom (*Noturus placidus*), flathead chub (*Platygobio gracilisa*)
Other invertebrates	ringed crayfish (*Orconectes neglectus neglectus*), Plains sand-burrowing mayfly (*Homoeoneuria ammophila*)
Amphibians	Plains spadefood toad (*Spea bombifrans*), Great Plains toad (*Bugo cognatus*), Great Plains narrowmouth toad (*Gastrophryne olivaceae*), Plains leopard frog (*Rana blairi*)

†Although not truly endemic to the central plains, these regionally extirpated mollusks were widely distributed in eastern Kansas prior to the onset of intensive agriculture.
SOURCE: Table 7 from Davies and Jackson (2006). Reprinted, with permission, from Davies and Jackson (2006). Copyright 2006 by Ecological Society of America.

tribute (7) includes the presence of anomalies (e.g., tumors, lesions, eroded fins, etc.) or the presence of large or long-lived individuals in a population. Most natural streams typically have few or incidental rates of "anomalies" associated with disease and stress. Natural waterbodies typically also have the entire range of life stages present, as would be expected. However, as stress is increased, larger individuals may disappear or emigrate, or reproductive failure may occur. Ecosystem function (attribute 8) is very difficult to measure directly (Davies and Jackson, 2006). However, certain functions can be inferred from structural measures common to various multimetric indices, examples of which are listed in Table 3-13. The last two attributes (9 and 10) may be of particular importance with regard to stormwater and urban impacts. Cumulative impacts are a characteristic of urbanization, and biological organisms typically integrate the effects of many small insults to the landscape. Additionally, most natural systems often have strong "connectance," such that aquatic life often has stages that rely on migrating across multiple types or sizes of waterbodies. Urbanized streams can decrease connectance by creating migration blocks, including vertical barriers at road crossings and small dams (Warren and Pardew, 1998).

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TABLE 3-13 Function Ecological Attributes or Process Rates and Their Structural Indicators

Biotic Level and Function or Process	**Structural Indicator**
Individual level	
Fecundity	Maximum individual size, number of eggs
Growth and metabolism	Length/mass (condition)
Morbidity	Percentage anomalies
Population Level	
Growth and fecundity	Density
Mortality	Size- or age-class distribution
Production	Biomass, standing crop, catch per unit effort
Sustainability	Size- or age-class distribution
Migration, reproduction	Presence or absence, density
Community or assemblage level	
Production/respiration ratio, autotrophy vs heterotrophy	Trophic guilds, indicator species
Primary production	Biomass, ash-free dry mass
Ecosystem level	
Connectivity	Degree of aquatic and riparian fragmentation longitudinally, vertically, and horizontally; presence or absence of diadromous and potadromous species

SOURCE: Table 4 from Davies and Jackson (2006). Reprinted, with permission, from Davies and Jackson (2006). Copyright 2006 by Ecological Society of America.

Construction of a BCG creates a conceptual framework for developing stressor–response gradients for particular urban areas. The initial work done to develop the BCG derived a series of six tiers to describe a gradient of biological condition that is anchored in pristine conditions ("as naturally occurs") and that extends to severely degraded conditions (see Figure 3-38). Exercises done by the national work group to derive such a gradient for macroinvertebrates in wadeable streams showed strong consistency in assigning tiers to datasets using the descriptions of taxa for each attribute along these gradients (Davies and Jackson, 2006). Substantial data already exist to populate many of the attributes of the BCG and to provide mechanistic underpinning for the expected directions of change.

The BCG is not a replacement for assessment tools such as the IBI or multivariate predictive models (e.g., RIVPACS approach), but rather a conceptual overlay for characterizing the anchor point-of-reference conditions and a consistent way to communicate biological condition along gradients of stress. As such, it has strong application to understanding stormwater impacts and to communicating where a goal is located along the gradient of biological condition. While most urban goals may be distant from "pristine" or "natural," the BCG process can dispel misconceptions that alternate urban goals are "dead streams" or unsafe in some manner.

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Factors Limiting Aquatic Assemblages in Urban Waters

A slew of recent investigations have quantified the responses of macroinvertebrates and other biological assemblages to multiple measures of urbanization and to stormwater in particular. One important conclusion of some of this work is that declines in the highest biological condition start with low levels of anthropogenic change (e.g., 5 to 25 percent impervious surface); higher levels of urbanization severely alter aquatic conditions (Horner et al., 2003). This has important consequences for protecting sites with the highest biological integrity, as they may be among the most vulnerable. The non-threshold nature of this aquatic response and the typical wedge-shaped response to multiple stressors by aquatic assemblages are discussed in Box 3-9.

BOX 3-9
Non-threshold Nature of the Decline of Biological Assemblages Along Urban Stressor Gradients

Several recent surveys have demonstrated that biological assemblages begin to decline in condition with even low levels of urban disturbance as measured by various gradients of urbanization (e.g., May, 1996; Horner et al., 1997; May et al., 1997; Horner et al., 2003; Moore and Palmer, 2005; Barbour et al., 2008). This box summarizes the work of Horner et al. (2003) in small streams in three regions: Montgomery County, Maryland; Austin, Texas; and the Puget Sound area of Washington. Geographic Information System (GIS) analyses using information such as land use, total impervious area, and riparian land use were used to develop multi-metric Watershed Condition Indices (WCIs) for each region. These in turn were related to fish and macroinvertebrate indices, e.g., benthic IBIs, (B-IBI, all three regions), a fish IBI (F-IBI for Maryland) and an index that was the ratio of the sensitive coho salmon to the more tolerant cutthroat trout in collections for the Puget Sound lowland area.

In each of these areas, no or extremely low urban development, substantial forest cover, and minimal disturbance of riparian zones characterized sites with the highest biological scores, but these conditions did not guarantee high scores because other impacts could limit biology even with these “natural” characteristics. In all three regions, high urbanization and loss of natural cover always led to biological degradation (Figures 3-39 and 3-40). The results of this study were similar to other recent studies such as Barbour et al. (2008) that identify a “wedge-shaped” relationship or a “polygonal” relationship (Carter and Fend, 2005) between urban gradients and biological condition. These types of relationships have also been termed “factor-ceiling” relationships (Thomson et al., 1996). The outer surface of these wedges or polygons reflects where the urban gradients limit biological assemblages, such that points below this surface typically represent sites affected by other stressors (e.g., combined sewer overflows, discharges, etc.). In all of these studies it is easier to predict loss of biological conditions as the urban gradients (e.g., WCI) worsen than it is to ensure high biological integrity at low proportions of urban stress (because some other stressor may still limit aquatic condition).

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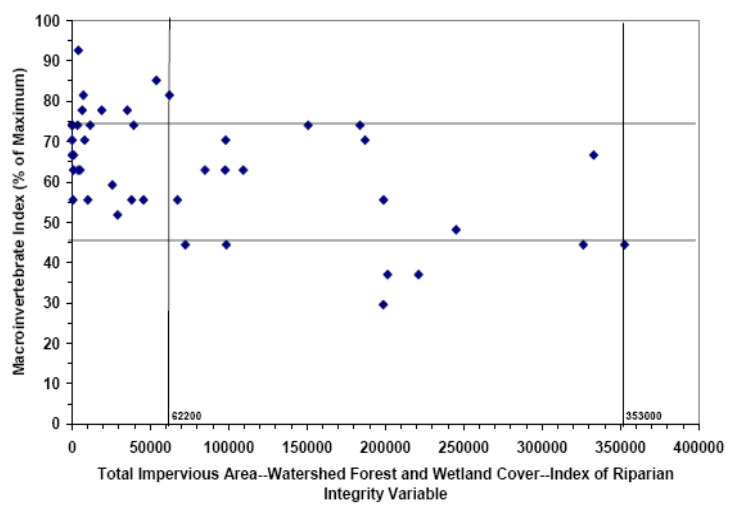
BOX 3-9 Continued



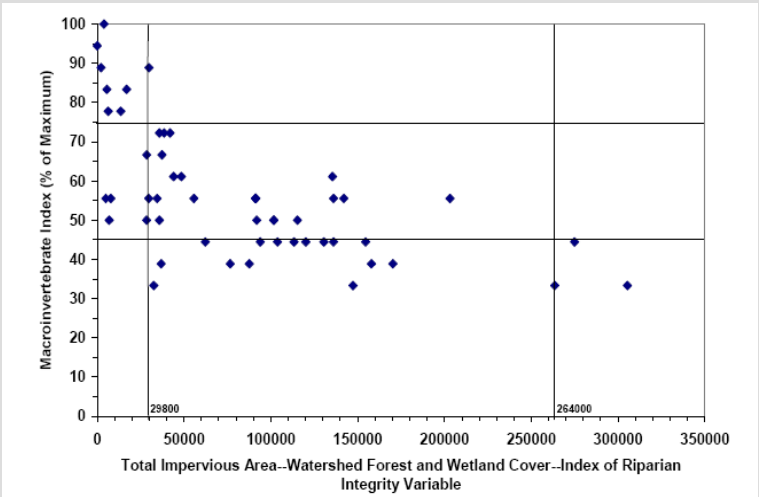


FIGURE 3-39 Plots of a measure of urbanization (TIA + Wetland & Forest Cover + IRI) versus B-IBIs for Austin, Texas (top), and Montgomery County, Maryland (bottom). SOURCE: Horner et al. (2003).

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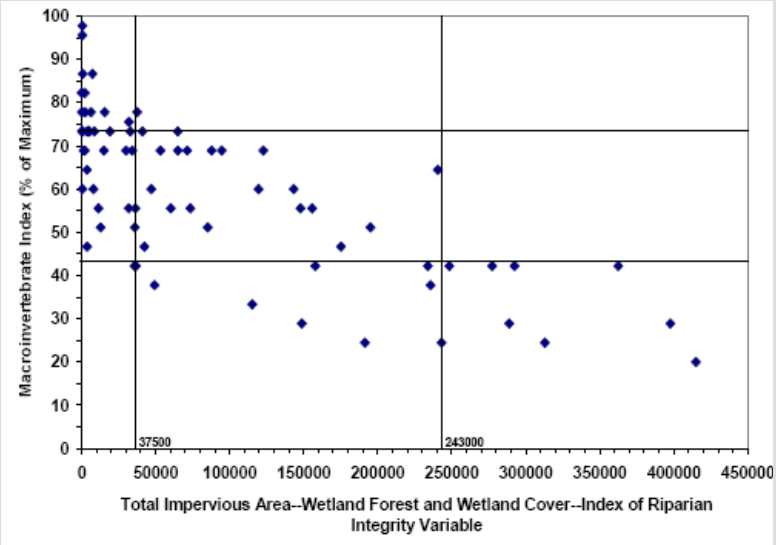
BOX 3-9 Continued



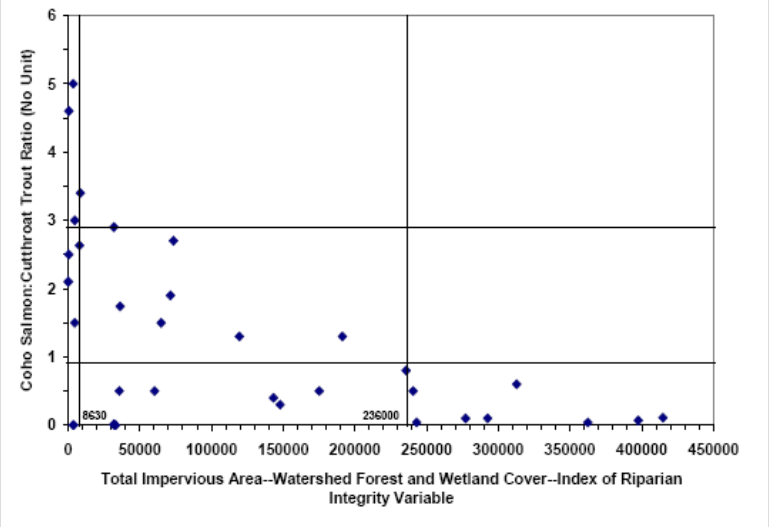


FIGURE 3-40 Plots of a measure of urbanization (TIA + Wetland & Forest Cover + IRI) versus B-IBIs for Puget Sound (top) and versus the ratio of coho salmon to cutthroat trout for Puget Sound (bottom). SOURCE: Horner et al. (2003).

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BOX 3-9 Continued

Horner et al. (2003) also focused on whether structural SCMs could moderate the effects of urbanization on biological assemblages. They made detailed observations of two subbasins in the Puget Sound lowland area, one with a greater degree of stormwater management than the other (although neither had what would be considered comprehensive stormwater management with a focus on water quality issues). As shown in Figure 3-41, at the highest levels of urbanization (triangles), the subbasin with the more extensive use of structural SCMs did have better biological conditions. There was less evidence of biological benefit in the watershed that used SCMs but it had only moderate urbanization and more natural land cover (squares and diamonds). There were no circumstances where high biological condition was observed along with the use of SCMs because high biological condition only occurred where little human alteration was present, and thus SCMs were not used.

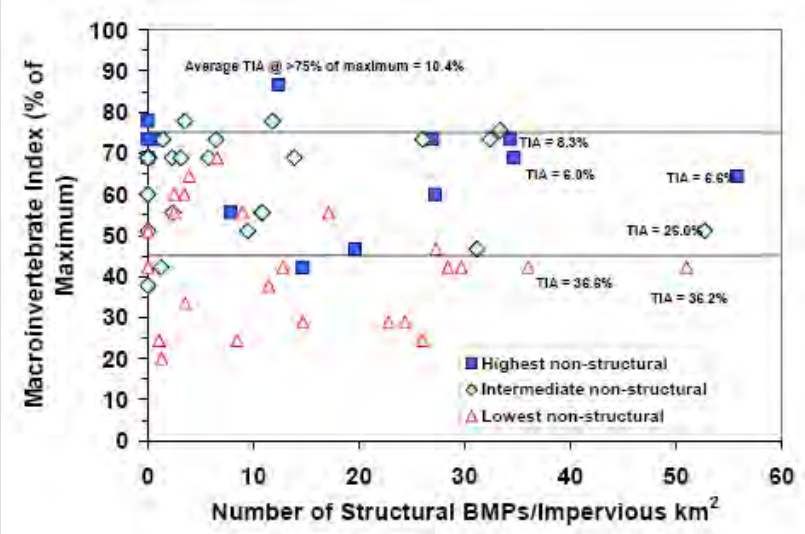

FIGURE 3-41 Macroinvertebrate community index versus structural SCM density with the highest, intermediate, and lowest one-third of natural watershed and riparian cover. The upper and lower horizontal lines represent indices considered to define relatively high and low levels of biological integrity, respectively. SOURCE: Horner et al. (2003).

The sections that follow review the evidence underlying biological responses to each of the major categories of stressors: chemical, hydrologic, physical habitat, biological, and energy-related factors. As will be evident in some of the examples, the stressors themselves can interact (e.g., flow can influence habitat, habitat can influence energy processing, etc.), which increases the complexity of understanding how stormwater affects aquatic ecosystems.

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Biological Responses to Toxic Pollutants

The chemical constituents of natural streams vary widely with climatic region, stream size, soil types, and geological setting. Most small natural streams, outside of unique areas wth naturally occurring toxicants, have very low levels of chemicals considered to be toxicants and have relatively low levels of dissolved and particulate materials in general. This applies to chemicals in the water column and in sediments. Increasing amounts of impervious surface in the watershed typically increase the concentrations of many chemical parameters in runoff derived from urban surfaces (e.g., Porcella and Sorenson, 1980; Sprague et al., 2007).

Stormwater concentrations of these pollutants can be variable and sometimes extreme or "toxic" depending on the timing of flows (e.g., first flush), although concentrations at base flows may not routinely exceed water quality benchmarks (Sprague et al., 2007). Historical deposition of toxics in sediments can also be responsible for extremely high pollutant concentrations within waterbodies, even though the stormwater discharges may no longer be active. These situations have been termed "legacy pollution" and are most commonly associated with urban centers that have a history of industrial production.

Natural constituents such as dissolved materials (e.g., chlorides), particulate material (e.g., fine sediments), nutrients (e.g., phosphorus and nitrogen compounds), as well as a myriad of man-made parameters such as heavy metals and organic chemicals (e.g., hydrocarbons, pesticides and herbicides) have been documented to be increased and at times pervasive in stormwater (Heany and Huber, 1984; Paul and Meyer, 2001; Roy et al., 2003; Gilliom et al., 2006) although specific patterns of concentrations can vary with region and ecological setting (Sprague et al., 2007). Water chemistry impacts can also arise from a complex array of permitted discharges, storm sewer discharges, and combined sewer overflows that are treated to certain limits but at times fail to remove all constituents from flows, especially when associated with storm events (Paul and Meyer, 2001).

Streams in urban settings can have increases in toxicant levels compared to background concentrations. In many instances these cases have been associated with loss of aquatic species and impairment of aquatic life goals (EPA, 2002), which are usually explained in terms of typical lethal responses. The complexity of urban systems with regard to pathways, magnitude, duration, and timing of toxicity as well as possible synergistic or antagonistic effects of mixtures of pollutants argues for a broad approach to characterizing effects including not only toxicity testing, but also novel approaches and direct monitoring of biological assemblages (Burton et al., 1999). What is problematic from a traditional management perspective is that aquatic communities may decline before exceedances of water quality criteria are evident (May et al., 1997; Horner et al., 2003).

The first three BCG attributes focus on populations of species of high to very high sensitivity, most of which are uncommon or absent in waters with any

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substantial level of urbanization. Multi-metric indices such as IBI, which reflect loss of these species, decline at least linearly with increasing urbanization (e.g., Miltner et al., 2004; Meador et al., 2005; Walters et al., 2005). Although toxicity to compounds varies with species, many species of federal and state endangered and threatened aquatic species are more sensitive than "commonly" used test species (Dwyer et al., 2005), such that the loss of aquatic species when toxicant levels exceed criteria are readily explained.

The mechanisms of species population declines in response to chemical contaminants are likely complex and not just limited to direct lethality of the pollutant. Indeed, initial chemical changes may have no "toxic" effects, but rather could change competitive and trophic dynamics by changing primary production and energy dynamics in streams. For example, exposures to aromatic and chlorinated organic compounds from sediments derived from urban areas have been found to increase the susceptibility of salmonids to the bacterial pathogen *Vibrio anguillarum* (Arkoosh et al., 2001). Recent work has found that salmonids show substantial behavioral changes from olfactory degradation related to copper at concentrations as low as 2 μg/L, well below copper water quality criteria and above levels measured in most stormwater-affected streams (Hecht et al., 2007; Sandahl et al., 2007). Salmonid and other fish depend extensively on olfactory cues for feeding, emigration, responding to prey and predators, social and spawning interactions, and other behaviors, such that loss or diminution of such cues may have population-level effects on these species (Sandahl et al., 2007). Copper has been shown to cause olfactory effects on other species (Beyers et al., 2001) and to impair the sensory ability of the fish lateral line (Hernandez et al., 2006), which is nearly ubiquitous in fishes and important for most freshwater species in feeding, schooling, spawning, and other behaviors.

Whole effluent toxicity testing or sediment toxicity testing may misclassify the effects of runoff and effluents in urban settings (Burton et al., 1999). Short-term toxicity tests of stormwater often result in no identified toxicity. However, longer studies (e.g., 30 days) have shown increasing toxicity with time (Masterson and Bannerman, 1994; Ramcheck and Crunkilton, 1995). This suggests that the mechanism of toxicity could be through an ingestion pathway, for example, rather than gill uptake. Metals are often in high concentrations where fine sediments accumulate, and their legacy can extend past the time period of active discharge. Metal concentrations in urban stream sediments have been associated with high rates of fish and invertebrate anomalies such as tumors, lesions, and deformities (Burton, 1992; Ingersoll et al., 1997; Smith et al., 2003).

Biological Responses to Non-Toxicant Chemicals

Non-toxic chemical compounds that occur in stormwater such as nutrients, dissolved oxygen (DO), pH, and dissolved solids as well as physical factors such as temperature can have impacts on aquatic life. The effects of some of these

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compounds (e.g., DO, pH) have been well documented from other impacts (e.g., wastewater, mining), such that nearly all states have developed water quality criteria for these parameters. For example, nutrient enrichment in stormwater runoff has been associated with declines of biological condition in streams (Miltner and Rankin, 1998). Chloride, sulfate, and other dissolved ions that are often elevated in urban areas can have effects on osmoregulation of aquatic organisms and have been associated with loss of species sensitive to dissolved materials such as mayflies (Kennedy et al., 2004). The concentrations of these compounds can vary regionally (Sprague et al., 2007) and with the degree of urbanization.

Water quality criteria for temperature were spurred by the need for thermal permits for industrial and power plant cooling water discharges. There is a very large literature on the importance of water temperature to aquatic organisms; preference, avoidance, and lethal temperature ranges have been derived for many aquatic species (e.g., Brungs and Jones, 1977; Coutant, 1977; Eaton et al., 1995). In addition, temperature is one of the key classification strata for aquatic life, in that streams are routinely classified as cold water, cool water, or warm water based on the geographic and natural settings of waters. The removal of catchment and riparian vegetation and the general increase in surface runoff from impervious, man-made, and heat-capturing surfaces has been associated with increasing water temperatures in urban waterbodies (Wang and Kanehl, 2003; Nelson and Palmer, 2007). A number of researchers have created models to predict in-stream temperatures based on urban characteristics (Krause et al., 2004; Herb et al., 2008).

Hydrologic Influences on Aquatic Life

The importance of "natural" flow regimes on aquatic life has been well documented (Poff et al., 1997; Richter et al., 1997a, 2003). As watersheds urbanize, flow regimes change from little runoff to over 40 to 90 percent of the rainfall becoming surface runoff (Roesner and Bledsoe, 2003). Flow regimes in urban streams typically are very "flashy," with higher and more frequent peak events, compared to undisturbed systems (Poff et al., 1997; Baker et al., 2004) and well as reduced base flows and more frequent desiccation (Bernhardt and Palmer, 2007). Richter et al. (1996) proposed a series of indicators that could be used to measure hydrologic disturbance, many of which have been used in the recent studies identifying the hydrologic effects of stormwater on aquatic biota (Barbour et al., 2008). Pomeroy et al. (2008) did an extensive review of which flow characteristics appear to have the greatest influence on biological metrics and biological integrity. No single measure of flow was found to be significant in all studies; however, important attributes included flow variability and flashiness, flood frequency, flow volume, flow variability, flow timing, and flow duration.

There are a number of mechanisms that may be responsible for the influ-

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ence of flow characteristics on aquatic assemblages. Aquatic species vary dramatically in their swimming performance and behaviors, and species are generally adapted to undisturbed flow regimes in an area. Many low- to moderate-gradient small streams in the United States, for example, have strong connections with their flood-prone areas and often possess habitat features that insulate poor swimming species from episodic natural high flows. Undercut banks, rootwads, oxbows, and backwater habitats all can act as refugia from high flows. Some aquatic species are more or less mobile within the sediments, like certain macroinvertebrates (meiofauna or hyporheos) and fish species such as sculpins and madtoms. Secondary impacts from hydrologic changes such as bank erosion and aggradation of fines can render substrates embedded and prohibit organisms, particularly the meiofauna, from moving vertically within the bottom substrates (Schmid-Araya, 2000). Substrate fining has been documented to occur with increasing urbanization, especially in the early stages of development, which can embed spawning habitats and eliminate or reduce spawning success of fish such as salmonids and minnows (Waters, 1995).

Flood flows can cause mortality in the absence of urbanization. For example, flood flows in streams under natural conditions have been documented as a cause of substantial mortality in young or larval fish such as smallmouth bass (Funk and Fleener, 1974; Lorantas and Kristine, 2004). Increased flashiness from urbanization is likely to exacerbate this effect. Thus, increases in the frequency of peak flows during spring will increase the probability of spawning failure, such that sensitive species may eventually be locally extirpated. In urban areas, culverts and other flow obstructions can create conditions that may preclude re-colonization of upstream reaches because weak-swimming fishes cannot move past flow constrictions or leap past vertical drops caused by artificial structures.

Hydrologic simplification and stream straightening that occur in urban streams, often as a result of increased peak flows or as a local management response, typically remove habitat used as temporary refuges from high flows, such as backwater areas, undercut banks, and rootwads. There is a large literature relating populations of fish and macroinvertebrates to various habitat features of streams, rivers, and wetlands. The first two attributes of the BCG identify taxa that are historically documented, sensitive, long-lived, or regionally endemic taxa or sensitive-rare taxa. Many of these taxa are endangered because of large-scale changes in flow-influenced habitats; that is, threats of extinction often center on habitat degradation that influence spawning, feeding, or other aspects of a species life history (Rieman et al., 1993). In contrast, many of the fish and macroinvertebrate taxa that compose regional lists of tolerant taxa are tolerant to habitat changes related to flow disturbance as well as chemical parameters. Understanding the life history attributes of certain species and how they may change with multiple stressors (Power, 1997) is an important tool for understanding complex responses of aquatic ecosystems to urban stressors.

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Geomorphic and Habitat Influences on Aquatic Life

In natural waters, geomorphic factors and climate, modified by vegetation and land use, constrain the types of physical habitat features likely to occur in streams (Webster and D'Angelo, 1997). For example, very-low-gradient streams may have few riffles and be dominated by woody debris and bank cover, whereas higher gradient waters may have more habitat types formed by rapidly flowing waters (riffles, runs). Aquatic life in streams is influenced directly by the habitat features that are present, such as substrate types, in-stream structures, bank structure, and flow types (e.g., deep-fast vs. shallow-slow).

As discussed previously, human alteration of landscapes, encroachment on riparian areas, and direct channel modifications (e.g., channelization) that acompany urbanization have often resulted in unstable channels, with negative consequences for aquatic habitat. As urbanization has increased, channel density has declined because streams have been piped, dewatered, and straightened (Meyer and Wallace, 2001; Paul and Meyer, 2001). Changes in the magnitude, relative proportions, and timing of sediment and water delivery have resulted in loss of aquatic life and habitat via a wide range of mechanisms, including changes in channel bed materials, increased suspended sediment loads, loss of riparian habitat due to bank erosion, and changes in the variability of flow and sediment transport characteristics relative to aquatic life cycles (Roesner and Bledsoe, 2003). There are still significant gaps in knowledge about how stormwater stressors can affect stream habitat, especially as one moves from the reach scale to the watershed scale. Understanding the stage and trajectory of channel evolution is critical to understanding channel recovery and expected habitat conditions or in choosing effective restoration options (Simon et al., 2007).

Across much of the United States, stream habitats have been altered to the imperilment of aquatic species (Williams et al., 1989; Richter et al., 1997b; Strayer et al., 2004). A study of rapidly urbanizing streams in central Ohio identified the loss of highly and moderately sensitive species as a key factor the decline in the IBI in these streams (Miltner et al., 2004). These streams had historical fish collections when they were primarily influenced by agricultural land use; sampling after the onset of suburban development documented the loss of many of these species attributable to land-use changes and habitat degradation along these urban streams. Along the BCGs that have been developed for streams, most of the species in attributes 1–3 are specialists requiring very specific habitats for spawning, feeding, and refuge. Habitat alteration, either direct or indirect, creates harsh environments that tend to favor tolerant taxa, which would otherwise be in low abundance. Often these tolerant species are characterized by high reproductive potential, generalist feeding behaviors, tolerance to chemical stressors such as low DO, and pioneering strategies that allow rapid recolonization following acute stressful events.

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Altered Energy Pathways in Urban Streams

The pathways of energy flow in streams are an important determinant of aquatic species distributions. In most natural temperate streams, headwaters transform and export energy from stream side vegetation and adjacent land uses into aquatic biomass. The types, amount, and timing of delivery of water, organic material, and debris have important consequences for conditions downstream (Dolloff and Webster, 2000). The energy-transforming aspect of stream ecosystems is difficult to capture directly, so most measures are surrogates, such as the trophic characteristics of assemblages and chemical and physical characteristics consistent with natural energy processes.

An increasingly urban landscape can have a complex array of effects on energy dynamics in streams (Allan, 2004). Loss of riparian areas and changes in riparian vegetation can reduce the supply and quality of coarse organic matter that forms the base of aquatic food webs in most small streams. The reduction in the amount of organic matter with riparian loss is obvious; however, changing species of vegetation (e.g., invasion or planting of exotic species) can affect the quality of organic matter and influence higher trophic levels because, for example, exotic species may have different nutrient values (e.g., C/N ratios, trace chemicals) or process nutrients at a different rate (Royer et al., 1999). Furthermore, native invertebrate taxa may not be adapted to utilize the exotic material (Miller and Boulton, 2005). For example, changes in leaf species in a stream may alter the macroinvertebrate community by favoring species that feed on fast-decaying versus slow-decaying leaves (Smock and MacGregor, 1988; Cummins et al., 1989; Gregory et al., 1991).

Other recent work is examining ways that changes in geomorphology with increasing urbanization can influence trophic structure in streams (Doyle, 2006). Groffman et al. (2005) examined nitrogen processing in stream geomorphic structures such as bars, riffles, and debris dams in suburban and forested areas. Although suburban areas had high rates of production in organic-rich debris dams and gravel bars, higher storm flow effects in urban streams may make these features less stable and able to be maintained (Groffman et al., 2005). Changes in habitat and riparian vegetation may greatly alter trophic patterns of energy transport. For example, local nutrient enrichments combined with reduced riparian vegetation can result in nuisance algal growths in waterbodies that are evidence of simpler energy pathways. Corresponding effects are further water chemistry changes from algal decomposition (e.g.., low DO) or very high algal activity (e.g., high pH) (Ehlinger et al., 2004).

The complexity of energy flow through simple ecosystems is illustrated in Figure 3-42, a “simplified” food web of a headwater stream published by Meyer (1994). The forms in which nutrients are delivered to streams may be more important than actual concentrations as well as the availability of carbon sources essential for nutrient transformation. The nutrient components that form the base of the food web in Figure 3-42 are the FPOM and CPOM boxes. In many natural streams, woody and leafy debris are the most common form of nutrient

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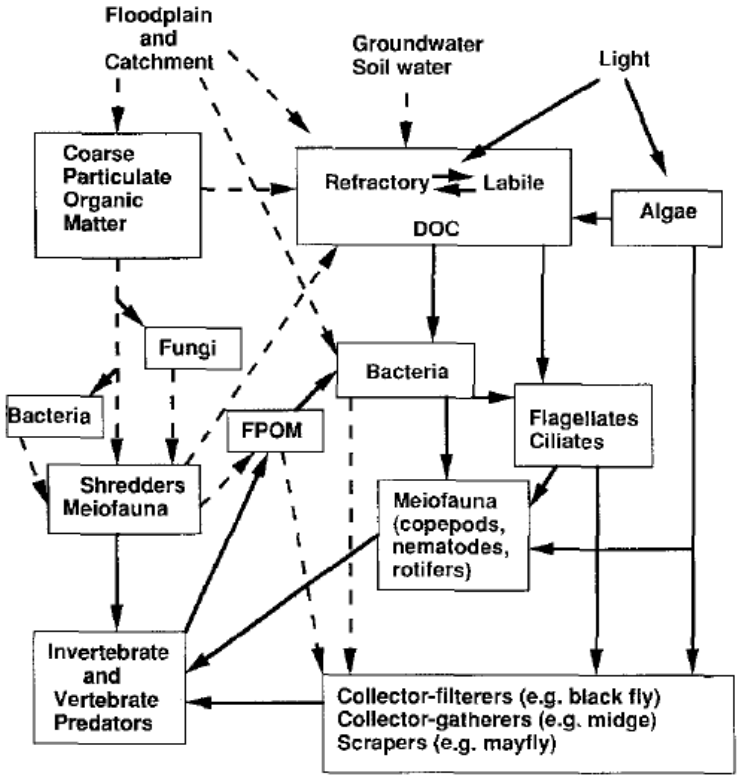

FIGURE 3-42 Simplified diagram of a lotic food web showing sources and major pathways of organic carbon. Dotted lines indicate flows that are a part of the microbial loop in flowing water but not in planktonic systems. SOURCE: Reprinted, with permission, from Meyer (1994). Copyright 1994 by Springer.

input, and changes to urban landscapes often change this to dissolved and finer forms. Urbanization can also reduce the retention of organic debris of streams (Groffman et al., 2005) and the timing of nutrient delivery. Timing can be of crucial importance since species spawning and growth periods may be specifically timed to take advantage of available nutrients.

As important as energy and nutrient dynamics are to stream function, many of the stream characteristics that determine effective energy flow are not typically considered when characterizing stormwater impacts. The best chance for considering these variables and maximizing ecosystem function is through inte-

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grated, biologically based monitoring programs that include urban areas (Barbour et al., 2008) and stressor identification procedures (EPA, 2000) to isolate likely causes of impact and to inform the choices of SCMs.

Biological Interactions in Urban Streams

Streams in urbanized environments often are characterized by fewer native and more alien species than natural streams (DeVivo, 1996; Meador et al., 2005). The influence of exotic species is not always predictable and may be most severe in lentic environments (e.g., wetlands, estuaries) and in riparian zones where various exotic aquatic plants can greatly alter natural systems in both structure and function (Hood and Naiman, 2000). Riley et al. (2005) foundthat the presence of alien aquatic amphibians was positively related to degree of urbanization, as was the absence of certain native amphibian species. In a review of possible reasons for this observation, he suggested that altered flow regimes were responsible. In the arid California streams they studied, flow became more constant with urbanization (i.e., natural streams were generally ephemeral), which allowed invasion by exotic species that can prey on, compete with, or hybridize with native species (Riley et al., 2005). The alteration of stream habitat that accompanies urbanization can also lead to predation by domestic cats and dogs or collection by humans, especially where species (e.g., California newts) are large and conspicuous (Riley et al., 2005).

The effects of specific exotic species on aquatic systems has been observed to vary geographically, although recent work has found correlations between total invasion rate and the number of high-impact exotic species (Ricciardi and Kipp, 2008). This suggests that overall efforts to reduce the importation or spread of all alien species should be helpful.

The Role of Biological Monitoring

The preceding sections illustrate the importance of biological data to understanding the complexities associated with urban and stormwater impacts to waterbodies. Although categories of urban stressors have been discussed individually, these stressors routinely, if not universally, co-occur in urban waterbodies. Their cumulative impacts are best measured with biological tools because the biota integrate the influence of all of these stressors.

Many programmatic aspects of the CWA arose as a response to rather obvious impacts of chemical pollutants that were occurring in surface waters during this time. The initial focus of water quality standards was on developing chemical criteria that could serve as engineering endpoints for waste treatment systems (e.g., NPDES permits). Rather general aquatic life goals for streams and rivers that were suitable for the initial focus of the CWA are now considered insufficient to deal with the complex suite of stressors limiting aquatic systems.

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To that end, refined aquatic life goals and improved biological monitoring are essential for effective water quality management, including stormwater issues (NRC, 2001). Practical biological and physical monitoring tools have even been developed for very small headwater streams (Ohio EPA, 2002; Fritz et al., 2006), which are particularly affected by stormwater because of their prevalence (greater than 95 percent of channels), their relatively high surface-to-volume ratio, their role in nutrient and material processing, and their vulnerability to direct modification such as channelization and piping (Meyer and Wallace, 2001).

Surrogate indicators of stormwater impacts to aquatic life (such as TSS concentrations) have been widely used because direct biological measures were poorly developed and these surrogates were assumed to be important to pollutant delivery to urban streams. However, biological assessment has rapidly advanced in many states and can be readily applied or if needed modified to be sensitive to stormwater stressors (Barbour et al., 2008). As Karr and Chu (1999) warned, the management of complex systems requires measures that integrate multiple factors. Stormwater permitting is no different, and care must be taken to ensure that permitting and regulatory actions retain ecological relevance. Surrogate measures have an essential role in the assessment of individual SCMs; however, this needs to be kept in context with the entire suite of stressors likely to be important to the aquatic life goals in streams.

Stormwater management programs should not necessarily bear the burden of biological monitoring; rather, well-conceived biological monitoring should be the prevue of state and local government agencies (as discussed more extensively in Chapter 6). Refined aquatic life goals developed for all waters, including urban waters, measured with appropriate biological measures, should be the final endpoint for management. The collection of biological data needs to be closely integrated across multiple disciplines in order to be effective. Pomeroy et al. (2008) describe a multidisciplinary approach to study the effects of stormwater in urban settings, and Scholz and Booth (2001) also propose a monitoring approach for urban watersheds. Such efforts are not necessarily easy, and many institutions find pitfalls when trying to integrate scientific information across disciplines (Benda et al., 2002).

EPA water programs, such as the Total Maximum Daily Load (TMDL) program, have been criticized for having too narrow a focus on a limited number of traditional pollutants to the exclusion of important stressors such as hydrology, habitat alteration, and invasive taxa (Karr and Yoder, 2004)—all serious problems associated with stormwater and urbanization. The science has advanced significantly over the past decade so that biological assessment should be an essential tool for identifying stormwater impacts and informing the choice of SCMs in a region or watershed. Although biological responses to stressors in the ambient environment are by their nature correlative exercises, ecological epidemiology principles or "stressor identification" methods can identify likely causative agents of impairment with relatively high certainty in many instances (Suter, 1993, 2006; EPA, 2000). Coupled with other ambient and source moni-

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toring information, biological information can form the basis for an effective stormwater program. As an example, Box 3-10 introduces the Impervious Cover Model (ICM), which was developed using correlative information on the association between impervious cover and biological metrics. The crux of the ICM is that stormwater management is tailored along a readily measureable gradient (impervious cover) that integrates multiple individual stressor categories that would otherwise be overlooked in the traditional pollutant-based approach to stormwater management. Even the form of the ICM (as conceptualized in Figure 3-43) matches that outlined for the BCG (Figure 3-38). Use of the ICM to improve the MS4 stormwater program is discussed in Chapter 6.

Human Health Impacts

Despite the unequivocal evidence of ecosystem consequences resulting from urban stormwater, a formal risk analysis of the human health effects associated with stormwater runoff is not yet possible. This is because (1) many of the most important waterborne pathogens have not been quantified in stormwater, (2) enumeration methods reported in the current literature are disparate and do not account for particle-bound pathogens, and (3) sampling times during storms have not been standardized nor are known to have occurred during periods of human exposure. Individual studies have investigated the runoff impacts on public health in freshwater (Calderon et al., 1991) and marine waters (Haile et al., 1999; Dwight et al,. 2004; Colford et al., 2007). Although these studies provide ample evidence that stormwater runoff can serve as a vector of pathogens with potential health implications (for example, Ahn et al., 2005, found that fecal indicator bacteria concentrations could exceed California ocean bathing water standards by up to 500 percent in surf zones receiving stormwater runoff), it is difficult to draw conclusive inferences about the specific human health impacts from microbial contamination of stormwater. Calderon et al. (1991) concluded that the currently recommended bacterial indicators are ineffective for predicting potential health effects associated with water contaminated by nonpoint sources of fecal pollution. Furthermore, in a study conducted in Mission Bay, California, which analyzed bacterial indicators using traditional and nontraditional methods (chromogenic substrate and quantitative polymerase chain reaction), as well as a novel bacterial indicator and viruses, traditional fecal indicators were not associated with identified human health risks such as diarrhea and skin rash (Colford et al., 2007).

The Santa Monica Bay study (Haile et al., 1999) indicated that the risks of several health outcomes were higher for people who swam at storm-drain locations compared to those who swam farther from the drain. However, the list of health outcomes that were more statistically significant (fever, chills, ear discharge, cough and phlegm, and significant respiratory) did not include highly

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BOX 3-10
The Impervious Cover Model: An Emerging Framework for Urban Stormwater Management

The Impervious Cover Model (ICM) is a management tool that is useful for diagnosing the severity of future stream problems in a subwatershed. The ICM defines four categories of urban streams based on how much impervious cover exists in their subwatershed: *high-quality streams*, *impacted streams, non-supporting streams,* and *urban drainage*. The ICM is then used to develop specific quantitative or narrative predictions for stream indicators within each stream category (see Figure 3-43). These predictions define the severity of current stream impacts and the prospects for their future restoration. Predictions are made for five kinds of urban stream impacts: changes in stream hydrology, alteration of the stream corridor, stream habitat degradation, declining water quality, and loss of aquatic diversity.

The general predictions of the ICM are as follows. Stream segments with less than 10 percent impervious cover (IC) in their contributing drainage area continue to function as **Sensitive Streams**, and are generally able to retain their hydrologic function and support good-to-excellent aquatic diversity. Stream segments that have 10 to 25 percent IC in their contributing drainage area behave as **Impacted Streams** and show clear signs of declining stream health. Most indicators of stream health will fall in the fair range, although some segments may range from fair to good as riparian cover improves. The decline in stream quality is greatest toward the higher end of the IC range. Stream segments that range between 25 and 60 percent subwatershed impervious cover are classified as **Non-Supporting Streams** (i.e., no longer supporting their designated uses in terms of hydrology, channel stability habitat, water quality, or biological diversity). These stream segments become so degraded that any future stream restoration or riparian cover improvements are insufficient to fully recover stream function and diversity (i.e., the streams are so dominated by subwatershed IC that they cannot attain predevelopment conditions). Stream segments whose subwatersheds exceed 60 percent IC are physically altered so that they merely function as a conduit for flood waters. These streams are classified as **Urban Drainage** and consistently have poor water quality, highly unstable channels, and very poor habitat and biodiversity scores. In many cases, these urban stream segments are eliminated altogether by earthworks and/or storm-drain enclosure. Table 3-14 shows in greater detail how stream corridor indicators respond to greater subwatershed impervious cover.

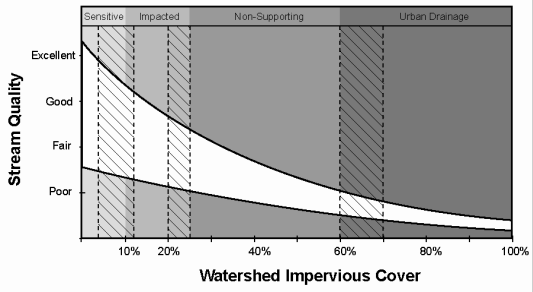

FIGURE 3-43 Changes in Stream Quality with Percent Impervious Cover in the Contributing Watershed. SOURCE: Chesapeake Stormwater Network (2008). Reprinted, with permission, from Chesapeake Stormwater Network (2008). Copyright 2008 by Chesapeake Stormwater Network.

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TABLE 3-14 General ICM Predictions Based on Urban Subwatershed Classification (CWP, 2004):

Prediction	Impacted (IC 11 to 25%) [8]	Non-supporting (IC 26 to 60%)	Urban Drainage (IC > 60%)
Runoff as a Fraction of Annual Rainfall [1]	10 to 20%	25 to 60%	60 to 90%
Frequency of Bankfull Flow per Year [2]	1.5 to 3 per year	3 to 7 per year	7 to 10 per year
Fraction of Original Stream Network Remaining	60 to 90%	25 to 60%	10 to 30%
Fraction of Riparian Forest Buffer Intact	50 to 70%	30 to 60%	Less than 30%
Crossings per Stream Mile	1 to 2	2 to 10	None left
Ultimate Channel Enlargement Ration [3]	1.5 to 2.5 larger	2.5 to 6 times larger	6 to 12 times larger
Typical Stream Habitat Score	Fair, but variable	Consistently poor	Poor, often absent
Increased Stream Warming [4]	2 to 4 °F	4 to 8 °F	8+ °F
Annual Nutrient Load [5]	1 to 2 times higher	2 to 4 times higher	4 to 6 times higher
Wet Weather Violations of Bacteria Standards	Frequent	Continuous	Ubiquitous
Fish Advisories	Rare	Potential risk of accumulation	Should be presumed
Aquatic Insect Diversity [6]	Fair to good	Fair	Very poor
Fish Diversity [7]	Fair to good	Poor	Very poor

[1] Based on annual storm runoff coefficient; ranges from 2 to 5% for undeveloped streams.
[2] Predevelopment bankfull flood frequency is about 0.5 per year, or about one bankfull flood every two years.
[3] Ultimate stream-channel cross-section compared to typical predevelopment channel cross section.
[4] Typical increase in mean summer stream temperature in degrees Fahrenheit, compared with shaded rural stream.
[5] Annual unit-area stormwater phosphorus and/or nitrogen load produced from a rural subwatershed.
[6] As measured by benthic index of biotic integrity. Scores for rural streams range from good to very good.
[7] As measured by fish index of biotic integrity. Scores for rural streams range from good to very good.
[8] IC is not the strongest indicator of stream health below 10% IC, so the sensitive streams category is omitted from this table.
SOURCE: Adapted from Schueler (2004).

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BOX 3-10 Continued

Scientific Support for the ICM

The ICM predicts that hydrological, habitat, water quality, and biotic indicators of stream health first begin to decline sharply at around 10 percent total IC in smaller catchments (Schueler, 1994). The ICM has since been extensively tested in ecoregions around the United States and elsewhere, with more than 200 different studies confirming the basic model for single stream indicators or groups of stream indicators (CWP, 2003; Schueler, 2004). Several recent research studies have reinforced the ICM as it is applied to first- to third-order streams (Coles et al., 2004; Horner et al., 2004; Deacon et al., 2005; Fitzpatrick et al., 2005; King et al., 2005; McBride and Booth, 2005; Cianfrina et al., 2006; Urban et al., 2006; Schueler et al., 2008).

Researchers have focused their efforts to define the specific thresholds where urban stream degradation first begins. There is robust debate as to whether there is a sharp initial threshold or merely a continuum of degradation as IC increases, although the latter is more favored. There is much less debate, however, about the dominant role of IC in defining the hydrologic, habitat, water quality, and biodiversity expectations for streams with higher levels of IC (15 to 60 percent).

Caveats to the ICM

The ICM is a powerful predictor of urban stream quality when used appropriately. The first caveat is that subwatershed IC is defined as total impervious area (TIA) and not effective impervious area (EIA). Second, the ICM should be restricted to first- to third-order alluvial streams with moderate gradient and no major point sources of pollutant discharge. The ICM is most useful in projecting the behavior of numerous stream health indicators, and it is not intended to be accurate for every individual stream indicator. In addition, management practices in the contributing catchment or subwatershed must not be poor (e.g., no deforestation, acid mine drainage, intensive row crops, etc.); just because a subwatershed has less than 10 percent IC does not automatically mean that it will have good or excellent stream quality if past catchment management practices were poor.

ICM predictions are general and may not apply to every stream within the proposed classifications. Urban streams are notoriously variable, and factors such as gradient, stream order, stream type, age of subwatershed development, and past land use can and will make some streams depart from these predictions. Indeed, these “outlier” streams are extremely interesting from the standpoint of restoration. In general, subwatershed IC causes a continuous but variable decline in most stream corridor indicators. Consequently, the severity of individual indicator impacts tends to be greater at the upper end of the IC range for each stream category.

Effects of Catchment Treatment on the ICM

Most studies that investigated the ICM were done in communities with some degree of catchment treatment (e.g., stormwater management or stream buffers). Detecting the effect of catchment treatment on the ICM involves a very complex and difficult paired watershed design. Very few catchments meet the criteria for either full treatment or the lack of it,

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no two catchments are ever really identical, and individual catchments exhibit great variability from year to year. Not surprisingly, the first generation of research studies has produced ambiguous results. For example, seven research studies showed that ponds and wetlands are unable to prevent the degradation of aquatic life in downstream channels associated with higher levels of IC (Galli, 1990; Jones et al., 1996; Horner and May, 1999; Maxted, 1999; MNCPPC, 2000; Horner et al., 2001; Stribling et al., 2001). The primary reasons cited are stream warming (amplified by ponds), changes in organic matter processing, the increased runoff volumes delivered to downstream channels, and habitat degradation caused by channel enlargement.

Riparian forest cover is defined as canopy cover within 100 meters of the stream, and is measured as the percentage of the upstream network in this condition. Numerous researchers have evaluated the relative impact of riparian forest cover and IC on stream geomorphology, aquatic insects, fish assemblages, and various indices of biotic integrity. As a group, the studies suggest that indicator values for urban streams improve when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Booth et al., 2002; Morley and Karr, 2002; Wang et al., 2003; Allan, 2004; Sweeney et al., 2004; Moore and Palmer, 2005; Cianfrina et al., 2006; Urban et al., 2006).

Application of the ICM to other Receiving Waters

Recent research has focused on the potential value of the ICM in predicting the future quality of receiving waters such as tidal coves, lakes, wetlands and small estuaries. The primary work on small estuaries by Holland et al. (2004) [references cited in CWP (2003), Lerberg et al. (2000)] indicates that adverse changes in physical, sediment, and water quality variables can be detected at 10 to 20 percent subwatershed IC, with a clear biological response observed in the range of 20 to 30 percent IC. The primary physical changes involve greater salinity fluctuations, greater sedimentation, and greater pollutant contamination of sediments. The biological response includes declines in diversity of benthic macroinvertebrates, shrimp, and finfish.

More recent work by King et al. (2005) reported a biological response for coastal plain streams at around 21 to 32 percent urban development (which is usually about twice as high as IC). The thresholds for important water quality indicators such as bacterial exceedances in shellfish beds and beaches appears to begin at about 10 percent subwatershed IC, with chronic violations observed at 20 percent IC (Mallin et al., 2001). Algal blooms and anoxia resulting from nutrient enrichment by stormwater runoff also are routinely noted at 10 to 20 percent subwatershed IC (Mallin et al., 2004).

The primary conclusion to be drawn from the existing science is that the ICM does apply to tidal coves and streams, but that the impervious levels associated with particular biological responses appear to be higher (20 to 30 percent IC for significant declines) than for freshwater streams, presumably due to their greater tidal mixing and inputs from nearshore ecosystems. The ICM may also apply to lakes (CWP, 2003) and freshwater wetlands (Wright et al., 2007) under carefully defined conditions. The initial conclusion is that the application of the ICM shows promise under special conditions, but more controlled research is needed to determine if IC (or other watershed metrics) is useful in forecasting receiving water quality conditions.

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BOX 3-10 Continued

Utility of the ICM in Urban Stream Classification and Watershed Management

The ICM is best used as an urban stream classification tool to set reasonable expectations for the range of likely stream quality indicators (e.g., physical, hydrologic, water quality, habitat, and biological diversity) over broad ranges of subwatershed IC. In particular, it helps define general thresholds where water quality standards or biological narrative conditions cannot be consistently met during wet weather conditions (see Table 6-2). These predictions help stormwater managers and regulators to devise appropriate and geographically explicit stormwater management and subwatershed restoration strategies for their catchments as part of MS4 permit compliance. More specifically, assuming that local monitoring data are available to confirm the general predictions of the ICM, it enables managers to manage stormwater within the context of current and future watershed conditions.

credible gastrointestinal illness, which is curious because the vast majority of epidemiological studies worldwide suggests a causal dose-related relationship between gastrointestinal symptoms and recreational water quality measured by bacterial indicator counts (Pruss, 1998). Dwight et al. (2004) found that surfers in an urban environment reported more symptoms than their rural counterparts; however, water quality was not specifically evaluated in that study.

To better assess the relationship between swimming in waters contaminated by stormwater, which have not been influenced by human sewage, and the risk of related illness, the California Water Boards and the City of Dana Point have initiated an epidemiological study. This study will be conducted at Doheny Beach, Orange County, California, which is a beach known to have high fecal indicator bacteria concentrations with no known human source. The project will examine new techniques for measuring traditional fecal indicator bacteria, new species of bacteria, and viruses to determine whether they yield a better relationship to human health outcomes than the indicators presently used in California. The study is expected to be completed in 2010. In addition, the State of California is researching new methods for rapid detection of beach bacterial indicators and ways to bring these methods into regular use by the environmental monitoring and public health communities to better protect human health.

CONCLUSIONS AND RECOMMENDATIONS

The present state of the science of stormwater reflects both the strengths and weaknesses of historic, monodisciplinary investigations. Each of the component disciplines—hydrology, geomorphology, aquatic chemistry, ecology, land use, and population dynamics—have well-tested theoretical foundations and useful predictive models. In particular, there are many correlative studies showing how parameters co-vary in important but complex and poorly understood ways (e.g., changes in fish community associated with watershed road

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density or the percentage of IC). Nonetheless, efforts to create mechanistic links between population growth, land-use change, hydrologic alteration, geomorphic adjustments, chemical contamination in stormwater, disrupted energy flows, and biotic interactions, to changes in ecological communities are still in development. Despite this assessment, there are a number of overarching truths that remain poorly integrated into stormwater management decision making, although they have been robustly characterized and have a strong scientific basis. These are expanded upon below.

There is a direct relationship between land cover and the biological condition of downstream receiving waters. The possibility for the highest levels of aquatic biological condition exists only with very light urban transformation of the landscape. Even then, alterations to biological communities have been documented at such low levels of imperviousness, typically associated with roads and the clearing of native vegetation, that there has been no real "urban development" at all. Conversely, the lowest levels of biological condition are inevitable with extensive urban transformation of the landscape, commonly seen after conversion of about one-third to one-half of a contributing watershed into impervious area. Although not every degraded waterbody is a product of intense urban development, all highly urban watersheds produce severely degraded receiving waters. Because of the close and, to date, inexorable linkage between land cover and the health of downstream waters, stormwater management is an unavoidable offshoot of watershed-based land-use planning (or, more commonly, its absence).

The protection of aquatic life in urban streams requires an approach that incorporates all stressors. Urban Stream Syndrome reflects a multitude of effects caused by altered hydrology in urban streams, altered habitat, and polluted runoff. Focusing on only one of these factors is not an effective management strategy. For example, even without noticeably elevated pollutant concentrations in receiving waters, alterations in their hydrologic regimes are associated with impaired biological condition. Achieving the articulated goals for stormwater management under the CWA will require a balanced approach that incorporates hydrology, water quality, and habitat considerations.

The full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. Permanently increased stormwater volume is only one aspect of an urban-altered storm hydrograph. It contributes to high in-stream velocities, which in turn increase streambank erosion and accompanying sediment pollution of surface water. Other hydrologic changes, however, include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These all can affect both the physical and biological conditions of streams, lakes, and wetlands. Thus, effective hydrologic mitigation for urban development cannot just

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aim to reduce post-development peak flows to predevelopment peak flows.

A single design storm cannot adequately capture the variability of rain and how that translates into runoff or pollutant loadings, and thus is not suitable for addressing the multiple objectives of stormwater management. Of particular importance to the types of problems associated with urbanization is the size of rain events. The largest and most infrequent rains cause near-bankfull conditions and may be most responsible for habitat destruction; these are the traditional "design storms" used to design safe drainage systems. However, moderate-sized rains are more likely to be associated with most of the annual mass discharges of stormwater pollutants, and these can be very important to the eutrophication of lakes and nearshore waters. Water quality standards for bacterial indicators and total recoverable heavy metals are exceeded for almost *every* rain in urban areas. Therefore, the whole distribution of storm size needs to be evaluated for most urban receiving waters because many of these problems coexist.

Roads and parking lots can be the most significant type of land cover with respect to stormwater. They constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in these highly impervious areas because of their close proximity to the variety of pollutants associated with automobiles. This is especially true in areas of the country having mostly small rainfall events (as in the Pacific Northwest). As rainfall amounts become larger, pervious areas in most residential land uses become more significant sources of runoff, sediment, nutrients, and landscaping chemicals. In all cases, directly connected impervious surfaces (roads, parking lots, and roofs that are directly connected to the drainage system) produce the first runoff observed at a storm-drain inlet and outfall because their travel times are the quickest.

Generally, the quality of stormwater from urbanized areas is well characterized, with the common pollutants being sediment, metals, bacteria, nutrients, pesticides, trash, and polycyclic aromatic hydrocarbons. These results come from many thousands of storm events from across the nation, systematically compiled and widely accessible; they form a robust data set of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate pollutant concentrations, which have been shown to vary by land cover and by region across the country. However, characterization data are relatively sparse for individual industrial operations, which makes these sources less amenable to generalized approaches based on reliable assumptions of pollutant types and loads. In addition, industrial operations vary greatly from site to site, such that it may be necessary to separate them into different categories in order to better understand industrial stormwater quality.

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Nontraditional sources of stormwater pollution must be taken into consideration when assessing the overall impact of urbanization on receiving waterbodies. These nontraditional sources include atmospheric deposition, snowmelt, and dry weather discharges, which can constitute a significant portion of annual pollutant loadings from storm systems in urban areas (such as metals in Los Angeles). For example, atmospheric deposition of metals is a very significant component of contaminant loading to waterbodies in the Los Angeles region relative to other point and nonpoint sources. Similarly, much of the sediment found in receiving waters following watershed urbanization can come from streambank erosion as opposed to being contributed by polluted stormwater.

Biological monitoring of waterbodies is critical to better understanding the cumulative impacts of urbanization on stream condition. Over 25 years ago, individual states developed the concept of regional reference sites and developed multi-metric indices to identify and characterize degraded aquatic assemblages in urban streams. Biological assessments respond to the range of non-chemical stressors identified as being important in urban waterways including habitat degradation, hydrological alterations, and sediment and siltation impacts, as well as to the influence of nutrients and other chemical stressors where chemical criteria do not exist or where their effects are difficult to measure directly (e.g., episodic stressors). The increase in biological monitoring has also helped to frame issues related to exotic species, which are locally of critical importance but completely unrecognized by traditional physical monitoring programs.

Epidemiological studies on the human health risks of swimming in freshwater and marine waters contaminated by urban stormwater discharges in temperate and warm climates are needed. Unlike with aquatic organisms, there is little information on the health risks of urban stormwater to humans. Standardized watershed assessment methods to identify the sources of human pathogens and indicator organisms in receiving waters need to be developed, especially for those waters with a contact-recreation use designation that have had multiple exceedances of pathogen or indicator criteria in a relatively short period of time. Given their difficulty and expense, epidemiological studies should be undertaken only after careful characterization of water quality and stormwater flows in the study area.

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4
Monitoring and Modeling

As part of its statement of task, the committee was asked to consider several aspects of stormwater monitoring, including how useful the activity is, what should be monitored and when and where, and how benchmarks should be established. As noted in Chapter 2, the stormwater monitoring requirements under the U.S. Environmental Protection Agency (EPA) stormwater program are variable and generally sparse, which has led to considerable skepticism about their usefulness. This chapter first considers the value of the data collected over the years by municipalities and makes suggestions for improvement. It then does the same for industrial stormwater monitoring, which has lagged behind the municipal separate storm sewer system (MS4) program both in requirements and implementation.

It should be noted upfront that this chapter does not discuss the fine details of MS4 and industrial monitoring that pertain to regulatory compliance—questions such as should the average end of pipe concentrations meet water quality standards, how many exceedances should be allowed per year, or should effluent concentrations be compared to acute or chronic criteria. Individual benchmarks and effluent limits for specific chemicals emanating from specific industries are not provided. The current state of MS4 and industrial stormwater monitoring and the paucity of high quality data are such that it is premature and in many cases impossible to make such determinations. Rather, the chapter suggests both *how* to monitor an individual industry and *how* to determine benchmarks and effluent limits for industrial categories. It suggests how monitoring requirements should be tailored to accommodate the risk level of an individual industrial discharger. Finally, it makes numerous technical suggestions for improving the monitoring of MS4s, building on the data already submitted and analyzed as part of the National Stormwater Quality Database. Policy recommendations about the monitoring of both industries and MS4s are found in Chapter 6.

This chapter's emphasis on monitoring of stormwater should not be interpreted as a disinterest in other types of monitoring, such as biomonitoring of receiving waters, precipitation measurements, or determination of land cover. Indeed, these latter activities are extremely important (they are introduced in the preceding chapter) and they underpin the new permitting program proposed in Chapter 6 (especially biological monitoring). Stormwater management would benefit most substantially from a well-balanced monitoring program that encompasses chemical, biological, and physical parameters from outfalls to receiving waters. Currently, however, decisions about stormwater management are usually made with incomplete information; for example, there are continued recommendations by many that street cleaning will solve a municipality's problems, even when the municipality does not have any information on the sources of the material being removed.

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A second charge to the committee was to define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria. As described in Chapter 3, many processes connect sources of pollution to an effect observed in a downstream receiving water. More and more, these processes can be represented in watershed models, which are the key to linking stormwater sources to effects observed in receiving waters. The latter half of the chapter explores the current capability of models to make such links, including simple models, statistical and conceptual models, and more involved mechanistic models. At the present time, associating a single discharger with degraded in-stream conditions is generally not possible because of the state of both modeling and monitoring of stormwater.

MONITORING OF MS4s

EPA's regulations for stormwater monitoring of MS4s is very limited, in that only the application requirements are stated [see 40 CFR § 122.26(d)]. The regulations require the MS4 program to identify five to ten stormwater discharge outfalls and to collect representative stormwater data for conventional and priority toxic pollutants from three representative storm events using both grab and composite sampling methods. Each sampled storm event must have a rainfall of at least 0.1 inch, must be preceded by at least 72 hours of a dry period, and the rain event must be within 50 percent of the average or median of the per storm volume and duration for the region. While the measurement of flow is not specifically required, an MS4 must make estimates of the event mean concentrations (EMCs) for pollutants discharged from all outfalls to surface waters, and in order to determine EMCs, flow needs to be measured or calculated.

Other than these requirements, the exact type of MS4 monitoring that is to be conducted during the permit term is left to the discretion of the permitting authority. EPA has not issued any guidance on what would be considered an adequate MS4 monitoring program for permitting authorities to evaluate compliance. Some guidance for MS4 monitoring based on desired management questions has been developed locally (for example, see the SCCWRP Technical Report No. 419, SMC 2004, Model Monitoring Program for MS4s in Southern California).

In the absence of national guidance from EPA, the MS4 monitoring programs for Phase I MS4s vary widely in structure and objectives, and Phase II MS4 programs largely do not perform any monitoring at all. The types of monitoring typically contained in Phase I MS4 permits include the (1) wet weather outfall screening and monitoring to characterize stormwater flows, (2) dry weather outfall screening and monitoring under illicit discharge detection and elimination programs, (3) biological monitoring to determine storm water impacts, (4) ambient water quality monitoring to characterize water quality conditions, and (5) stormwater control measure (SCM) effectiveness monitoring.

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The Nationwide Stormwater Quality Database

Stormwater monitoring data collected by a portion of Phase I MS4s has been evaluated for years by the University of Alabama and the Center for Watershed Protection and compiled in a database called the Nationwide Stormwater Quality Database (NSQD). These data were collected in order to describe the characteristics of stormwater on a national level, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas with limited data. The MS4 monitoring data collected over the past ten years from more than 200 municipalities throughout the country have great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. Version 3 of the NSQD is available online at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml. It contains data from more than 8,500 events and 100 municipalities throughout the country. About 5,800 events are associated with homogeneous land uses, while the remainder are for mixed land uses.

The general approach to data collection was to contact EPA regional offices to obtain state contacts for the MS4 data, then the individual municipalities with Phase I permits were targeted for data collection. Selected outfall data from the International BMP Database were also included in NSQD version 3, eliminating any source area and any treated stormwater samples. Some of the older National Urban Runoff Program (NURP) (EPA, 1983) data were also included in the NSQD, along with some data from specialized U.S. Geological Survey (USGS) stormwater monitoring activities in order to better represent nationwide conditions and additional land uses. Because there were multiple sources of information, quality assurance and quality control reviews were very important to verify the correctness of data added to the database, and to ensure that no duplicate entries were added.

The NSQD includes sampling location information such as city, state, land use, drainage area, and EPA Rain Zone, as well as date, season, and rain depth. The constituents commonly measured for in stormwater include total suspended solids (TSS), 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrite plus nitrate (NO_2+NO_3), total copper (Cu), total lead (Pb), and total zinc (Zn). Less information is available for many other constituents (including filterable heavy metals and bacteria). Figure 4-1 is a map showing the EPA Rain Zones in the United States, along with the locations of the communities contributing to the NSQD, version 3. Table 4-1 shows the number of samples for each land use and for each Rain Zone. This table does not show the number of mixed land-use site samples. Rain Zones 8 and 9 have very few samples, and institutional and open-space areas are poorly represented. However, residential, commercial, industrial, and freeway data are plentiful, except for the few Rain Zones noted above.

Land use has an important impact on the quality of stormwater. For example, the concentrations of heavy metals are higher for industrial land-use areas

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TABLE 4-1 Number of Samples per Land Use and EPA Rain Zone

Single Land Use	1	2	3	4	5	6	7	8	9	Total
Commercial	234	484	131	66	42	37	64	0	22	1080
Freeways	0	241	14	0	262	189	28	0	0	734
Industrial	100	327	90	51	83	74	146	0	22	893
Institutional	9	46	0	0	0	0	0	0	0	55
Open Space	68	37	0	18	0	2	0	0	0	125
Residential	294	1470	290	122	105	32	532	7	81	2933
Total	705	2605	525	257	492	334	770	7	125	5820

Note: there are no mixed-use sites in this table. SOURCE: National Stormwater Quality Database.

due to manufacturing processes and other activities that generate these materials. Fecal coliform concentrations are relatively high for residential and mixed residential land uses, and nitrate concentrations are higher for the freeway land use. Open-space land-use areas show consistently low concentrations for the constituents examined. Seasons could also be a factor in the variation of nutrient concentrations in stormwater due to seasonal uses of fertilizers and leaf drop occurring during the fall season. Most studies also report lower bacteria concentrations in the winter than in the summer. Lead concentrations in stormwater have also significantly decreased since the elimination of lead in gasoline (see Figure 2-6). Most of the statistical tests used are multivariate statistical evaluations that compare different constituent concentrations with land use and geographical location. More detailed discussions of the earlier NSQD results are found in various references, including Maestre et al. (2004, 2005) and Pitt et al. (2003, 2004).

How to use the NSQD to Calculate Representative EMC Values

EMC values were initially used during the NURP to describe typical concentrations of pollutants in stormwater for different monitoring locations and land uses. An EMC is intended to represent the average concentration for a single monitored event, usually based on flow-weighted composite sampling. It can also be calculated from discrete samples taken during an event if flow data are also available. Many individual subsamples should be taken throughout most of the event to calculate the EMC for that event. Being an overall average value, an EMC does not represent possible extremes that may occur during an event.

The NSQD includes individual EMC values from about 8,500 separate events. Stormwater managers typically want a representative single value for a land use for their area. As such, they typically evaluate a series of individual

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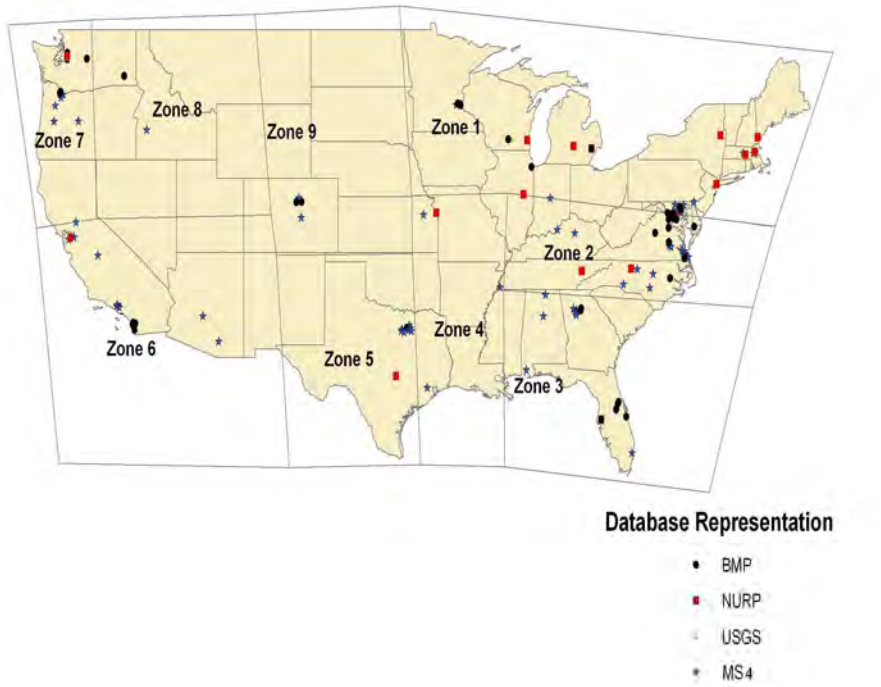

FIGURE 4-1 Sampling Locations for Data Contained in the National Stormwater Quality Database, version 3.

storm EMC values for conditions similar to those representing their site of concern. With the NSQD in a spreadsheet form, it is relatively simple to extract suitable events representing the desired conditions. However, the individual EMC values will likely have a large variability. Maestre and Pitt (2006) reviewed the NSQD data to better explain the variability according to different site and sampling conditions (land use, geographical location, season, rain depth, amount of impervious area, sampling methods, antecedent dry period, etc.). The most common significant factor was land use, with some geographical and fewer seasonal effects observed. As with the original NURP data, EMCs in the NSQD are usually expressed using medians and coefficients of variation to reflect uncertainty, assuming lognormal distributions of the EMC values. Figure 4-2 shows several lognormal probability plots for a few constituents from the NSQD. Probability plots shown as straight lines indicate that the concentrations can be represented by lognormal distributions (see Box 4-1).

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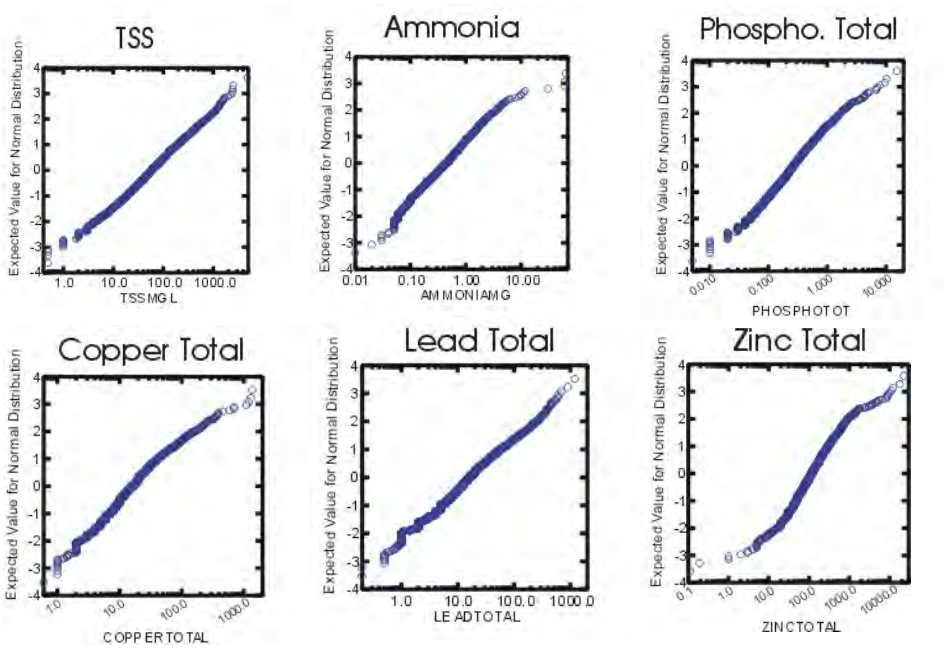

FIGURE 4-2 Lognormal probability plots of stormwater quality data for selected constituents (pooled data from NSQD version 1.1).

Fitting a known distribution is important as it helps indicate the proper statistical tests that may be conducted. Using the *median* EMC value in load calculations, without considering the data variability, will result in smaller mass loads compared to actual monitored conditions. This is due to the medians underrepresenting the larger concentrations that are expected to occur. The use of *average* EMC values will represent the larger values better, although they will still not represent the variability likely to exist. If all of the variability cannot be further explained adequately (such as being affected by rain depth), which would be highly unlikely, then a set of random calculations (such as that obtained using Monte Carlo procedures) reflecting the described probability distribution of the constituents would be the best method to use when calculating loads.

Municipal Monitoring Issues

As described in Chapter 2, typical MS4 monitoring requirements involve sampling during several events per year at the most common land uses in the area. Obviously, a few samples will not result in very useful data due to

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BOX 4-1
Probability Distributions of Stormwater Data

The coefficient of variation (COV) values for many constituents in the NSQD range from unusually low values of about 0.1 (for pH) to highs between 1 and 2. One objective of a data analysis procedure is to categorize the data into separate stratifications, each having small variations in the observed concentrations. The only stratification usually applied is for land use. However, further analyses indicated many differences by geographical area and some differences by season. When separated into appropriate stratifications, the COV values are reduced, ranging between about 0.5 to 1.0. With a reasonable confidence of 95 percent (α= 0.05) and power of 80 percent (β= 0.20), and a suitable allowable error goal of 25 percent, the number of samples needed to characterize these conditions would therefore range from about 25 to 50 (Burton and Pitt, 2002). In a continuing monitoring program (such as the Phase I stormwater National Pollutant Discharge Elimination System [NPDES] permit monitoring effort) characterization data will improve over time as more samples are obtained, even with only a few samples collected each year from each site.

Stormwater managers have generally accepted the assumption of lognormality of stormwater constituent concentrations between the 5th and 95th percentiles. Based on this assumption, it is common to use the log-transformed EMC values to evaluate differences between land-use categories and other characteristics. Statistical inference methods, such as estimation and tests of hypothesis, and analysis of variance, require statistical information about the distribution of the EMC values to evaluate these differences. The use of the log-transformed data usually includes the location and scale parameter, but a lower-bound parameter is usually neglected.

Maestre et al. (2005) conducted statistical tests using NSQD data to evaluate the lognormality assumptions of selected common constituents. It was found in almost all cases that the log-transformed data followed a straight line between the 5th and 95th percentile, as illustrated in Figure 4-3 for total dissolved solids (TDS) in residential areas.

For many statistical tests focusing on the central tendency (such as for determining the concentrations that are to be used for mass balance calculations), this may be a suitable fit. As an example, the model WinSLAMM (Pitt, 1986; Pitt and Voorhees, 1995) uses a Monte Carlo component to describe the likely variability of stormwater source flow pollutant concentrations using either lognormal or normal probability distributions for each constituent. However, if the most extreme values are of importance, such as when dealing with the influence of many non-detectable values on the predicted concentrations, or determining the frequency of observations exceeding a numerical standard, a better description of the extreme values may be important.

The NSQD contains many factors for each sampled event that likely affect the observed concentrations. These include such factors as seasons, geographical zones, and rain intensities. These factors may affect the shape of the probability distribution. The only way to evaluate the required number of samples in each category is by using the power of the test, where power is the probability that the test statistic will lead to a rejection of the null hypothesis (Gibbons and Chakraborti, 2003).

In the NSQD, most of the data were from residential land uses. The Kolmogorov-Smirnov test was used to indicate if the cumulative empirical probability distribution of the residential stormwater constituents can be adequately represented with a lognormal distribution. The number of collected samples was sufficient to detect if the empirical distribu-

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BOX 4-1 Continued

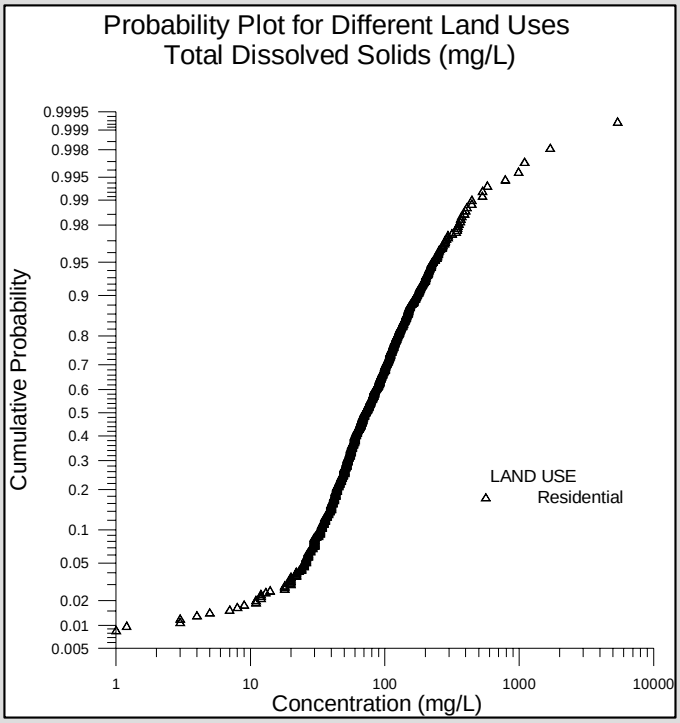

FIGURE 4-3 Probability plot of total dissolved solids in residential land uses (NSQD version 1.1 data).

tion was located inside an interval of width 0.1 above and below the estimated cumulative probability distribution. If the interval was reduced to 0.05, the power varies between 40 and 65 percent. Another factor that must be considered is the importance of relatively small errors in the selected distribution and the problems of false-negative determinations. It may not be practical to collect as many data observations as needed when the distributions are close. Therefore, it is important to understand what types of further statistical and analysis problems may be caused by having fewer samples than optimal. For example, Figure 4-4 (total phosphorus in residential areas) shows that most of the data fall along the straight line (indicating a lognormal fit), with fewer than 10 observations (out of 933) in the tails being outside of the obvious path of the line, or a false-negative rate of about 0.01 (1 percent).

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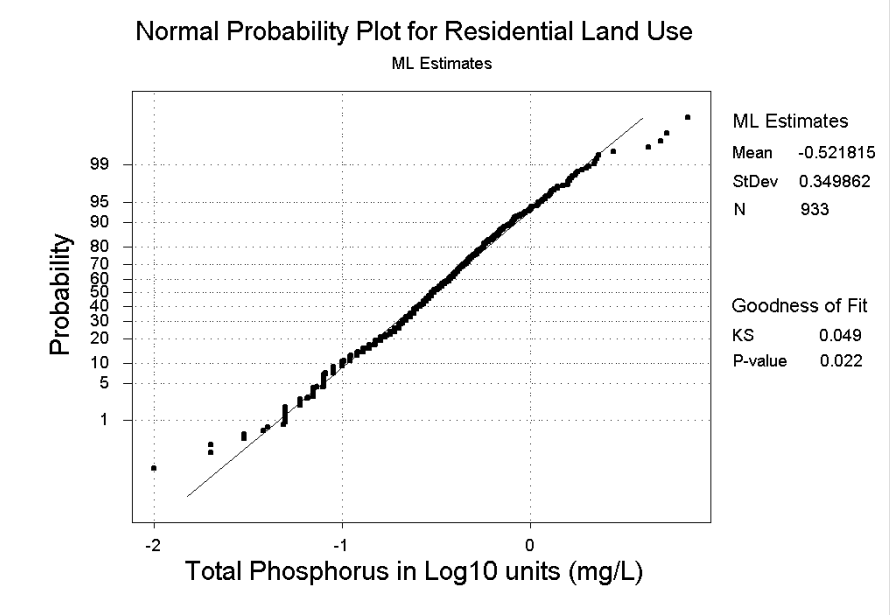

FIGURE 4-4 Normality test for total phosphorus in residential land uses using the NSQD.

Further analyses to compare the constituent concentration distributions to other common probability distributions (normal, lognormal, gamma, and exponential) were also conducted for all land uses by Maestre et al. (2004). Most of the stormwater constituents can be assumed to follow a lognormal distribution with little error. The use of a third parameter in the estimated lognormal distribution may be needed, depending on the number of samples. When the number of samples is large per category (approximately more than 400 samples) the maximum likelihood and the two-parameter lognormal distribution better fit the empirical distribution. For large sample sizes, the L-moments method usually unacceptably truncates the distribution in the lower tail. However, when the sample size is more moderate per category (approximately between 100 and 400 samples), the three-parameter lognormal method, estimated by L-moments, better fits the empirical distribution. When the sample size is small (less than 100 samples, as is common for most stormwater programs), the use of the third parameter does not improve the fit with the empirical distribution and the common two-parameter lognormal distribution produces a better fit than the other two methods. The use of the lognormal distribution also has an advantage over the other distribution types because it can be easily transformed to a normal distribution and the data can then be correctly examined using a wide variety of statistical tests.

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the variability of stormwater characteristics. However, during the period of a five-year permit with three samples per year, about 15 events would be sampled for each land use. While still insufficient for many analyses, this number of data points likely allows the confidence limits to be reasonably calculated for the average conditions. When many sites of the same land use are monitored for a region, substantial data may be collected during a permit cycle. This was the premise of the NSQD where MS4 data were collected for many locations throughout the country. These data were evaluated and various findings made. The following comments are partially based on these analyses, along with additional data sources.

Sampling Technique and Compositing

There are a variety of methods for collecting and compositing stormwater samples that can result in different values for the EMC. The first distinction is the mode of sample collection, either as grab samples or automatic sampling. Obviously, grab sampling is limited by the speed and accuracy of the individuals doing the sampling, and it is personnel intensive. It is for this reason that about 80 percent of the NSQD samples are collected using automatic samplers. Manual sampling has been observed to result in slightly lower TSS concentrations compared to automatic sampling procedures. This may occur, for example, if the manual sampling team arrives after the start of runoff and therefore misses an elevated first flush (if it exists for the site), resulting in reduced EMCs.

A second important concept is how and whether the samples are combined following collection. With *time-based discrete sampling*, **s**amplers (people or machines) are programmed to take an aliquot after a set period of time (usually in the range of every 15 minutes) and each aliquot is put into a separate bottle (usually 1 liter). Each bottle is processed separately, so this method can have high laboratory costs. This is the only method, however, that will characterize the changes in pollutant concentrations during the event. *Time-based composite sampling* refers to samplers being programmed to take an aliquot after a set period of time (as short as every 3 minutes), but then the aliquots are combined into one container prior to analysis (compositing). All parts of the event receive equal weight with this method, but the large number of aliquots can produce a reasonably accurate composite concentration. Finally, *flow-weighted composite sampling* refers to samplers being programmed to collect an aliquot (usually 1 liter) for a set volume of discharge. Thus, more samples are collected during the peak of the hydrograph than toward the trailing edge of the hydrograph. All of the aliquots are composited into one container, so the concentration for the event is weighted by flow.

Most communities calculate their EMC values using flow-weighted composite sample analyses for more accurate mass discharge estimates compared to time-based compositing. This is especially important for areas with a first flush of very short duration, because time-composited samples may overly emphasize

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these higher flows. An automatic sampler with flow-weighted samples, in conjunction with a bed-load sampler, is likely the most accurate sampling method, but only if the sampler can obtain a representative sample at the location (such as sampling at a cascading location, or using an automated depth-integrated sampler) (Clark et al., 2008).

Time- and flow-weighted composite options have been evaluated in residential, commercial, and industrial land uses in EPA Rain Zone 2 and in industrial land uses in EPA Rain Zone 3 for the NSQD data. No significant differences were observed for BOD_5 concentrations using either of the compositing schemes for any of the four categories. TSS and total lead median concentrations in EPA Rain Zone 2 were two to five times higher in concentration when time-based compositing was used instead of flow-based compositing. Nutrients in EPA Rain Zone 2 collected in residential, commercial, and industrial areas showed no significant differences using either compositing method. The only exceptions were for ammonia in residential and commercial land-use areas and total phosphorus in residential areas where time-based composite samples had higher concentrations. Metals were higher when time-based compositing was used in residential and commercial land-use areas. No differences were observed in industrial land-use areas, except for lead. Again, in most cases, mass discharges are of the most importance in order to show compliance with TMDL requirements. Flow-weighted sampling is the most accurate method to obtain these values (assuming sufficient numbers of subsamples are obtained). However, if receiving water effects are associated with short-duration high concentrations, then discrete samples need to be collected and analyzed, with no compositing of the samples during the event. Of course, this is vastly more costly and fewer events are usually monitored if discrete sampling is conducted.

Numbers of Data Observations Needed

The biggest issue associated with most monitoring programs is the number of data points needed. In many cases, insufficient data are collected to address the objectives of the monitoring program with a reasonable amount of confidence and power. Burton and Pitt (2002) present much guidance in determining the amount of data that should be collected. A basic equation that can be used to estimate the number of samples to characterize a set of conditions is as follows:

$$n = [COV(Z_{1-\alpha} + Z_{1-\beta})/(error)]^2$$

where:

n = number of samples needed.

α = false-positive rate ($1-\alpha$ is the degree of confidence; a value of α of 0.05 is usually considered statistically significant, corresponding to a $1-\alpha$ degree

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of confidence of 0.95, or 95%).

β = false-negative rate (1–β is the power; if used, a value of β of 0.2 is common, but it is frequently and improperly ignored, corresponding to a β of 0.5).

$Z_{1-\alpha}$ = Z score (associated with area under a normal curve) corresponding to 1–α; if α is 0.05 (95% degree of confidence), then the corresponding $Z_{1-\alpha}$ score is 1.645 (from standard statistical tables).

$Z_{1-\beta}$ = Z score corresponding to 1–β value; if β is 0.2 (power of 80%), then the corresponding $Z_{1-\beta}$ score is 0.85 (from standard statistical tables); however, if power is ignored and β is 0.5, then the corresponding $Z_{1-\beta}$ score is 0.

error = allowable error, as a fraction of the true value of the mean.

COV = coefficient of variation (sometimes noted as CV), the standard deviation divided by the mean (dataset assumed to be normally distributed).

Figures 4-5 and 4-6 can be used to estimate the sampling effort, based on the expected variability of the constituent being monitored, the allowable error in the calculated mean value, and the associated confidence and power. Figure 4-5 can be used for a single sampling point that is being monitored for basic characterization information, while Figure 4-6 is used for paired sampling when two locations are being compared. Confidence and power are needed to control the likelihood of false negatives and false positives. The sample needs increase dramatically as the difference between datasets becomes small when comparing two conditions with a paired analysis, as shown in Figure 4-6 (above and below an outfall, influent vs. effluent, etc.). Typically, being able to detect a difference of at least about 25 percent (requiring about 50 sample pairs with typical sample variabilities) is a reasonable objective for most stormwater projects. This is especially important when monitoring programs attempt to distinguish test and control conditions associated with SCMs. It is easy to confirm significant differences between influent and effluent conditions at wet detention ponds, as they have relatively high removal rates. Less effective controls are much more difficult to verify, as the sampling program requirements become very expensive.

First-Flush Effects

First flush refers to an assumed elevated load of pollutants discharged in the beginning of a runoff event. The first-flush effect has been observed more often in small catchments than in large catchments (Thompson et al., 1995, cited by WEF and ASCE, 1998). Indeed, in large catchments (>162 ha, 400 acres), the

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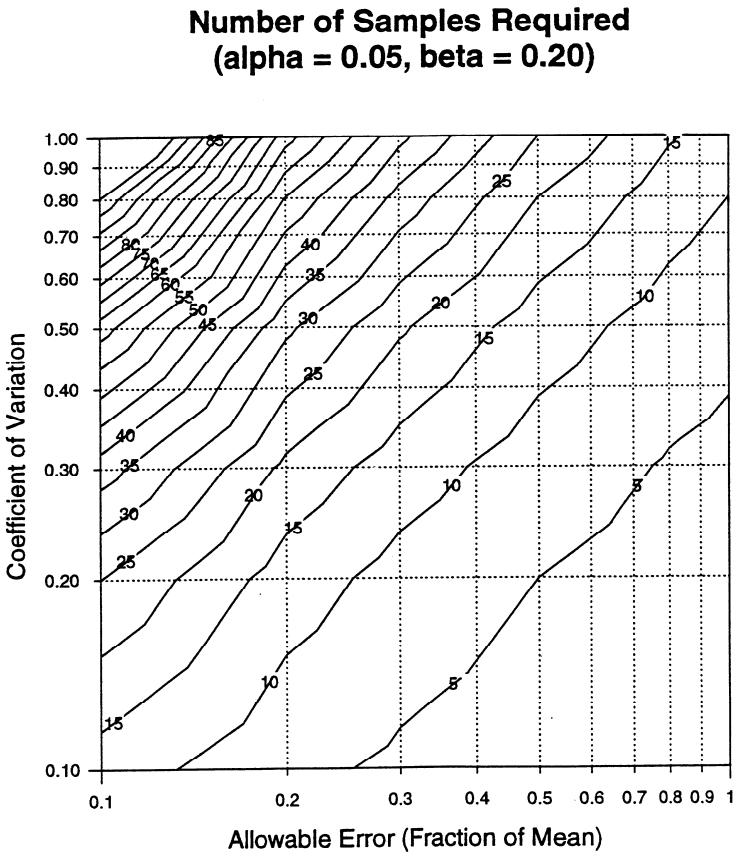

FIGURE 4-5 Number of samples to characterize median (power of 80% and confidence of 95%). SOURCE: Reprinted, with permission from, Burton and Pitt (2002). Copyright 2002 by CRC Press.

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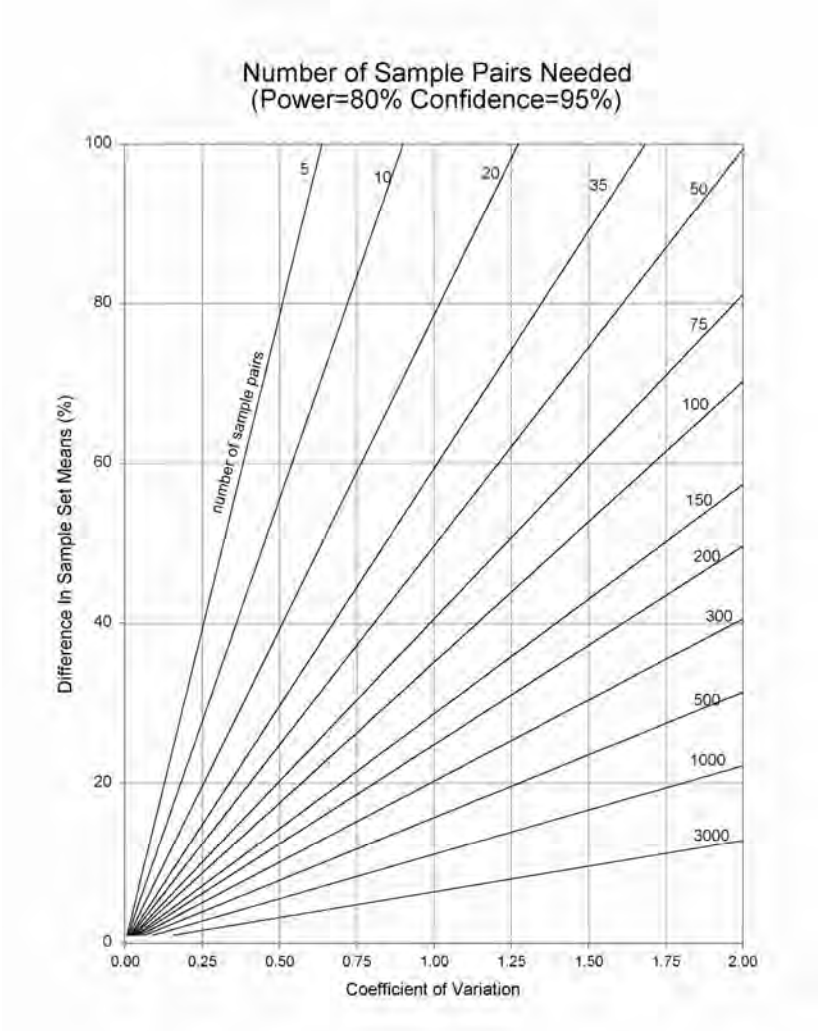

FIGURE 4-6 Number of paired samples needed to distinguish between two sets of observations (power 80% and confidence of 95%). SOURCE: Reprinted, with permission from, Burton and Pitt (2002). Copyright 2002 by CRC Press.

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highest concentrations are usually observed at the times of flow peak (Brown et al., 1995; Soeur et al., 1995). Adams and Papa (2000) and Deletic (1998) both concluded that the presence of a first flush depends on numerous site and rainfall characteristics.

Figure 4-7 is a plot of monitoring data from the Villanova first-flush study (Batroney, 2008) showing the flows, rainfall, TSS concentration, TDS concentration, and TDS and TSS event mean concentrations for the inflow to an infiltration trench. Because of the first-flush effect, a grab sample early in the storm would have over-predicted the TSS event mean concentration of the site, and a later sample would have under-predicted this same value, although for TDS the results would have been similar.

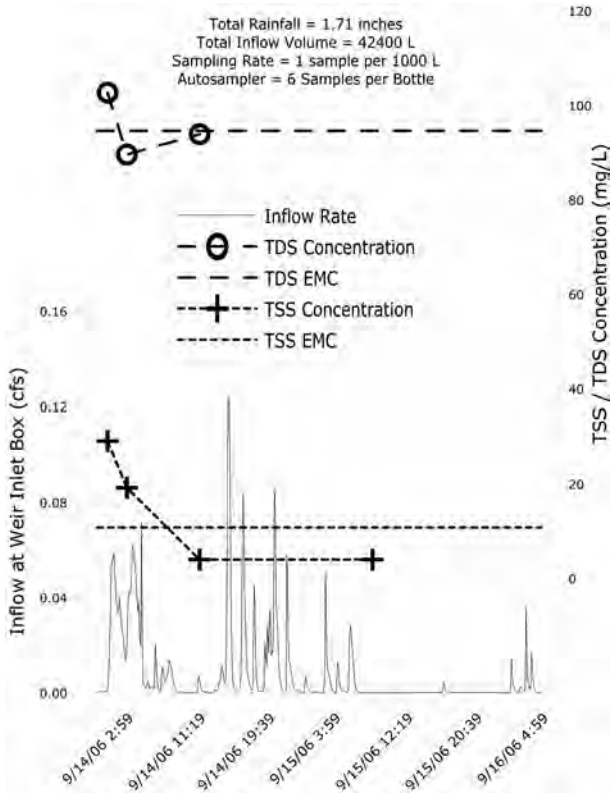

FIGURE 4-7 Villanova first-flush study showing pollutant concentration as a function of inflow rainfall volume. This study collected runoff leaving the top floor of a parking garage. Samples were taken of the runoff in one-quarter-inch increments, up to an inch of rain, and then every inch thereafter. The plot of TSS concentration versus rainfall increment shows a strong first flush for this storm, while the TDS concentration does not. SOURCE: Reprinted, with permission, Batroney (2008). Copyright 2008 by T. Thomas Batroney.

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Figure 4-8 shows data for a short-duration, high-intensity rain in Tuscaloosa, Alabama, that had rain intensities as great a 6 inches per hour for a 10-minute period. The drainage area was a 0.4-ha paved parking lot with some landscaping along the edges. The turbidity plot shows a strong first flush for this event, and the particle size distributions indicate larger particles at the beginning of the event, then becoming smaller as the event progresses, and then larger near the end. Most of the other pollutants analyzed had similar first-flush patterns like the turbidity, with the notable exception of bacteria. Both *E. coli* and enterococci concentrations started off moderately low, but then increased substantially near the end of the rain. Several rains have been monitored at this site so far, and most show a similar pattern with decreasing turbidity and increasing bacteria as the rain continues.

Sample collection conducted for some of the NPDES MS4 Phase I permits required both a grab and a composite sample for each event. A grab sample was to be taken during the first 30 minutes of discharge to capture the first flush, and a flow-weighted composite sample was to be taken for the entire time of discharge (every 15 to 20 minutes for at least three hours or until the event ended). Maestre et al. (2004) examined about 400 paired sets of 30-minute and 3-hour samples from the NSQD, as shown in Table 4-2. Generally, a statistically significant first flush is associated with a median concentration ratio of about 1.4 or greater (the exceptions are where the number of samples in a specific category is much smaller). The largest ratios observed were about 2.5, indicating that for these conditions the first 30-minute flush sample concentrations are about 2.5 times greater than the composite sample concentrations. More of the larger ratios are found for the commercial and institutional land-use categories, where larger paved areas are likely to be found. The smallest ratios are associated with the residential, industrial, and open-space land uses—locations where there may be larger areas of unpaved surfaces.

The data in Table 4-2 were from North Carolina (76.2 percent), Alabama (3.1 percent), Kentucky (13.9 percent), and Kansas (6.7 percent) because most other states' stormwater permits did not require this sampling strategy. The NSQD investigation of first-flush conditions for these data locations indicated that a first-flush effect was not present for all the land-use categories and certainly not for all constituents. Commercial and residential areas were more likely to show this phenomenon, especially if the peak rainfall occurred near the beginning of the event. It is expected that this effect will more likely occur in a watershed with a high level of imperviousness, but even so, the data indicated first flushes for less than 50 percent of the samples for the most impervious areas. This reduced frequency of observed first flushes in areas most likely to have first flushes is probably associated with the varying rain conditions during the different events, including composite samples that did not represent the complete runoff duration.

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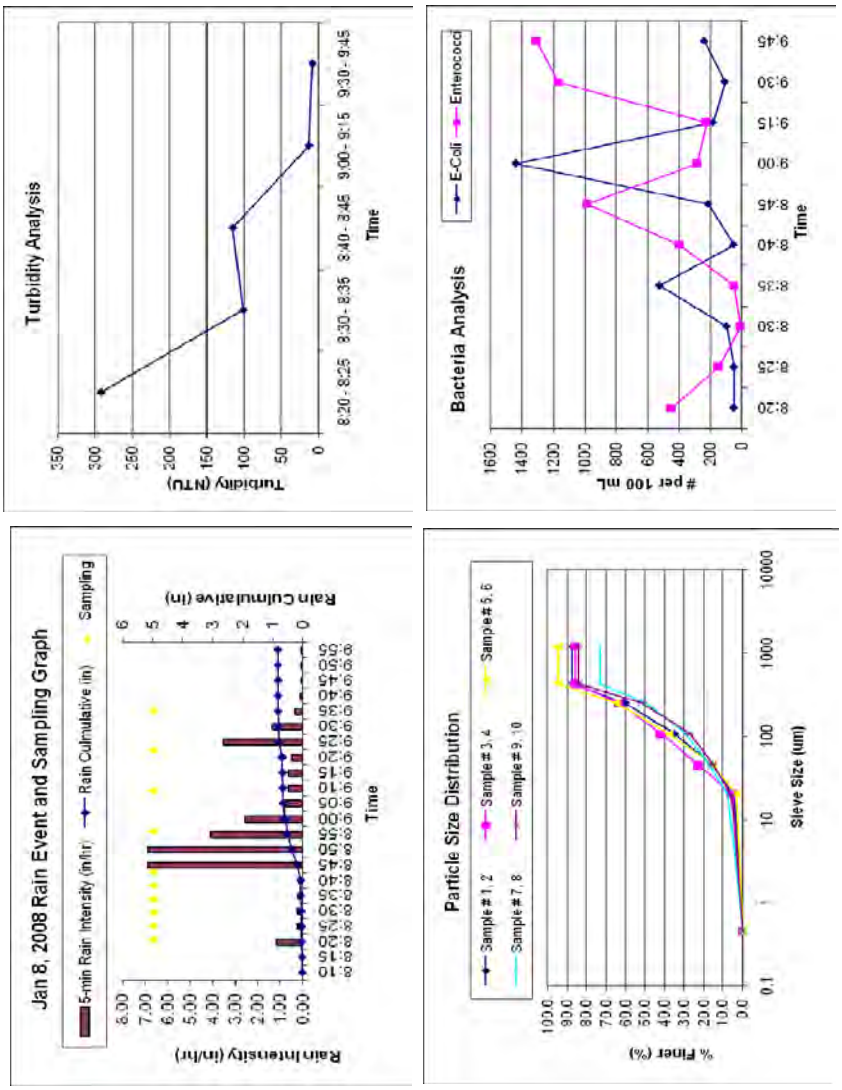

FIGURE 4-8 Pollutant variations during rain period (0.4-ha drainage area, mostly paved parking with small fringe turf area, Tuscaloosa, Alabama). SOURCE: Robert Pitt, University of Alabama.

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TABLE 4-2 Significant First Flush Ratios (First Flush to Composite Median Concentration)

Parameter	Commercial				Industrial				Institutional			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU	11	11	=	1.32			X				X	
COD, mg/L	91	91	≠	2.29	84	84	≠	1.43	18	18	≠	2.73
TSS, mg/L	90	90	≠	1.85	83	83	=	0.97	18	18	≠	2.12
Fecal coliform, col/100mL	12	12	=	0.87			X				X	
TKN, mg/L	93	86	≠	1.71	77	76	≠	1.35			X	
Phosphorus total, mg/L	89	77	≠	1.44	84	71	=	1.42	17	17	=	1.24
Copper, total, µg/L	92	82	≠	1.62	84	76	≠	1.24	18	7	=	0.94
Lead, total, µg/L	89	83	≠	1.65	84	71	≠	1.41	18	13	≠	2.28
Zinc, total, µg/L	90	90	≠	1.93	83	83	≠	1.54	18	18	≠	2.48

Parameter	Open Space				Residential				All Combined			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU			X		12	12	=	1.24	26	26	=	1.26
COD, mg/L	28	28	=	0.67	140	140	≠	1.63	363	363	≠	1.71
TSS, mg/L	32	32	=	0.95	144	144	≠	1.84	372	372	≠	1.60
Fecal coliform, col/100mL			X		10	9	=	0.98	22	21	=	1.21
TKN, mg/L	32	14	=	1.28	131	123	≠	1.65	335	301	≠	1.60
Phosphorus, total, mg/L	32	20	=	1.05	140	128	≠	1.46	363	313	≠	1.45
Copper, total, µg/L	30	22	=	0.78	144	108	≠	1.33	368	295	≠	1.33
Lead, total, µg/L	31	16	=	0.90	140	93	≠	1.48	364	278	≠	1.50
Zinc, total, µg/L	21	21	=	1.25	136	136	≠	1.58	350	350	≠	1.59

Note: n, number of total possible events; sc, number of selected events with detected values; R, result; X, not enough data; =, not enough evidence to conclude that median values are different; ≠, median values are different. "Ratio" is the ratio of the first flush to the full-period sample concentrations.
SOURCE: NSQD, as reported by Maestre et al. (2004).

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Groups of constituents showed different behaviors for different land uses. All the heavy metals evaluated showed higher concentrations at the beginning of the event in the commercial land-use category. Similarly, all the nutrients showed higher initial concentrations in residential land-use areas, except for total nitrogen and orthophosphorus. This phenomenon was not found in the bacterial analyses. None of the land uses showed a higher population of bacteria at the beginning of the event.

The general conclusion from these data is that, in areas having low and generally even-intensity rains, first-flush observations are more common, especially in small and mostly paved areas. As an area increases in size, multiple routing pathways tend to blend the water, and runoff from the more distant locations reaches the outfall later in the event. SCMs located at outfalls in areas having low levels of impervious cover should be selected and sized to treat the complete event, if possible. Preferential treatment of first flushes may only be justified for small impervious areas, but even then, care needs to be taken to prevent undersizing and missing substantial fractions of the event.

Seasonal first flushes refer to larger portions of the annual runoff and pollutant discharges occurring during a short rain season. Seasonal first flushes may be observed in more arid locations where seasonal rainfalls are predominant. As an example, central and southern California can have dry conditions for extended periods, with the initial rains of the season occurring in the late fall. These rains can be quite large and, since they occur after prolonged dry periods, may carry substantial portions of the annual stormwater pollutant load. This is especially pronounced if later winter rains are more mild in intensity and frequent. For these areas, certain types of seasonally applied SCMs may be effective. As an example, extensive street, channel, and inlet cleaning in the late summer and early fall could be used to remove large quantities of debris and leaves from the streets before the first heavy rains occur. Other seasonal maintenance operations benefiting stormwater quality should also be scheduled before these initial rains.

Rain Depth Effects

An issue related to first flushes pertains to the effects of rain depth on stormwater quality. The NSQD contains much rainfall data along with runoff data for most areas of the country. Figure 4-9 contains scatter plots showing concentrations plotted against rain depth for some NSQD data. Although many might assume a correlation between concentrations and rain depth, in fact there are no obvious trends of concentration associated with rain depth. Rainfall energy determines erosion and wash-off of particulates, but sufficient runoff volume is needed to carry the particulate pollutants to the outfalls. Different travel times from different locations in the drainage areas results in these materials arriving at different times, plus periods of high rainfall intensity (that increase pollutant wash-off and movement) occur randomly throughout the storm. The

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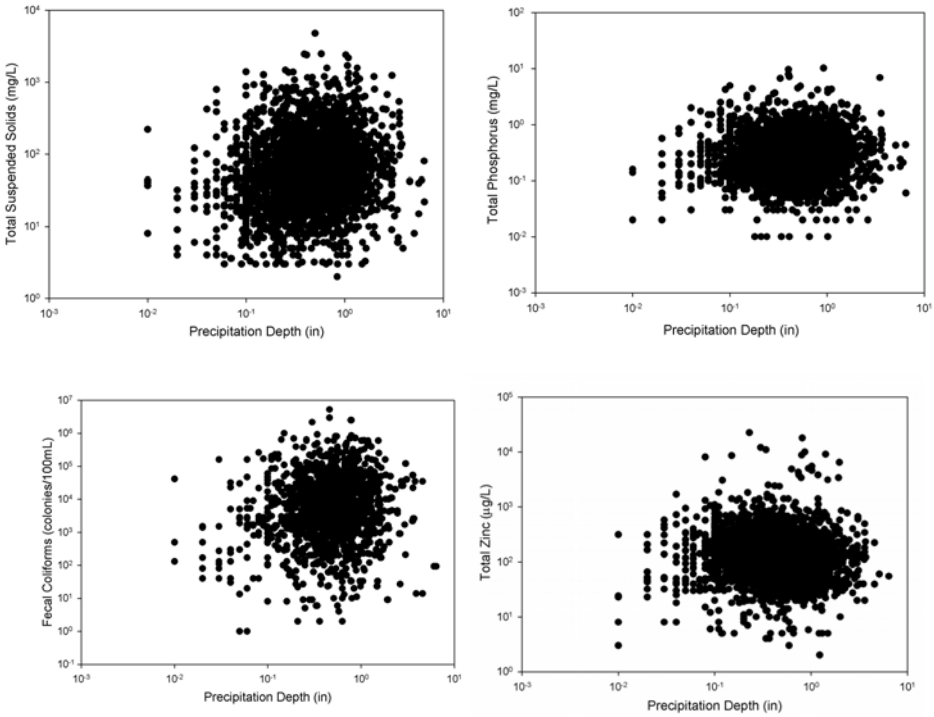

FIGURE 4-9 Examples of scatter plots by precipitation depth. SOURCE: NSQD.

resulting outfall stormwater concentration patterns for a large area having various surfaces is therefore complex and rain depth is just one of the factors involved.

Reported Monitoring Problems

A number of monitoring problems were described in the local Phase I community MS4 annual monitoring reports that were summarized as part of assembling the NSQD. About 58 percent of the communities described monitoring problems. Problems were mostly associated with obtaining reliable data for the targeted events. These problems increased costs because equipment failures had to be corrected and sampling excursions had to be rescheduled. One of the basic sampling requirements was to collect three samples every year for each

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of the land-use stations. These samples were to be collected at least one month apart during storm events having at least 0.1-inch rains, and with at least 72 hours from the previous 0.1-inch storm event. It was also required (when feasible) that the variance in the duration of the event and the total rainfall not exceed the median rainfall for the area. About 47 percent of the communities reported problems meeting these requirements. In many areas of the country, it was difficult to have three storm events per year with these characteristics. Furthermore, the complete range of site conditions needs to be represented in the data-collection effort; focusing only on a narrow range of conditions limits the representativeness of the data.

The second most frequent problem, reported by 26 percent of the communities, concerned backwater tidal influences during sampling, or that the outfall became submerged during the event. In other cases, it was observed that there was flow under the pipe (flowing outside of the pipe, in the backfill material, likely groundwater), or sometimes there was no flow at all. These circumstances all caused contamination of the collected samples, which had to be discarded, and prevented accurate flow monitoring. Greater care is obviously needed when locating sampling locations to eliminate these problems.

About 12 percent of the communities described errors related to malfunctions of the sampling equipment. When reported, the equipment failures were due to incompatibility between the software and the equipment, clogging of the rain gauges, and obstruction in the sampling or bubbler lines. Memory losses in the equipment recording data were also periodically reported. Other reported problems were associated with lighting, false starts of the automatic sampler before the runoff started, and operator error due to misinterpretation of the equipment configuration manual.

The reported problems suggest that the following changes should be made. First, the rain gauges need to be placed close to the monitored watersheds. Large watersheds cannot be represented with a single rain gauge at the monitoring station. In all cases, a standard rain gauge needs to supplement a tipping bucket rain gauge, and at least three rain gauges should be used in the research watersheds. Second, flow-monitoring instrumentation also needs to be used at all water quality monitoring stations. The lack of flow data greatly hinders the value of the chemical data. Third, monitoring needs to cover the complete storm duration. Automatic samplers need to be properly programmed and maintained to handle very short to very long events. It is unlikely that manual samplers were able to initiate sampling near the beginning of the events, unless they were deployed in anticipation of an event later in the day. A more cost-effective and reliable option would be to have semi-permanent monitoring stations at the various locations with sampling equipment installed in anticipation of a monitored event. Most monitoring agencies operated three to five land-use stations at one time. This number of samplers, and flow equipment, could have been deployed in anticipation of an acceptable event and would not need to be continuously installed in the field at all sampling locations.

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Non-Detected Analyses

Left-censored data involve observations that are reported as below the limits of detection, whereas right-censored data involve above-range observations. Unfortunately, many important stormwater measurements (such as for filtered heavy metals) have large fractions of undetected values. These incomplete data greatly hinder many statistical tests. To estimate the problems associated with censored values, it is important to identify the probability distributions of the data in the dataset and the level of censoring. As discussed previously, most of the constituents in the NSQD follow a lognormal distribution. When the frequencies of the censored observations were lower than 5 percent, the means, standard deviations, and COVs were almost identical to the values obtained when the censored observations were replaced by half of the detection limit. As the percentage of nondetected values increases, replacing the censored observation by half of the detection limit instead of estimating them using Cohen's maximum likelihood method produced lower means and larger standard deviations. Replacing the censored observations by half of the detection limit is not recommended for levels of censoring larger than 15 percent. Because the Cohen method uses the detected observations to estimate the nondetected values, it is not very accurate, and therefore not recommended, when the percentage of censored observations is larger than 40 percent (Burton and Pitt, 2002). In this case, summaries should only be presented for the detected observations, with clear notations stating the level of nondetected observations.

The best method to eliminate problems associated with left-censored data is to use an appropriate analytical method. By keeping the nondetectable level below 5 percent, there are many fewer statistical analysis problems and the value of the datasets can be fully realized. Table 4-3 summarizes the recommended minimum detection limits for various stormwater constituents to obtain manageable nondetection frequencies (< 5 percent), based on the NSQD data observations. Some of the open-space stormwater measurements (lead, and oil and grease, for example) would likely have greater than 5 percent nondetections, even with the detection limits shown. The detection limits for filtered heavy metals should also be substantially less than shown on this table.

Seasonal Effects

Another factor that some believe may affect stormwater quality is the season when the sample was obtained. If the few samples collected for a single site were all collected in the same season, the results may not be representative of the whole year. The NPDES sampling protocols were designed to minimize this effect by requiring the three samples per year to be separated by at least one month. The few samples still could be collected within a single season, but not within the same week. Seasonal variations for residential fecal coliform data are shown in Figure 4-10 for NSQD data for all residential areas. These data were

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TABLE 4-3 Suggested Analytical Detection Limits for Stormwater Monitoring Programs to Obtain Less Than 5 Percent Nondetections

Parameter	Residential, Commercial, Industrial, Freeway		Open Space	
Conductivity	20	μS/cm	20	μS/cm
Hardness	10	mg/L	10	mg/L
Oil and grease	0.5	mg/L	0.5	mg/L
TDS	10	mg/L	10	mg/L
TSS	5	mg/L	1	mg/L
BOD_5	2	mg/L	1	mg/L
COD	10	mg/L	5	mg/L
Ammonia	0.05	mg/L	0.01	mg/L
$NO_2 + NO_3$	0.1	mg/L	0.05	mg/L
TKN	0.2	mg/L	0.2	mg/L
Dissolved P	0.02	mg/L	0.01	mg/L
Total P	0.05	mg/L	0.02	mg/L
Total Cu	2	μg/L	2	μg/L
Total Pb	3	μg/L (residential μg/L)	1	μg/L
Total Ni	2	μg/L	1	μg/L
Total Zn	20	μg/L (residential 10 μg/L)	5	μg/L

SOURCE: Maestre and Pitt (2005).

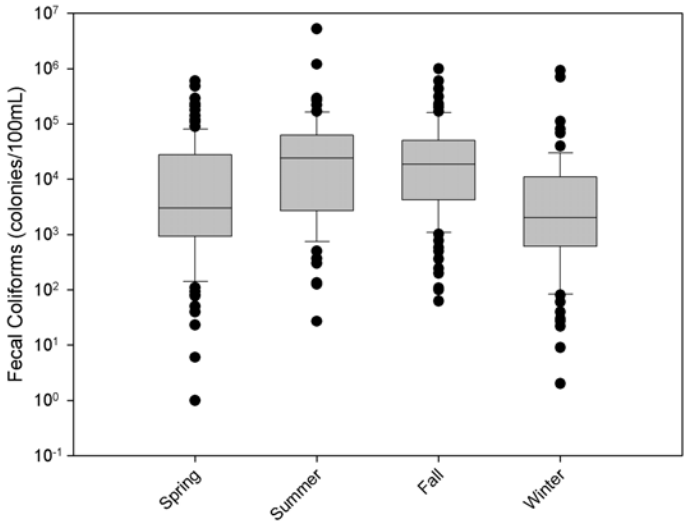

FIGURE 4-10 Fecal coliform concentrations in stormwater by season. SOURCE: NSQD.

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the only significant differences in concentration by season for any constituent measured. The bacteria levels are lowest during the winter season and highest during the summer and fall (a similar conclusion was obtained during the NURP data evaluations).

Recommendations for MS4 Monitoring Activities

The NSQD is an important tool for the analysis of stormwater discharges at outfalls. About a fourth of the total existing information from the NPDES Phase I program is included in the database. Most of the statistical analyses in this research were performed for residential, commercial, and industrial land uses in EPA Rain Zone 2 (the area of emphasis according to the terms of the EPA-funded research). Many more data are available from other stormwater permit holders that are not included in this database. Acquiring these additional data for inclusion in the NSQD is a recommended and cost-effective activity and should be accomplished as additional data are also being obtained from ongoing monitoring projects.

The use of automatic samplers, coupled with bed-load samplers, is preferred over manual sampling procedures. In addition, flow monitoring and on-site rainfall monitoring need to be included as part of all stormwater characterization monitoring. The additional information associated with flow and rainfall data will greatly enhance the usefulness of the much more expensive water quality monitoring. Flow monitoring must also be correctly conducted, with adequate verification and correct base-flow subtraction methods applied. A related issue frequently mentioned by the monitoring agencies is the lack of on-site precipitation information for many of the sites. Using regional rainfall data from locations distant from the monitoring location is likely to be a major source of error when rainfall factors are being investigated.

Many of the stormwater permits only required monitoring during the first three hours of the rain event. This may have influenced the EMCs if the rain event continued much beyond this time. Flow-weighted composite monitoring should continue for the complete rain duration. Monitoring only three events per year from each monitoring location requires many years before statistically adequate numbers of observations are obtained. In addition, it is much more difficult to ensure that such a small fraction of the total number of annual events is representative. Also, there is minimal value in obtaining continued data from an area after sufficient information is obtained. It is recommended that a more concentrated monitoring program be conducted for a two- or three-year period, with a total of about 30 events monitored for each site, covering a wide range of rain conditions. Periodic checks can be made in future years, such as repeating concentrated monitoring every 10 years or so (and for only 15 events during the follow-up surveys).

Finally, better watershed area descriptions, especially accurate drainage-area delineations, are needed for all monitored sites. While the data contained in

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the NSQD are extremely useful, future monitoring information obtained as part of the stormwater permit program would be greatly enhanced with these additional considerations.

MONITORING OF INDUSTRIES INCLUDING CONSTRUCTION

The various industrial stormwater monitoring requirements of the EPA Stormwater Program have come under considerable scrutiny since the program's inception. Input to the committee at its first meeting conveyed the strong sense that monitoring as it is being done is nearly useless, is burdensome, and produces data that are not being utilized. The requirements consist of the following. All industrial sectors covered under the Multi-Sector General Permit (MSGP) must conduct visual monitoring four times a year. This visual monitoring is performed by collecting a grab sample within the first hour of stormwater discharge and observing its characteristics qualitatively (except for construction activities—see below). A subset of MSGP industries are required to perform analytical monitoring for benchmark pollutant parameters (see Table 2-5) four times in year 2 of permit coverage and again in year 4 if benchmarks are exceeded in year 2. A benchmark sample is collected as a grab sample within the first hour of stormwater discharge after a rainfall event of 0.1 inch or greater and with an interceding dry period of at least 72 hours. An even smaller subset of MSGP industries that are subject to numerical effluent guidelines under 40 C.F.R. must, in addition, collect grab samples of their stormwater discharge after every discharge event and analyze it for specific pollutant parameters as specified in the effluent guidelines (see Table 2-6). There is no monitoring requirement for stormwater discharges from construction activity in the Construction General Permit. There is only an elective requirement that the construction site be visually inspected within 24 hours after the end of a storm event that is 0.5 inch or greater, if inspections are not performed weekly.

EPA selected the benchmark analytical parameters for industry subsectors to monitor using data submitted by industrial groups in 1993 as part of their group applications. The industrial groups were required to sample a minimum of 10 percent of facilities within an industry group for pH, TSS, BOD_5, oil and grease, COD, TKN, nitrate plus nitrite nitrogen, and total phosphorous. Each sampling facility within a group collected a minimum of one grab sample within the first 30 minutes of discharge and one flow-weighted composite sample. Other nonconventional pollutants such as fecal coliform bacteria, iron, and cobalt were analyzed only if the industry group expected it to be present. Similarly, toxic pollutants such as lead, copper, and zinc were not sampled but rather self-identified only if expected to be present in the stormwater discharge. As a result of the self-directed nature of these exercises, the data submitted with the group applications were often incomplete, inconsistent, and not representative of the potential risk posed by the stormwater discharge to human health and aquatic

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life. EPA has not conducted or funded independent investigations and has relied solely on the data submitted by industry groups to determine which pollutant parameters are appropriate for the analytical monitoring of an industry subsector. Thus, there are glaring deficiencies; for example, the only benchmark parameter for asphalt paving and roofing materials is TSS, even though current science shows that the most harmful pollutants in stormwater discharges from the asphalt manufacturing industry are polycyclic aromatic hydrocarbons (compare Table 2-5 with Mahler et al., 2005).

Aside from the suitability of benchmark parameters is the fact the too few samples are collected to sufficiently characterize the variability of pollutant concentrations associated with industrial facilities within a sector. This is discussed in detail in Box 4-2, which describes one of the few efforts to collect and analyze data from the benchmark monitoring of industries done in Southern California. EPA has not requested a nationwide effort to compile these data, as was done for the MS4 program, although this could potentially lead to average effluent concentrations by industrial sector that could be used for a variety of purposes, including more considerate regulations. Finally, the compliance monitoring that is presently being conducted under the MSGP is of limited usefulness because it is being done to comply with effluent guidelines that have not been updated to reflect the best available technology relevant to pollutants of most concern. All of these factors have led to an industrial stormwater monitoring program that is not very useful for the purposes of reducing stormwater pollution from industries or informing operators on which harmful pollutants to expect from their sites.

Industrial-Area Monitoring Issues

Monitoring at industrial sites has some unique issues that must be overcome. The most important aspect for any monitoring program is understanding and specifying the objectives of the monitoring program and developing and following a detained experimental design to allow these objectives to be met. The following discussion is organized around the reasons why monitoring at industrial sites may be conducted.

Regional Monitoring of Many Facilities

An important monitoring objective would be regional monitoring to calibrate and verify stormwater quality models, to randomly verify compliance at facilities not normally requiring monitoring, and to establish benchmarks for compliance. As shown in Box 4-2, haphazard monitoring throughout an area would require a very large effort, and would still likely result in large errors in the expected data. It is recommended that a regional stormwater authority coordinate regional monitoring as part of the MS4 monitoring requirements, possibly

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BOX 4-2
The Plight of Industrial Stormwater Data

Unlike the data collected by municipalities and stored in the NSQD, the benchmark monitoring data collected by permitted industries are not compiled or analyzed on a national basis. However, there has been at least one attempt to compile these data on a more local basis. California required that industrial facilities submit their benchmark monitoring data over a nine-year period, and it was subsequently analyzed by Michael Stenstrom and colleagues at UCLA (Stenstrom and Lee, 2005; Lee et al., 2007). The collected data were for such parameters as pH, turbidity, specific conductance, oil and grease (or total organic carbon), and several metals. There are more than 6,000 industries covered under the California general permit, each of which was to have collected two grab samples per year for a limited number of parameters. Whether these data were collected each year and for each industry was highly variable.

The analysis of the data from Los Angeles and Ventura counties revealed that stormwater monitoring data are not similar to the types of data that the environmental engineering field is used to collecting, in particular wastewater data. Indeed, as shown in Figure 4-11, stormwater data are many orders of magnitude more variable than drinking water and wastewater data. The coefficients of variation for municipal and industrial stormwater were almost two orders of magnitude higher than for drinking water and wastewater, with the industrial stormwater data being particularly variable. This variability comes from various sources, including intrinsic variability given the episodic nature of storm events, analytical methods that are more variable when applied to stormwater, and sampling technique problems and error.

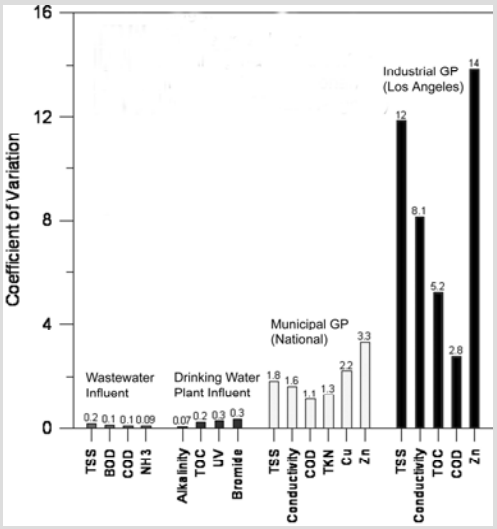

FIGURE 4-11 A comparison of data from four sources: wastewater influent, drinking water plant effluent, municipal stormwater, and industrial stormwater. SOURCE: Reprinted, with permission, from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

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BOX 4-2 Continued

This enormous variability means that it is extremely difficult to make meaningful statements. For example, it was impossible, using different analyses, to correlate certain chemical pollutants with certain industries. Furthermore, although the data revealed that there are exceedances of benchmark values for certain parameters (Al, Cu, Fe, Pb, and Zn in particular), the data are not of sufficient quantity or quality to identify problem polluters. Finally, there were also large numbers of outliers (that is, samples whose concentrations were well above the 75th percentile range).

Because of these large coefficients of variation, greater numbers of samples are needed to be able to say there is a significant difference between samples. As shown in Figure 4-12 using COD and a 50 percent difference in means as an example, one would need six data points to tell the difference between two wastewater influents, 80 data points if one had municipal stormwater data, and around 1,000 data points for industrial stormwater. These numbers obviously eclipse what is required under all states' MSGPs.

For drinking water treatment, monitoring is done to ensure the quality of the product, while for wastewater, there is a permit that requires the plant to meet a specific quality of water. Unlike these other areas of water resources, there are few incentives that might compel an industry to increase its frequency of stormwater monitoring. As a result, industries are less invested in the process and rarely have the expertise needed to carry out self-monitoring.

Permitted industries are not required to sample flow. However, Stenstrom and colleagues used Los Angeles rainfall data (see Figure 4-13) as a surrogate for flow and demonstrated that there is a seasonal first-flush phenomenon occurring in early fall. That is, samples taken after a prolonged dry spell will have higher pollutant concentrations. There are always high concentrations of contaminants during the first rainfall because contaminants have had time to accumulate since the previous rainfall. This is important because EPA asks the industrial permittees to collect data from the first rainfall, such that they may end up overestimating the mass emissions for the year. Furthermore, it shows that numeric limits for grab samples would be risky because the measured data are highly affected by the timing of the storm.

The controversy about numeric limits for industrial stormwater dischargers has existed for more than ten years in California. A recent expert panel concluded that in some cases, numeric limits are appropriate (for construction, but not for municipalities). Stenstrom's recommendations are that industrial monitoring should be either ended or upgraded (for competent industries). If upgraded, it should include more types of monitored parameters, a sampling method with a lower coefficient of variation, real-time monitoring as opposed to grab samples, more quality assurance/quality control, and web-based reporting. A fee-based program with a subset of randomly selected industries may be better than requiring every industry to sample. Stenstrom and Lee (2005) suggest who might do this monitoring if the industry does not have the necessary trained personnel. There is concern that the California water boards are too understaffed to administer such programs and respond to high emitters.

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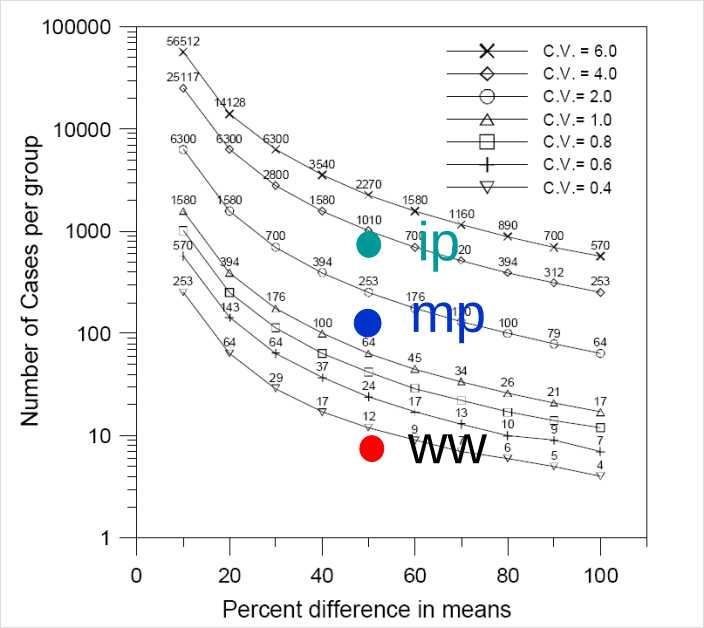

FIGURE 4-12 Number of cases needed to detect a certain percentage difference in the means, using COD as an example. SOURCE: Reprinted, with permission, from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

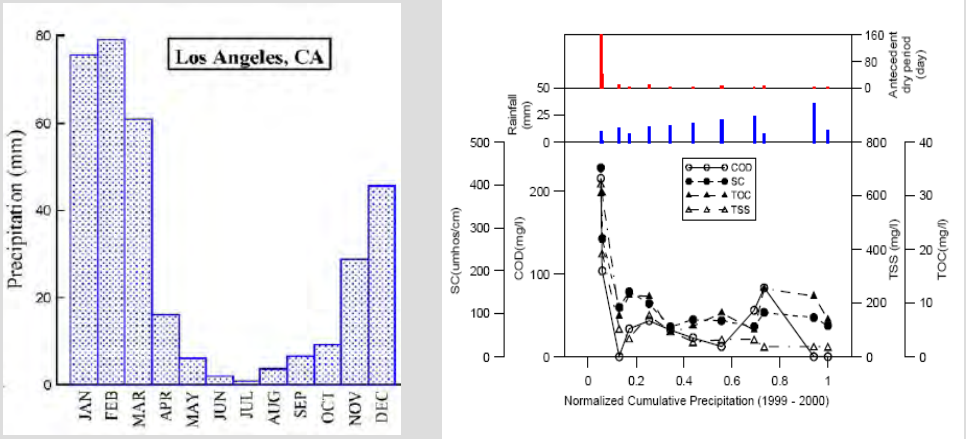

FIGURE 4-13 Annual precipitation in Los Angeles (left) and seasonal first flushes of various contaminants (right). SOURCE: Reprinted, with permission, from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

SOURCES: Stenstrom and Lee (2005), Lee et al. (2007), Stenstrom (2007).

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even at the state level covering several Phase I municipalities. A coordinated effort would be most cost-effective with the results compiled for a specific objective. The general steps in this effort would include the following.

(1) Compiling available regional stormwater quality data and comparing the available data to the needs (such as calibration of a regional model; verifying compliance of facilities not requiring monitoring; and establishing regional benchmarks). This may include expanding the NSQD for the region to include all of the collected data, plus examination of data collected as part of other specialized monitoring activities. These objectives will result in different data needs, so it is critical that the uses of the data are identified before sampling plans are established.

(2) Identifying monitoring opportunities as part of other on-going activities that can be expanded to also meet data gaps for these specific objectives. It is important to understand the time frame for the monitoring and ensure that it will meet the needs. As an example, current NPDES stormwater monitoring only requires a few events to be sampled per year at a facility. It may take many years before sufficient data are obtained unless the monitoring effort is accelerated.

(3) Preparing an experimental design that identifies the magnitude of the needed data, considering the allowable errors in the results, and carrying out the sampling program. Different types of data may have varying data quality objectives, depending on their use. It may be possible to truncate some of the monitoring when a sufficient understanding is obtained.

A regionally calibrated and verified model can be used to review development plans and proposed SCMs for new facilities. When suitably integrated with receiving-water modeling tools, a stormwater model can also be used to develop discharge objectives and numeric discharge limits that are expected to meet regulatory requirements. Eventually, it may be possible to couple watershed stormwater models with regional receiving water assessments and beneficial use studies. Haphazard monitoring of a few events each year will be very difficult to correlate with regional receiving water objectives, while a calibrated and verified watershed model, along with receiving water assessments, will result in a much more useful tool and understanding of the local problems.

Regional monitoring can also be targeted to categories of industries that were previously determined to be of low priority. This monitoring activity would randomly target a specific number of these facilities for monitoring to verify the assumption that they are of low priority and are still carrying out the minimum management practices. This activity would also quantify the discharges from these facilities and the performance of the minimum controls. If the discharges are excessive when compared to the initial assumptions, or the management practices being used are not adequate, then corrective actions would be instigated. A single category of specific industries could be selected for any one year, and a team from the regional stormwater management author-

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ity could randomly select and monitor a subset of these facilities. An efficient experimental design would need to be developed based on expected conditions, but it is expected that from 10 to 15 such facilities would be monitored for at least a year in a large metropolitan area that has a Phase I stormwater permit, or even state-wide.

Regional monitoring is also necessary to more accurately establish benchmarks for numeric permits. Geographical location, along with land use, is normally an important factor affecting stormwater quality. Receiving water impacts and desired beneficial uses also vary greatly for different locations. It is therefore obvious that compliance benchmarks also be established that consider these regional differences. This could be a single statewide effort if the state agency has the permit authority and if the state has minimal receiving water and stormwater variations. However, in most cases, significant variations occur throughout the state and separate monitoring activities would be needed for each region. In the simplest case, probability distributions of stormwater discharge quality can be developed for different discharge categories and the benchmarks would be associated with a specific probability value. In some cases, an overall distribution may be appropriate, and only the sites having concentrations greater than the benchmark value would need to have additional treatment. In all cases, a basic level of stormwater management should be expected for all sites, but the benchmark values would identify sites where additional controls are necessary. The random monitoring of sites not requiring extensive monitoring could be used to identify and adjust the basic levels of control needed for all categories of stormwater dischargers.

Identification of Critical Source Areas Associated with Specific Industrial Operations

The objective of this monitoring activity would be to identify and characterize critical source areas for specific industries of concern. If critical source areas can be identified, targeted control or treatment can be much more effective than relying only on outfall monitoring. Many of the treatment strategies for industrial sites involve pollution prevention, ranging from covering material or product storage areas to coating galvanized metal. Other treatment strategies involve the use of highly effective treatment devices targeting a small area, such as filters used to treat zinc in roof runoff or lamella plate separators for pretreatment of storage yard runoff before wet pond treatment. Knowledge of the characteristics of the runoff from the different areas at a facility is needed in order to select and design the appropriate treatment methods.

Box 4-3 is a case study of one such group monitoring effort—for a segment of the telecommunications industry targeting a specific maintenance practice. Instead of having each telecommunication company throughout the country conduct a detailed monitoring program for individual stormwater permits associated with maintenance efforts, many of the companies joined together under an

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BOX 4-3
Monitoring to Support a General Stormwater Group Permit Application for the Telecommunications Industry

This monitoring program was conducted to support a group permit application for the telecommunications industry, specifically to cover maintenance operations associated with pumping water out of communications manholes that is then discharged into the storm drainage system. Under federal and state environmental statues, the generator (owner or operator) is responsible for determining if the discharged water needs treatment. The work performed under this project covered characterization, prevention, and treatment methods of water found in manholes.

The objective of this project was to develop a test method to quickly evaluate water in manholes and then to recommend on-site treatment and preventative methods. To meet the telecommunication industry needs, the evaluating tests of water found in manholes need to be simple, quick, inexpensive, field applicable, and accurate indicators of contaminated conditions. The on-site treatment methods must be cost-effective and quickly reduce the concentrations of the contaminant of concern to acceptable levels before the water from manholes is discharged, to result in a safe environment for workers.

A sampling effort was conducted by Pitt et al. (1998) to characterize the quality of the water and sediment found in manholes. More than 700 water samples and 300 sediment samples were analyzed over a three-year period, representing major land-use, age, season, and geographical factors from throughout the United States. The samples were analyzed for a wide range of common and toxic constituents. The statistical procedures identified specific relationships between these main factor categories and other manhole characteristics. Part of the project was to evaluate many field analytical methods. Finally, research was also conducted to examine possible water treatment methods for water being pumped from telecommunication manholes.

Summary of Sampling Effort and Strategy

The objective of the monitoring program was to characterize telecommunication manhole water and sediment. Important variables affecting the quality of these materials were also determined. A stratified random sampling design was followed, with the data organized in a full 2^4 factorial design, with repeated sampling of the same manholes for each season. The goal for the minimum number of samples per strata was ten. This sampling effort enabled the determination of errors associated with the results, which was expected to be less than 25 percent. In addition, this level of effort enabled comparison tests to be made outside of the factorial design. Table 4-4 lists the constituents that were evaluated for each of the sample types.

The immense amount of data collected during this project and the adherence to the original experimental design enabled a comprehensive statistical evaluation of the data. Several steps in data analysis were performed, including:

- exploratory data analyses (mainly probability plots and grouped box plots),
- simple correlation analyses (mainly Pearson correlation matrices and associated scatter plots),
- complex correlation analyses (mainly cluster and principal component analyses, plus Kurskal-Wallis comparison tests), and

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• model building (based on complete 2^4 factorial analyses of the most important factors).

The toxicity screening tests (using the Azur Microtox® method) conducted on both unfiltered and filtered water samples from telecommunication manholes indicated a wide range of toxicity, with no obvious trends for season, land use, or age. About 60 percent of the samples were not considered toxic (less than an I25 light reduction of 20 percent, the light reduction associated with phosphorescent bacteria after a 25-minute exposure to undiluted samples), about 20 percent were considered moderately toxic, while about 10 percent were considered toxic (light reductions of greater than 40 percent), and 10 percent were considered highly toxic (light reductions of greater than 60 percent). Surprisingly, samples from residential areas generally had greater toxicities than samples from commercial and industrial areas. Samples from newer areas were also more toxic than those from older areas. Further statistical tests of the data indicated that the high toxicity levels were likely associated with periodic high concentrations of salt (in areas using de-icing salt), heavy metals (especially filterable zinc, with high values found in most areas), and pesticides (associated with newer residential areas).

TABLE 4-4 Constituents Examined in Water and Sediment from Telecommunication Manholes

Constituent	Unfiltered Water	Filtered Water	Sediment
Solids, volatile solids, COD, Cu, Pb, and Zn	X	X	X
Turbidity, color, and toxicity (Microtox screening method)	X	X	
pH, conductivity, hardness, phosphate, nitrate, ammonia, boron, fluoride, potassium, and detergents	X		
Odor, color, and texture			X
E. coli, enterococci, particle size, and chromium	Selected		
Metal scan (ICP)			Selected
PAHs, phenols (GC/MSD), and pesticides	X	Selected	Selected

SOURCE: Modified from Pitt et al. (1998).

Concentrations of copper, lead, and zinc were evaluated in almost all of the water samples, and some filtered samples were also analyzed for chromium. From 470 to 548 samples (75 to 100 percent of all unfiltered samples analyzed) had detectable concentrations of these metals. Filterable lead concentrations in the water were as high as 160 μg/L, while total lead concentrations were as high as 810 μg/L. Zinc values in filtered and unfiltered samples were as high as about 3,500 μg/L. Some of the copper concentrations were also high in both filtered and unfiltered samples (as high as 1,400 μg/L). Chromium concentrations as high as 45 μg/L were also detected.

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BOX 4-3 Continued

About 300 sediment samples were analyzed and reviewed for heavy metals. An ICP/MS was used to obtain a broad range of metals with good detection limits. The following list shows the median observed concentrations for some of the constituents found in the sediments (expressed as milligrams of the constituent per kilogram of dry sediment):

Aluminum	14,000 mg/kg
COD	85,000 mg/kg
Chromium	<10 mg/kg
Copper	100 mg/kg
Lead	200 mg/kg
Strontium	35 mg/kg
Zinc	1,330 mg/kg

Geographical area had the largest effect on the data observations, while land use, season, and age influenced many fewer parameters. The most obvious relationship was found for high dissolved solids and conductivity associated with winter samples from snowmelt areas. The high winter concentrations slowly decreased with time, with the lowest concentrations noted in the fall. Another important observation was the common association between zinc and toxicity. Residential-area samples generally had larger zinc concentrations than the samples from commercial and industrial areas. Samples from the newest areas also had higher zinc concentrations compared to samples from older areas. No overall patterns were observed for zinc concentrations in sediment samples obtained from manholes. Other constituents (especially nutrients and pesticides) were also found to have higher concentrations in water collected from manholes in newer residential areas. Very few organic toxicants were found in the water samples, but sediment sample organic toxicant concentrations appeared to be well correlated to sediment texture and color. About 10 to 25 percent of the sediment samples had relatively large concentrations of organics. Bacteria analyses indicated some relatively high bacteria counts in a small percentage of the samples. Bacteria were found in lower amounts during sampling periods that were extremely hot or extremely cold. Pacific Northwest samples also had the lowest bacteria counts.

The data were used to develop and test predictive equations based on site conditions. These models were shown to be valid for most of the data, but the highest concentrations were not well predicted. Therefore, special comparisons of many site conditions were made for the manholes having water with the highest concentrations of critical constituents for comparison to the other locations. It was interesting to note that about half of the problem manholes were repeated samples from the same sites (after complete pumping), but at different seasons, indicating continuous problems and not discrete incidents. In addition, the problem manholes were found for all areas of the country and for most rain conditions. Water clarity and color, along with sediment texture, were found to be significant factors associated with the high concentrations of other constituents, while land use was also noted as a significant factor. These factors can be used to help identify problem manholes, but the rates of false positives and false negatives were found to be high. Therefore, these screening criteria can be used to identify more likely problematic manholes, but other methods (such as confirmation chemical analyses) are also needed to identify those that could not be identified using these simpler methods.

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BOX 4-3 Continued

The field analytical test methods worked reasonably well, but had much higher detection limits than advertised, limiting their usefulness. Due to the complexity and time needs for many of these on-site analyses, it is usually more effective to analyze samples at a central facility. For scheduled maintenance operations, a crew could arrive at the site before the maintenance time to collect samples and have them analyzed before the maintenance crew arrives. For emergency repairs, it is possible to pump the collected water into a tank truck for later analyses, treatment, and disposal.

The treatment scenario developed and tested is relatively rapid and cheap and can be used for all operations, irrespective of screening analyses. Chemical addition (using ferric chloride) to the standing water in the manhole was found to reduce problematic levels of almost all constituents to low levels. Slow pumping from the water surface over about a 15- to 30-minute period, with the discharged water then treated in 20-µm cartridge filters, allows the manhole to be entered and the repairs made relatively rapidly, with the water safely discharged. The remaining several inches of water in the bottom of the manhole, along with the sediment, can be removed at a later time for proper disposal.

SOURCE: Pitt et al. (1998).

industrial trade group to coordinate the monitoring and to apply for a group permit. This was a significant effort that was conducted over several years and involved the participation of many regional facilities throughout the nation. This coordinated effort spread the cost over these different participants, and also allowed significant amounts of data to be collected, control practices to be evaluated, and the development of screening methods that allow emergency maintenance operations of the telecommunication system to proceed in a timely manner. The experimental design of this monitoring program allowed an efficient examination of factors affecting stormwater discharges from these operations. This enabled the efficient implementation of effective control programs that targeted specific site and operational characteristics. Although the total cost for this monitoring program was high, it was much less costly than if each individual company had conducted their own monitoring. In addition, this group effort resulted in much more useful information for the industry as a whole.

Outfall Monitoring at a Single Industrial Facility for Permit Compliance and to Demonstrate Effectiveness of Control Practices

Sampling at an individual facility results in outfall data that can be compared to pre-control conditions and numeric standards. There are many guidance documents and reports available describing how to monitor stormwater at an outfall. Two comprehensive sources that describe stormwater monitoring procedures include the handbook written by Burton and Pitt (2002) and a recent guidance report prepared by Shaver et al. (2007). There are a number of basic

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components that need to be included for an outfall characterization monitoring effort, many which have been described in this report. These include the following:

- rainfall monitoring in the drainage area (rate and depth, at least at two locations).
- flow monitoring at the outfall (calibrated with known flow or using dye dilution methods).
- flow-weighted composite sampler, with sampler modified to accommodate a wide range of rain events.
- recommended use of water quality sonde to obtain high-resolution and continuous measurements of such parameters as turbidity, conductivity, pH, oxidation reduction potential, dissolved oxygen (DO), and temperature.
- preparation of adequate experimental design that quantifies the needed sampling effort to meet the data quality objectives (adequate numbers of samples in all rain categories and seasons).
- selection of constituents that meet monitoring objectives. In addition, the analytical methods must be appropriately selected to minimize "nondetected" values.
- monitoring station maintenance must also be conducted appropriately to ensure reliable sample collection. Sampling plan must also consider sample retrieval, sample preparation and processing, and delivery to the analytical laboratory to meet quality control requirements.

Burton and Pitt (2002) describe these monitoring components in detail, along with many other monitoring elements of potential interest (e.g., receiving water biological, physical, and chemical monitoring, including sediment and habitat studies), and include many case studies addressing these components, along with basic statistical analyses and interpretation of the collected data. Box 4-4 provides a detailed example of industrial stormwater monitoring at individual sites in Wisconsin.

In general, monitoring of industries should be tailored to their stormwater pollution potential, considering receiving water uses and problems. There are a number of site survey methods that have been developed to rank industry by risk that mostly rely on visual inspections and information readily available from regional agencies. The Center for Watershed Protection developed a hot-spot investigation procedure that is included in the Urban Subwatershed Restoration Manual No. 11 (Wright et al., 2005). This site survey reconnaissance method ranks each site according to its likely stormwater pollutant discharge potential. A detailed field sheet is used when surveying each site to assist with the visual inspections. Cross and Duke (2008) developed a methodology, described in greater detail in Chapter 6, to visually assess industrial facilities based on the level of activities exposed to stormwater. They devised four categories—Category A, no activities exposed to stormwater; Category B, low intensity; Category C, medium intensity; and Category D, high intensity—and tested this

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BOX 4-4
Wisconsin's Monitoring of Industrial Stormwater

The State of Wisconsin also uses a site assessment method to rank industrial operations into three tiers, mostly based on their standard industrial codes. This system groups facilities by industry and how likely they are to contaminate stormwater. The general permits differ in monitoring requirements, inspection frequency, plan development requirements, and the annual permit fee. The Tier 1 general permit covers the facilities that are considered "heavy" industries, such as paper manufacturing, chemical manufacturing, petroleum refining, ship building/repair, and bulk storage of coal, minerals, and ores. The monitoring required of these facilities is presented in this box. The Tier 2 general permit covers facilities that are considered "light" industries and includes such sites as furniture manufacturing, printing, warehousing, and textiles. Facilities with no discharge of contaminated stormwater are in the Tier 3 category and include sites that have no outdoor storage of materials or waste products.

In accordance with the Wisconsin MSGP, Tier 1 industries are required to perform an annual chemical stormwater sampling at each outfall for those residual pollutants listed in the industry's stormwater pollution prevention plan. The one runoff event selected for sampling must occur between March and November and the rainfall depth must be at least 0.1 inch. At least 72 hours must separate the sampled event and the previous rainfall of 0.1 inch. The concentration of the pollutant must represent a composite of at least three grab samples collected in the first 30 minutes of the runoff event. There is concern about the value of collecting so few samples from just one storm each year.

To evaluate how well this sampling protocol characterizes pollutant concentrations in industrial runoff, the Wisconsin Department of Natural Resources partnered with the USGS to collect stormwater samples from three Tier 2 industrial sites (Roa-Espinosa and Bannerman, 1994). Seven runoff events were monitored at each site, and the samples were collected using five different sampling methods, including (1) flow-weighted composites, (2) time-based discrete samples, (3) time-based composites, (4) a composite of discrete samples from first 30 minutes, and (5) time-based composite sheet flow samples. The first three methods have been described previously. For the composite of discrete samples from the first 30 minutes, the sampler is programmed to take an aliquot after a set period of time (usually every 5 minutes) and the aliquots are combined into one container. The sampler stops collecting samples after 30 minutes. For many sites the samples are collected manually, so there is a high probability the sample does not represent the first 30 minutes of the event. For the time-based composite sheet flow samples, a sheet flow sampler is programmed to take an aliquot of sheet flow after a set period of time (usually about every 5 to 15 minutes). All the aliquots are deposited in one bottle beneath the surface of the ground. All of the parts of the hydrograph receive equal weight in the final concentration, but the larger number of aliquots makes for a reasonably accurate composite concentration. This method is unique in that it can be placed near the source of concern. Automatic samplers were used for the first four methods, while sheet flow samplers designed by the USGS were used for the fifth method (Bannerman et al., 1993). Samples were collected during the entire event. All the automatic samplers had to be installed at a location with concentrated flow, such as an outfall pipe, while the sheet flow samplers could be installed in the pavement near a potential source, such as a material storage area.

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BOX 4-4 Continued

The time-based discrete, time-based composite, first-30-minute composite, and sheet flow samples were analyzed for COD, total recoverable copper, total recoverable lead, total recoverable zinc, TSS, total solids, and hardness. In addition to these constituents, the flow-weighted composite samples were analyzed for antimony, arsenic, beryllium, chromium, ammonia-N, nitrate plus nitrite, TKN, and TP. All the analysis was done at the State Laboratory of Hygiene in Madison, Wisconsin, and the data are stored in the USGS's QWDATA database.

The number of samples collected during a runoff event varied greatly among the five types of sampling. By design, the median number of samples collected for the first 30 minutes was three. Limits on the funds available for laboratory cost limited the time-based discrete sampling to about six per storm. Since they are not restricted by laboratory cost, the composites can be based on more sub-samples during a storm. Thus, the median numbers of sub-samples collected for the flow-weighted composite and time-based composite were 13 and 24, respectively. The time-based composite sheet flow sample could not document the number of samples it collected, but it was set to collect a sample every few minutes.

To judge the accuracy of the sampling methods, one method had to be selected as the most representative of the concentration and load affecting the receiving water. Because a relatively large number of samples are collected and the timing of the sampling is weighted by volume, the flow-weighted composite concentrations were used as the best representation of the quality of the industrial runoff. Concentrations in water samples collected by the time-based composite method compared very well to those collected by the flow-weighted composite method, especially if the time-based composite resulted in 20 sub-samples or more. This was not true for the discrete sampling method, because many fewer sub-samples were used to represent changes across the hydrograph. The time-based composite sheet flow sampler produced concentrations slightly higher than the time-based composite samplers collecting water in the concentrated flow. Concentrations from the sheet flow sampler are probably not diluted by other source areas such as the roof.

Concentrations of total recoverable zinc and TSS collected in the first 30 minutes of the event were usually two to three times higher than the flow-weighted composite samples. For many of the events, the highest concentration of these constituents occurred in the first 10 minutes of the event. Although the concentrations might be higher in the first part of the event, the earlier parts of the event might only represent one third or less of the total runoff volume. Thus, using the concentrations from the first 30 minutes of the event could greatly overestimate the constituent load from the site.

Along with accuracy, the selection of an appropriate sampling method must consider cost and the criteria for installing the sampling equipment. To measure flow, the site must have a location where the flow is concentrated, such as a pipe or well-defined channel, and the runoff is just coming from the site. Out of 474 sites evaluated for this project, only 14 met the criteria for an accurate flow measurement. A few more sites might be suitable for using an automatic sampler without flow measurements, but the number of sites would still be limited. Sheet flow samplers can be used on most sites, since they are simply installed in the pavement near the source of concern.

For each sampling method, approximate costs were determined including equipment, installation of equipment, and the analysis of one sample (Table 4-5). Collecting the samples and processing the data should also be included, but they were not because this cost is highly variable. Flow-weighted composite and time-based discrete sampling had the highest cost. Flow measurements made the composite sampling more expensive, while the laboratory cost of analyzing six discrete samples increased the cost of the time-based

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TABLE 4-5 Cost of Using Different Sampling Methods in 1993 Dollars

Method	Estimated Cost for Equipment, Installation, and Analysis of One Sample
Flow-weighted composite	$16,052
Time-based discrete	$22,682
Time-based composite	$5,920
First-30-minutes (automatic sampler)	$6,000
First-30-minutes (grab sample)	$1,800[1]
Time-based composite sheet flow sampler	$2,889

[1]Cost of laboratory analysis only. SOURCE: Reprinted, with permission, from Roa-Espinosa and Bannerman (1994). Copyright 1994 by the American Society of Civil Engineers.

discrete method. It should be noted that hand grab samples could be used to collect the discrete samples in the first 30 minutes at lower cost, although this depends strongly on the skill of the person collecting the sample. The sheet flow sampler could be the most cost effective approach to sampling an industrial site.

A determination must be made of how many runoff events should be sampled in order to accurately characterize a site's water quality. As shown in Table 4-6, representing a site with the results from one storm can be very misleading. Concentrations in Table 4-6 were collected by the flow-weighted composite method. The geometric means of EMCs from five or more events were very different than the lowest or highest concentration observed for the set of storms. The chances of observing an extreme value by sampling just one event is increased by selecting a sampling method designed to collect a limited number of sub-samples, such as the first-30-minutes method. Too few storms were monitored in this project to properly evaluate the variability in the EMCs, but sufficient changes occur between the zinc and TSS geometric means in Table 4-6 to suggest that a compliance monitoring schedule should include a minimum of five events be sampled each year.

To overcome the high COV observed for municipal stormwater data collected in Wisconsin, EMCs should be determined for about 40 events (Selbig and Bannerman, 2007; Horwatich et al., 2008). The 40 event mean concentrations would probably represent the long-range distribution of rainfall depths, and there would be sufficient data available to perform some trend analysis, such as evaluating the benefits of an SCM implemented at an industrial site. Monitoring 40 events each year, however, would be too costly for an annual compliance monitoring schedule for each industrial site.

Results from this project indicate that the stormwater monitoring required at industrial sites cannot adequately characterize the quality of runoff from an industrial site. Only collecting samples from the first 30 minutes of a storm is probably an overestimate of the concentration, and a load calculated from this concentration would exaggerate the impact of the site on the receiving waters. Time- and flow-based composite sampling would be much better methods for monitoring a site if there are locations to operate an automatic sampler. For sites without such a location, the time-based composite sheet flow sampler offers the best results at the least cost. Given all the variability in concentrations between runoff events, the annual monitoring schedule for any site should include sampling multiple storms.

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BOX 4-4 Continued

TABLE 4-6 Effects of Including a Different Number of Events in the Geometric Mean Calculation for Zinc and TSS[a]

Number of Events	Total Recoverable Zinc	Total Suspended Solids
	AC Rochester	
1 (Lowest Concentration)	57	8
1 (Highest Concentration)	150	84
3	76	24
5	91	36
	PPG Industries	
1 (Lowest Concentration)	140	32
1 (Highest Concentration)	330	49
3	153	57
6	186	53
	Warman International	
1 (Lowest Concentration)	68	17
1 (Highest Concentration)	140	56
3	67	15
5	81	26
7	74	19

[a]Samples were collected using the flow-weighted composite method. SOURCE: Reprinted, with permission, from Roa-Espinosa and Bannerman (1994). Copyright 1994 by the American Society of Civil Engineers.

scheme by examining many southern Florida industrial facilities. About 25 percent of the facilities surveyed that were officially included in the stormwater permit program had no stormwater exposure (Category A), but very few had submitted the necessary application to qualify for an exception under the "no exposure" rule. Slightly more than half of the of the surveyed facilities were included in the "no exposure" and "low exposure" categories, obviously deserving less attention compared to the higher impact categories.

Recommendations for Industrial Stormwater Monitoring

Suitable industrial monitoring programs can be implemented for different categories of industrial activities. The following is one such suggestion, based on the likely risks associated with stormwater discharges from each type of facility.

No Exposure to Industrial Activities and Other Low-Risk Industrial Operations

For sites having limited stormwater exposure to industrial operations, such as no outdoor storage of materials or waste products, basic monitoring would

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not normally be conducted. However, roof runoff (especially if galvanized metals are used) and large parking areas need to be addressed under basic stormwater regulations dealing with these common sources of contaminants and the large amounts of runoff that may be produced. Simple SCM guidance manuals can be used to select and size any needed controls for these sites, based on the areas of concern at the facility. For these facilities, simple visual inspections with no monitoring requirements may be appropriate to ensure compliance with the basic stormwater regulations. A regionally calibrated stormwater quality model can be used to evaluate these basic stormwater conditions and to calculate the expected benefits of control measures. Periodic random monitoring of sites in this category should be conducted to verify the small magnitude of discharges from these sites and the performance of SCMs.

Medium-Risk Industrial Operations

For "medium-intensity" industry facilities, site inspections and modeling should be supplemented with suitable outfall monitoring to ensure compliance. As noted in Box 4-2, there can be a tremendous amount of variability in industrial runoff characteristics. However, the dataset described in that example was a compilation of data from many different types of facilities, with no separation by industrial type. Even different facilities in a single industrial group may have highly variable runoff characteristics. However, a single facility has much less variability, and reasonable monitoring strategies can be developed for compliance purposes. As noted in Box 4-4, about 40 samples were expected to be needed for each site in that example. With typical permit periods of five years, this would require that less than ten samples per year (more than the three samples per year currently obtained at many locations) be collected in order to determine the EMC for the site for comparison to allowable discharge conditions. Obviously, the actual number of samples needed is dependent on the variability of the runoff characteristics and the allowable error, as described elsewhere. After about 10 to 15 storms have been monitored for a site, it would be possible to better estimate the total number of samples actually needed based on the data quality objectives. If the monitoring during the permit period indicated excessive stormwater discharges, then the SCMs are obviously not adequate and would need improvement. The permit for the next five-year period could then be modified to reflect the need for more stringent controls, and suitable fines accessed if the facility was not in compliance. It is recommended that absolute compliance not be expected in the industrial permits, but that appropriate benchmarks be established that allow a small fraction of the monitored events to exceed the goals. This is similar to discharge permit requirements for combined sewers, and for air quality regulations, where a certain number of excessive periods are allowed per year.

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High-Risk Industrial Facilities

For "high-risk" industrial sites of the most critical nature, especially if noncompliance may cause significant human and environmental health problems, visual inspections and site modeling should be used in conjunction with monitoring of each event during the permit period. Because of the potential danger associated with noncompliance, the most stringent and robust controls would be required, and frequent monitoring would be needed to ensure compliance. If noncompliance was noted, immediate action would be needed to improve the discharge conditions. This is similar to industrial and municipal NPDES monitoring requirements for point sources.

MODELING TO LINKING SOURCES OF POLLUTION TO EFFECTS IN RECEIVING WATERS

Stormwater permitting is designed to regulate dischargers, develop information, and reduce the level of stormwater pollutants and impact on receiving waterbodies. An important assumption is that the level of understanding of the stormwater system, through a combination of monitoring and modeling, is sufficient to associate stormwater discharges with receiving waterbody impacts. Impairment of waterbodies can occur for a variety of physical, chemical, and biological reasons, often with a complex combination of causes. The ambient water quality of a receiving waterbody, which may result in a determination of impairment, is itself a function of the total mass loading of pollutant; dilution with stream discharge or standing waterbody volume; the capacity of the aquatic ecosystem to assimilate, transform, or disperse the pollutant; and transport out of the waterbody. In addition to the chemical and physical attributes of the water, impairment may also be characterized by degraded biologic structure or geomorphic form of the waterbody (e.g., channel incision in urban areas). Interactions between multiple pollutant loadings, long turnover and residence times, saturation effects, and cascading feedbacks with biological communities complicate the apparent response of waterbodies to pollutant discharge. This is particularly important when considering cumulative watershed effects, in which interactions between stressors and long-term alteration of watershed conditions may contribute to threshold responses of a waterbody to continued loading or alteration. Under these conditions, simple "loading-response" relations are often elusive and require consideration of historical and local watershed conditions.

As an example, pollutant loading at high stream flow or into strong tidally flushed systems may be advected downstream or into the coastal ocean without building up significant concentrations, while pollutant loading at low flow may not be effectively transported and dispersed and may build up to harmful concentrations. In the former case the pollutant may be rapidly transported out of the local waterbody, but may impact a more distant, downstream system. In addition, certain pollutants, such as inorganic nitrogen, may be discharged into

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surface waters and subsequently transformed and removed from the water column into vegetation or outgassed (e.g., volatilized or denitrified) into the atmosphere under certain ecosystem conditions. Sediment and other pollutants may be stored for long time periods in alluvial or lacustrine deposits, and then remobilized long after the initial loading into a stream reach or standing waterbody in response to extreme climate events, land-use change, reservoir management, or even reductions in the pollutant concentrations in the water column. Consequently, long lags may exist between the actual discharge of the sediment (and any pollutants adsorbed or otherwise stored within the deposits) and their contribution to waterbody impairment. Therefore, understanding the fate of pollutants, particularly nonconservative forms, may require consideration of the full ecosystem cycling and transport of the material over long time periods.

Impairment of waterbodies can be assessed on the basis of biological indicators, as discussed in Chapter 2. As organisms and communities respond to multiple stressors, it is not always clear what the direct or indirect effects of any specific pollutant discharge is, or how that may be exacerbated by correlated or interacting activity in the watershed. The association of specific types of impairment with surrounding land use implicitly accounts for these interactions but does not provide a mechanistic understanding of the linkage sufficient to specify effective remedial activity. However, much progress has been made in determining toxic effects of certain contaminants on different aquatic species assemblages (see, e.g., Shaver et al., 2007) and on quantifying impacts of land use on flow duration curves, EMCs, and loading rates for a number of pollutants (Maestre and Pitt, 2005). For the latter effort, it has been shown that there is large variability within land-use categories, both as a function of specific SCMs and of innate differences due to historical legacies, climate, and hydrogeology.

A protocol linking pollutants in stormwater discharges to ambient water quality criteria should be based on conservation of mass, in which the major inputs, outputs, transformations, and stores of the pollutant can be quantified. Indeed, these are the components of hydrologic and watershed models used to simulate the fate and transport of stormwater and its pollutants. SCMs that improve ambient water quality criteria are designed to act on one or more of these mass balance terms. A number of these measures act to reduce the magnitude of a stormwater source (e.g., porous pavement), while others are designed to absorb or dissipate a pollutant within a hydrologic flowpath downstream from a source (e.g., rain garden, detention pond, stream restoration). The latter requires some consideration of the flowpath from the source to the receiving waterbody. Therefore, determining the major sources, sinks, and transformations of the pollutant should be the first step in this procedure. For a number of pollutants there may be very few potential sources, while for others there may be multiple significant sources. The spatial diversity of these sources and sinks may also range from uniform distribution to “hot spot” patterns that are difficult to detect and quantify. Many stormwater models work effectively with sources, but are not structured to follow the transport or transformation of pollutants from source to waterbody along hydrologic flowpaths.

Figure 4-14 shows the drainage area of Jordan Lake, an important regional

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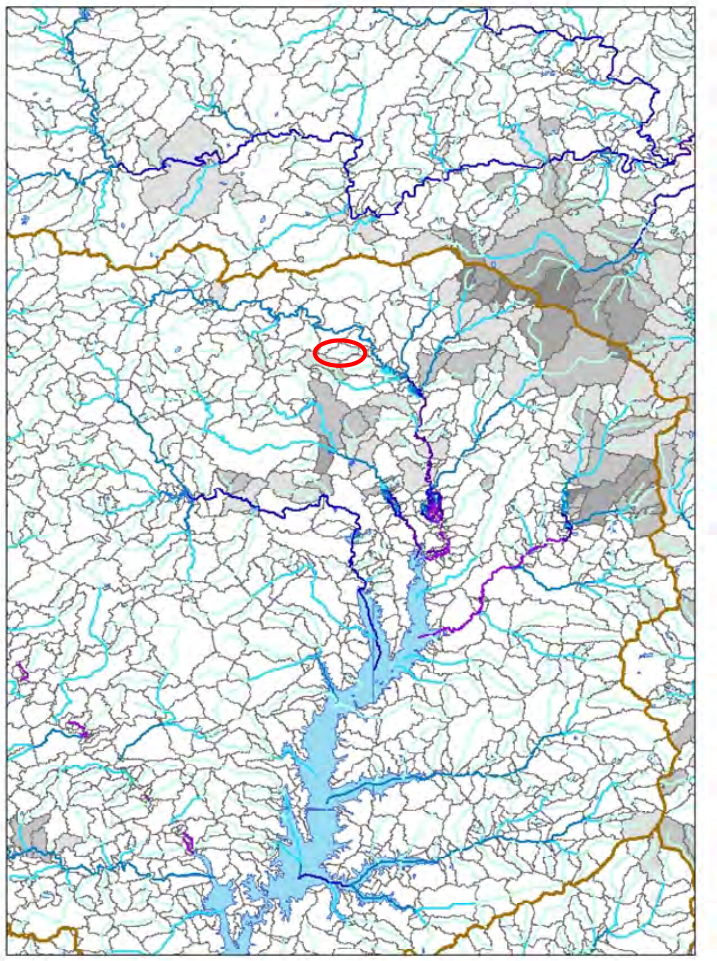

FIGURE 4-14 The drainage area to Jordan Lake, a major drinking water reservoir in the Triangle area of North Carolina, is under nutrient-sensitive rules, requiring reductions in total nitrogen and phosphorus. Drainage flowlines and catchment areas are from NHDplus, and are shaded according to their percentage of industrial and commercial land cover from the NLCD. The area outlined in black is a small urban catchment, detailed in Figure 4-15, and comprised of a wooded central region, surrounded by residential and institutional land use. SOURCE: Data from the NHD+.

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drinking water source in the Triangle area of North Carolina. Catchment areas are shaded to relate the percentage of industrial and commercial land cover, according to the National Land Cover Database (NLCD). Figure 4-15 shows a small tributary within the Jordan Lake watershed in Chapel Hill (outlined in Figure 4-14) with a high-resolution image of all impervious surfaces overlain on the topographically defined surface flowpath network. Each of the distributed sources of stormwater is routed through a flowpath consisting of other pervious and impervious segments, within which additions, abstractions, and transformations of water and pollutants occur depending on weather, hydrologic, and ecosystem conditions. The cumulative delivery and impact of all stormwater sources include the transformations occurring along the flowpaths, which could include specific SCMs such as detention or infiltration facilities or simply infiltration or transformations in riparian areas or low-order streams. The riparian area may be bypassed depending on stormwater concentration or piping, and it may have various levels of effectiveness on reducing pollutants depending on geomorphic, ecosystem, and hydrologic conditions. The ability of a stormwater model to capture these types of effects is a key property influencing its ability to associate a stormwater source with a waterbody outcome.

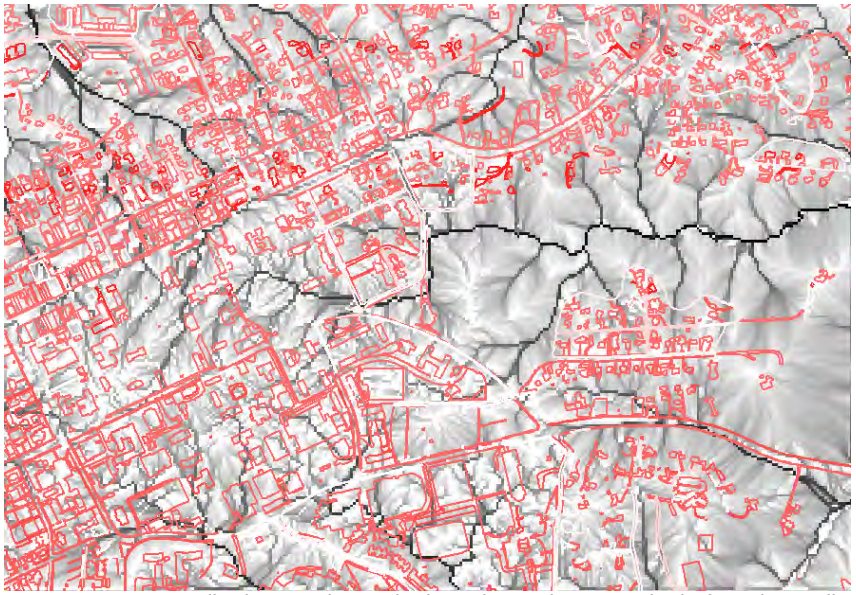

FIGURE 4-15 A small urban catchment in the Lake Jordan watershed of North Carolina with distributed sources of impervious surface (buildings and roads) stormwater arranged within the full surface drainage flowpath system. Stormwater from each source is routed down surface and subsurface flowpaths to the nearest tributary and out the drainage network, with additions and abstractions of water and pollutants along each flowpath segment. SOURCE: Data from the NHD^{+}.

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This section discusses the fundamentals of stormwater modeling and the capabilities of commonly used models. Much of this information is captured in a summary table at the end of the section (Table 4-7). The models included are the following:

- The Rational Method, or $Q = C*I*A$, where Q is the peak discharge for small urban catchments, A is the catchment area, I is the rainfall intensity, and C is a rainfall-runoff coefficient.
- The Simple Method, which classifies stormwater generation and impact regimes by the percent impervious cover
- TR-20 and TR-55
- The Generalized Watershed Loading Function (GWLF)
- Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (P8)
- Model for Urban Stormwater Improvement Conceptualization (MUSIC)
- Stormwater Management Model (SWMM)
- Source Loading and Management Model (WinSLAMM)
- Soil and Water Assessment Tool (SWAT)
- Hydrologic Simulation Program–Fortran (HSPF)
- Western Washington Hydrologic Model
- Chesapeake Bay Watershed Model (CBWM)

Fundamentals of Stormwater Models

Stormwater models are designed to evaluate the impacts of a stormwater discharge on a receiving waterbody. In order to do this, the model must have the capability of describing the nature of the source term (volumes, constituents), transport and transformation to the receiving waterbody, and physical, chemical, and biological interaction with the receiving water body and ecosystem. No model can mechanistically reproduce all of these interactions because of current limitations in available data, incomplete understanding of all processes, and large uncertainties in model and data components. Computer resources, while rapidly advancing, still limit the complexity of certain applications, especially as spatial data become increasingly available and it is tempting to model at ever-increasing resolution and comprehensiveness. Therefore, models must make a set of simplifying assumptions, emphasizing more reliable and available data, while attempting to retain critical processes, feedbacks, and interactions. Models are typically developed for a variety of applications, ranging from hydraulic design for small urban catchments to urban and rural pollutant loading at a range of watershed scales.

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An evaluation of the current state of stormwater modeling should say much about our ability to link pollutant sources with effects in receiving waters. Both stormwater models and models supporting the evaluation of SCM design and effectiveness are based on simulating a mass budget of water and specific pollutants. The detail of mass flux, transformation, and storage terms vary depending on the scale and purpose of the application, level of knowledge regarding the primary processes, and available data. In many cases, mechanisms of transformation may be either poorly understood or may be dependent on detailed interactions. As an example, nitrogen-cycle transformations are sensitive to very short temporal and spatial conditions, termed "hot spots" and "hot moments" relative to hydrologic flowpaths and moisture conditions (McClain et al., 2003).

Stormwater runoff production and routing are common components of these models. All models include an approach to estimate the production of stormwater runoff from one or more zones in the watershed, although runoff routing from the location(s) of runoff production to a point or waterbody is not always included explicitly. Major divisions between approaches are found in the representation of the watershed "geography" in terms of patterns and heterogeneity, and in runoff production and routing. Some stormwater models do not consider the effects of routing from a runoff source to a local waterbody directly, but may attempt to reproduce net impacts at larger scales through the use of unit hydrograph theory to estimate peak flows, and delivery ratios or stormwater control efficiency factors to estimate export to a waterbody.

There are a number of different approaches and paradigms used in stormwater models that include varying degrees of watershed physical, biological, and chemical process detail, as well as spatial and temporal resolution and the representation of uncertainty in model estimates. A number of researchers have written about the nature of watershed models (e.g., Beven, 2001; Pitt and Vorhees, 2002). At present, many hydrologic and stormwater models have become so complex, with multiple choices for different components, that standard descriptions apply only to specific components of the models. The following discussion is generalized; most models fit the descriptions only to certain degrees or only under specific conditions in which they are operated.

Lumped Versus Distributed Approaches

Central to the design of watershed models is the concept of a "control volume," which is a unit within which material and energy contents and balances are defined, with boundaries across which material and energy transport occurs. Control volumes can range from multiple subsurface layers and vegetation canopy layers bounded in three dimensions to a full watershed. Lumped models ignore or average spatial heterogeneity and patterns of watershed conditions, representing all control volumes, and the stores, sources, and sinks of water and pollutants in a vertically linked set of conceptual components, such as surface interception, unsaturated and saturated subsurface zones, and a single stream or

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river reach. For example, SWAT or HSPF are conceptually lumped at the scale of subwatersheds (e.g., the level of geography in Figure 4-14) and do not show any spatial patterns at higher resolutions (e.g., Figure 4-15) than these units. While multiple land-use/soil combinations may be represented, these models do not represent the connectivity of the land segments (e.g., which land segments drain into which land segments) and assume all unique land segment types drain directly to a stream.

Distributed models include some scheme to represent spatial heterogeneity of the watershed environment pertinent to stormwater generation, including land cover, soils, topography, meteorological inputs, and stream reach properties distributed through a set of linked control volumes. Control volumes representing land elements, including vertically linked surface and subsurface stores, are connected by a representation of water and pollutant lateral routing through a network of flowpaths that may be predefined or set by the dynamics of surface, soil, and saturated zone water storage. The land elements may be grid cells in a regular lattice, or irregular elements (e.g., triangles) with the pattern adapted to variations in land surface characteristics or hydraulic gradients.

A number of models are intermediate between lumped and distributed, with approaches such as lumping at the subwatershed scale, incorporating statistical distributions of land element types within subwatersheds but without explicit pattern representation, or lumping some variables and processes (such as groundwater storage and flux), while including distributed representation of topography and land cover. Thus, within the model SLAMM (Pitt and Vorhees, 2002), the catchment is described in sufficient detail to summarize the breakdown of different drainage sequences. As an example, roof area will be broken down to the proportion that drains to pervious areas and to directly connected impervious areas. An important distinction is that there is no routing of the output of one land element into another, such that there is no drainage sequence that may significantly modify the stormwater runoff from its source to the stream. Implicitly, all land elements drain directly into a stream, although a loss rate or delivery ratio can be specified.

The choice of a more lumped or distributed model is often dependent on available data and overall complexity of the model. Simpler, lumped models may be preferred in the absence of sufficient data to effectively parameterize a distributed approach, or for simplicity and computational speed. However, fully lumped models may be limited in their ability to represent spatial dependency, such as the development and dynamics of riparian zones, or the effects of SCM patterns and placement. As there is typically an irreducible level of spatial heterogeneity in land surface characteristics down to very small levels below the resolution of individual flow elements, we note that all models lump at some scale (Beven, 2000).

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Mechanistic Versus Conceptual Process Representation

Mechanistic, or process-based, approaches attempt to reproduce key stormwater transport and transformation processes with more physically, chemically, or biologically based detail, while conceptual models represent fluxes between stores and transformations with aggregate, simplified mathematical forms. No operational models are built purely from first principles, so the distinction between mechanistic and conceptual process basis is one of degree.

The level of sampling necessary to support detailed mechanistic models, as well as remaining uncertainty in physicochemical processes active in heterogeneous environments typically limits the application of first-principle methods. The development or application of more mechanistic approaches is currently limited by available measurements, which require both time and resources to adequately carry out. Unfortunately, modeling and monitoring have often been mutually exclusive in terms of budgets, although it is necessary for both to be carefully planned and integrated. A new generation of sensors and a more rigorous and formal sampling protocol for existing methods will be necessary to advance beyond the current practice.

At present, most operational hydrologic and transport models are based on a strong set of simplifying assumptions regarding active processes and/or the spatial variation of sources, sinks, and stores in the watershed. Runoff production can be computed by a range of more mechanistic to more conceptual or empirical methods. More mechanistic methods include estimation of infiltration capacities based on soil hydraulic properties and moisture conditions, excess runoff production, and hydraulic routing over land surfaces into and through a stream-channel network. More conceptual approaches use a National Resources Conservation Service (NRCS) curve number approach (see Box 4-5) and unit hydrograph methods to estimate runoff volume and time of concentration. Pollutant concentrations or loads are often estimated on the basis of look-up tables using land use or land cover. Land use- or land cover-specific EMC or unit area loading for pollutants can be developed directly from monitoring data or from local, regional, or national databases. The NSQD statistically summarizes the results of a large number of stormwater monitoring projects (as discussed previously in this chapter). The effects of SCM performance (typically percent removal) can be estimated from similar databases (e.g., www.bmpdatabase.org). A set of models, such as SWAT, incorporate fairly detailed descriptions of nutrient cycling as an alternative to using EMC, requiring more detailed inputs of soil, crop, and management information. Unfortunately, the detailed biogeochemistry of this and similar models is typically not matched by the hydrology, which remains lumped at individual Hydrologic Response Unit (HRU) levels using NRCS curve number methods, although options exist to incorporate more mechanistic infiltration excess runoff.

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BOX 4-5
NRCS Technical Release 55

NRCS methods to estimate runoff volumes and flows have been popular since the early 1950s (Rallison, 1980). Fundamentally they can be broken into the separation of runoff from the rainfall volume (Curve Number Method), the pattern of runoff over time (dimensionless unit hydrograph), and their application within computer simulation models. In the late 1970s these components were packaged together in a desktop hydrology method known as Technical Release 55 (TR-55). TR-55 became the primary model used by the majority of stormwater designers, and there is considerable confusion over the terms used to describe what aspects of the NRCS methods are in use.

The NRCS Curve Number Method was first derived in the 1950s for prediction of runoff from ungauged agricultural areas. It relates two summation ratios, that of runoff to rainfall and that of moisture retained to maximum potential retention. Two statistically based relations were developed to drive the ratio, the first of which is based on a "curve number" which depicts the soil type, land cover, and initial moisture content. The second or initial abstraction is defined as the volume of losses that occur prior to the initiation of runoff, and is also related to the curve number. Data were used to derive curve numbers for each soil type and cover as shown in Figure 4-16 (Rallison, 1980).

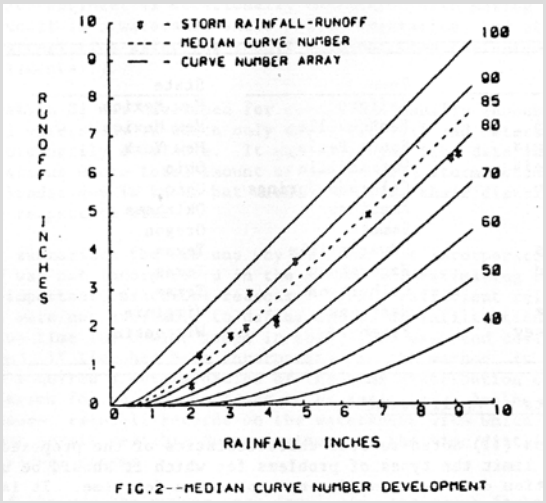

FIGURE 4-16 Development of curve number from collected data. SOURCE: Reprinted, with permission, from Rallison (1980). Copyright 1980 by the American Society of Civil Engineers.

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The Curve Number method is a very practical method that gives "average" runoff results from a watershed and is used in many models (WIN TR-55, TR-20, SWMM, GWLF, HEC-HMS, etc.). Caution has to be exercised when using it for smaller urbanizing storm events. For example, past practice was to average curve numbers for developments for pavement and grass based on percent imperviousness. While this works well for large storms, for smaller storms it gives erroneous answers through violation of the initial abstraction relationship. Current state manuals (MDE, 2000; PaDEP, 2006) do not allow paved- and unpaved-area curve numbers to be averaged. When applied to continuous simulation models (such as in SWMM or GWLF), it requires an additional method to recover the capacity to remove runoff because the soil capacity to infiltrate water is restored over time.

The NRCS Dimensionless Unit Hydrograph has also evolved over many years and simply creates a temporal pattern from the runoff generated from the curve number method. This transformation is based upon the time of concentration, defined as the length of time the water takes to travel from the top to the bottom of the watershed. The dimensionless curve ensures that conservation of mass is maintained. The main purpose of this method is to estimate how long it takes the runoff generated by the curve number to run off the land and produce discharge at the watershed outlet.

The NRCS curve number and dimensionless unit hydrograph were first incorporated in the Soil Conservation Service (SCS) TR-20 hydrologic computer model developed in the 1960s. As most stormwater professionals did not have access to mainframes, SCS put together TR-55, which created a hand or calculator method to apply the curve number and dimensionless unit hydrograph. In order to create this hand method, many runs were generated using TR-20 to develop patterns for different times of concentration. The difficulty with using the original TR-55 in the modern era is that the simplifications to the hydrograph development do not allow the benefits of SCMs to be easily accounted for.

The use of the term TR-55 has been equated with the curve number method; this has created confusion, especially when it is included in municipal code. Further clouding the issue, there are two types of TR-55 computer models available. One is based on the original, outdated, simplified hand method, and the other (Win TR-55) returns to the more appropriate application of the curve number and dimensionless hydrograph methods. In either case, the focus of these models is on single event hydrology and cannot easily incorporate or demonstrate the benefits of the wide range of structural and nonstructural SCMs. Note that the curve number and dimensionless unit hydrograph methods are incorporated in many continuous flow models, including SWMM and GWLF, as the basis of runoff generation and runoff timing.

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Deterministic Versus Stochastic Methods

Deterministic models are fully determined by their equation sets, initial and boundary conditions, and forcing meteorology. There are no components that include random variation. In a stochastic model, at least one parameter or variable is drawn from a probability distribution function such that the same model set-up (initial and boundary conditions, meteorology, parameter sets) will have randomly varying results. The advantage of the latter approach is the ability to generate statistical variability of outcomes, reflecting uncertainty in parameters, processes, or any other component. In fact, any deterministic model can be operated in a stochastic manner by sampling parameter values from specified probability distributions.

It is recognized that information on the probability distribution of input parameters may be scarce. For situations with limited information on parameter values, one option is to assume a uniform distribution that brackets a range of values of the parameter reported in the literature. This would at least be a start in considering the impacts of the variability of model inputs on outputs. A thorough discussion on methods for incorporating uncertainty analysis into model evaluation is provided in Chapter 14 of Ramaswami et al. (2005). It should be noted that the ability to generate probability distribution information on stormwater outcomes requires a potentially large number of model runs, which may be difficult for detailed mechanistic and distributed models that have large computational loads.

Continuous Versus Event-Based Approaches

Another division between modeling approaches is the time domain of the simulation. Event-based models limit simulation time domains to a storm event, covering the time of rainfall and runoff generation and routing. Initial conditions need to be estimated on the basis of antecedent moisture or precipitation conditions. For catchments in which runoff is dominated by impervious surfaces, this is a reasonable approach. In landscapes dominated by variable source area runoff dynamics in which runoff is generated from areas that actively expand and contract on the basis of soil moisture conditions, a fuller accounting of the soil moisture budget is required. Furthermore, event-based modeling is inappropriate for water quality purposes because it will not reproduce the full distribution of receiving water problems. Continuous models include simulation of a full time domain composed of storm and inter-storm periods, thus tracking soil moisture budgets up to and including storm events.

Outfall Models

After beneficial use impairments are recognized, cause-and-effect relation-

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ships need to be established and restorative discharge goals need to be developed. Models are commonly used to calculate the expected discharges for different outfalls affecting the receiving water in a community. All of the models shown in Table 4-7 can calculate outfall discharge quantities, although some may only give expected average annual discharge. Models calculate these discharges using a variety of processes, but all use an urban hydrology component to determine the runoff quantity and various methods to calculate the quality of the runoff. The runoff quantity is multiplied by the pollutant concentration in the outfall to obtain the mass discharges of the different pollutants. The outfall mass discharge from the various outfalls in the area can then be compared to identify the most significant outfalls that should be targeted for control.

The most common hydrology "engines" in simple stormwater models are the NRCS curve number method or a simple volumetric runoff coefficient—R_v, the ratio of runoff to rainfall—for either single rainfall events or the total annual rainfall depth. Runoff quality in the simple models is usually calculated based on published EMCs for similar land uses in the same geographical area. More complex models may use build-up and wash-off of pollutants from impervious surfaces in a time series or they may derive pollutant concentrations from more detailed biogeochemical cycling mechanisms, including atmospheric deposition and other inputs (e.g., fertilizer). Some models use a combination of these processes depending on the area considered, and others offer choices to the model user. Again, these processes all need local calibration and verification to reduce the likely uncertainty associated with the resultant calculated discharge conditions.

Source Area

When the outfalls are ranked according to their discharges of the pollutants of importance, further detailed modeling can be conducted to identify sources of the significant pollutants within the outfall drainage area. Lumped parameter models cannot be used, as the model parameters vary within the drainage area according to the different source areas. Distributed area models can be used to calculate contributions from different source areas within the watershed area. This information can then be used to rank the land uses and source area contributions. In-stream responses can be calculated if the land-area models are linked to appropriate receiving-water models.

Need for Coupling Models

As urban areas become increasingly extensive and heterogeneous, including a gradient of dense urban to forest and agricultural areas, linkage and coupling of models to develop feedback and interactions (e.g., impacts of urban runoff hydraulics with stream scour and sedimentation, mixed with agricultural nutrient

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and sediment production on receiving waterbodies) is a critical area that requires more development. In general, stormwater models were designed to track and predict discharges from sources by surface water flowpaths into receiving waterbodies, such that infiltration was considered to be a loss (or retention) of water and its constituents. To fully evaluate catchment-scale impacts of urbanization on receiving waterbodies, the infiltration term needs to be considered a source term for the groundwater, and a groundwater component or model needs to be coupled to complete the surface–subsurface hydrologic interactions and loadings to the waterbody.

Finally, each of the models may or may not incorporate explicit consideration of SCM performance based on design, implementation and location within the catchment. As discussed in the next chapter, SCM models can range from simple efficiency factors (0–1 multipliers on source discharge) to more detailed treatment of physical, chemical, and biological transport and transformations.

Linking to Receiving-Water Models

Specific problems for urban receiving waters need to be identified through comprehensive field monitoring and modeling. Monitoring can identify current problems and may identify the stressors of importance (see Burton and Pitt [2002] for tools to evaluate receiving water impairments). However, monitoring cannot predict conditions that do not yet exist and for other periods of time that are not represented at the time of monitoring. Modeling is therefore needed to gain a more comprehensive understanding of the problem. In small-scale totally urbanized systems, less complex receiving-water models are needed. However, as the watershed becomes more complex and larger with multiple land uses, the receiving-water models also need to become more complex. Complex receiving-water models need to include transport and transformations of the pollutants of concern, for example. Examples of models shown on the comparison table that include receiving-water processes are MUSIC and HSPF. Other models (such as WinSLAMM) provide direct data links to external receiving-water models. Calibration and verification of important receiving-water processes that are to be implemented in a model can be very expensive and time consuming, and still result in substantial uncertainty.

Model Calibration and Verification

Calibration is the process where model parameters are adjusted to minimize the difference between model output and field measurements, with an aim of keeping model parameters within a range of values reported in the literature. Model *verification*, similar to model validation, is used to mean comparison between calibrated model results using part of a data set as input and results from application of the calibrated model using a second (independent) part of

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the data set as input. Oreskes et al. (1994) present the viewpoint that no model can really be verified; at best, verification should be taken to mean that a model is consistent with a physical system under a given set of comparison data. This is not synonymous with saying that the model can reliably represent the real system under any set of conditions. In general, the water quantity aspects of stormwater modeling are easier to calibrate and verify than the water quality aspects, in part because there are more water quantity data available and because chemical transformations are more complex to simulate. A thorough discussion of the broad topic of model evaluation is provided by several excellent texts on this subject, including Schnoor (1996) and Ramaswami et al. (2005).

Models in Practice Today

Table 4-7 presents a set of models used for stormwater evaluation that range in complexity from first-generation stormwater models making use of simple empirical land cover/runoff and loading relations to more detailed and information-demanding models. The columns in Table 4-7 provide an abbreviated description of some of the attributes of these models—common usage, typical application scales, the degree of model complexity, some data requirements (for the hydrologic component), whether the model addresses groundwater, and whether the model has the ability to simulate SCMs. Models capable of simulating a water quality component require EMC data, with some models also having a simple build-up/wash-off approach to water quality simulation (e.g., SWMM, WinSLAMM, and MUSIC) and others simulating more complex geochemistry (e.g., SWAT and HSPF). The set of columns in Table 4-7 is not meant to be exhaustive in describing the models, which is why websites are provided for comprehensive model descriptions and data requirements.

In addition to the models listed in Table 4-7, a representative set of emerging research models that are not specifically designed for stormwater, but may offer some advantages for specific uses, are also described below. In general, it is important that models that integrate hydrologic, hydraulic, meteorologic, water quality, and biologic processes maintain balance in their treatment of process details. Both model design and data collection should proceed in concert and should be geared toward evaluating and diagnosing the consistency of model or coupled model predictions and the uncertainty attached to each component and the integrated modeling system. The models should be used in a manner that produces both best estimates of stormwater discharge impacts on receiving waterbodies, as well as the level of uncertainty in the predictions.

The Rational Method is a highly simplified model widely used to estimate peak flows for in sizing storm sewer pipes and other low level drainage pathways. The method assumes a constant rainfall rate (intensity), such that the runoff rate will increase until the time at which all of the drainage area contributes to flow at its outlet (termed the *time of concentration*). The product of the drainage area and rainfall intensity is considered to be the input flow rate to the

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drainage area under consideration; the ratio of the input flow rate to an outflow discharge rate is termed the runoff coefficient. Runoff coefficients for a variety of land surface types and slopes have been compiled in standard tables (see e.g., Chow et al., 1988). The outflow is determined by multiplying inflow (rainfall intensity times drainage area) by the runoff coefficient for the land-surface type. As pointed out by Chow et al. (1988), this method is often criticized owing to its simplified approach, so its use is limited to stormwater inlet and piping designs.

The Simple Method estimates stormwater pollutant loads for urban areas, and it is most valuable for assessing and comparing the relative stormwater pollutant load changes of different land use and stormwater management scenarios. It requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater pollutant concentrations (as defined by the EMC), and annual precipitation. The subwatershed can be broken up into specific land uses, such that annual pollutant loads are calculated for each type of land use. Stormwater pollutant concentrations are usually estimated from local or regional data, or from national data sources. The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as $L = 0.226\ R \times C \times A$, where L = annual load (lbs), R = annual runoff (inches), C = pollutant concentration (mg/l), and A = area (acres).

Of slightly increased complexity are those models initially developed decades ago by the Soil Conservation Service, now the NRCS of the U.S. Department of Agriculture (USDA). NRCS Technical Releases (TR) 20 and 55 are widely used in many municipalities, despite the availability of more rigorous, updated stormwater models. Box 4-5 provides an overview of the NRCS TR-55 assumptions and approaches.

A number of watershed models that are used for stormwater assessment are lumped, conceptual forms, with varying levels of process simplification and spatial patterns aggregated at the subwatershed level, with aspatial statistical distribution of land types as described above. The GWLF model (Haith and Shoemaker, 1987) is an example of this type of approach, using simple land use-based EMC with NRCS curve number estimates of runoff within a watershed context. GWLF is a continuous model with simplified upper- and lower-zone subsurface water stores, and a simple linear aquifer to deliver groundwater flow. EMCs are assigned or calibrated for subsurface and surface flow delivery, while sediment erosion and delivery are computed with the use of the Universal Soil Loss Equation and delivery coefficients. The methods are easily linked to a Geographical Information System (GIS), which provides land-use composition at the subwatershed level and develops estimates of runoff and loading that are typically used to estimate annual loading. AVGWLF links GWLF with ArcView and is used as a planning- or screening-level tool. A recent example of AVGWLF for nutrient loading linked to a simple stream network nutrient decay model for the development of a TMDL for a North Carolina water supply area is given in Box 4-6.

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BOX 4-6
The B. Everett Jordan Lake GWLF Watershed Model Development

Jordan Lake is a regionally important water supply reservoir at the base of the 1,686-square-mile Haw watershed in North Carolina (see Figure 4-17). It is considered a nutrient-sensitive waterbody. Officials are now in the process of implementing watershed goals to reduce nitrogen and phosphorus, with the reduction goals differentiated by geographic location within the basin. In support of the development of these rules as part of a TMDL effort, the North Carolina Division of Water Quality commissioned a water quality modeling study (Tetra Tech, 2003). The modeling effort was needed to support the evaluation of nutrient reduction strategies in different parts of the watershed relative to Jordan Lake, which requires both a model of nutrient loading, as well as river transport and transformation. Given data and resource restrictions, a more detailed model was not considered feasible. As GWLF does not support nutrient transformations in the stream network, the model was used in conjunction with a method to decay nutrient source loading by river transport distance to the lake. A spreadsheet model was designed to take as input GWLF estimates of seasonal loads for 14-digit hydrologic unit code (HUC) subbasins of the Haw, and to reduce the loads by river miles between the subwatershed and Jordan Lake. The GWLF loading model was calibrated to observations in small subwatersheds within the Haw using HRUs developed from soil and NLCD land classes, updated with additional information from county GIS parcel databases and the 2000 Census. This information was used to estimate subwatershed impervious surface cover, fertilizer inputs, runoff curve numbers, soil water capacity, and vegetation cover to adjust evapotranspiration rates. Wastewater disposal (sewer or septic) was estimated on the basis of urban service boundaries. GWLF was used to provide loading estimates, using limited information on soil and groundwater nutrient concentrations, and calibrated delivery ratios. In-stream loss was based on a first-order exponential decay function of river travel time to Jordan Lake, with the decay coefficient generated by estimates of residence time in the river network, and upstream/downstream nutrient loads following non-linear regression methods used in SPARROW (Alexander et al., 2000). Further adjustments based on impoundment trapping of sediment and associated nutrient loads were carried out for larger reservoirs in the Haw. The results provided estimates of both loading and transport efficiency to Jordan Lake, with estimates of relative effectiveness of sectoral loading reductions in different parts of the watershed.

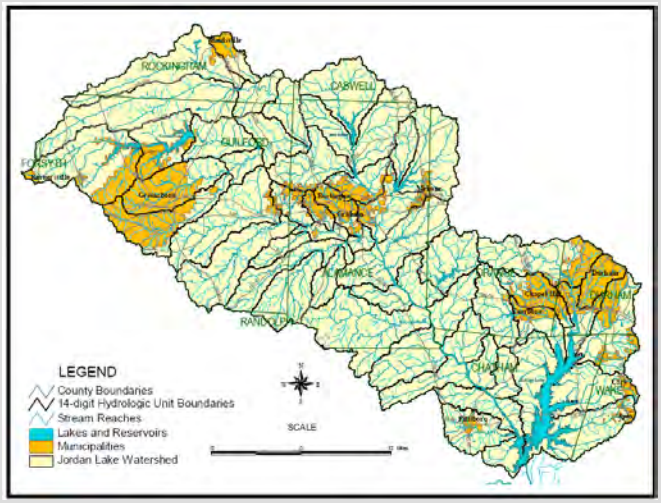

FIGURE 4-17 14 digit HUCs draining to Jordan Lake in the Haw River watershed of North Carolina. SOURCE: Tetra Tech (2003).

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P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds) is a curve number-based model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds, originally developed to help design and evaluate nutrient control in wet detention ponds (Palmstrom and Walker, 1990; http://wwwalker.net/p8/). Continuous water-balance and mass-balance calculations are performed and consist of the following elements: watersheds, devices, particle classes, and water quality components. Continuous simulations use hourly rainfall and daily air temperature time series. The model was initially calibrated to predict runoff quality typical of that measured under NURP (EPA, 1983). SCMs in P8 include detention ponds (wet, dry, extended), infiltration basins, swales, and buffer strips. Groundwater and baseflows are also included in the model using linear reservoir processes.

MUSIC is a part of the Catchment Modelling Toolkit (www.toolkit.net.au) developed by the Cooperative Research Center for Catchment Hydrology in Australia (Wong et al., 2001). The model concentrates on the quality and quantity of urban stormwater, including detailed accounting of multiple SCMs acting within a treatment train and life-cycle costing. It employs a simplified rainfall–runoff model (Chiew and McMahon, 1997) based on impervious area and two moisture stores (shallow and deep). TSS, total nitrogen, and total phosphorus are based on EMCs, sampled from lognormal distributions. The model does not contain detailed hydraulics required for routing or sizing of SCMs, and it is designed as a planning tool.

EPA's SWMM has the capability of simulating water quantity and quality for a single storm event or for continuous runoff. The model is commonly used to design and evaluate storm, sanitary, and combined sewer systems. SWMM accounts for hydrologic processes that produce runoff from urban areas, including time-varying rainfall, evaporation, snow accumulation and melting, depression storage, infiltration into soil, percolation to groundwater, interflow between groundwater and the drainage system, and nonlinear reservoir routing of overland flow. Spatial variability is modeled by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between subcatchments, or between entry points of a drainage system. SWMM can also be used to estimate the production of pollutant loads associated with runoff for a number of user-defined water quality constituents. Transport processes include dry-weather pollutant buildup over different land uses, pollutant wash-off from specific land uses, direct contribution of rainfall deposition, and the action of such SCMs as street cleaning, source control, and treatment in storage units, among others.

Watershed models such as SWAT (Arnold et al., 1998) or HSPF (Bicknell et al., 1997, 2005) have components based on similar land-use runoff and loading factors, but also incorporate options to utilize detailed descriptions of interception, infiltration, runoff, routing, and biogeochemical transformations. Both models are based on hydrologic models that were developed prior to the availability of detailed digital spatial information on watershed form and use concep-

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tual control volumes that are not spatially linked. HRUs are based on land use, soils, and vegetation (and crop) type, among other characteristics, and are considered uniformly distributed through a subbasin. Within each HRU, simplified representations of soil upper and lower zones, or unsaturated and saturated components, are vertically integrated with a conceptual groundwater storage-release component. There is no land surface routing and all runoff from a land element is considered to reach the river reach, with some delivery ratio if appropriate for sediment and other constituents. Like GWLF, the models are typically not designed to estimate loadings from individual dischargers, but are used to help guide and develop TMDL for watersheds. SWAT and HSPF are integrated within the EPA BASINS system (http://www.epa.gov/waterscience/basins) with GIS tools designed to use available spatial data to set up and parameterize simulations for watersheds within the United States. Examples of combining one of these models, typically designed for larger-scale applications (such as the area shown in Figure 4-14) with more site-specific models such as SLAMM or SWMM, are given in Box 4-7.

BOX 4-7
Using SWAT and WinSLAMM to Predict Phosphorus Loads in the Rock River Basin, Wisconsin

Wisconsin Administrative Code NR 217 states that wastewater treatment facilities in Wisconsin must achieve an effluent concentration of 1 mg/L for phosphorus. Alternative limits are allowed if it can be demonstrated that achieving the 1 mg/L limit will not "result in an environmentally significant improvement in water quality" (NR 217.04(2)(b)1). In response to NR 217, a group of municipal wastewater treatment facilities formed the Rock River Partnership (RRP) to assess water quality management issues (Kirsch, 2000). The RRP and the Wisconsin Department of Natural Resources funded a study to seek water quality solutions across all media, and not just pursue additional reductions from point sources. A significant portion of the study required a modeling effort to determine the magnitude of various nutrient sources and determine potential reductions through the implementation of global SCMs.

The Rock River Basin covers approximately 9,530 square kilometers and lies within the glaciated portion of south central and eastern Wisconsin (Figure 4-18). The Rock River and its numerous tributaries thread their way through this landscape that spreads over 10 counties inhabited by more than 750,000 residents. There are 40 permitted municipalities in the watershed, representing 4 percent of the land area, and they are served by 57 sewage treatment plants. Urban centers include Madison, Janesville, and Beloit as well as smaller cities such as Waupun, Watertown, Oconomowoc, Jefferson, and Beaver Dam. Although the basin is experiencing rapid growth, it is still largely rural in character with agriculture using nearly 75 percent of the land area. Crops range from continuous corn and corn–soybean rotations in the south to a mix of dairy, feeder operations, and cash cropping in the north. The basin enjoys a healthy economy with a good balance of agricultural, industrial, and service businesses.

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BOX 4-7 Continued

The focus of the modeling was to construct an intermediate-level macroscale model to better quantify phosphorus loads from point and nonpoint sources throughout the basin. The three goals of the modeling effort were to (1) estimate the average annual phosphorus load, (2) estimate the relative contribution of phosphorus loads from both nonpoint (urban and agricultural) and point sources, and (3) estimate changes in average annual phosphorus loads from the application of global SCMs and point source controls.

SWAT was selected for the agricultural analysis and WinSLAMM was selected to develop phosphorus loads for the urban areas. WinSLAMM was selected to make estimates of stormwater loads, because it is already calibrated in Wisconsin for stormwater volumes and pollutant concentrations. Outputs of phosphorus loads from WinSLAMM were used as input to SWAT. One output of SWAT was a total nonpoint phosphorus load based on agricultural loads calculated in SWAT and stormwater loads estimated by WinSLAMM.

SWAT was calibrated with data from 23 USGS gauging stations in the Rock River Basin. Hydrology was balanced first on a yearly basis looking at average annual totals, then monthly to verify snowfall and snowmelt routines, and then daily. Daily calibration was conducted to check crop growth, evapotranspiration, and daily peak flows. Crop yields predicted by SWAT were calibrated to those published in the USDA Agricultural Statistics.

Under current land-use and management conditions, the model predicted an average annual load of approximately 1,680,000 pounds of total phosphorus for the basin with 41 percent from point sources and 59 percent from nonpoint sources. Less than 10 percent of the annual phosphorus load is generated by the urban areas in the watershed. Evaluation of various SCM scenarios shows that with implementation of NR 217 (applicable point source effluent at 1 mg/L) and improvement in tillage practices and nutrient management practices, total phosphorus can be reduced across the basin by approximately 40 percent. It is important to note that the nonpoint management practices that were analyzed were limited to two options: modifications in tillage practices, and adoption of recommended nutrient application rates. No other management practices (i.e., urban controls, riparian buffer strips, etc.) were simulated. Urban controls were not included because the urban areas contributed a relatively small percentage of the total phosphorus load. Thus, loadings depicted by SWAT under these management scenarios do not necessarily represent the lowest attainable loads. Results suggest that a combination of point and nonpoint controls will be required to attain significant phosphorus reductions.

The CBWM is a detailed watershed model that is extended from HSPF as a base, but includes additional components to incorporate stormwater controls at the land segment level. HSPF is operated for a number of subbasins, and each subbasin model includes different land segments based on land cover and soil units as aspatial, lumped distribution functions, but also includes representation of SCMs and (large) stream routing. Model implementation at the scale of the full Chesapeake Bay watershed requires fairly coarse-grained land partitioning. A threshold of 100 cfs mean annual flow is used to represent streams and rivers, and the one-to-one mapping of land segment to river reach produces large, heterogeneous land segments as the basic runoff-producing zones. SCMs are implemented either at the field or runoff production unit as distinct land segment types in terms of management or land cover, or as “edge-of-field” reductions of runoff or pollutant loads. The latter are assigned as static efficiency factors irrespective of flow conditions or season, with all SCMs within a land segment integrated into a single weighted efficiency value.

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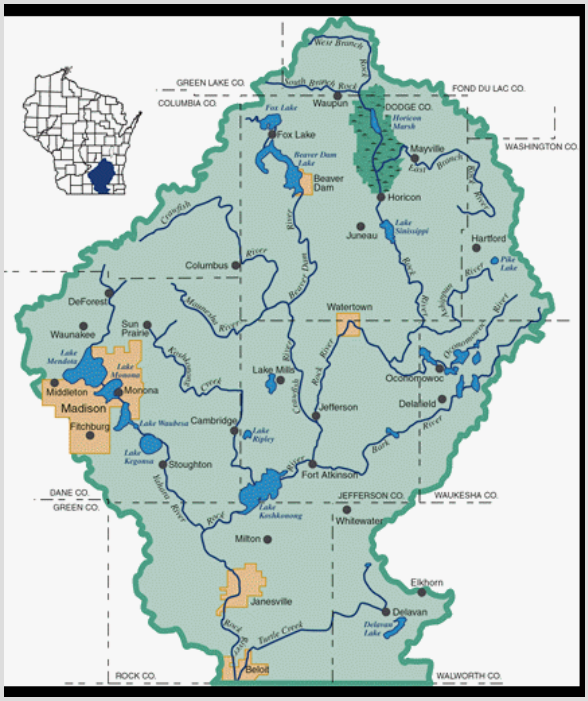

FIGURE 4-18 Rock River Basin, Wisconsin. SOURCE: Reprinted, with permission, from Kirsch (2000). Copyright 2000 by American Society for Biological and Agricultural Engineers.

SLAMM is designed for complex, urban catchments and is used as a planning tool to assess both stormwater and pollutant runoff production and the capability of specific stormwater control strategies to reduce stormwater discharges from urban sources. It is specifically designed to capture the most significant distributed and sequential drainage effects of variable source areas in urban catchments (Pitt and Vorhees, 2002) and is based on detailed descriptions of the catchment composition, including both type and relative position (drainage sequence) of land elements. The model is dependent on high-resolution classification or description of the catchment that has become increasingly available in urban areas over the past two decades, and comprehensive field assessment of runoff and pollutant loading from different urban land elements. SLAMM uses continuous simulation for some aspects, such as the build up of street pollutant loads between storms, while using event-based simulation for runoff. The description of build-up and wash-off is a critical component in urban stormwater models applied to areas with substantial impervious surfaces and is a good example of the need to match detailed and rigorous field sampling in

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order to adequately describe and represent dominant processes. Details of measurement and model representation for build-up and wash-off of contaminants are given in Box 4-8.

Potential New Applications of Coupled Distributed Models

The advent of high-resolution digital topographic and land-cover data over the past two decades has fueled a significant shift in runoff modeling towards "spatially explicit" simulations that distinguish and connect runoff producing elements in a detailed flow routing network. While models developed prior to the availability of high-resolution data or based on older paradigms developed in the absence of this information required spatial and conceptual lumping of control volumes, more recently developed distributed models may contain control volumes linked in multiple vertical layers (soil and aquifer elements) and laterally from a drainage divide to the stream, including stream-channel and riparian segments. A set of models has been developed and applied to stormwater generation using this paradigm that can be applied at the scale of residential neighborhoods, resolving land cover and topography at the parcel level. These models also vary in terms of their emphasis, with some models better representing coupled surface water–groundwater interactions, water, carbon and nutrient cycling, or land–atmosphere interactions. Boyer et al. (2006) have recently reviewed a set of hydrologic and ecosystem models in terms of their ability to simulate sources, transport, and transformation of nitrogen within terrestrial and aquatic ecosystems. Data and information requirements are typically high, and the level of process specificity may outstrip the available information necessary to parameterize the integrated models. However, an emphasis is placed on providing mechanistic linkage and feedbacks between important surface, subsurface, atmospheric, and ecosystem components. Examples of these models include the Distributed Hydrology Soil Vegetation model (DHSVM, Wigmosta et al., 1994); the Regional Hydro-Ecologic Simulation System (RHESSys, Band et al., 1993; Tague and Band, 2004); ParFlow-Common Land Model (CLM, Maxwell and Miller, 2007); the Penn State Integrated Hydrologic Model (PIHM, Qu and Duffy, 2007); the Soil Moisture Distribution and Routing (SMDR) model (Easton et al., 2007); and that of Xiao et al. (2007).

One advantage of integrating surface and subsurface flow systems within any of these model structures is the ability to incorporate different SCMs by specifying characteristics of specific locations within the flow element networks linked to the subsurface drainage. Examples can include alteration of surface detention storage and release curves to simulate detention ponds, or soil depth, texture, vegetation, and drainage release for rainfall gardens. The advantage of this approach is the tight coupling of these SCM features with the connected surface and subsurface drainage systems, allowing the direct incorporation of the SCM as sink or source terms within the flowpath network. Burgess et al. (1998) effectively demonstrated that suburban lawns can become the major

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BOX 4-8
Build-up and Wash-off of Contaminants from Impervious Surfaces

The accumulation and wash-off of street particulates have been studied for many years (Sartor and Boyd, 1972; Pitt, 1979, 1985, 1987) and are important considerations in many stormwater models, such as SWMM, HSPF, and SLAMM, that require information pertaining to the movement of pollutants over land surfaces. Accumulation rates are usually obtained through trial and error during calibration, with little, if any, actual direct measurements. Furthermore, those direct measurements that have been made are often misapplied in modeling applications, resulting in unreasonable model predictions.

Historically, streets have been considered the most important directly connected impervious surface. Therefore, much early research was directed toward measuring the processes on these surfaces. Although it was eventually realized that other surfaces can also be significant pollutant sources (see Pitt et al., 2005a,b for reviews), additional research to study accumulation and wash-off for these other areas has not been conducted, such that the following discussion is focused on street dirt accumulation and wash-off.

Accumulation of Particulates on Street Surfaces

The permanent storage component of street surface particulates is a function of street texture and condition and is the quantity of street dust and dirt that cannot be removed naturally by rain or wind, or by street cleaning equipment. It is literally trapped in the texture of the street. The street dirt loading at any time is this initial permanent loading plus the accumulation amount corresponding to the exposure period, minus the resuspended material removal by wind and traffic-induced turbulence.

One of the first research studies to attempt to measure street dirt accumulation was conducted by Sartor and Boyd (1972). Field investigations were conducted between 1969 and 1971 in several cities throughout the United States and in residential, commercial, and industrial land-use areas. Figure 4-19 is a plot of the 26 test area measurements collected from different cities, but separated by the three land uses. The data are the accumulated solids loading plotted against the number of days since the street had been cleaned by the municipal street cleaning operation or a “significant” rain. There is a large amount of variability. The street cleaning and this rain were both assumed to remove all of the street dirt; hence, the curves were all forced through zero loading at zero days.

A more thorough study was conducted in San Jose, California by Pitt (1979), during which the measured street dirt loading for a smooth street was also found to be a function of time. As shown in Figure 4-20, both accumulation rates and increases in particle size of the street dirt increase as time between street cleaning lengthens. However, it is also evident that there is a substantial residual loading on the streets immediately after the street cleaning, which differs substantially from the assumption of Sartor and Boyd that rains reduce street dirt to zero.

The San Jose study also investigated the role of different street textures, which resulted in very different street dirt loadings. Although the accumulation and deposition rates are quite similar, the initial loading values (the permanent storage values) are very different, with greater amounts of street dirt trapped by the coarser (oil and screens) pavement. Street cleaning and rains are not able to remove this residual material. The early, uncorrected Sartor and Boyd accumulation rates that ignored the initial loading values were almost ten times the corrected values that had reasonable “initial loads.”

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BOX 4-8 Continued

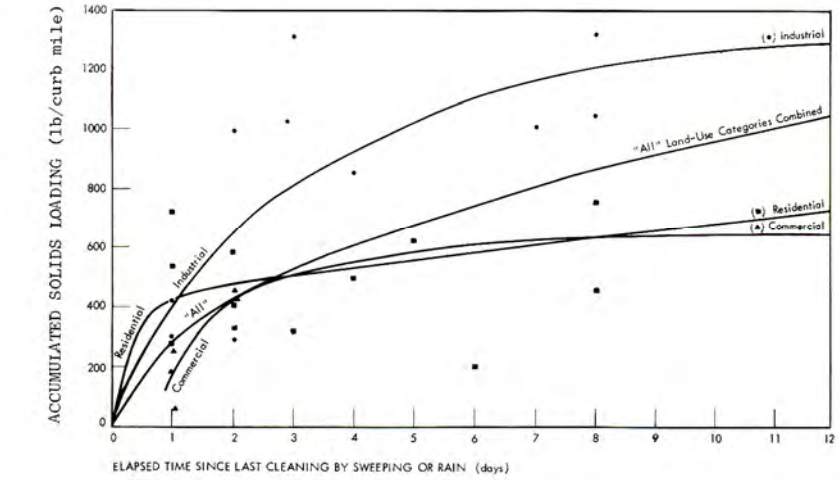

FIGURE 4-19 Accumulation curves developed during early street cleaning research. SOURCE: Sartor and Boyd (1972).

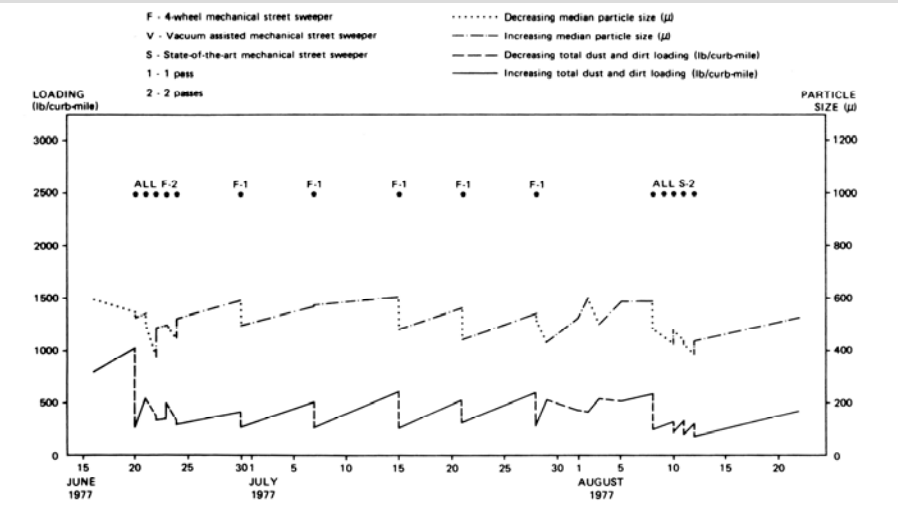

FIGURE 4-20 Street dirt accumulation and particle size changes on good asphalt streets in San Jose, California. SOURCE: Pitt (1979).

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Finally, it was found that, at very long accumulation periods relative to the rain frequency, the wind losses (fugitive dust) may approximate the deposition rate, resulting in very little increases in loading. In Bellevue, Washington, with inter-event rain periods averaging about three days, steady loadings were observed after about one week (Pitt, 1985). However, in Castro Valley, California, the rain inter-event periods were much longer (ranging from about 20 to 100 days), and steady loadings were never observed (Pitt and Shawley, 1982).

Taking many studies into account (Sartor and Boyd 1972—corrected; Pitt, 1979, 1983, 1985; Pitt and Shawley, 1982; Pitt and Sutherland, 1982; Pitt and McLean, 1986), the most important factors affecting the initial loading and maximum loading values have been found to be street texture and street condition, and not land use. When data from many locations are studied, it is apparent that smooth streets have substantially less loadings at any accumulation period compared to rough streets for the same land use. Very long accumulation periods relative to the rain frequency result in high street dirt loadings. However, during these conditions the wind losses of street dirt (as fugitive dust) may approximate the deposition rate, resulting in relatively constant street dirt loadings.

Wash-off of Street Surface Pollutants

Wash-off of particulates from impervious surfaces is dependent on the available supply of particulates on the surface that can be removed by rains, the rain energy available to loosen the material, and the capacity of the runoff to transport the loosened material. Observations of particulate wash-off during controlled tests have resulted in empirical wash-off models. The earliest controlled street dirt wash-off experiments were conducted by Sartor and Boyd (1972) to estimate the percentage of the available particulates on the streets that would wash off during rains of different magnitudes. Sartor and Boyd fitted their data to an exponential curve, as shown in Figure 4-21 (accumulative wash-off curves for several particle sizes). The empirical equation that they developed, $N = N_o\, e^{-kR}$, is only sensitive to the total rain depth up to the time of interest and the initial street dirt loading.

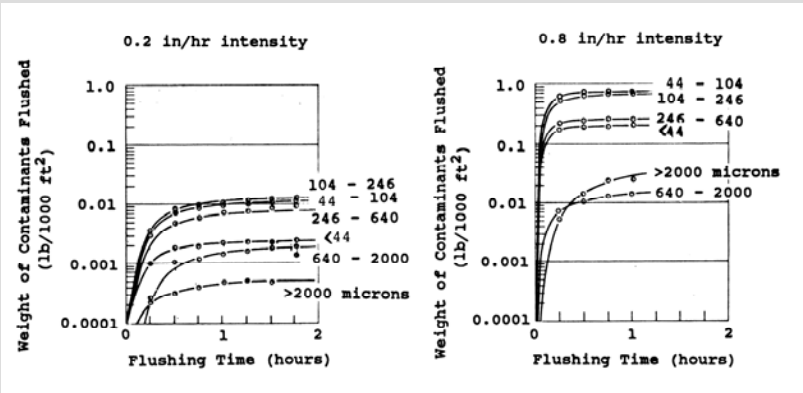

FIGURE 4-21 Street dirt wash-off during high-intensity rain tests. SOURCE: Sartor and Boyd (1972).

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BOX 4-8 Continued

There are several problems with this approach. First, these figures did not show the total street dirt loading that was present before the wash-off tests. Most modelers have assumed that the asymptotic maximum shown was the total "before-rain" street dirt loading; that is, the N_o factor has been assumed to be the total initial street loading, when in fact it is only the portion of the total street load available for wash-off (the maximum asymptotic wash-off load observed during the wash-off tests). The actual total street dirt loadings were several times greater than the maximum wash-off amounts observed. STORM and SWMM now use an availability factor (*A*) for particulate residue as a calibration procedure in order to reduce the wash-off quantity for different rain intensities (Novotny and Chesters, 1981). Second, the proportionality constant, *k*, was found by Sartor and Boyd to be slightly dependent on street texture and condition, but was independent of rain intensity and particle size. The value of this constant is usually taken as 0.18/mm, assuming that 90 percent of the particulates will be washed from a paved surface in one hour during a 13 mm/h rain. However, Alley (1981) fitted this model to watershed outfall runoff data and found that the constant varied for different storms and pollutants for a single study area. Novotny examined "before" and "after" rain-event street particulate loading data using the Milwaukee NURP stormwater data (Bannerman et al., 1983) and found almost a three-fold difference between the proportionality constant value for fine (<45 μm) and medium-sized particles (100 to 250 μm). Jewell et al. (1980) also found large variations in outfall "fitted" values for different rains compared to the typical default value. They stressed the need to have local calibration data before using the exponential wash-off equation, as the default values can be very misleading. The exponential wash-off equation for impervious areas is justified, but wash-off coefficients for each pollutant would improve its accuracy. The current SWMM5 version discourages the use of accumulation and wash-off functions due to lack of data, and the misinterpretation of available data.

It turns out that particle dislodgement and transport characteristics at impervious areas can be directly measured using relatively simple wash-off tests. The Bellevue, Washington, urban runoff project (Pitt, 1985) included about 50 pairs of street dirt loading observations close to the beginnings and ends of rains to determine the differences in loadings that may have been caused by the rains. The observations were affected by rains falling directly on the streets, along with flows and particulates originating from non-street areas. When all the data were considered together, the net loading difference was about 10 to 13 g/curb-m removed, which amounted to a street dirt load reduction of about 15 percent. Large reductions in street dirt loadings for the small particles were observed during these Bellevue rains. Most of the weight of solid material in the runoff was concentrated in fine particle sizes (<63 μm). Very few wash-off particles greater than 1,000 μm were found; in fact, street dirt loadings increased for the largest sizes, presumably due to settled erosion materials. Urban runoff outfall particle size analyses in Bellevue (Pitt, 1985) resulted in a median particle size of about 50 μm; similar results were obtained in the Milwaukee NURP study (Bannerman et al., 1983). The results make sense because the rain energy needed to remove larger particles is much greater than for small particles.

In order to clarify street dirt wash-off, Pitt (1987) conducted numerous controlled wash-off tests on city streets in Toronto. The experimental factors examined included rain intensity, street texture, and street dirt loading. The differences between available and total street dirt loads were also related to the experimental factors. The runoff flow quantities were also carefully monitored to determine the magnitude of initial and total rain water losses on impervious surfaces. The test setup was designed and tested to best represent actual rainfall conditions, such as rain intensities (3 mm/h) and peak rain intensities (12 mm/h). The kinetic energies of the "rains" during these tests were therefore comparable to actual rains under investigation. Figure 4-22 shows the asymptotic wash-off values observed in the tests, along with the measured total street dirt loadings. The maximum asymptotic values are the "available" street dirt loadings (N_o). As can be seen, the measured

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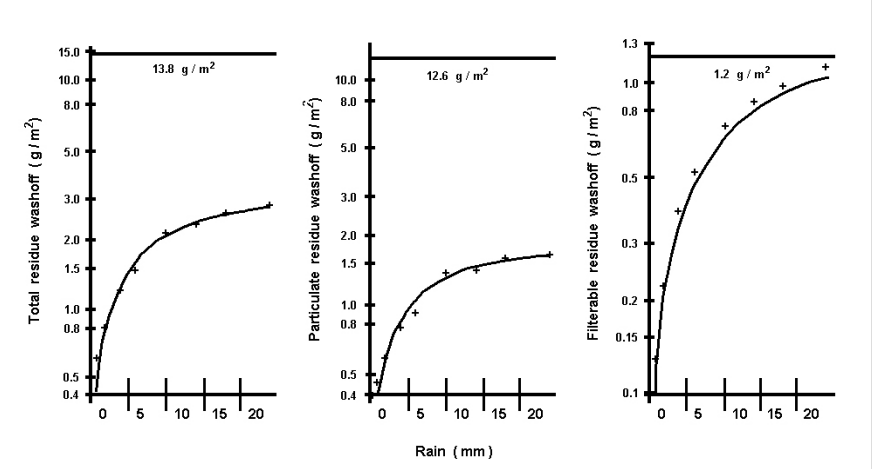

FIGURE 4-22 Wash-off plots for high rain intensity, dirty street, and smooth street test, showing the total street dirt loading. SOURCE: Pitt (1987).

total loadings are several times larger than these "available" loading values. For example, the asymptotic available total solids value for the high-intensity rain–dirty street–smooth street test was about 3 g/m^2 while the total load on the street for this test was about 14 g/m^2, or about five times the available load. The differences between available and total loadings for the other tests were even greater, with the total loads typically about ten times greater than the available loads. The total loading and available loading values for dissolved solids were quite close, indicating almost complete wash-off of the very small particles.

The availability factor (the ratio of the available loading, N_0, to the total loading) depended on the rain intensity and the street roughness, such that wash-off was more efficient for the higher rain energy and smoother pavement tests. The worst case was for a low rain intensity and rough street, where only about 4.5 percent of the street dirt would be washed from the pavement. In contrast, the high rain intensities on the smooth streets were more than four times more efficient in removing street dirt (20 percent removal).

A final important consideration in calculating wash-off of street dirt during rains is the carrying capacity of the flowing water to transport sediment. If the calculated wash-off is greater than the carrying capacity (such as would occur for relatively heavy street dirt loads and low to moderate rain intensities), then the carrying capacity is limiting. For high rain intensities, the carrying capacity is likely sufficient to transport most or all of the wash-off material. Figure 4-23 shows the maximum wash-off amounts (g/m^2) for the different tests conducted on smooth streets plotted against the rain intensity (mm/h) used for the tests (data from Sartor and Boyd, 1972, and Pitt, 1987). Wash-off limitations for rough streets would be more restrictive.

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BOX 4-8 Continued

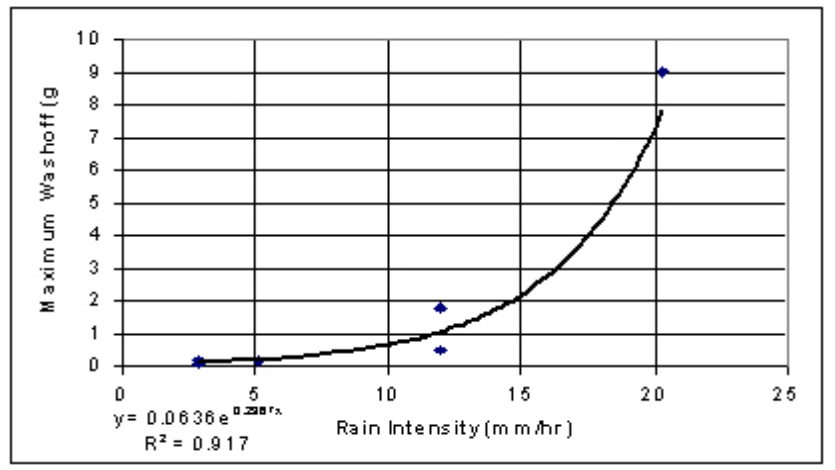

FIGURE 4-23 Maximum wash-off capacity for smooth streets (based on measurements of Sartor and Boyd, 1972; Pitt, 1987). If the predicted wash-off, using the previous "standard" wash-off equations, is smaller than the values shown in this figure, then those values can be used directly. However, if the predicted wash-off is greater than the values shown in this figure, then the values in the figure should be used.

Accumulation and Wash-off Summary

This discussion summarized street particulate wash-off observations obtained during special wash-off tests, along with associated street dirt accumulation measurements. The objectives of these tests were to identify the significant rain and street factors affecting particulate wash-off and to develop appropriate wash-off models. The controlled wash-off experiments identified important relationships between "available" and "total" particulate loadings and the significant effects of the test variables on the wash-off model parameters. Past modeling efforts have typically ignored or misused this relationship to inaccurately predict the importance of street particulate wash-off. The available loadings were almost completely washed off streets during rains of about 25 mm (as previously assumed). However, the fraction of the total loading that was available was at most only 20 percent of the total loading, and averaged only 10 percent, with resultant actual wash-offs of only about 9 percent of the total loadings.

In many model applications, total initial loading values (as usually measured during field studies) are used in conjunction with model parameters as the available loadings, resulting in predicted wash-off values that are many times larger than observed. This has the effect of incorrectly assuming greater pollutant contributions originating from streets and less from other areas during rains. This in turn results in inaccurate estimates of the effectiveness of different source area urban runoff controls. Although streets can be important sources of runoff and stormwater pollutants, their significance varies greatly depending on the land use and rainfall pattern. They are much more important sources in areas having relatively mild rains (e.g., the Pacific Northwest), where contaminants from other potential sources are not effectively transported to the storm drainage system.

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source of stormwater in seasonally wet conditions (Seattle), while Cuo et al. (2008) have explored the modification of DHSVM to include detention SCMs. Xiao et al. (2007) explicitly integrated and evaluated parcel scale SCM design and efficiency into their model. Wang et al. (2008) integrated a canopy interception model with a semi-distributed subsurface moisture scheme (TOPMODEL) to evaluate the effectiveness of urban tree canopy interception on stormwater production, utilizing a detailed spatial dataset of urban tree cover. Band et al. (2001) and Law (2003) coupled a water-, carbon-, and nitrogen-cycling model to a distributed water routing system modified from DHSVM to simulate nitrogen cycling and export in a high-spatial-resolution representation of forested and suburban catchments. While these models have the potential to directly link stormwater generation with specific dischargers, the challenge of scaling to larger watersheds remains. SMDR (Easton et al., 2007) has recently been used to integrate rural and urban stormwater production, including dissolved phosphorus source and transport in New York State.

Alternatives to mass budget-based models include fully statistical approaches such as simple regressions based on watershed land use and population (e.g., Boyer et al., 2002); nonlinear regression using detailed watershed spatial data and observed loads to estimate retention parameters and loading of nutrients, sediment, and other pollutants (e.g., Smith et al., 1997; Brakebill and Preston, 1999; Schwarz et al., 2006); and Bayesian chain models (e.g., Reckhow and Chapra, 1999; Borsuk et al., 2001). These models have the advantage of being data-based, and therefore capable of assimilating observations as they become available to update water quality probabilities, but also lack a process basis that might support management intervention. A major debate exists within the literature as to the relative advantages of detailed process-based models that may not have inadequate information for parameterization, and the more empirical, data-based approaches.

Limitations in Extending Stormwater Models to Biological Impacts

The mass budget approach may be successful in developing the physical and chemical characteristics of the receiving waterbody in terms of the flow (or stage) duration curve, the distribution of concentrations over time, and the integrated pollutant storage and flux (load) terms. However, the biological status of the waterbody requires a link between the physical and chemical conditions, primary productivity, and trophic system interactions. Progressing from aquatic ecosystem productivity to trophic systems includes increasingly complex ecological processes such as competition, herbivory, predation, and migration. To date, mechanistic linkage between flow path hydraulics, biogeochemistry, and the ecological structure of the aquatic environment has not been developed. Instead, habitat suitability for different communities is identified through empirical sampling and analysis, with the implicit assumption that, as relative

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TABLE 4-7 Example Mathematical Models That Have Been or Can Be Used in Stormwater Modeling

Model	Common Use	Typical Scale	Complexity	Data Requirements	Ground-water	SCM	Reference
Rational Method	Urban hydraulic design—peak flow	Small	Simple	Land cover, rainfall intensity, T_c	None	None	Standard hydrology text
Simple Method	Urban annual runoff, loads	Small to medium	Simple	Impervious surface cover, land use, annual rainfall	None	None	http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm
TR-20 TR-55	Rural/urban runoff production for simple stormwater models, hydraulic design	Small to medium	Simple to medium	Land use, soil texture, T_c	None	Pond sizing for hydraulic benefits and others through CN modification	http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models
GWLF	Rural/urban runoff, pollutant loading	Medium to watershed	Simple to medium	Land use, soil texture, precipitation time series	Simple linear reservoir	Runoff reduction with CN modification	Haith and Shoemaker (1987) http://www.avgwlf.psu.edu/overview.htm
P8	Urban runoff, pollutant loading	Small to large	Simple to medium	Land use, soil texture, precipitation time series, SCM type and sizing	Simple linear reservoir	Runoff reduction with CN modification, ponds (evaluation and sizing), infiltration, street cleaning	Palmstrom and Walker (1990) http://www.wwwalker.net/p8/
MUSIC	Urban runoff, pollutant loading, hydraulic design, simple receiving water	Small to large	Medium to complex	Land use, soil texture, precipitation/PET? time series, drainage system details, SCM type and sizing	Simple linear reservoir	Comprehensive evaluation of SCM systems	Wong (2000) (proprietary) http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit.woa/wa/productDetails?productID=1000000

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SWMM	Urban runoff, pollutant loading, hydraulic design	Small to large	Medium to complex	Land use, soil texture, meteorological time series, drainage system details, SCM type and sizing	Simple linear reservoir?	Infiltration practices, ponds, street cleaning	http://www.epa.gov/ednnrmrl/models/swmm
PCSWMM	Same as above	Same as above	Same as above	Same as above	Same as above	Enhanced SCM compared to SWMM	(proprietary) http://www.computationalhydraulics.com/Software/PCSWMM.NET
WinSLAMM	Urban runoff, pollutant loads	Small to large	Intermediate	Land cover, land use, development characteristics, soil texture, compaction, rainfall event time series, monthly PET, monthly water evaporation, SCM type and sizing	Mounding under infiltration controls	Comprehensive evaluation of SCM systems	(proprietary) http://www.winslamm.com/prod01.htm
SWAT	Rural runoff, loading	Medium to watershed	Intermediate	Land cover/land use, soil texture, precipitation, temperature, humidity, solar radiation time or PET series	Simple subbasin reservoir	Impoundments, agricultural conservation practices, nutrient management, buffers	http://www.epa.gov/waterscience/BASINS/bsnsdocs.html#swat
HSPF	Comprehensive watershed evaluation, receiving water dynamics	Medium to watershed	Complex	Land cover/land use, soil texture, precipitation, temperature, humidity, solar radiation or PET time series	Subbasin reservoir	Infiltration, ponds	Bicknell et al. (2005) http://www.epa.gov/ceampubl/swater/hspf/index.htm http://www.epa.gov/waterscience/BASINS/bsnsdocs.html#hspf
WWHM	HSPF engine with regional modifications,	Puget Sound	Complex	Same as above	Same as above	Enhanced infiltration, ponds (from HSPF)	http://www.ecy.wa.gov/programs/wq/stormwater/wwhm_training/index.html.
CBWM	HSPF engine with regional modifications,	Chesapeake Bay Watershed	Complex	Same as above	Same as above	Enhanced infiltration, ponds (from HSPF)	http://www.chesapeakebay.net/phase5.htm

Note: CN, curve number

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habitat suitability changes, transitions will occur between species or assemblages. These methods may work well at the base of the trophic system (algae, phytoplankton) and for specific conditions such as DO limitations on fish communities, but the impacts of low to moderate concentrations of pollutants on aquatic ecosystems may still be poorly understood. A critical assumption in these and similar models (e.g., ecological community change resulting from physical changes to the watershed or climate) is the substitution of space for time. More detailed understanding of the mechanisms leading to a shift in ecological communities and interactions with the physical environment is necessary to develop models of transient change, stability of the shifts, and feedback to the biophysical environment.

Given these limitations, it should be noted that statistical databases on species tolerance to a range of aquatic conditions have been compiled that will allow the development of habitat suitability mapping as a mechanism for (1) targeting ecosystem restoration, (2) determining vulnerable sites (for use in application of the Endangered Species Act), and (3) assessing aquatic ecosystem impairment and "best use" relative to reference sites.

***

Stormwater models have been developed to meet a range of objectives, including small-scale hydraulic design (e.g., siting and sizing a detention pond), estimation of potential contributions of stormwater pollutants from different land covers and locations using empirically generated EMC, and large watershed hydrology and gross pollutant loading. The ability to associate a given discharger with a particular waterbody impairment is limited by the scale and complexity of watersheds (i.e., there maybe multiple discharge interactions); by the ability of a model to accurately reproduce the distribution function of discharge events and their cumulative impacts (as opposed to focusing only on design storms of specific return periods); and by the availability of monitoring data of sufficient number and design to characterize basic processes (e.g., build-up/wash-off), to parameterize the models, and to validate model predictions.

In smaller urban catchments with few dominant dischargers and significant impervious area, current modeling capabilities may be sufficient to associate the cumulative impact of discharge to waterbody impairment. However, many impaired waterbodies have larger, more heterogeneous stormwater sources, with impacts that are complex functions of current and past conditions. The level of sampling that would be necessary to support linked model calibration and verification using current measurement technologies is both time-consuming and expensive. In order to develop a more consistent capability to support stormwater permitting needs, there should be increased investment in improving model paradigms, especially the practice and methods of model linkage as described above, and in stormwater monitoring. The latter may require investment in a new generation of sensors that can sample at temporal resolutions that can adjust to characterize low flow and the dynamics of storm flow, but are sufficiently

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inexpensive and autonomous to be deployed in multiple locations from distributed sources to receiving waterbodies of interest. Finally, as urban areas extend to encompass progressively lower-density development, the interactions of surface water and groundwater become more critical to the cumulative impact of stormwater on impaired waterbodies.

EPA needs to ensure continuous support and development of their water quality models and spatial data infrastructure. Beyond this, a set of distributed watershed models has been developed that can resolve the location and position of parcels within hydrologic flow fields; these are being modified for use as urban stormwater models. These models avoid the pitfalls of lumping, but they require much greater volumes of spatial data, provided by current remote sensing technology (e.g., lidar, airborne digital optical and infrared sensors) as well as the emerging set of in-stream sensor systems. While these methods are not yet operational or widespread, they should be further investigated and tested for their capabilities to support stormwater management.

CONCLUSIONS AND RECOMMENDATIONS

This chapter addresses what might be the two weakest areas of the stormwater program—monitoring and modeling of stormwater. The MS4 and particularly the industrial stormwater monitoring programs suffer from (1) a paucity of data, (2) inconsistent sampling techniques, (3) a lack of analyses of available data and guidance on how permittees should be using the data to improve stormwater management decisions, and (4) requirements that are difficult to relate to the compliance of individual dischargers. The current state of stormwater modeling is similarly limited. Stormwater modeling has not evolved enough to consistently say whether a particular discharger can be linked to a specific waterbody impairment, although there are many correlative studies showing how parameters co-vary in important but complex and poorly understood ways (see Chapter 3). Some quantitative predictions can be made, particularly those that are based on well-supported causal relationships of a variable that responds to changes in a relatively simple driver (e.g., modeling how a runoff hydrograph or pollutant loading change in response to increased impervious land cover). However, in almost all cases, the uncertainty in the modeling and the data, the scale of the problems, and the presence of multiple stressors in a watershed make it difficult to assign to any given source a specific contribution to water quality impairment. More detailed conclusions and recommendations about monitoring and modeling are given below.

Because of a ten-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized. These results come from many thousands of storm events, systematically compiled and widely accessible; they form a robust dataset of utility to theoreticians and practitioners alike. These data make it possible to

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accurately estimate the EMC of many pollutants. Additional data are available from other stormwater permit holders that were not originally included in the database and from ongoing projects, and these should be acquired to augment the database and improve its value in stormwater management decision-making.

Industry should monitor the quality of stormwater discharges from certain critical industrial sectors in a more sophisticated manner, so that permitting authorities can better establish benchmarks and technology-based effluent guidelines. Many of the benchmark monitoring requirements and effluent guidelines for certain industrial subsectors are based on inaccurate and old information. Furthermore, there has been no nationwide compilation and analysis of industrial benchmark data, as has occurred for MS4 monitoring data, to better understand typical stormwater concentrations of pollutants from various industries. The absence of accurate benchmarks and effluent guidelines for critical industrial sectors discharging stormwater may explain the lack of enforcement by permitting authorities, as compared to the vigorous enforcement within the wastewater discharge program.

Industrial monitoring should be targeted to those sites having the greatest risk associated with their stormwater discharges. Many industrial sites have no or limited exposure to runoff and should not be required to undertake extensive monitoring. Visual inspections should be made, and basic controls should be implemented at these areas. Medium-risk industrial sites should conduct monitoring so that a sufficient number of storms are measured over the life of the permit for comparison to regional benchmarks. Again, visual inspections and basic controls are needed for these sites, along with specialized controls to minimize discharges of the critical pollutants. Stormwater from high-risk industrial sites needs to be continuously monitored, similar to current point source monitoring practices. The use of a regionally calibrated stormwater model and random monitoring of the lower-risk areas will likely require additional monitoring.

Continuous, flow-weighted sampling methods should replace the traditional collection of stormwater data using grab samples. Data obtained from too few grab samples are highly variable, particularly for industrial monitoring programs, and subject to greater uncertainly because of experimenter error and poor data-collection practices. In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications. It should be replaced by more accurate and frequent continuous sampling methods that are flow weighted. Flow-weighted composite monitoring should continue for the duration of the rain event. Emerging sensor systems that provide high temporal resolution and real-time estimates for specific pollutants should be further investigated, with the aim of providing lower costs and more extensive monitoring systems to sample both streamflow and constituent loads.

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Flow monitoring and on-site rainfall monitoring need to be included as part of stormwater characterization monitoring. The additional information associated with flow and rainfall data greatly enhance the usefulness of the much more expensive water quality monitoring. Flow monitoring should also be correctly conducted, with adequate verification and correct base-flow subtraction methods applied. Using regional rainfall data from locations distant from the monitoring location is likely to be a major source of error when rainfall factors are being investigated. The measurement, quality assurance, and maintenance of long-term precipitation records are both vital and nontrivial to stormwater management.

Whether a first flush of contaminants occurs at the start of a rainfall event depends on the intensity of rainfall, the land use, and the specific pollutant. First flushes are more common for smaller sites with greater imperviousness and thus tend to be associated with more intense land uses such as commercial areas. Even though a site may have a first flush of a constituent of concern, it is still important that any SCM be designed to treat as much of the runoff from the site as possible. In many situations, elevated discharges may occur later in an event associated with delayed periods of peak rainfall intensity.

Stormwater runoff in arid and semi-arid climates demonstrates a seasonal first-flush effect (i.e., the dirtiest storms are the first storms of the season). In these cases, it is important that SCMs are able to adequately handle these flows. As an example, early spring rains mixed with snowmelt may occur during periods when wet detention ponds are still frozen, hindering their performance. The first fall rains in the southwestern regions of the United States may occur after extended periods of dry weather. Some SCMs, such as street cleaning targeting leaf removal, may be more effective before these rains than at other times of the year.

Watershed models are useful tools for predicting downstream impacts from urbanization and designing mitigation to reduce those impacts, but they are incomplete in scope and typically do not offer definitive causal links between polluted discharges and downstream degradation. Every model simulates only a subset of the multiple interconnections between physical, chemical, and biological processes found in any watershed, and they all use a grossly simplified representation of the true spatial and temporal variability of a watershed. To speak of a "comprehensive watershed model" is thus an oxymoron, because the science of stormwater is not sufficiently far advanced to determine causality between all sources, resulting stressors, and their physical, chemical, and biological responses. Thus, it is not yet possible to create a protocol that mechanistically links stormwater dischargers to the quality of receiving waters. The utility of models with more modest goals, however, can still be high—as long as the questions being addressed by the model are in fact relevant and important to the functioning of the watershed to which that model is being applied, and sufficient data are available to calibrate the model for the processes

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included therein.

EPA needs to ensure that the modeling and monitoring capabilities of the nation are continued and enhanced to avoid losing momentum in understanding and eliminating stormwater pollutant discharges. There is a need to extend, develop, and support current modeling capabilities, emphasizing (1) the impacts of flow energy, sediment transport, contaminated sediment, and acute and chronic toxicity on biological systems in receiving waterbodies; (2) more mechanistic representation (physical, chemical, biological) of SCMs; and (3) coupling between a set of functionally specific models to promote the linkage of source, transport and transformation, and receiving water impacts of stormwater discharges. Stormwater models have typically not incorporated interactions with groundwater and have treated infiltration and recharge of groundwater as a loss term with minimal consideration of groundwater contamination or transport to receiving waterbodies. Emerging distributed modeling paradigms that simulate interactions of surface and subsurface flowpaths provide promising tools that should be further developed and tested for applications in stormwater analysis.

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5
Stormwater Management Approaches

A fundamental component of the U.S. Environmental Protection Agency's (EPA) Stormwater Program, for municipalities as well as industries and construction, is the creation of stormwater pollution prevention plans. These plans invariably document the stormwater control measures that will be used to prevent the permittee's stormwater discharges from degrading local waterbodies. Thus, a consideration of these measures—their effectiveness in meeting different goals, their cost, and how they are coordinated with one another—is central to any evaluation of the Stormwater Program. This report uses the term stormwater control measure (SCM) instead of the term best management practice (BMP) because the latter is poorly defined and not specific to the field of stormwater.

The committee's statement of task asks for an evaluation of the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality. As discussed in the last two chapters, the state of the science has yet to reveal the mechanistic links that would allow for a full assessment of that relationship. However, enough is known to design systems of SCMs, on a site scale or local watershed scale, to lessen many of the effects of urbanization. Also, for many regulated entities the current approach to stormwater management consists of choosing one or more SCMs from a preapproved list. Both of these facts argue for the more comprehensive discussion of SCMs found in this chapter, including information on their characteristics, applicability, goals, effectiveness, and cost. In addition, a multitude of case studies illustrate the use of SCMs in specific settings and demonstrate that a particular SCM can have a measurable positive effect on water quality or a biological metric. The discussion of SCMs is organized along the gradient from the rooftop to the stream. Thus, pollutant and runoff prevention are discussed first, followed by runoff reduction and finally pollutant reduction.

HISTORICAL PERSPECTIVE ON STORMWATER CONTROL MEASURES

Over the centuries, SCMs have met different needs for cities around the world. Cities in the Mesopotamian Empire during the second millennium BC had practices for flood control, to convey waste, and to store rain water for household and irrigation uses (Manor, 1966) (see Figure 5-1). Today, SCMs are considered a vital part of managing flooding and drainage problems in a city. What is relatively new is an emphasis on using the practices to remove pollutants from stormwater and selecting practices capable of providing groundwater recharge. These recent expectations for SCMs are not readily accepted and re-

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quire an increased commitment to the proper design and maintenance of the practices.

With the help of a method for estimating peak flows (the Rational Method, see Chapter 4), the modern urban drainage system came into being soon after World War II. This generally consisted of a system of catch basins and pipes to prevent flooding and drainage problems by efficiently delivering runoff water to the nearest waterbody. However, it was soon realized that delivering the water too quickly caused severe downstream flooding and bank erosion in the receiving water. To prevent bank erosion and provide more space for flood waters, some stream channels were enlarged and lined with concrete (see Figure 5-2). But while hardening and enlarging natural channels is a cost-effective solution to erosion and flooding, the modified channel increases downstream peak flows and it does not provide habitat to support a healthy aquatic ecosystem.



FIGURE 5-1 Cistern tank, Kamiros, Rhodes (ancient Greece, 7th century BC). SOURCE: Robert Pitt, University of Alabama.

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FIGURE 5-2 Concrete channel in Lincoln Creek, Milwaukee, Wisconsin. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.

Some way was needed to control the quantity of water reaching the end of pipes during a runoff event, and on-site detention (Figure 5-3) became the standard for accomplishing this. Ordinances started appearing in the early 1970s, requiring developers to reduce the peaks of different size storms, such as the 10-year, 24-hour storm. The ordinances were usually intended to prevent future problems with peak flows by requiring the installation of flow control structures, such as detention basins, in new developments. Detention basins can control peak flows directly below the point of discharge and at the property boundary. However, when designed on a site-by-site basis without taking other basins into account, they can lead to downstream flooding problems because volume is not reduced (McCuen, 1979; Ferguson, 1991; Traver and Chadderton, 1992; EPA, 2005d). In addition, out of concerns for clogging, openings in the outlet structure of most basins are generally too large to hold back flows from smaller, more frequent storms. Furthermore, low-flow channels have been constructed or the basins have been graded to move the runoff through the structure without delay to prevent wet areas and to make it easier to mow and maintain the detention basin.

Because of the limitations of on-site detention, infiltration of urban runoff to control its volume has become a recent goal of stormwater management. Without stormwater infiltration, municipalities in wetter regions of the country can expect drops in local groundwater levels, declining stream base flows (Wang et al., 2003a), and flows diminished or stopped altogether from springs feeding wetlands and lakes (Leopold, 1968; Ferguson, 1994).

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FIGURE 5-3 On-site detention. SOURCE: Tom Schueler, Chesapeake Stormwater Network, Inc.

The need to provide volume control marked the beginning of low-impact development (LID) and conservation design (Arendt, 1996; Prince George's County, 2000), which were founded on the seminal work of landscape architect Ian McHarg and associates decades earlier (McHarg and Sutton, 1975; McHarg and Steiner, 1998). The goal of LID is to allow for development of a site while maintaining as much of its natural hydrology as possible, such as infiltration, frequency and volume of discharges, and groundwater recharge. This is accomplished with infiltration practices, functional grading, open channels, disconnection of impervious areas, and the use of fewer impervious surfaces. Much of the LID focus is to manage the stormwater as close as possible to its source—that is, on each individual lot rather than conveying the runoff to a larger regional SCM. Individual practices include rain gardens (see Figure 5-4), disconnected roof drains, porous pavement, narrower streets, and grass swales. In some cases, LID site plans still have to include a method for passing the larger storms safely, such as a regional infiltration or detention basin or by increasing the capacity of grass swales.

Infiltration has been practiced in a few scattered locations for a long time. For example, on Long Island, New York, infiltration basins were built starting in 1930 to reduce the need for a storm sewer system and to recharge the aquifer, which was the only source of drinking water (Ferguson, 1998). The Cities of Fresno, California, and El Paso, Texas, which faced rapidly dropping groundwater tables, began comprehensive infiltration efforts in the 1960s and 1970s. In the 1980s Maryland took the lead on the east coast by creating an ambitious

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FIGURE 5-4 Rain Garden in Madison, Wisconsin. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.

statewide infiltration program. The number of states embracing elements of LID, especially infiltration, has increased during the 1990s and into the new century and includes California, Florida, Minnesota, New Jersey, Vermont, Washington, and Wisconsin.

Evidence gathered in the 1970s and 1980s suggested that pollutants be added to the list of things needing control in stormwater (EPA, 1983). Damages caused by elevated flows, such as stream habitat destruction and floods, were relatively easy to document with something as simple as photographs. Documentation of elevated concentrations of conventional pollutants and potentially toxic pollutants, however, required intensive collection of water quality samples during runoff events. Samples collected from storm sewer pipes and urban streams in the Menomonee River watershed in the late 1970s clearly showed the concentrations of many pollutants, such as heavy metals and sediment, were elevated in urban runoff (Bannerman et al., 1979). Levels of heavy metals were especially high in industrial-site runoff, and construction-site erosion was calculated to be a large source of sediment in the watershed. This study was followed by the National Urban Runoff Program, which added more evidence about the high levels of some pollutants found in urban runoff (Athayde et al., 1983; Bannerman et al., 1983).

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With new development rapidly adding to the environmental impacts of existing urban areas, the need to develop good stormwater management programs is more urgent than ever. For a variety of reasons, the greatest potential for stormwater management to reduce the footprint of urbanization is in the suburbs. These areas are experiencing the fastest rates of growth, they are more amenable to stormwater management because buildings and infrastructure are not yet in place, and costs for stormwater management can be borne by the developer rather than by taxpayers. Indeed, most structural SCMs are applied to new development rather than existing urban areas. Many of the most innovative stormwater programs around the country are found in the suburbs of large cities such as Seattle, Austin, and Washington, D.C. When stormwater management in ultra-urban areas is required, it entails the retrofitting of detention basins and other flow control structures or the introduction of innovative below-ground structures characterized by greater technical constraints and higher costs, most of which are charged to local taxpayers.

Current-day SCMs represent a radical departure from past practices, which focused on dealing with extreme flood events via large detention basins designed to reduce peak flows at the downstream property line. As defined in this chapter, SCMs now include practices intended to meet broad watershed goals of protecting the biology and geomorphology of receiving waters in addition to flood peak protection. The term encompasses such diverse actions as using more conventional practices like basins and wetland to installing stream buffers, reducing impervious surfaces, and educating the public.

REVIEW OF STORMWATER CONTROL MEASURES

Stormwater control measures refer to what is defined by EPA (1999) as "a technique, measure, or structural control that is used for a given set of conditions to manage the quantity and improve the quality of stormwater runoff in the most cost-effective manner." SCMs are designed to mitigate the changes to both the quantity and quality of stormwater runoff that are caused by urbanization. Some SCMs are engineered or constructed facilities, such as a stormwater wetland or infiltration basin, that reduce pollutant loading and modify volumes and flow. Other SCMs are preventative, including such activities as education and better site design to limit the generation of stormwater runoff or pollutants.

Stormwater Management Goals

It is impossible to discuss SCMs without first considering the goals that they are expected to meet. A broadly stated goal for stormwater management is to reduce pollutant loads to waterbodies and maintain, as much as possible, the natural hydrology of a watershed. On a practical level, these goals must be made specific to the region of concern and embedded in the strategy for that

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region. Depending on the designated uses of the receiving waters, climate, geomorphology, and historical development, a given area may be more or less sensitive to both pollutants and hydrologic modifications. For example, goals for groundwater recharge might be higher in an area with sandy soils as compared to one with mostly clayey soils; watersheds in the coastal zone may not require hydrologic controls. Ideally, the goals of stormwater management should be linked to the water quality standards for a given state's receiving waters. However, because of the substantial knowledge gap about the effect of a particular stormwater discharge on a particular receiving water (see Chapter 3 conclusions), surrogate goals are often used by state stormwater programs in lieu of water quality standards. Examples include credit systems, mandating the use of specific SCMs, or achieving stormwater volume reduction. Credit systems might be used for practices that are known to be productive but are difficult to quantify, such as planting trees. Specific SCMs might be assumed to remove a percent of pollutants, for example 85 percent removal of total suspended solids (TSS) within a stormwater wetland. Reducing the volume of runoff from impervious surfaces (e.g., using an infiltration device) might be assumed to capture the first flush of pollutants during a storm event. Before discussing specific state goals, it is worth understanding the broader context in which goals are set.

Trade-offs Between Stormwater Control Goals and Costs

The potentially substantial costs of implementing SCMs raise a number of fundamental social choices concerning land-use decisions, designated uses, and priority setting for urban waters. To illustrate some of these choices, consider a hypothetical urban watershed with three possible land-cover scenarios: 25, 50, and 75 percent impervious surface. A number of different beneficial uses could be selected for the streams in this watershed. At a minimum, the goal may be to establish low-level standards to protect public health and safety. To achieve this, sufficient and appropriate SCMs might be applied to protect residents from flooding and achieve water quality conditions consistent with secondary human contact. Alternatively, the designated use could be to achieve the physical, chemical, and/or biological conditions sufficient to provide exceptional aquatic habitat (e.g., a high-quality recreational fishery). The physical, biological, and chemical conditions supportive of this use might be similar to a reference stream located in a much less disturbed watershed. Achieving this particular designated use would require substantially greater resources and effort than achieving a secondary human contact use. Intermediate designated uses could also be imagined, including improving ambient water quality conditions that would make the water safe for full-body emersion (primary human contact) or habitat conditions for more tolerant aquatic species.

Figure 5-5 sketches what the marginal (incremental) SCM costs (opportunity costs) might be to achieve different designated uses given different amounts of impervious surface in the watershed. The horizontal axis orders potential

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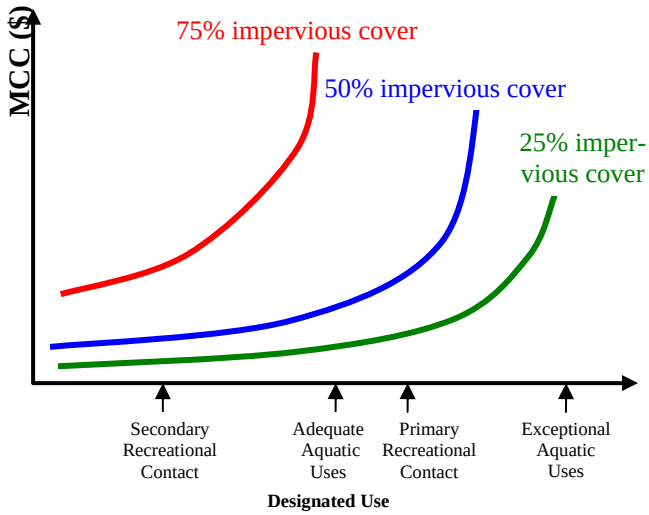

FIGURE 5-5 Cost of achieving designated uses in a hypothetical urban watershed. MCC is the marginal control cost, which represents the incremental costs to achieve successive expansion of designated uses through SCMs. The curves are constructed on the assumption that the lowest cost combination of SCMs would be implemented at each point on the curve.

designated uses in terms of least difficult to most difficult to achieve. The three conceptual curves represent the SCM costs under three different impervious surface scenarios. The relative positions of the cost curves indicate that achieving any specific designated use will be more costly in situations with a higher percentage of the watershed in impervious cover. All cost curves are upward sloping, reflecting the fact that incremental improvements in designated uses will be increasingly costly to achieve. The cost curves are purely conceptual, but nonetheless might reasonably reflect the relative costs and direction of change associated with achieving specific designated uses in different watershed conditions.

The locations of the cost curves suggest that in certain circumstances not all designated uses can be achieved or can be achieved only at an extremely high cost. For example, the attainment of exceptional aquatic uses may be unachievable in areas with 50 percent impervious surface even with maximum application of SCMs. In this illustration, the cost of achieving even secondary human contact use is high for areas with 75 percent impervious surfaces. In such highly urbanized settings, achievement of only adequate levels of aquatic uses could be exceedingly high and strain the limits of what is technically achievable. Finally, the existing and likely expected future land-use conditions have significant im-

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plications for what is achievable and at what cost. Clearly land-use decisions have an impact on the cost and whether a use can be achieved, and thus they need to be included in the decision process. The trade-off between costs and achieving specific designated uses can change substantially given different development patterns.

The purpose of Figure 5-5 is not to identify the precise location of the cost curves or to identify thresholds for achieving specific designated uses. Rather, these concepts are used to illustrate some fundamental trade-offs that confront public and private investment and regulatory decisions concerning stormwater management. The general relationships shown in Figure 5-5 suggest the need for establishing priorities for investments in stormwater management and controls, and connecting land usage and watershed goals. Setting overly ambitious or costly goals for urban streams may result in the perverse consequence of causing more waters to fail to meet designated uses. For example, consider efforts to secure ambitious designated uses in highly developed areas or in an area slated for future high-density development. Regulatory requirements and investments to limit stormwater quantity and quality through open-space requirements, areas set aside for infiltration and water detention, and strict application of maximum extent practicable controls have the effect of both increasing development costs and diminishing land available for residential and commercial properties. Policies designed to achieve exceedingly costly or infeasible designated uses in urban or urbanizing areas could have the net consequence of shifting development (and associated impervious surface) out into neighboring areas and watersheds. The end result might be minimal improvements in "within-watershed" ambient conditions but a decrease in designated uses (more impairments) elsewhere. In such a case, it might be sound water quality policy to accept higher levels of impervious surface in targeted locations, more stormwater-related impacts, and less ambitious designated uses in urban watersheds in order to preserve and protect designated uses in other watersheds.

Setting unrealistic or unachievable water quality objectives in urban areas can also pose political risks for stormwater management. The cost and difficulty of achieving ambitious water quality standards for urban stream goals may be understood by program managers but pursued nonetheless in efforts to demonstrate public commitment to achieving high-quality urban waters. Yet, promising what cannot be realistically achieved may act to undermine public support for urban stormwater programs. Increasing costs without significant observable improvements in ambient water conditions or achievement of water quality standards could ultimately reduce public commitment to the program. Thus, there are risks of "setting the bar" too high, or not coordinating land use and designated stream uses.

The cost of setting the bar too low can also be significant. Stormwater requirements that result in ineffective stormwater management will not achieve or maintain the desired water uses and can result in impairments. Loss of property, degraded waters, and failed infrastructure are tangible costs to the public (Johnston et al., 2006). Streambank rehabilitation costs can be severe, and loss of con-

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fidence in the ability to meet stormwater goals can result.

The above should not be construed as an argument for or against devoting resources to SCMs; rather, such decisions should be made with an open and transparent acknowledgment and understanding of the costs and consequences involved in those decisions.

Common State Stormwater Goals

Most states do not and have never had an overriding water quality objective in their stormwater program, but rather have used engineering criteria for SCM performance to guide stormwater management. These criteria can be loosely categorized as:

- Erosion and sedimentation control,
- Recharge/base flow,
- Water quality,
- Channel protection, and
- Flooding events.

The SCMs used to address these goals work by minimizing or eliminating increases in stormwater runoff volume, peak flows, and/or the pollutant load carried by stormwater.

The criteria chosen by any given state usually integrate state, federal, and regional laws and regulations. Areas of differing climates may emphasize one goal over another, and the levels of control may vary drastically. Contrast a desert region where rainwater harvesting is extremely important versus a coastal region subject to hurricanes. Some areas like Seattle have frequent smaller volume rainfalls—the direct opposite of Austin, Texas—such that small volume controls would be much more effective in Seattle than Austin. Regional geology (karst) or the presence of Brownfields may affect the chosen criteria as well.

The committee's survey of State Stormwater Programs (Appendix C) reflects a wide variation in program goals as reflected in the criteria found in their SCM manuals. Some states have no specific criteria because they do not produce SCM manuals, while others have manuals that address every category of criteria from flooding events to groundwater recharge. Some states rely upon EPA or other states' or transportation agencies' manuals. In general, soil and erosion control criteria are the most common and often exist in the absence of any other state criteria. This wide variation reflects the difficulties that states face in keeping up with rapidly changing information about SCM design and performance.

The criteria are ordered below (after the section on erosion and sediment control) according to the size of the storm they address, from smallest to most extreme. The criteria can be expressed in a variety of ways, from a simple requirement to control a certain volume of rainfall or runoff (expressed as a depth)

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to the size of a design storm to more esoteric requirements, such as limiting the time that flow can be above a certain threshold. The volumes of rainfall or runoff are based on statistics of a region's daily rainfall, and they approximate one another as the percentage of impervious cover increases. Design storms for larger events that address channel protection and flooding are usually based on extreme event statistics and tend to represent a temporal pattern of rainfall over a set period, usually a day. Finally, it should be noted that the categories are not mutually exclusive; for example, recharge of groundwater may enhance water quality via pollutant removal during the infiltration process.

Erosion and Sedimentation Control. This criterion refers to the prevention of erosion and sedimentation of sites during construction and is focused at the site level. Criteria usually include a barrier plan to prevent sedimentation from leaving the site (e.g., silt fences), practices to minimize the potential erosion (phased construction), and facilities to capture and remove sediment from the runoff (detention). Because these measures are considered temporary, smaller extreme events are designated as the design storm than what typically would be used if flood control were the goal.

Recharge/Base Flow. This criterion is focused on sustaining the preconstruction hydrology of a site as it relates to base flow and recharge of groundwater supplies. It may also include consideration of water usage of the property owners and return through septic tanks and tile fields. The criterion, expressed as a volume requirement, is usually to capture around 0.5 to 1.0 inch of runoff from impervious surfaces depending on the climate and soil type of the region. (For this range of rainfall, very little runoff occurs from grass or forested areas, which is why runoff from impervious surfaces is used as the criterion.)

Water Quality. Criteria for water quality are the most widespread, and are usually crafted as specific percent removal for pollutants in stormwater discharge. Generally, a water quality criterion is based on a set volume of stormwater being treated by the SCM. The size of the storm can run from the first inch of rainfall off impervious surfaces to the runoff from the one-year, 24-hour extreme storm event. It should be noted that the term "water quality" covers a wide range of groundwater and surface water pollutants, including water temperature and emerging contaminants.

Many of the water quality criteria are surrogates for more meaningful parameters that are difficult to quantify or cannot be quantified, or they reflect situations where the science is not developed enough to set more explicit goals. For example, the Wisconsin state requirement of an 80 percent reduction in TSS in stormwater discharge does not apply to receiving waters themselves. However, it presumes that there will be some water quality benefits in receiving waters; that is, phosphorus and fecal coliform might be captured by the TSS requirement. Similarly water quality criteria may be expressed as credits for good practices, such as using LID, street sweeping, or stream buffers.

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Channel Protection. This criterion refers to protecting channels from accelerated erosion during storm events due to the increased runoff. It is tied to either the presumed "channel-forming event"—what geomorphologists once believed was the storm size that created the channel due to erosion and deposition—or to the minimum flow that accomplishes any degree of sediment transport. It is generally defined as somewhere between the one- and five-year, 24-hour storm event or a discharge level typically exceeded once to several times per year. Some states require a reduction in runoff volume for these events to match preconstruction levels. Others may require that the average annual duration of flows that are large enough to erode the streambank be held the same on an annual basis under pre- and postdevelopment conditions.

It is not uncommon to find states where a channel protection goal will be written poorly, such that it does not actually prevent channel widening. For example, MacRae (1997) presented a review of the common "zero runoff increase" discharge criterion, which is commonly met by using ponds designed to detain the two-year, 24-hour storm. MacRae showed that stream bed and bank erosion occur during much lower events, namely mid-depth flows that generally occur more than once a year, not just during bank-full conditions (approximated by the two-year event). This finding is entirely consistent with the well-established geomorphological literature (e.g., Pickup and Warner, 1976; Andrews, 1984; Carling, 1988; Sidle, 1988). During monitoring near Toronto, MacRae found that the duration of the geomorphically significant predevelopment mid-bankfull flows increased by more than four-fold after 34 percent of the basin had been urbanized. The channel had responded by increasing in cross-sectional area by as much as three times in some areas, and was still expanding.

Flooding Events. This criterion addresses public safety and the protection of property and is applicable to storm events that exceed the channel capacity. The 10- through the 100-year storm is generally used as the standard. Volume-reduction SCMs can aid or meet this criterion depending on the density of development, but usually assistance is needed in the form of detention SCMs. In some areas, it may be necessary to reduce the peak flow to below preconstruction levels in order to avoid the combined effects of increased volume, altered timing, and a changed hydrograph. It should be noted that some states do not consider the larger storms (100-year) to be a stormwater issue and have separate flood control requirements.

Each state develops a framework of goals, and the corresponding SCMs used to meet them, which will depend on the scale and focus of the stormwater management strategy. A few states have opted to express stormwater goals within the context of watershed plans for regions of the state. However, the setting of goals on a watershed basis is time-consuming and requires study of the watersheds in question. The more common approach has been to set generic or minimal controls for a region that are not based on a watershed plan. This has been done in Maryland, Wisconsin (see Box 5-1), and Pennsylvania (see Box 5-2). This strategy has the advantage of more rapid implementation of

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BOX 5-1
Wisconsin Statewide Goal of TSS Reduction for Stormwater Management

To measure the success of stormwater management, Wisconsin has statewide goals for sediment and flow (Wisconsin DNR, 2002). A lot is known about the impacts of sediment on receiving waters, and any reduction is thought to be beneficial. Flow can be a good indicator of other factors; for example, reducing peak flows will prevent bank erosion.

Developing areas in Wisconsin are required to reduce the annual TSS load by 80 percent compared to no controls (Wisconsin DNR, 2002). Two flow-rated requirements for developing areas are in the administrative rules. One is that the site must maintain the peak flow for the two-year, 24-hour rainfall event. Second, the annual infiltration volume for postdevelopment must be within 90 percent of the predevelopment volumes for residential land uses; the number for non-residential is 60 percent. Both of these flow control goals are thought to also have water quality benefits.

The goal for existing urban areas is an annual reduction in TSS loads. Municipalities must reduce their annual TSS loads by 20 percent, compared to no controls, by 2008. This number is increased to 40 percent by 2013. All of these goals were partially selected to be reasonable based on cost and technical feasibility.

BOX 5-2
Volume-Based Stormwater Goals in Pennsylvania

Pennsylvania has developed a stormwater *Best Management Practices* manual to support the Commonwealth's Storm Water Management Act. This manual and an accompanying sample ordinance advocates two methods for stormwater control based on volume, termed Control Guidance (CG) 1 and 2. The first (CG-1) requires that the runoff volume be maintained at the two-year, 24-hour storm level (which corresponds to approximately 3.5 inches of rainfall in this region) through infiltration, evapotranspiration, or reuse. This criterion addresses recharge/base flow, water quality, and channel protection, as well as helping to meet flooding requirements.

The second method (CG-2) requires capture and removal of the first inch of runoff from paved areas, with infiltration strongly recommended to address recharge and water quality issues. Additionally, to meet channel protection criteria, the second inch is required to be held for 24 hours, which should reduce the channel-forming flows. (This is an unusual criterion in that it is expressed as what an SCM can accomplish, not as the flow that the channel can handle.) Peak flows for larger events are required to be at preconstruction levels or less if the need is established by a watershed plan. These criteria are the starting point for watershed or regional plans, to reduce the effort of plan development. Some credits are available for tree planting, and other nonstructural practices are advocated for dissolved solids mitigation. See http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/stormwatermanagement/default.htm.

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some SCMs because watershed management plans are not required. In order to be applicable to all watersheds in the state, the goals must target common pollutants or flow modification factors where the processes are well known. It must also be possible for these goals to be stated in National Pollutant Discharge Elimination System (NPDES) permits. Many states have selected TSS reduction, volume reduction, and peak flow control as generic goals. A generic goal is not usually based on potentially toxic pollutants, such as heavy metals, due to the complexity of their interaction in the environment, the dependence on the existing baseline conditions, and the need for more understanding on what are acceptable levels. The difficulty with the generic approach is that specific watershed issues are not addressed, and the beneficial uses of waters are not guaranteed.

One potential drawback of a strategy based on a generic goal coupled to the permit process is that the implementation of the goal is usually on a site-by-site basis, especially for developing areas. Generic goals may be appropriate for certain ubiquitous watershed processes and are clearly better than having no goals at all. However, they do not incorporate the effects of differences in past development and any unique watershed characteristics; they should be considered just a good starting point for setting watershed-based goals.

Role of SCMs in Achieving Stormwater Management Goals

One important fundamental change in SCM design philosophy has come about because of the recent understanding of the roles of smaller storms and of impervious surfaces. This is demonstrated by Box 3-4, which shows that for the Milwaukee area more than 50 percent of the rainfall by volume occurs in storms that have a depth of less then 0.75 inch. If extreme events are the only design criteria for SCMs, the vast majority of the annual rainfall will go untreated or uncontrolled, as it is smaller than the minimum extreme event. This relationship is not the same in all regions. For example, in Austin, Texas, the total yearly rainfall is smaller than in Milwaukee, but a large part of the volume occurs during larger storm events, with long dry periods in between.

The upshot is that the design strategy for stormwater management, including drainage systems and SCMs, should take a region's rainfall and associated runoff conditions into account. For example, an SCM chosen to capture the majority of the suspended solids, recharge the baseflow, reduce streambank erosion, and reduce downstream flooding in Pennsylvania or Seattle (which have moderate and regular rainfall) would likely not be as effective in Texas, where storms are infrequent and larger. In some areas, a reduction in runoff volume may not be sufficient to control streambank erosion and flooding, such that a second SCM like an extended detention stormwater wetland may be needed to meet management goals.

Finally, as discussed in greater detail in a subsequent section, SCMs are most effective from the perspective of both efficiency and cost when stormwater

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management is incorporated in the early planning stages of a community. Retrofitting existing development with SCMs is much more technically difficult and costly because the space may not be available, other infrastructure is already installed, or utilities may interfere. Furthermore, if the property is on private land or dedicated as an easement to a homeowners association, there may be regulatory limitations to what can be done. Because of these barriers, retrofitting existing urban areas often depends on engineered or manufactured SCMs, which are more expensive in both construction and operation.

Stormwater Control Measures

SCMs reduce or mitigate the generation of stormwater runoff and associated pollutants. These practices include both "structural" or engineered devices as well as more "nonstructural measures" such as land-use planning, site design, land conservation, education, and stewardship practices. Structural practices may be defined as any facility constructed to mitigate the adverse impacts of stormwater and urban runoff pollution. Nonstructural practices, which tend to be longer-term and lower-maintenance solutions, can greatly reduce the need for or increase the effectiveness of structural SCMs. For example, product substitution and land-use planning may be key to the successful implementation of an infiltration SCM. Preserving wooded areas and reducing street widths can allow the size of detention basins in the area to be reduced.

Table 5-1 presents the expansive list of SCMs that are described in this chapter. For most of the SCMs, each listed item represents a class of related practices, with individual methods discussed in greater detail later in the chapter. There are nearly 20 different broad categories of SCMs that can be applied, often in combination, to treat the quality and quantity of stormwater runoff. A primary difference among the SCMs relates to which stage of the development cycle they are applied, where in the watershed they are installed, and who is responsible for implementing them.

The development cycle extends from broad planning and zoning to site design, construction, occupancy, retrofitting, and redevelopment. As can be seen, SCMs are applied throughout the entire cycle. The scale at which the SCM is applied also varies considerably. While many SCMs are installed at individual sites as part of development or redevelopment applications, many are also applied at the scale of the stream corridor or the watershed or to existing municipal stormwater infrastructure. The final column in Table 5-1 suggests who would implement the SCM. In general, the responsibility for implementing SCMs primarily resides with developers and local stormwater agencies, but planning agencies, landowners, existing industry, regulatory agencies, and municipal separate storm sewer system (MS4) permittees can also be responsible for implementing many key SCMs.

In Table 5-1, the SCMs are ordered in such a way as to mimic natural systems as rain travels from the roof to the stream through combined application of

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TABLE 5-1 Summary of Stormwater Control Measures—When, Where, and Who

Stormwater Control Measure	When	Where	Who
Product Substitution	Continuous	National, state, regional	Regulatory agencies
Watershed and Land-Use Planning	Planning stage	Watershed	Local planning agencies
Conservation of Natural Areas	Site and watershed planning stage	Site, watershed	Developer, local planning agency
Impervious Cover Minimization	Site planning stage	Site	Developer, local review authority
Earthwork Minimization	Grading plan	Site	Developer, local review authority
Erosion and Sediment Control	Construction	Site	Developer, local review authority
Reforestation and Soil Conservation	Site planning and construction	Site	Developer, local review authority
Pollution Prevention SCMs for Stormwater Hotspots	Post-construction or retrofit	Site	Operators and local and state permitting agencies
Runoff Volume Reduction—Rainwater harvesting	Post-construction or retrofit	Rooftop	Developer, local planning agency and review authority
Runoff Volume Reduction—Vegetated	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Runoff Volume Reduction—Subsurface	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Peak Reduction and Runoff Treatment	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Runoff Treatment	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Aquatic Buffers and Managed Floodplains	Planning, construction and post-construction	Stream corridor	Developer, local planning agency and review authority, landowners
Stream Rehabilitation	Postdevelopment	Stream corridor	Local planning agency and review authority

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TABLE 5-1 Continued

Stormwater Control Measure	When	Where	Who
Municipal Housekeeping	Postdevelopment	Streets and stormwater infrastructure	MS4 Permittee
Illicit Discharge Detection and Elimination	Postdevelopment	Stormwater infrastructure	MS4 Permittee
Stormwater Education	Postdevelopment	Stormwater infrastructure	MS4 Permittee
Residential Stewardship	Postdevelopment	Stormwater infrastructure	MS4 Permittee

Note: Nonstructural SCMs are in italics.

a series of practices throughout the entire development site. This order is upheld throughout the chapter, with the implication that no SCM should be chosen without first considering those that precede it on the list.

Given that there are 20 different SCM groups and a much larger number of individual design variations or practices within each group, it is difficult to authoritatively define the specific performance or effectiveness of SCMs. In addition, our understanding of their performance is rapidly changing to reflect new research, testing, field experience, and maintenance history. The translation of these new data into design and implementation guidance is accelerating as well. What is possible is to describe their basic hydrologic and water quality objectives and make a general comparative assessment of what is known about their design, performance, and maintenance as of mid-2008. This broad technology assessment is provided in Table 5-2, which reflects the committee's collective understanding about the SCMs from three broad perspectives:

- Is widely accepted design or implementation guidance available for the SCM and has it been widely disseminated to the user community?
- Have enough research studies been published to accurately characterize the expected hydrologic or pollutant removal performance of the SCM in most regions of the country?
- Is there enough experience with the SCM to adequately define the type and scope of maintenance needed to ensure its longevity over several decades?

Affirmative answers to these three questions are needed to be able to reliably quantify or model the ability of the SCM, which is an important element in defining whether the SCM can be linked to improvements in receiving water quality. As will be discussed in subsequent sections of this chapter, there are many SCMs for which there is only a limited understanding, particularly those that are nonstructural in nature.

The columns in Table 5-2 summarize several important factors about each SCM, including the ability of the SCM to meet hydrologic control objectives

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and water quality objectives, the availability of design guidance, the availability of performance studies, and whether there are maintenance protocols. The hydrologic control objectives range from complete prevention of stormwater flow to reduction in runoff volume and reduction in peak flows. The column on water quality objectives describes whether the SCM can prevent the generation of, or remove, contaminants of concern in stormwater.

The availability of design guidance tends to be greatest for the structural practices. Some but not all nonstructural practices are of recent origin, and communities lack available design guidance to include them as an integral element of local stormwater solutions. Where design guidance is available, it may not yet have been disseminated to the full population of Phase II MS4 communities.

TABLE 5-2 Current Understanding of Stormwater Control Measure Capabilities

SCM	Hydrologic Control Objectives	Water Quality Objectives	Available Design Guidance	Performance Studies Available	Defined Maintenance Protocols
Product Substitution	NA	Prevention	NA	Limited	NA
Watershed and Land-Use Planning	All objectives	Prevention	Available	Limited	Yes
Conservation of Natural Areas	Prevention	Prevention	Available	None	Yes
Impervious Cover Minimization	Prevention and reduction	Prevention	Available	Limited	No
Earthwork Minimization	Prevention	Prevention	Emerging	Limited	Yes
Erosion and Sediment Control	Prevention and reduction	Prevention and removal	Available	Limited	Yes
Reforestation and Soil Conservation	Prevention and reduction	Prevention and removal	Emerging	None	No
Pollution Prevention SCMs for Hotspots	NA	Prevention	Emerging	Very few	No
Runoff Volume Reduction—Rainwater harvesting	Reduction	NA	Emerging	Limited	Yes
Runoff Volume Reduction—Vegetated (Green Roofs, Bioretention, Bioinfiltration, Bioswales)	Reduction and some peak attenuation	Removal	Available	Limited	Emerging
Runoff Volume Reduction—Subsurface (Infiltration Trenches, Pervious Pavements)	Reduction and some peak attenuation	Removal	Available	Limited	Yes

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TABLE 5-2 Continued

SCM	Hydrologic Control Objectives	Water Quality Objectives	Available Design Guidance	Performance Studies Available	Defined Maintenance Protocols
Peak Reduction and Runoff Treatment (Stormwater Wetlands, Dry/Wet Ponds)	Peak attenuation	Removal	Available	Adequate	Yes
Runoff Treatment (Sand Filters, Manufactured Devices)	None	Removal	Emerging	Adequate—sand filters Limited—manufactured devices	Yes
Aquatic Buffers and Managed Floodplains	NA	Prevention and removal	Available	Very few	Emerging
Stream Rehabilitation	NA	Prevention and removal	Emerging	Limited	Unknown
Municipal Housekeeping (Street Sweeping/ Storm-Drain Cleanouts)	NA	Removal	Emerging	Limited	Emerging
Illicit Discharge Detection/ Elimination	NA	Prevention and removal	Available	Very few	No
Stormwater Education	Prevention	Prevention	Available	Very few	Emerging
Residential Stewardship	Prevention	Prevention	Emerging	Very few	No

Note: Nonstructural SCMs are in italics.

Key:		
Hydrologic Objective	Water Quality Objective	Available Design Guidance?
Prevention: Prevents generation of runoff **Reduction:** Reduces volume of runoff **Treatment:** Delays runoff delivery only **Peak Attenuation**: Reduction of peak flows through detention	**Prevention**: Prevents generation, accumulation, or wash-off of pollutants and/or reduces runoff volume **Removal:** Reduces pollutant concentrations in runoff by physical, chemical, or biological means	**Available:** Basic design or implementation guidance is available in most areas of the country are readily available **Emerging:** Design guidance is still under development, is missing in many parts of the country, or requires more performance data
Performance Data Available?	Defined Maintenance Protocol?	Notes:
Very Few: Handful of studies, not enough data to generalize about SCM performance **Limited:** Numerous studies have been done, but results are variable or inconsistent **Adequate**: Enough studies have been done to adequately define performance	**No:** Extremely limited understanding of procedures to maintain SCM in the future **Emerging:** Still learning about how to maintain the SCM **Yes**: Solid understanding of maintenance for future SCM needs	**NA:** Not applicable for the SCM

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The column on the availability of performance data is divided into those SCMs where enough studies have been done to adequately define performance, those SCMs where limited work has been done and the results are variable, and those SCMs where only a handful of studies are available. A large and growing number of performance studies are available that report the efficiencies of structural SCMs in reducing flows and pollutant loading (Strecker et al., 2004; ASCE, 2007; Schueler et al., 2007; Selbig and Bannerman, 2008). Many of these are compiled in the Center for Watershed Protection's National Pollutant Removal Performance Database for Stormwater Treatment Practices (http://www.cwp.org/Resource_Library/Center_Docs/SW/bmpwriteup_092007_v3.pdf), in the International Stormwater BMP Database (http://www.bmpdatabase.org/Docs/Performance%20Summary%20June%202008.pdf), and by the Water Environment Research Foundation (WERF, 2008). In cases where there is incomplete understanding of their performance, often information can be gleaned from other fields including agronomy, forestry, petroleum exploration, and sanitary engineering. Current research suggests that it is not a question if whether structural SCMs "work" but more of a question of to what degree and with what longevity (Heasom et al., 2006; Davis et al., 2008; Emerson and Traver, 2008). There is considerably less known about the performance of nonstructural practices for stormwater treatment, partly because their application has been uneven around the country and it remains fairly low in comparison to structural stormwater practices.

Finally, defined maintenance protocols for SCMs can be nonexistent, emerging, or fully available. SCMs differ widely in the extent to which they can be considered permanent solutions. For those SCMs that work on the individual site scale on private property, such as rain gardens, local stormwater managers may be reluctant to adopt such practices due to concerns about their ability to enforce private landowners to conduct maintenance over time. Similarly, those SCMs that involve local government decisions (such as education, residential stewardship practices, zoning, or street sweeping) may be less attractive because governments are likely to change over time.

The following sections contain more detailed information about the individual SCMs listed in Tables 5-1 and 5-2, including the operating unit processes, the pollutants treated, the typical performance for both runoff and pollutant reduction, the strengths and weaknesses, maintenance and inspection requirements, and the largest sources of variability and uncertainty.

Product Substitution

Product substitution refers to the classic pollution prevention approach of reducing the emissions of pollutants available for future wash-off into stormwater runoff. The most notable example is the introduction of unleaded gasoline, which resulted in an order-of-magnitude reduction of lead levels in stormwater runoff in a decade (Pitt et al., 2004a,b). Similar reductions are expected with the

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phase-out of methyl tert-butyl ether (MTBE) additives in gasoline. Other examples of product substitution are the ban on coal-tar sealants during parking lot renovation that has reduced PAH runoff (Van Metre et al., 2006), phosphorus-free fertilizers that have measurably reduced phosphorus runoff to Minnesota lakes (Barten and Johnson, 2007), the painting of galvanized metal surfaces, and alternative rooftop surfaces (Clark et al., 2005). Given the importance of coal power plant emissions in the atmospheric deposition of nitrogen and mercury, it is possible that future emissions reductions for such plants may result in lower stormwater runoff concentrations for these two pollutants.

The level of control afforded by product substitution is quite high if major reductions in emissions or deposition can be achieved. The difficulty is that these reductions require action in another environmental regulatory arena, such as air quality, hazardous waste, or pesticide regulations, which may not see stormwater quality as a core part of their mission.

Watershed and Land-Use Planning

Communities can address stormwater problems by making land-use decisions that change the location or quantity of impervious cover created by new development. This can be accomplished through zoning, watershed plans, comprehensive land-use plans, or Smart Growth incentives.

The unit process that is managed is the amount of impervious cover, which is strongly related to various residential and commercial zoning categories (Cappiella and Brown, 2000). Numerous techniques exist to forecast future watershed impervious cover and its probable impact on the quality of aquatic resources (see the discussion of the Impervious Cover Model in Chapter 3; CWP, 1998a; MD DNR, 2005). Using these techniques and simple or complex simulation models, planners can estimate stormwater flows and pollutant loads through the watershed planning process and alter the location or intensity of development to reduce them.

The level of control that can be achieved by watershed and land-use planning is theoretically high, but relatively few communities have aggressively exercised it. The most common application of downzoning has been applied to watersheds that drain to drinking water reservoirs (Kitchell, 2002). The strength of this practice is that it has the potential to directly address the underlying causes of the stormwater problem rather than just treating its numerous symptoms. The weakness is that local decisions on zoning and Smart Growth are reversible and often driven by other community concerns such as economic development, adequate infrastructure, and transportation. In addition, powerful consumer and market forces often have promoted low-density sprawl development. Communities that use watershed-based zoning often require a compelling local environmental goal, since state and federal regulatory authorities have traditionally been extremely reluctant to interfere with the local land-use and zoning powers.

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Conservation of Natural Areas

Natural-area conservation protects natural features and environmental resources that help maintain the predevelopment hydrology of a site by reducing runoff, promoting infiltration, and preventing soil erosion. Natural areas are protected by a permanent conservation easement prescribing allowable uses and activities on the parcel and preventing future development. Examples include any areas of undisturbed vegetation preserved at the development site, including forests, wetlands, native grasslands, floodplains and riparian areas, zero-order stream channels, spring and seeps, ridge tops or steep slopes, and stream, wetland, or shoreline buffers. In general, conservation should maximize contiguous area and avoid habitat fragmentation.

While natural areas are conserved at many development sites, most of these requirements are prompted by other local, state, and federal habitat protections, and are not explicitly designed or intended to provide runoff reduction and stormwater treatment. To date, there are virtually no data to quantify the runoff reduction and/or pollutant removal capability of specific types of natural area conservation, or the ability to explicitly link them to site design.

Impervious Cover Reduction

A variety of practices, some of which fall under the broader term "better site design," can be used to minimize the creation of new impervious cover and disconnect or make more permeable the hard surfaces that are needed (Nichols et al., 1997; Richman, 1997; CWP, 1998a). A list of some common impervious cover reduction practices for both residential and commercial areas is provided below.

Elements of Better Site Design: Single-Family Residential

- Maximum residential street width
- Maximum street right-of-way width
- Swales and other stormwater practices can be located within the right-of-way
- Maximum cul-de-sac radius with a bioretention island in the center
- Alternative turnaround options such as hammerheads are acceptable if they reduce impervious cover
- Narrow sidewalks on one side of the street (or move pedestrian pathways away from the street entirely)
- Disconnect rooftops from the storm-drain systems
- Minimize driveway length and width and utilize permeable surfaces
- Allow for cluster or open-space designs that reduce lot size or setbacks in exchange for conservation of natural areas
- Permeable pavement in parking areas, driveways, sidewalks, walkways, and patios

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Elements of Better Site Design: Multi-Family Residential and Commercial

- Design buildings and parking to have multiple levels
- Store rooftop runoff in green roofs, foundation planters, bioretention areas, or cisterns
- Reduce parking lot size by reducing parking demand ratios and stall dimensions
- Use landscaping areas, tree pits, and planters for stormwater treatment
- Use permeable pavement over parking areas, plazas, and courtyards

CWP (1998a) recommends minimum or maximum geometric dimensions for subdivisions, individual lots, streets, sidewalks, cul-de-sacs, and parking lots that minimize the generation of needless impervious cover, based on a national roundtable of fire safety, planning, transportation and zoning experts. Specific changes in local development codes can be made using these criteria, but it is often important to engage as many municipal agencies that are involved in development as possible in order to gain consensus on code changes.

At the present time, there is little research available to define the runoff reduction benefits of these practices. However, modeling studies consistently show a 10 to 45 percent reduction in runoff compared to conventional development (CWP, 1998b,c, 2002). Several monitoring studies have documented a major reduction in stormwater runoff from development sites that employ various forms of impervious cover reduction and LID in the United States and Australia (Coombes et al., 2000; Philips et al., 2003; Cheng et al., 2005) compared to those that do not.

Unfortunately, better site design has been slowly adopted by local planners, developers, designers, and public works officials. For example, although the project pictured in Figure 5-6 has been very successful in terms of controlling stormwater, the better-site-design principles used have not been widely adopted in the Seattle area. Existing local development codes may discourage or even prohibit the application of environmental site design practices, and many engineers and plan reviewers are hesitant to embrace them. Impervious cover reduction must be incorporated at the earliest stage of site layout and design to be effective, but outdated development codes in many communities can greatly restrict the scope of impervious cover reduction (see Chapter 2). Finally, the performance and longevity of impervious cover reduction are dependent on the infiltration capability of local soils, the intensity of development, and the future management actions of landowners.

Earthwork Minimization

This source control measure seeks to limit the degree of clearing and grading on a development site in order to prevent soil compaction, conserve soils, prevent erosion from steep slopes, and protect zero-order streams. This is accomplished by (1) identifying key soils, drainage features, and slopes to protect

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FIGURE 5-6 110th Street, Seattle, part of the Natural Drainage Systems Project. This location exhibits several elements of impervious cover reduction. In particular, vegetated swales were installed and curbs and gutters removed. There are sidewalks on only one side of the street, and they are separated from the road by the swales. The residences' rooftops have been disconnected from the storm-drain systems and are redirected into the swales. SOURCE: Seattle Public Utilities.

and then (2) establishing a limit of disturbance where construction equipment is excluded. This element is an important, but often under-utilized component of local erosion and sediment control plans.

Numerous researchers have documented the impact of mass grading, clearing, and the passage of construction equipment on the compaction of soils, as measured by increase in bulk density, declines in soil permeability, and increases in the runoff coefficient (Lichter and Lindsey, 1994; Legg et al., 1996; Schueler, 2001a,b; Gregory et al., 2006). Another goal of earthwork minimization is to protect zero-order streams, which are channels with defined banks that emanate from a hollow or ravine with convergent contour lines (Gomi et al., 2002). They represent the uppermost definable channels that possess temporary or intermittent flow. Functioning zero-order channels provide major watershed functions, including groundwater recharge and discharge (Schollen et al., 2006; Winter, 2007), important nutrient storage and transformation functions (Bernot and Dodds, 2005; Groffman et al., 2005), storage and retention of eroded hillslope sediments (Meyers, 2003), and delivery of leaf inputs and large woody debris. Compared to high-order network streams, zero-order streams are disproportionately disturbed by mass grading, enclosure, or channelization (Gomi et al., 2002; Meyer, 2003).

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The practice of earthwork minimization is not widely applied across the country. This is partly due to the limited performance data available to quantify its benefits, and the absence of local or national design guidance or performance benchmarks for the practice.

Erosion and Sediment Control

Erosion and sediment control predates much of the NPDES stormwater permitting program. It consists of the temporary installation and operation of a series of structural and nonstructural practices throughout the entire construction process to minimize soil erosion and prevent off-site delivery of sediment. Because construction is expected to last for a finite and short period of time, the design standards are usually smaller and thus riskier (25-year versus the 100-year storm). By phasing construction, thereby limiting the exposure of bare earth at any one time, the risk to the environment is reduced significantly.

The basic practices include clearing limits, dikes, berms, temporary buffers, protection of drainage-ways, soil stabilization through hydroseeding or mulching, perimeter controls, and various types of sediment traps and basins. All plans have some component that requires filtration of runoff crossing construction areas to prevent sediment from leaving the site. This usually requires a sediment collection system including, but not limited to, conventional settling ponds and advanced sediment collection devices such as polymer-assisted sedimentation and advanced sand filtration. Silt fences are commonly specified to filter distributed flows, and they require maintenance and replacement after storms as shown in Figure 5-7. Filter systems are added to inlets until the streets are paved and the surrounding area has a cover of vegetation (Figure 5-8). Sedimentation basins (Figure 5-9) are constructed to filter out sediments through rock filters, or are equipped with floating skimmers or chemical treatment to settle out pollutants. Other common erosion and sediment control measures include temporary seeding and rock or rigged entrances to construction sites to remove dirt from vehicle tires (see Figure 5-10).

Control of the runoff's erosive potential is a critical element. Most erosion and sediment control manuals provide design guidance on the capacity and ability of swales to handle runoff without eroding, on the design of flow paths to transport runoff at non-erosive velocities, and on the dissipation of energy at pipe outlets. Examples include rock energy dissipaters, level spreaders (see Figure 5-11), and other devices.

Box 5-3 provides a comprehensive list of recommended construction SCMs. The reader is directed to reviews by Brown and Caraco (1997) and Shaver et al. (2007) for more information. Although erosion and sediment control practices are temporary, they require constant operation and maintenance during the complicated sequence of construction and after major storm events. It is exceptionally important to ensure that practices are frequently inspected and repaired and that sediments are cleaned out. Erosion and sediment control are

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FIGURE 5-7 A functioning silt fence (top) and an improperly maintained silt fence (bottom). SOURCES: Top, EPA NPDES Menu of BMPs (available at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=56) and, bottom, Robert Traver, Villanova University.



FIGURE 5-8 Sediment filter left in place after construction. SOURCE: Robert Traver, Villanova University.

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FIGURE 5-9 Sediment basin. SOURCE: EPA NPDES Menu of BMPs (available at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&vew=specific&bmp=56).



FIGURE 5-10 Rumble strips to remove dirt from vehicle tires. SOURCE: Laura Ehlers, National Research Council.

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FIGURE 5-11 Level spreader. SOURCE: Robert Traver, Villanova University.

BOX 5-3
Recommended Construction Stormwater Control Measures

1. As the top priority, emphasize construction management SCMs as follows:
   - Maintain existing vegetation cover, if it exists, as long as possible.
   - Perform ground-disturbing work in the season with smaller risk of erosion, and work off disturbed ground in the higher risk season.
   - Limit ground disturbance to the amount that can be effectively controlled in the event of rain.
   - Use natural depressions and planning excavation to drain runoff internally and isolate areas of potential sediment and other pollutant generation from draining off the site, so long as safe in large storms.
   - Schedule and coordinate rough grading, finish grading, and erosion control application to be completed in the shortest possible time overall and with the shortest possible lag between these work activities.

2. Stabilize with cover appropriate to site conditions, season, and future work plans. For example:
   - Rapidly stabilize disturbed areas that could drain off the site, and that will not be worked again, with permanent vegetation supplemented with highly effective temporary erosion controls until achievement of at least 90 percent vegetative soil cover.
   - Rapidly stabilize disturbed areas that could drain off the site, and that will not be worked again for more than three days, with highly effective temporary erosion controls.
   - If at least 0.1 inch of rain is predicted with a probability of 40 percent or more, before rain falls stabilize or isolate disturbed areas that could drain off the site, and that are being actively worked or will be within three days, with measures that will prevent or minimize transport of sediment off the property.

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BOX 5-3 Continued

3. As backup for cases where all of the above measures are used to the maximum extent possible but sediments still could be released from the site, consider the need for sediment collection systems including, but not limited to, conventional settling ponds and advanced sediment collection devices such as polymer-assisted sedimentation and advanced sand filtration.

4. Specify emergency stabilization and/or runoff collection (e.g., using temporary depressions) procedures for areas of active work when rain is forecast.

5. If runoff can enter storm drains, use a perimeter control strategy as backup where some soil exposure will still occur, even with the best possible erosion control (above measures) or when there is discharge to a sensitive waterbody.

6. Specify flow control SCMs to prevent or minimize to the extent possible:
- Flow of relatively clean off-site water over bare soil or potentially contaminated areas;
- Flow of relatively clean intercepted groundwater over bare soil or potentially contaminated areas;
- High velocities of flow over relatively steep and/or long slopes, in excess of what erosion control coverings can withstand; and
- Erosion of channels by concentrated flows, by using channel lining, velocity control, or both.

7. Specify stabilization of construction entrance and exit areas, provision of a nearby tire and chassis wash for dirty vehicles leaving the site with a wash water sediment trap, and a sweeping plan.

8. Specify construction road stabilization.

9. Specify wind erosion control.

10. Prevent contact between rainfall or runoff and potentially polluting construction materials, processes, wastes, and vehicle and equipment fluids by such measures as enclosures, covers, and containments, as well as berming to direct runoff.

widely applied in many communities, and most states have some level of design guidance or standards and specifications. Nonetheless, few communities have quantified the effectiveness of a series of construction SCMs applied to an individual site, nor have they clearly defined performance benchmarks for individual practices or their collective effect at the site. In general, there has been little monitoring in the past few decades to characterize the performance of construction SCMs, although a few notable studies have been recently published (e.g., Line and White, 2007). Box 5-4 describes the effectiveness of filter fences and filter fences plus grass buffers to reduce sediment loadings from construction activities and the resulting biological impacts.

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BOX 5-4
Receiving Water Impacts Associated with Construction Site Discharges

The following is a summary of a recent research project that investigated in-stream biological conditions downstream of construction sites having varying levels of erosion controls (none, the use of filter fences, and filter fences plus grass buffers) for comparison. The project title is *Studies to Evaluate the Effectiveness of Current BMPs in Controlling Stormwater Discharges from Small Construction Sites* and was conducted for the Alabama Water Resources Research Institute, Project 2001AL4121B, by Drs. Robert Angus, Ken Marion, and Melinda Lalor of the University of Alabama at Birmingham. The initial phase of the project, described below, was completed in 2002 (Angus et al., 2002). While this case study is felt to be representative of many sites across the United States, there are other examples of where silt fences have been observed to be more effective (e.g., Barrett et al., 1998).

Methods

This study was conducted in the upper Cahaba River watershed in north central Alabama, near Birmingham. The study areas had the following characteristics. (1) Topography and soil types representative of the upland physiographic regions in the Southeast (i.e., southern Appalachian and foothill areas); thus, findings from this study should be relevant to a large portion of the Southeast. (2) The rainfall amounts and intensities in this region are representative of many areas of the Southeast and (3) the expanding suburbs of the Birmingham metropolitan area are rapidly encroaching upon the upper Cahaba River and its tributaries. Stormwater runoff samples were manually collected from sheet flows above silt fences, and from points below the fence within the vegetated buffer. Water was sampled during "intense" (≥1 inch/hour) rain events. The runoff samples were analyzed for turbidity, particle size distribution (using a Coulter Counter Multi-Sizer IIe), and total solids (dissolved solids plus suspended/non-filterable solids). Sampling was only carried out on sites with properly installed and well-maintained silt fences, located immediately upgrade from areas with good vegetative cover.

Six tributary or upper mainstream sites were studied to investigate the effects of sedimentation from construction sites on both habitat quality and the biological "health" of the aquatic ecosystem (using benthic macroinvertebrates and fish). EPA's Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers was used to assess the habitat quality at the study sites. Each site was assessed in the spring to evaluate immediate effects of the sediment, and again during the following late summer or early fall to evaluate delayed effects.

Results

Effectiveness of Silt Fences. Silt fences were found to be better than no control measures at all, but not substantially. The mean counts of small particles (<5 μm) below the silt fences were about 50 percent less than that from areas with no erosion control measures, even though the fences appeared to be properly installed and in good order. However, the variabilities were large and the difference between the means was not statistically significant. For every variable measured, the mean values of samples taken below silt fences were significantly higher ($p < 0.001$) than samples collected from undisturbed vegetated control sites collected nearby and at the same time. These data therefore indicate that silt fences are only marginally effective at reducing soil particulates in runoff water.

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Effectiveness of Filter Fences with Vegetated Buffers. Runoff samples were also collected immediately below filter fences, and below filter fences after flow over buffers having 5, 10, and 15 feet of dense (intact) vegetation. Mean total solids in samples collected below silt fences and a 15-foot-wide vegetated buffer zone were about 20 percent lower, on average, than those samples collected only below the silt fence. The installation of filter fences above an intact, good vegetated buffer removes sediment from construction site runoff more effectively than with the use of filter fences alone.

Biological Metrics Sensitive to Sedimentation Effects (Fish). Analysis of the fish biota indicates that various metrics used to evaluate the biological integrity of the fish community also are affected by highly sedimented streams. As shown in Figure 5-12, the overall composition of the population, as quantified by the Index of Biotic Integrity (IBI) is lower; the proportion and biomass of darters, a disturbance-sensitive group, is lower; the proportion and biomass of sunfish is higher; the Shannon-Weiner diversity index is lower; and the number of disturbance-tolerant species is higher as mean sediment depth increases.

Benthic Macroinvertebrates. A number of stream benthic macroinvertebrate community characteristics were also found to be sensitive to sedimentation. Metrics based on these characteristics differ greatly between sediment-impacted and control sites (Figure 5-13). Some of the metrics that appear to reflect sediment-associated stresses include the Hilsenhoff Biotic Index (HBI), a variation of the EPT index (percent EPT minus Baetis), and the Sorensen Index of Similarity to a reference site. The HBI is a weighted mean tolerance value; high HBI values indicate sites dominated by disturbance-tolerant macroinvertebrate taxa. The EPT% index is the percent of the collection represented by organisms in the generally disturbance-sensitive orders *Ephemeroptera, Plecoptera,* and *Trichoptera*. Specimens of the genus *Baetis* were not included in the index as they are relatively disturbance-tolerant. The HBI and the EPT indices also show positive correlations to several other measures of disturbance, such as percent of the watershed altered by development.

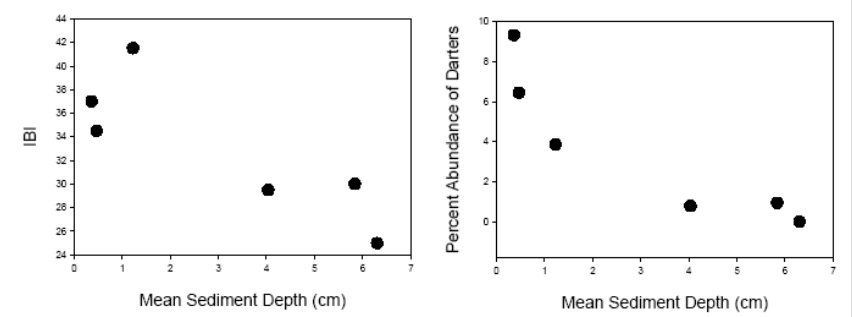

FIGURE 5-12 Association between two fish metrics and amount of stream sediment. NOTE: The IBI is based on numerous characteristics of the fish population. The percent relative abundance of darters is the percentage of darters to all the fish collected at a site. SOURCE: Angus et al. (2002).

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BOX 5-4 Continued

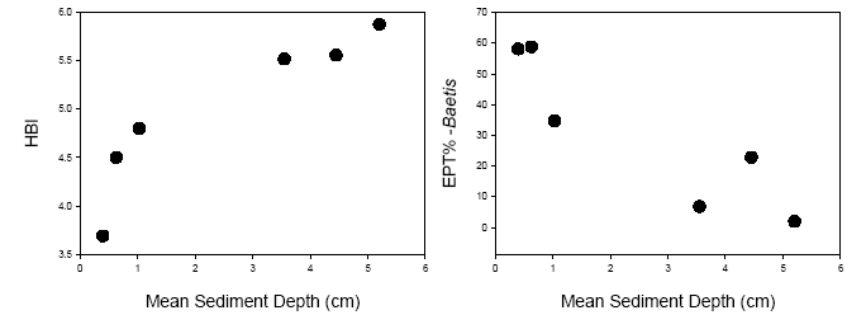

FIGURE 5-13 Associations between two macroinvertebrate metrics and the amount of stream sediment. SOURCE: Angus et al. (2002).

Reforestation and Soil Compost Amendments

This set of practices seeks to improve the quality of native vegetation and soils present at the site. Depending on the ecoregion, this may involve forest, prairie, or chapparal plantings, tilling, and amending compacted soils to improve their hydrologic properties.

The goal is to maintain as much predevelopment hydrologic function at a development site as possible by retaining canopy interception, duff/soil layer interception, evapotranspiration, and surface infiltration. The basic methods to implement this practice are described in Cappiella et al. (2006), Pitt et al. (2005), Chollak and Rosenfeld (1998), and Balusek (2003).

At this time, there are few monitoring data to assess the degree to which land reforestation or soil amendments can improve the quality of stormwater runoff at a particular development site, apart from the presumptive watershed research that has shown that forests with undisturbed soils have very low rates of surface runoff and extremely low levels of pollutants in runoff (Singer and Rust, 1975; Johnson et al., 2000; Chang, 2006). More data are needed on the hydrologic properties of urban forests and soils whose ecological functions are stressed or degraded by the urbanization process (Pouyat et al., 1995, 2007).

Pollution Prevention SCMs for Stormwater Hotspots

Certain classes of municipal and industrial operations are required to maintain a series of pollution prevention practices to prevent or minimize contact of pollutants with rainfall and runoff. Pollution prevention practices involve a wide range of operational practices at a site related to vehicle repairs, fueling, washing and storage, loading and unloading areas, outdoor storage of materials, spill prevention and response, building repair and maintenance, landscape and

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turf management, and other activities that can introduce pollutants into the stormwater system (CWP, 2005). Training of personnel at the affected area is needed to ensure that industrial and municipal managers and employees understand and implement the correct stormwater pollution prevention practices needed for their site or operation.

Examples of municipal operations that may need pollution prevention plans include public works yards, landfills, wastewater treatment plants, recycling and solid waste transfer stations, maintenance depots, school bus and fleet storage and maintenance areas, public golf courses, and ongoing highway maintenance operations. The major industrial categories that require stormwater pollution prevention plans were described in Table 2-3. Both industrial and municipal operations must develop a detailed stormwater pollution prevention plan, train employees, and submit reports to regulators. Compliance has been a significant issue with this program in the past, particularly for small businesses (Duke and Augustenberg, 2006; Cross and Duke, 2008) Recently filed investigations of stormwater hotspots indicate many of these operations are not fully implementing their stormwater pollution prevention plans, and a recent GAO report (2007) indicates that state inspections and enforcement actions are extremely rare.

The goal of pollution prevention is to prevent contact of rainfall or stormwater runoff with pollutants, and it is an important element of the post-construction stormwater plan. However, with the exception of a few industries such as auto salvage yards (Swamikannu, 1994), basic research is lacking on how much greater event mean concentrations are at municipal and industrial stormwater hotspots compared to other urban land uses. In addition, little is presently known about whether aggressive implementation of stormwater pollution prevention plans actually can reduce stormwater pollutant concentrations at hot spots.

Runoff Volume Reduction—Rainwater Harvesting

A primary goal of stormwater management is to reduce the volume of runoff from impervious surfaces. There are several classes of SCMs that can achieve this goal, including rainwater harvesting systems, vegetated SCMs that evapotranspirate part of the volume, and infiltration SCMs. For all of these measures, the amount of runoff volume to be captured depends on watershed goals, site conditions including climate, upstream nonstructural practices employed, and whether the chosen SCM is the sole management measure or part of a treatment train. Generally, runoff-volume-reduction SCMs are designed to handle at least the first flush from impervious surfaces (1 inch of rainfall). In Pennsylvania, control of the 24-hour, two-year storm volume (about 8 cm) is considered the standard necessary to protect stream-channel geomorphology, while base flow recharge and the first flush can be addressed by capturing a much smaller volume of rain (1–3 cm). Where both goals must be met, the designer is permitted to either oversize the volume reduction device to control the

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larger volume, or build a smaller device and use it in series with an extended detention basin to protect the stream geomorphology (PaDEP, 2006). Some designers have reported that in areas with medium to lower percentage impervious surfaces they are able to control up to the 100-year storm by enlarging runoff-volume-reduction SCMs and using the entire site. In retrofit situations, capture amounts as small as 1 cm are a distinct improvement. It should be noted that there are important, although indirect, water quality benefits of all runoff-volume-reduction SCMs—(1) the reduction in runoff will reduce streambank erosion downstream and the concomitant increases in sediment load, and (2) volume reductions lead to pollutant load reductions, even if pollutant concentrations in stormwater are not decreased.

Rainwater harvesting systems refer to use of captured runoff from roof tops in rain barrels, tanks, or cisterns (Figures 5-14 and 5-15). This SCM treats runoff as a resource and is one of the few SCMs that can provide a tangible economic benefit through the reduction of treated water usage. Rainwater harvesting systems have substantial potential as retrofits via the use of rain barrels or cisterns that can replace lawn or garden sprinkling systems. Use of this SCM to provide gray water within buildings (e.g., for toilet flushing) is considerably more complicated due to the need to construct new plumbing and obtain the necessary permits.



FIGURE 5-14 Rainwater harvesting tanks at a Starbucks in Austin, Texas. SOURCE: Laura Ehlers, National Research Council.

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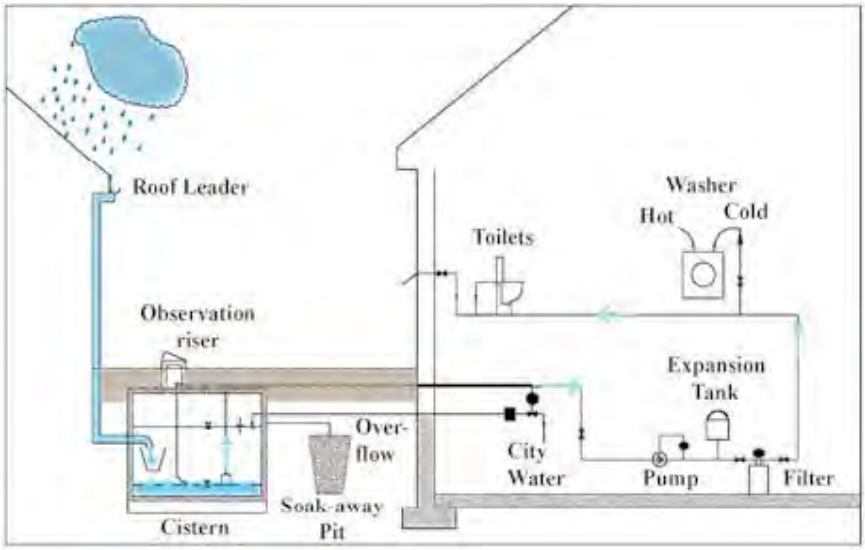

FIGURE 5-15 A Schematic of rainwater harvesting. SOURCE: PaDEP (2006).

The greatest challenge with these systems is the need to use the stored water and avoid full tanks, since these cannot be responsive in the event of a storm. That is, these SCMs are effective only if the captured runoff can be regularly used for some grey water usage, like car washing, toilet flushing, or irrigation systems (golf courses, landscaping, nurseries). In some areas it might be possible to use the water for drinking, showering, or washing, but treatment to potable water quality would be required. Sizing of the required storage is dependent on the climate patterns, the amount of impervious cover, and the frequency of water use. Areas with frequent rainfall events require less storage as long as the water is used regularly, while areas with cold weather will not be able to utilize the systems for irrigation in the winter and thus require larger storage.

One substantial advantage of these systems is their ability to reduce water costs for the user and the ability to share needs. An example of this interaction is the Pelican Hill development in Irvine, California, where excess runoff from the streets and houses is collected in enormous cisterns and used for watering of a nearby golf course. Furthermore, compared to other SCMs, the construction of rainwater harvesting facilities provide a long-term benefit with minimal maintenance cost, although they do require an upfront investment for piping and storage tanks.

Coombes et al. (2000) found that rainwater harvesting achieved a 60 to 90 percent reduction in runoff volume; in general, few studies have been conducted to determine the performance of these SCMs. It should be noted that rainwater harvesting systems do collect airborne deposition and acid rain.

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Runoff Volume Reduction—Vegetated

A large and very promising class of SCMs includes those that use infiltration and evapotranspiration via vegetation to reduce the volume of runoff. These SCMs also directly address water quality of both surface water and groundwater by reducing streambank erosion, capturing suspended solids, and removing other pollutants from stormwater during filtration through the soil (although the extent to which pollutants are removed depends on the specific pollutant and the local soil chemistry). Depending on their design, these SCMs can also reduce peak flows and recharge groundwater (if they infiltrate). These SCMs can often be added as retrofits to developed areas by installing them into existing lawns, rights of way, or traffic islands. They can add beauty and property value.

Flow volume is addressed by this SCM group by first capturing runoff, creating a temporary holding area, and then removing the stored volume through infiltration and evapotranspiration. Examples include bioswales, bioretention, rain gardens, green roofs, and bioinfiltration. Swales refer to grassy areas on the side of the road that convey drainage. These were first designed to move runoff away from paved areas, but can now be designed to achieve a certain contact time with runoff so as to promote infiltration and pollutant removal (see Figure 5-16). Bioretention generally refers to a constructed sand filter with soil and vegetation growing on top to which stormwater runoff from impervious surfaces is directed (Figure 5-17). The original rain garden or bioretention facilities were constructed with a fabric at the bottom of the prepared soil to prevent infiltration and instead had a low-level outflow at the bottom. Green roofs (Figure 5-18) are very similar to bioretention SCMs. They tend to be populated with a light expanded shale-type soil and succulent plants chosen to survive wet and dry periods. Finally, bioinfiltration is similar to bioretention but is better engineered to achieve greater infiltration (Figure 5-19). All of these devices are usually at the upper end of a treatment train and designed for smaller storms, which minimizes their footprint and allows for incorporation within existing infrastructure (such as traffic control devices and median strips). This allows for distributed treatment of the smaller volumes and distributed volume reduction.

These SCMs work by capturing water in a vegetated area, which then infiltrates into the soil below. They are primarily designed to use plant material and soil to evapotranspirate the runoff over several days. A shallow depth of ponding is required, since the inflows may exceed the possible infiltration ability of the native soil. This ponding is maintained above an engineered sandy soil mixture and is a surface-controlled process (Hillel, 1998). Early in the storm, the soil moisture potential creates a suction process that helps draw water into the SCM. This then changes to a steady rate that is “practically equal to the saturated hydraulic conductivity” of the subsurface (Hillel, 1998). The hydrologic design goal should be to maximize the volume of water that can be held in the soil, which necessitates consideration of the soil hydraulic conductivity (which varies with temperature), climate, depth to groundwater, and time to drain.

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FIGURE 5-16 Vegetated swale. SOURCE: PaDEP (2006).



FIGURE 5-17 Bioretention during a storm event at the University of Maryland. SOURCE: Reprinted, with permission, from Davis et al. (2008). Copyright 2008 by the American Society of Civil Engineers.

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FIGURE 5-18 City Hall in the center of Chicago's downtown was retrofitted with a green roof to reduce the heat island effect, remove airborne pollutants, and attenuate stormwater flows as a demonstration of innovative stormwater management in an ultra-urban setting. SOURCE: Courtesy of the Conservation Design Forum.



FIGURE 5-19 Retrofit bioinfiltration at Villanova University immediately following a storm event. SOURCE: Robert Traver, Villanova University.

Usually these devices are designed to empty between 24 and 72 hours after a storm event. In some cases (usually bioretention), these SCMs have an underdrain.

The choice of vegetation is an important part of the design of these SCMs. Many sites where infiltration is desirable have highly sandy soils, and the vegetation has to be able to endure both wet and dry periods. Long root growths are desired to promote infiltration (Barr Engineering Co., 2001), and plants that attract birds can reduce the insect population. Bioretention cells may be wet for

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longer periods than bioinfiltration sites, requiring different plants. Denser plantings or "thorns" may be needed to avoid the destruction caused by humans and animals taking shortcuts through the beds.

The pollutant removal mechanism operating for volume-reduction SCMs are different for each pollutant type, soil type, and volume-reduction mechanism. For bioretention and SCMs using infiltration, the sedimentation and filtration of suspended solids in the top layers of the soil are extremely efficient. Several studies have shown that the upper layers of the soil capture metals, particulate nutrients, and carbon (Pitt, 1996; Deschesne et al., 2005; Davis et al., 2008). The removal of dissolved nutrients from stormwater is not as straightforward. While ammonia is caught by the top organic layer, nitrate is mobile in the soil column. Some bioretention systems have been built to hold water in the soil for longer periods in order to create anaerobic conditions that would promote denitrification (Hunt and Lord, 2006a). Phosphorus removal is related to the amount of phosphorus in the original soil. Some studies have shown that bioretention cells built with agricultural soils increased the amount of phosphorus released. Chlorides pass through the system unchecked (Ermilio and Traver, 2006), while oils and greases are easily removed by the organic layer. Hunt et al. (2008) have reported in studies in North Carolina that the drying cycle appears to kill off bacteria. Temperature is not usually a concern as most storms do not overflow these devices. Green roofs collect airborne deposition and acid rain and may export nutrients when they overflow. However, this must be tempered by the fact that in larger storms, most natural lands would produce nutrients.

A group of new research studies from North America and Australia have demonstrated the value of many of these runoff-volume-reduction practices to replicate predevelopment hydrology at the site. The results from 10 recent studies are given in Table 5-3, which shows the runoff reduction capability of bioretention. As can be seen, the reduction in runoff volume achieved by these practices is impressive—ranging from 20 to 99 percent with a median reduction of about 75 percent. Box 5-5 discusses the excellent performance of the bioswales installed during Seattle's natural drainage systems project (see also Horner et al., 2003; Jefferies, 2004; Stagge, 2006). Bioinfiltration has been less studied, but one field study concluded that close to 30 percent of the storm volume was able to be removed by bioinfiltration (Sharkey, 2006). A very recent case study of bioinfiltration is provided in Box 5-6, which demonstrates that the capture of small storms through these SCMs is extremely effective in areas where the majority of the rainfall falls in smaller storms.

The strengths of vegetated runoff-volume-reduction SCMs include the flexibility to utilize the drainage system as part of the treatment train. For example, bioswales can replace drainage pipes, green roofs can be installed on buildings, and bioretention can replace parking borders (Figure 5-27), thereby reducing the footprint of the stormwater system. Also, through the use of swales and reducing pipes and inlets, costs can be offset. Vegetated systems are more tolerant of the TSS collected, and their growth cycle maintains pathways for

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TABLE 5-3 Volumetric Runoff Reduction Achieved by Bioretention

Bioretention Design	Location	Runoff Reduction	Reference
Infiltration	CT	99%	Dietz and Clausen (2006)
	PA	86%	Ermilio and Traver (2006)
	FL	98%	Rushton (2002)
	AUS	73%	Lloyd et al. (2002)
Underdrain	ONT	40%	Van Seters et al. (2006)
	Model	30%	Perez-Perdini et al. (2005)
	NC	40 to 60%	Smith and Hunt (2007)
	NC	20 to 29%	Sharkey (2006)
	NC	52 to 56%	Hunt et al. (2008)
	MD	52 to 65%	Davis et al. (2008)

BOX 5-5
Bioswale Case Study 110th Street Cascade, Seattle, Washington

A recent example of the ability of SCMs to accomplish a variety of goals was illustrated for water quality swales in Seattle, Washington. As part of its Natural Drainage Systems Project, the City of Seattle retrofitted several blocks of an urban residential neighborhood with curbside vegetated swales. On NW 110th Street, the two-block-long system was developed as a cascade, due to the steep slope (6 percent). Twelve stepped, in-series biofilters were installed between properties and the road, each of which contains a storage area and an overflow weir. During rain events, the cells were designed to fill before emptying into the cell downstream. The soils in the bottom of each cell were over one foot thick and consisted of river rocks overlain by a swale mix. Native plants were chosen to vegetate the sides of the swale.



Extensive flow and water quality sampling occurred during 2003–2006 at the inflow and outflow of the biofilters as well as at references points elsewhere in the neighborhood that are not served by the new SCMs. Perhaps the most profound observation was that almost 50 percent of all rainfall flowing into the cascade was infiltrated, resulting in a corresponding reduction in runoff. Indeed, the cascade discharged measurable flow only during 49 of 235 storm events during the period. Depending on preceding conditions, the cascade was able to retain all of the flow for storms up to 1 inch in magnitude. In addition to the reduction in runoff affected by the swales, they also achieved significant peak flow reduction, as shown in Figure 5-20. Many peak flow rates were entirely dampened, even those where the inflow peak rate was as high as 0.7 cfs.

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BOX 5-5 Continued

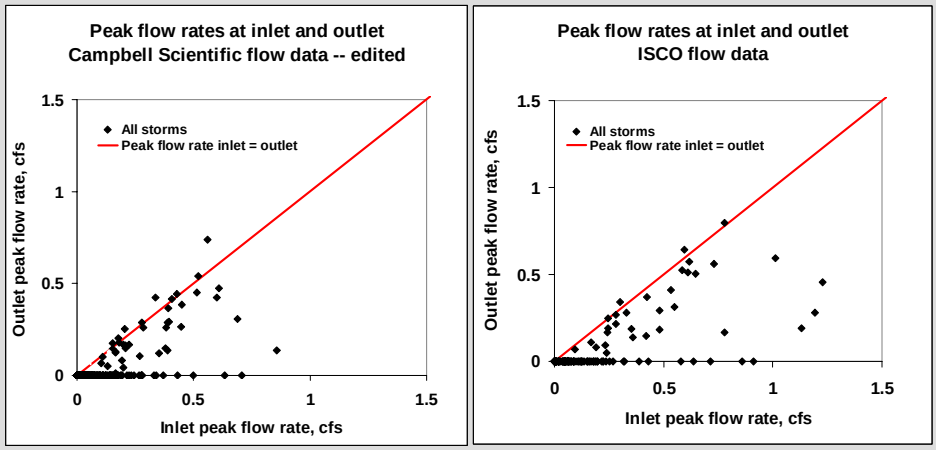

FIGURE 5-20 Peak flow rates at the inlet and outlet of the cascade, as measured by two different devices: Campbell Scientific (left) and ISCO (right). SOURCE: Horner and Chapman (2007).

Water quality data were also extremely encouraging, as shown in Table 5-4. For total suspended solids, influent concentration of 94 mg/L decreased to 29 mg/L at the outlet of the cascade. Similar percent removals were observed for total copper, total phosphorus, total zinc, and total lead (see Table 5-4). Soluble phosphorus concentrations tended to increase from the inflow of the cascade to the outflow.

TABLE 5-4 Typical Outflow Quality from the 110th Street Cascade.

Pollutant	Range (mg/L)
Total Suspended Solids	10–40
Total Nitrogen	0.6–1.4
Total Phosphorus	0.09–0.23
Soluble Reactive Phosphorus	0.02–0.05
Total Copper	0.004–0.008
Dissolved Copper	0.002–0.005
Total Zinc	0.04–0.11
Dissolved Zinc	0.02–0.06
Total Lead	0.002–0.007
Dissolved Lead	<0.001
Motor Oil	0.11–0.33

SOURCE: Horner and Chapman (2007).

Taking both measured concentrations and volume reduction into account, the cascade reduced the mass loadings for the contaminants by 60 percent to greater than 90 percent. As shown in Table 5-5, pollutants associated with sediments were reduced to the greatest extent, while dissolved pollutants were less readily removed.

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BOX 5-5 Continued

TABLE 5-5 Pollutant Mass Loading Reductions at 110th Street Cascade.

Pollutant	Percent Reduction (90% Confidence Interval)
Total Suspended Solids	84 (72–92)
Total Nitrogen	63 (53–74)
Total Phosphorus	63 (49–74)
Total Copper	83 (77–88)
Dissolved Copper	67 (50–78)
Total Zinc	76 (46–85)
Dissolved Zinc	55 (21–70)
Total Lead	90 (84–94)
Motor Oil	92 (86–97)

SOURCE: Horner and Chapman (2007).

This level of performance was compared to other parts of the neighborhood treated with conventional ditch and pipe systems. The concentrations of almost all pollutants at the outlet of the 100th Cascade was significantly lower than a corresponding outlet at 120th Street. Furthermore, the ability of this SCM to attenuate peak flows and reduce runoff was remarkable.

BOX 5-6
SCM Evaluation Through Monitoring: Villanova Bioinfiltration SCM

The Bioinfiltration Traffic Island located on the campus of Villanova University in Southeastern Pennsylvania is part of the Villanova Urban Stormwater Partnership (VUSP) BMP Demonstration Park (see Figure 5-21). Originally funded through the Pennsylvania Growing Greener Program, and now through the State's 319 nonpoint source monitoring program, the site has been monitored continuously since soon after it was constructed in 2001. This monitoring has lead to a wealth of information about the performance and monitoring needs of infiltration SCMs.



FIGURE 5-21 Villanova Bioinfiltration Traffic Island SCM. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

The SCM is a retrofit of an existing curb-enclosed traffic island in the parking lot of a university dormitory complex. The original grass area was dug out to approximately six feet. The soil removed during the excavation was then mixed with sand onsite to create a 50 percent sand–soil mixture. This soil mixture was then placed back into the excavation to

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BOX 5-6 Continued

a depth of approximately four feet, leaving a surface depression that is an average of two feet deep. Care was taken during construction to prevent any compaction of either the soil mixture or the undisturbed soil below. Placement of the mixed soil is shown in Figure 5-22.



FIGURE 5-22 Placement of the mixed soil in the basin. Notice the construction equipment being kept away from the basin to avoid potential compaction of the sub-base. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

During construction two curb cuts were created to direct runoff into the SCM. Creation of one of the cuts entailed filling and paving over an existing stormwater inlet to redirect the runoff that previously entered the stormwater drainage system of the parking lot. Another existing inlet was used to collect and redirect runoff into the SCM. Plants were chosen based on their ability to thrive in both extreme wet and dry conditions; the species chosen are commonly found on sand dunes where similar wet/dry conditions may exist.

The contributing watershed is approximately 50,000 square feet and is 52 percent impervious surfaces. The design goal of the SCM was for it to temporarily store the first inch of runoff. The one-inch capture depth is based on an analysis of local historical rainfall data showing that capture of the first inch of each storm would account for approximately 96 percent of the annual rainfall. This capture depth would therefore also account for the majority of the annual pollutant load coming from the drainage area.

Continuous monitoring over multiple years has increased our understanding of how this type of structure operates and its benefits. For example, Heasom et al. (2006) was able to produce a continuous hydrologic flow model of the site based on season. Figure 5-23 shows the variability of the infiltration rate on a seasonal basis, and the relationship between infiltration and temperature (Emerson and Traver, 2008). This work has also shown no statistical change in performance over the five-year monitoring period.

When examining the yearly performance of the site from a surface water standpoint, it is easily shown that on a regular basis approximately 50 to 60 percent of the runoff that reaches the site is removed from the surface waters, and 80 to 85 percent of the rainfall is infiltrated (Figure 5-24).

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BOX 5-6 Continued

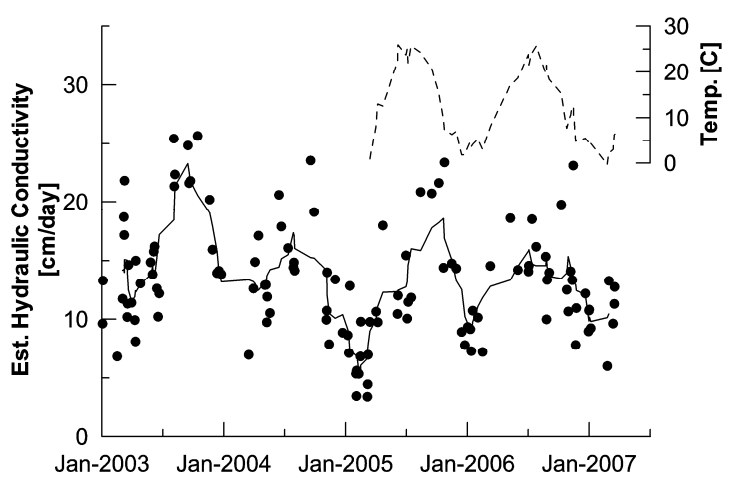

FIGURE 5-23 Seasonal Infiltration Rate. SOURCE: Reprinted, with permission, from Emerson and Traver (2008). Copyright 2008 by Journal of Irrigation and Drainage Engineering.

The performance of the SCM during individual storm events was examined in 2005. Out of 77 rainfall events, overflow was recorded for only seven events. Generally overflow did not occur for rainfalls less than 1.95 inches except for one occasion. As the bowl volume is much less than this value, substantial infiltration must be occurring during the storm event. When one extreme 6-inch storm was recorded (Figure 5-25), it was surprising to note that infiltration occurred all during the storm event, as did some unexpected peak flow reduction. What is even more impressive is to examine the reduction in the duration of flows, which is directly related to downstream channel erosion (Figure 5-26). Clearly the bioinfiltration SCM exceeded its design goals.

Research on this site is currently examining water quality benefits and groundwater interactions. When evaluating the pollutant removal of bioinfiltration, it is critical to consider flow volumes and pollutant levels together. For example, during many of the overflow events, there were higher nutrient levels leaving the SCM than entering due to the plants contained within the SCM. However, when the runoff volume reduction is considered, the total nitrogen and phosphorus removed from the influent is impressive (Davis et al., 2008). Water quality studies of the infiltrated water are still incomplete but generally show some conversion of nitrate to nitrite, and high chlorides from snow melt chemicals moving through the system. Nutrient levels are relatively low in the samples at the 8-foot depth.

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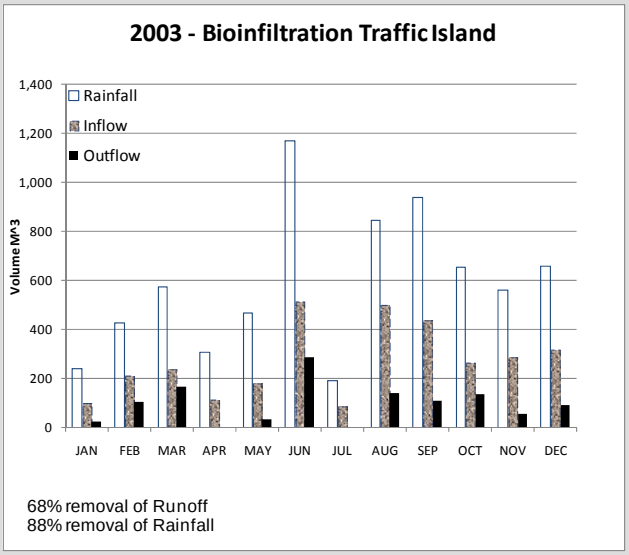

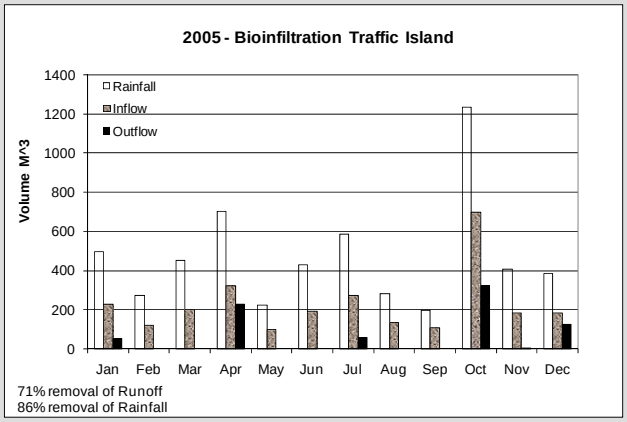

FIGURE 5-24 2003 Performance and 2005 Performance. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

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BOX 5-6 Continued

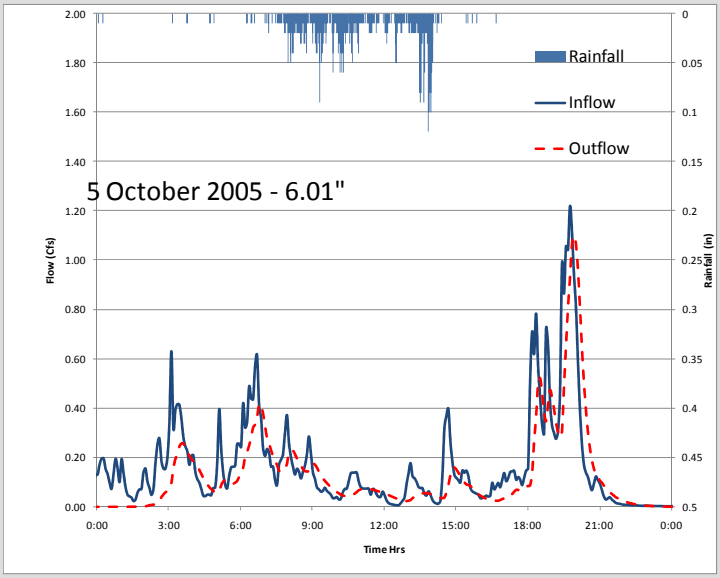

FIGURE 5-25 October 2005 extreme storm event. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

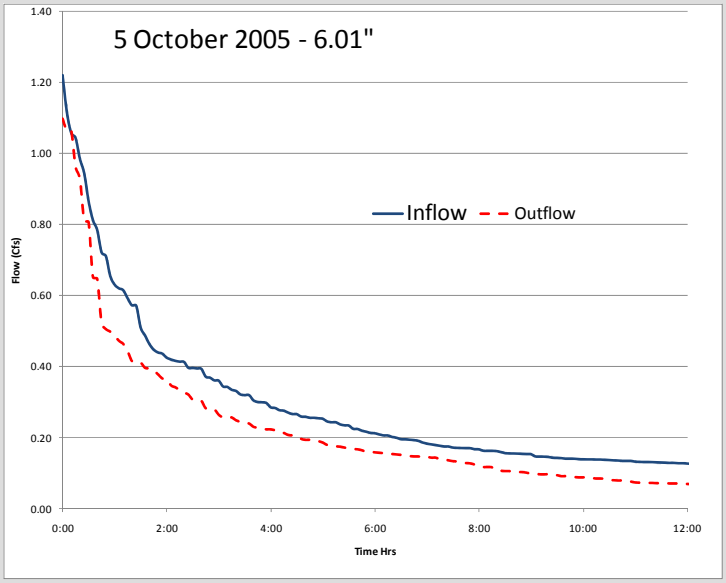

FIGURE 5-26 Flow duration curves, October 2005. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

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FIGURE 5-27 North Carolina Retrofit Bioretention SCMs. SOURCE: Robert Traver, Villanova University.

infiltration and prevents clogging. Freeze–thaw cycles also contribute to pathway maintenance. The aesthetic appeal of vegetated SCMs is also a significant strength.

Weaknesses include the dependence of these SCMs on native soil infiltration and the need to understand groundwater levels and karst geology, particularly for those SCMs designed to infiltrate. For bioinfiltration and bioretention, most failures occur early on and are caused by sedimentation and construction errors that reduce infiltration capacity, such as stripping off the topsoil and compacting the subsurface. Once a good grass cover is established in the contributing area, the danger of sedimentation is reduced. Nonetheless, the need to prevent sediment from overwhelming these structures is critical. The longevity of these SCMs and their vulnerability to toxic spills are a concern (Emerson and Traver, 2008), as is their failure to reduce chlorides. Finally, in areas where the land use is a hot spot, or where the SCM could potentially contaminate the groundwater supply, bioretention, non-infiltrating bioswales, and green roofs may be more suitable than infiltration SCMs.

The role of infiltration SCMs in promoting groundwater recharge deserves additional consideration. Although this is a benefit of infiltration SCMs in regions where groundwater levels are dropping, it may be undesirable in a few limited scenarios. For example, in the arid southwest contributions to base flow from irrigation have turned some dry ephemeral stream systems into perennial streams that support the growth of dense vegetation, which may be less desirable habitat for certain riparian species (like the Arroyo toad in Southern California). Infiltration SCMs could contribute to changing the flow regime in cases such as these. In most urban areas, there is so much impervious cover that it would be

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difficult to "overinfiltrate." Nonetheless, the use of infiltration SCMs will change local subsurface hydrology, and the ramifications of this—good and bad—should be considered prior to their installation.

Maintenance of vegetated runoff-volume-reduction SCMs is relatively simple. A visit after a rainstorm to check for plant health, to check sediment buildup, and to see if the water is ponded can answer many questions. Maintenance includes trash pickup and seasonal removal of dead grasses and weeds. Sediment removal from pretreatment devices is required. Depending on the pollutant concentrations in the influent, the upper layer of organic matter may need to be removed infrequently to maintain infiltration and to prevent metal and nutrient buildup.

At the site level, the chief factors that lead to uncertainty are the infiltration performance of the soil, particular for the limiting subsoil layer, and how to predict the extent of pollutant removal. Traditional percolation tests are not effective to estimate the infiltration performance; rather, testing hydraulic conductivity is required. Furthermore, the infiltration rate varies depending on temperature and season (Emerson and Traver, 2008). Basing measurements on percent removal of pollutants is extremely misleading, since every site and storm generates different levels of pollutants. The extent of pollutant removal depends on land use, time between storms, seasons, and so forth. These factors should be part of the design philosophy for the site. Finally, it should also be pointed out that climate is a factor determining the effectiveness of some of these SCMs. For example, green roofs are more likely to succeed in areas having smaller, more frequent storms (like the Pacific Northwest) compared to areas subjected to less frequent, more intense storms (like Texas).

Runoff Volume Reduction—Subsurface

Infiltration is the primary runoff-volume-reduction mechanism for subsurface SCMs, such that much of the previous discussion is relevant here. Thus, like vegetated SCMs, these SCMs provide benefits for groundwater recharge, water quality, stream channel protection, peak flow reduction, capture of the suspended solids load, and filtration through the soil (Ferguson, 2002). Because these systems can be built in conjunction with paved surfaces (i.e., they are often buried under parking lots), the amount of water captured, and thus stream protection, may be higher than for vegetated systems. They also have lower land requirements than vegetated systems, which can be an enormous advantage when using these SCMs during retrofitting, as long as the soil is conducive to infiltration.

Similar to vegetated SCMs, this SCM group works primarily by first capturing runoff and then removing the stored volume through infiltration. The temporary holding area is made either of stone or using manufactured vaults. Examples include pervious pavement, infiltration trenches, and seepage pits (see Figures 5-28, 5-29, 5-30, 5-31, and 5-32). As with vegetated SCMs, a shallow

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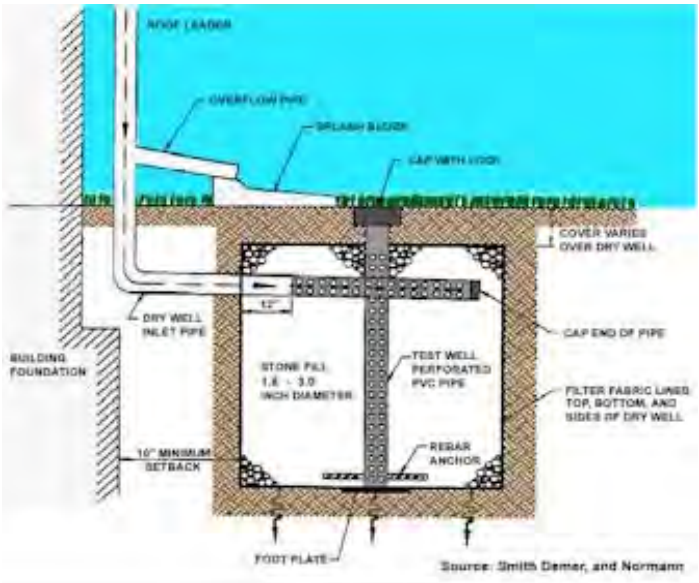

FIGURE 5-28 Schematic of a seepage pit. SOURCE: PaDEP (2006).



FIGURE 5-29 Porous asphalt. SOURCE: PaDEP (2006).

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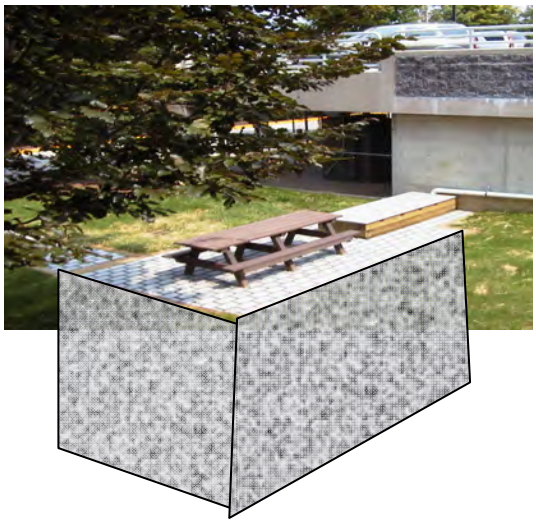

FIGURE 5-30 A retrofitted infiltration trench at Villanova University. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

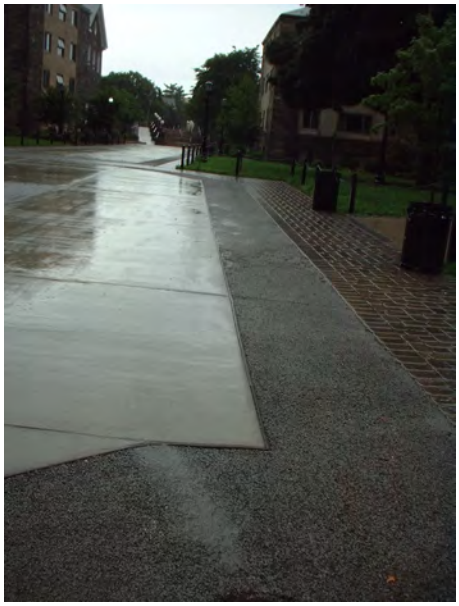

FIGURE 5-31 Pervious concrete at Villanova University. SOURCE: Reprinted, with permission from Villanova University. Copyright by VUSP.

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FIGURE 5-32 A small office building conversion at the edge of downtown Denver included the replacement of a portion of the site's parking with modular block porous pavement underlain by an 18-inch layer of crushed rock. Rainfall on the porous pavement and roof runoff for most storm events are contained in the reservoir created by the crushed rock. The pavement infiltrates runoff from most storm events for one-third of the impervious area on the half-acre site. SOURCE: Courtesy of Wenk Associates.

depth of ponding is required, since the inflows may exceed the possible infiltration ability of the native soil. In this case, the ponding is maintained within a rock bed under a porous pavement or in an infiltration trench. These devices are usually designed to empty between 24 and 72 hours after the storm event.

The infiltration processes operating for these subsurface SCMs are similar to those for the vegetated devices previously discussed. Thus, much like for

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vegetated systems, the level of control achieved depends on the infiltration ability of the native soils, the percent of impervious surface area in the contributing watershed, land use contributing to the pollutant loadings, and climate. A large number of recent studies have found that permeable pavement can reduce runoff volume by anywhere from 50 percent (Rushton, 2002; Jefferies, 2004; Bean et al., 2007) to as much as 95 percent or greater (van Seters et al., 2006; Kwiatkowski et al., 2007). Box 5-7 describes the success of a recent retrofitting of asphalt with pervious pavement at Villanova University.

The strengths of subsurface runoff-volume-reduction SCMs are similar to those of their vegetated counterparts. Additional attributes include their ability to be installed under parking areas and to manage larger volumes of rainfall. These SCMs typically have few problems with safety or vector-borne diseases because of their subsurface location and storage capacity, and they can be very aesthetically pleasing. The potential of permeable pavement could be particularly far-reaching if one considers the amount of impervious surface in urban areas that is comprised of roads, driveways, and parking lots.

The weaknesses of these SCMs are also similar to those of vegetated systems, including their dependence on native soil infiltration and the need to understand groundwater levels and karst geology. Simply estimating the soil hydraulic conductivity can have an error rate of an order of magnitude. Specifically for subsurface systems that use geotextiles (not permeable pavement), there is a danger of TSS being compressed against the bottom of the geotextile, preventing infiltration. There are no freeze–thaw cycles or vegetated processes that can reopen pathways, so the control of TSS is even more critical to their life span. In most cases (permeable pavement is an exception), pretreatment is required, except for the cleanest of sources (like a slate roof). Typically, manufactured devices, sediment forebays, or grass strips are part of the design of subsurface SCMs to capture the larger sediment particles.

The maintenance of subsurface runoff-volume-reduction SCMs is relatively simple but critical. If inspection wells are installed, a visit after a rainstorm will check that the volume is captured, and later that it has infiltrated. Porous surfaces should undergo periodic vacuum street sweeping when a sediment source is present. Pretreatment devices require sediment removal. The difficulty with this class of SCMs is that, if a toxic spill occurs or maintenance is not proactive, there are no easy corrective measures other than replacement.

Low-Impact Development. LID refers primarily to the use of small, engineered, on-site stormwater practices to treat the quality and quantity of runoff at its source. It is discussed here because the SCMs that are thought of as LID—particularly vegetated swales, green roofs, permeable pavement, and rain gardens—are all runoff-volume-reduction SCMs. They are designed to capture the first portion of a rainfall event and to treat the runoff from a few hundred square meters of impervious cover.

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BOX 5-7
Evaluation Through Monitoring: Villanova Pervious Concrete SCM

Villanova University's Stormwater Research and Demonstration Park is home to a pervious concrete infiltration site (Figure 5-33). The site, formerly a standard asphalt paved area, is located between two dormitories. The area was reconstructed in the summer of 2002 and outfitted with three infiltration beds overlain with pervious concrete. Usage of the site consists primarily of pedestrian traffic with some light automobile traffic. The pervious concrete site is designed to infiltrate small-volume storms (1 to 2 inches). Roof top runoff is directly piped to the rock bed under the concrete. For these smaller events, there is essentially no runoff from the site.



FIGURE 5-33 Villanova University pervious concrete retrofit site. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

The pervious concrete is outlined with decorative pavers that divide the pervious concrete into three separate sections as seen in Figure 5-33. Underneath these three sections are individual storage beds. Since the site lies on a significant slope it was necessary to create earthen dams that isolate each storage area. At the top of each dam there is an overflow pipe which connects the storage area with the next one downstream. The final storage bed has an overflow that connects to the existing storm sewer. The beds are approximately 4 feet deep and are filled with stone, producing about 40 percent void space within the beds. A geotextile pervious liner was laid down to separate the storage beds from the undisturbed soil below (Figure 5-34). The primary idea was to avoid any upward migration of the in-situ soil, which could possibly reduce the capacity of the beds over time.

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BOX 5-7 Continued



FIGURE 5-34 Infiltration bed under construction. Pervious concrete has functionality and workability similar to that of regular concrete. However, the pervious concrete mix lacks the sand and other fine particles found in regular concrete. This creates a significant amount of void space which allows water to flow relatively unobstructed through the concrete. This site was the first attempt at creating a pervious concrete SCM in the area, and there were construction and material problems. Since that time the industry has matured, and a second site on campus constructed in 2007 has not had any significant difficulties. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

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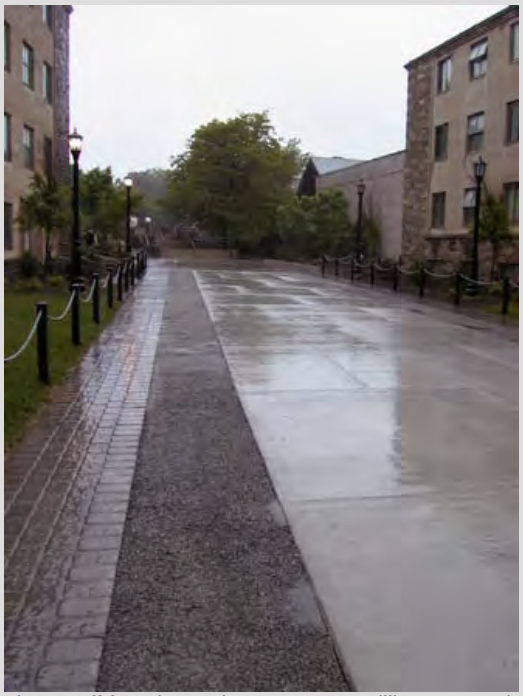

Note the runoff from impervious concrete spilling over to the pervious concrete. SOURCE: Robert Traver, Villanova University

Continuous monitoring of the site over a number of years has considerably increased our understanding of infiltration. Similar to the bioinfiltration site (Box 5-6), the infiltration rate of permeable concrete does vary as a function of temperature (Braga et al., 2007; Emerson and Traver, 2008), and the SCM volume reduction is impressive. As shown in Figure 5-35, over 95 percent of the yearly rainfall was infiltrated with minimal overflow. Besides hydrologic plots, water quality plots also show the benefits of permeable concrete (Kwiatkowski et al., 2007). Because over 95 percent of the runoff is infiltrated, well over 95 percent of the pollutant mass is also removed. Figure 5-36 shows the level of copper extracted from lysimeters buried under the rock bed and surrounding grass. The plot is arranged in quartiles, with readings in milligrams per liter. Lysimeter samples from under the surrounding grass and one foot and four feet under the infiltration bed all report almost no copper, compared to samples taken from the port in the rock bed and from the gutters draining the roof tops.

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BOX 5-7 Continued

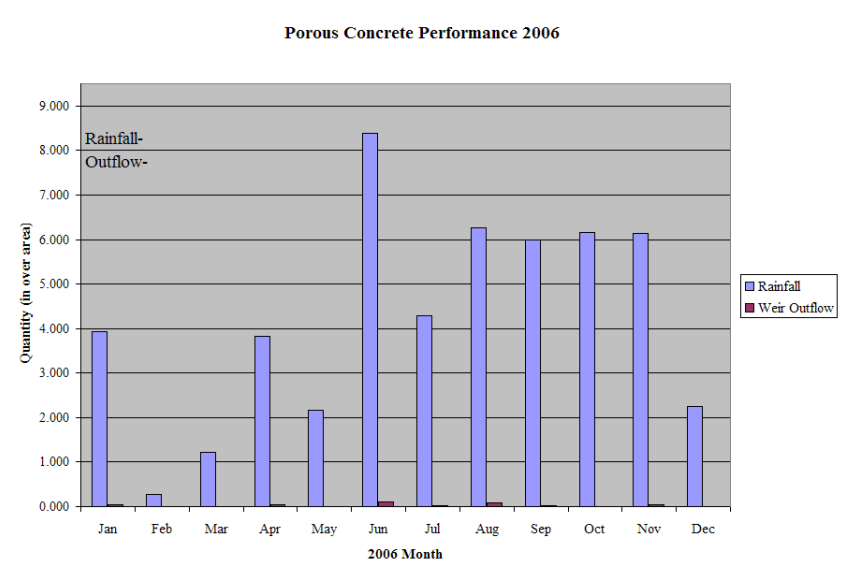

FIGURE 5-35 Rainfall and corresponding outflow from the weir of the SCM. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

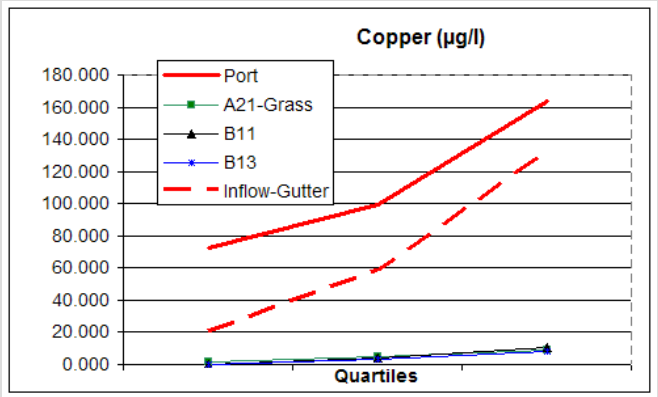

FIGURE 5-36 Copper measured at various locations. The three quartiles correspond to the 25th, 50th, and 75th percentile value of all data collected. A21 is a lysimeter location under the surrounding grass, while B11 and B13 refer to locations that are one foot and four feet under the infiltration bed, respectively. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

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As discussed earlier, several studies have measured the runoff volume reduction of individual LID practices. Fewer studies are available on whether multiple LID practices, when used together, have a cumulative benefit at the neighborhood or catchment scale. Four monitoring studies have clearly documented a major reduction in runoff from developments that employ LID and Better Site Design (see Box 5-8) compared to those that do not. In addition, six studies have documented the runoff reduction benefits of LID at the catchment or watershed scale using a modeling approach (Alexander and Heaney, 2002; Stephens et al., 2002; Holman-Dodds et al., 2003; Coombes, 2004; Hardy et al., 2004; Huber et al., 2006).

Peak Flow Reduction and Runoff Treatment

After efforts are made to prevent the generation of pollutants and to reduce the volume of runoff that reaches stormwater systems, stormwater management focuses on the reduction of peak flows and associated treatment of polluted runoff. The main class of SCMs used to accomplish this is extended detention basins, versions of which have dominated stormwater management for decades. These include a wide variety of ponds and wetlands, including wet ponds (also known as retention basins), dry extended detention ponds (as known as detention basins), and constructed wetlands. By holding a volume of stormwater runoff for an extended period of time, extended detention SCMs can achieve both water quality improvement and reduced peak flows. Generally the goal is to hold the flows for 24 hours at a minimum to maximize the opportunity of settling, adsorption, and transformation of pollutants (based on past pollutant removal studies) (Rea and Traver, 2005). For smaller storm events (one- to two-year storms), this added holding time also greatly reduces the outflows from the SCM to a level that the stream channel can handle. Most wet ponds and stormwater wetlands can hold a "water quality" volume, such that the flows leaving in smaller storms have been held and "treated" for multiple days. Extended detention dry ponds greatly reduce the outflow peaks to achieve the required residence times.

Usually extended detention devices are lower in the treatment train of SCMs, if not at the end. This is both due to their function (they are designed for larger events) and because the required water sources and less permeable soils needed for these SCMs are more likely to be found at the lower areas of the site. Some opportunities exist to naturalize dry ponds or to retrofit wet ponds into stormwater wetlands but it depends on their site configuration and hydrology. Stormwater wetlands are shown in Figures 5-40 and 5-41. A wet pond and a dry extended detention basin are shown in Figures 5-42 and 5-43.

Simple ponds are little more than a hole in the ground, in which stormwater is piped in and out. Dry ponds are meant to be dry between storms, whereas wet ponds have a permanent pool throughout the year. Detention basins reduce peak flows by restricting the outflows and creating a storage area. Depending on the

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BOX 5-8
Jordan Cove—An LID Watershed Project

LID refers to the use of a system of small, on-site SCMs to counteract increases in flow and pollution following development and to control smaller runoff events. Although some studies are available that measure the runoff volume reduction of individual LID practices, fewer studies are available on whether multiple LID practices, when used together, have a cumulative benefit at the neighborhood or catchment scale. Of those listed in Table 5-6, Jordan Cove is the most extensively studied, as it was monitored for ten years as part of a paired watershed study that included a site with no SCMs and a site with traditional (detention) SCMs. The watersheds were monitored during calibration, construction, and post-construction periods. The project consisted of 12 lots, and the SCMs used were bioretention, porous pavements, no-mow areas, and education for the homeowners (Figure 5-37).

TABLE 5-6 Review of Recent LID Monitoring Research on a Catchment Scale

Location	Practices	Runoff Reduction
Jordan Cove, USA Dietz and Clausen (2008)	Permeable pavers, bioretention, grass swales, education	84%
Somerset Heights, USA Cheng et al. (2005)	Grass swale, bioretention, and roof-top disconnection	45%
Figtree Place, Australia Coombes et al. (2000)	Rain tanks, infiltration trenches, swales	100%



FIGURE 5-37 Jordan Cove LID subdivision. SOURCE: Reprinted, with permission, from Clausen (2007). Copyright 2007 by John Clausen.

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Figure 5-38 (right panel) displays the hydrograph from a post-construction storm comparing the LID, traditional, and control watersheds. Note that the traditional watershed shows the delay and peak reduction from the detention basins, while the LID watershed has almost no runoff. The LID watershed was found to reduce runoff volume by 74 percent by increasing infiltration over preconstruction levels.

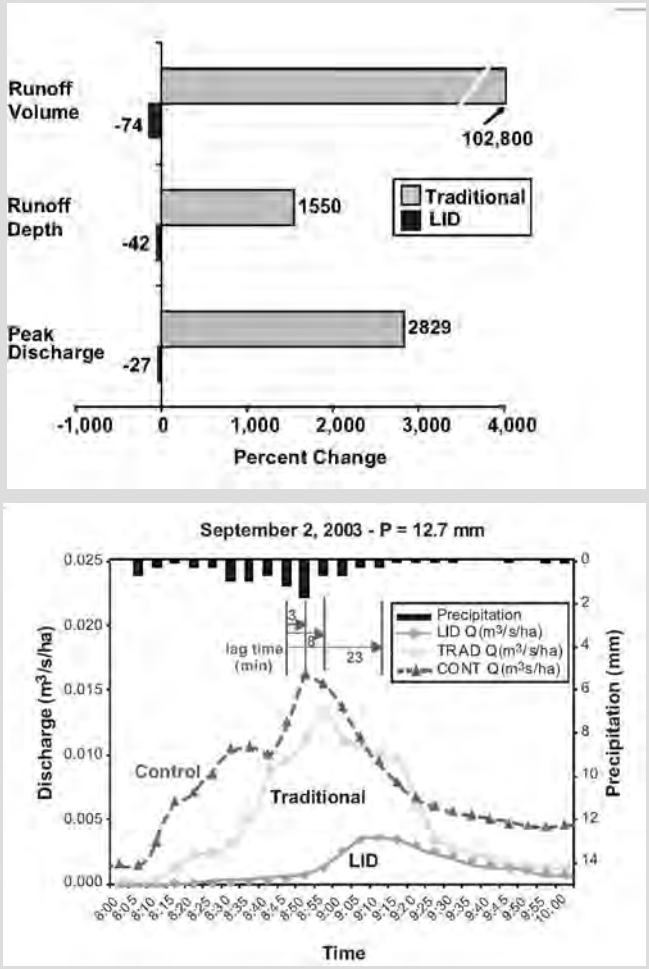

FIGURE 5-38. Significant changes in runoff volume (m^3/week), runoff depth (cm/week) and peak discharge (m^3/sec/week) after construction was completed (top panel). Hydrograph of all three subdivisions in the project, showing the larger volume and rate of runoff from the traditional and control subdivisions, as compared to the LID (bottom panel). SOURCE: Reprinted, with permission, from Clausen (2007). Copyright 2007 by John Clausen.

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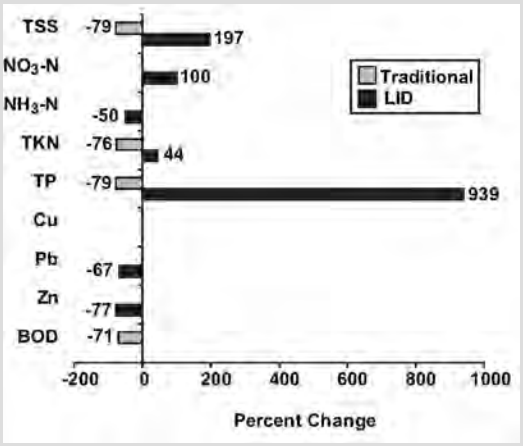
BOX 5-8 Continued

Comparisons of nutrient and metal concentrations and total export in the surface water shows the value of the LID approach as well as the significance of the reduction in runoff volume. Figure 5-39 shows the changes in pollutant concentration and mass export before and after construction for the traditional and LID subdivisions. Note that concentrations of TSS and nutrients are increased in the LID subdivision (left-hand panel); this is because swales and natural systems are used in place of piping as a "green" drainage system and because only larger storms leave the site. The right-hand panel shows how the large reduction in runoff achieved through infiltration can dramatically reduce the net export of pollutants from the LID watershed.



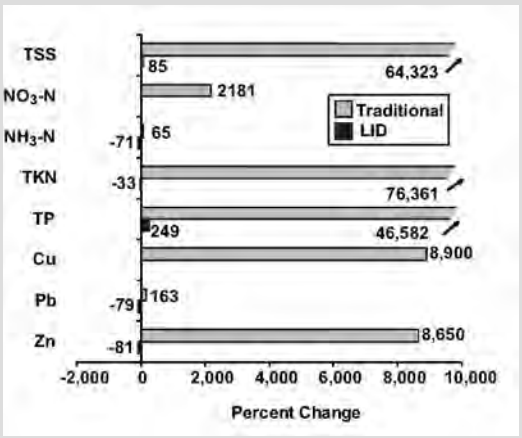


FIGURE 5-39 Significant changes in pollutant concentration, after construction was completed (top). Units are mg/L for NO_3-N, NH_3-N, TKN, TP, and BOD, and µg/L for Cu, Pb, and Zn. Significant changes in mass export (kg/ha/year) after construction was completed (bottom). SOURCE: Reprinted, with permission, from Clausen (2007). Copyright 2007 by John Clausen.

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FIGURE 5-40 Constructed wetland. SOURCE: PaDEP (2006).



FIGURE 5-41 Retrofitted stormwater wetland at Villanova University. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.



FIGURE 5-42 Wet pond. SOURCE: PaDEP (2006).

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FIGURE 5-43 Dry extended detention pond. SOURCE: PaDEP (2006).

detention time, outflows can be reduced to levels that do not accelerate erosion, that protect the stream channel, and that reduce flooding.

The flow normally enters the structure through a sediment forebay (Figure 5-44), which is included to capture incoming sediment, remove the larger particles through settling, and allow for easier maintenance. Then a meandering path or cell structure is built to "extend" and slow down the flows. The main basin is a large storage area (sometimes over the meandering flow paths). Finally, the runoff exits through an outflow control structure built to retard flow.

Wet ponds, stormwater wetlands, and (to a lesser extent) dry extended detention ponds provide treatment. The first step in treatment is the settling of larger particles in the sediment forebay. Next, for wet ponds a permanent pool of water is maintained so that, for smaller storms, the new flows push out a volume that has had a chance to interact with vegetation and be "treated." This volume is equivalent to an inch of rain over the impervious surfaces in the drainage area. Thus, what exits the SCM during smaller storm events is baseflow contributions and runoff that entered during previous events. For dry extended detention ponds, there is no permanent pool and the outlet is instead greatly restricted. For all of these devices, vegetation is considered crucial to pollutant removal. Indeed, wet ponds are designed with an aquatic bench around the edges to promote contact with plants. The vegetation aids in reduction of flow velocities, provides growth surfaces for microbes, takes up pollutants, and provides filtering (Braskerud, 2001).

The ability of detention structures to achieve a certain level of control is size related—that is, the more peak flow reduction or pollutant removal required, the more volume and surface area are needed in the basin. Because it is not simply the peak flows that are important, but also the duration of the flows that cause damage to the stream channels (McCuen, 1979; Loucks et al., 2005),

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FIGURE 5-44 Villanova University sediment forebay. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

some detention basins are currently sized and installed in series with runoff-volume-reduction SCMs.

The strength of extended detention devices is the opportunity to create habitats or picturesque settings during stormwater management. The weaknesses of these measures include large land requirements, chloride buildup, possible temperature effects, and the creation of habitat for undesirable species in urban areas. There is a perception that these devices promote mosquitoes, but that has not been found to be a problem when a healthy biological habitat is created (Greenway et al., 2003). Another drawback of this class of SCMs is that they often have limited treatment capacity, in that they can reduce pollutants in stormwater only to a certain level. These so-called irreducible effluent concentrations have been documented mainly for ponds and stormwater wetlands, as well as sand filters and grass channels (Schueler, 1998). Finally, it should be noted that either a larger watershed (10–25 acres; CWP, 2004) or a continuous water source is needed to sustain wet ponds and stormwater wetlands.

Maintenance requirements for extended detention basins and wetlands include the removal of built-up sediment from the sediment forebay, harvesting of grasses to remove accumulated nutrients, and repair of berms and structures after storm events. Inspection items relate to the maintenance of the berm and sediment forebay.

While the basic hydrologic function of extended detention devices is well known, their performance on a watershed basis is not. Because they do not significantly reduce runoff volume and are designed on a site-by-site basis using synthetic storm patterns, their exclusive use as a flood reduction strategy at the

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watershed scale is uncertain (McCuen, 1979; Traver and Chadderton, 1992). Much of this variability is reduced when they are coupled with volume reduction SCMs at the watershed level. Pollutant removal is effected by climate, short-circuiting, and by the schedule of sediment removal and plant harvesting. Extreme events can resuspend captured sediments, thus reintroducing them into the environment. Although there is debate, it seems likely that plants will need to be harvested to accomplish nutrient removal (Reed et al., 1998).

Runoff Treatment

As mentioned above, many SCMs associated with runoff volume reduction and extended detention provide a water quality benefit. There are also some SCMs that focus primarily on water quality with little peak flow or volume effect. Designed for smaller storms, these are usually based on filtration, hydrodynamic separation, or small-scale bioretention systems that drain to a subsequent receiving water or other device. Thus, often these SCMs are used in conjunction with other devices in a treatment train or as retrofits under parking lots. They can be very effective as pretreatment devices when used "higher up" in the watershed than infiltration structures. Finally, in some cases these SCMs are specifically designed to reduce peak flows in addition to providing water quality benefits by introducing elements that make them similar to detention basins; this is particularly the case for sand filters.

The sand filter is relied on as a treatment technology in many regions, particular those where stream geomorphology is less of a concern and thus peak flow control and runoff volume reduction are not the primary goals. These devices can be effective at removing suspended sediments and can extend the longevity and performance of runoff-volume-reduction SCMs. They are also one of the few urban retrofits available, due to the ability to implement them within traditional culvert systems. Figures 5-45 and 5-46 show designs for the Austin sand filter and the Delaware sand filter.

Filters use sand, peat, or compost to remove particulates, similar to the processes used in drinking water plants. Sand filters primarily remove suspended solids and ammonia nitrogen. Biological material such as peat or compost provides adsorption of contaminants such as dissolved metals, hydrocarbons, and other organic chemicals. Hydrodynamic devices use rotational forces to separate the solids from the flow, allowing the solids to settle out of the flow stream. There is a recent class of bioretention-like manufactured devices that combine inlets with planters. In these systems, small volumes are directed to a soil planter area, with larger flows bypassing and continuing down the storm sewer system. In any event, for manufactured items the user needs to look to the manufacturer's published and reviewed data to understand how the device should be applied.

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FIGURE 5-45 Austin sand filter. SOURCE: Robert Traver, Villanova University.



FIGURE 5-46 Delaware sand filter. SOURCE: Tom Schueler, Chesapeake Stormwater Network.

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The level of control that can be achieved with these SCMs depends entirely on sizing of the device based on the incoming flow and pollutant loads. Each unit has a certified removal rate depending on inflow to the SCM. Also all units have a maximum volume or rate of flow they can treat, such that higher flows are bypassed with no treatment. Thus, the user has to determine what size unit is needed and the number to use based on the area's hydrologic cycle and what criteria are to be met.

With the exception of some types of sand filters, the strengths of water quality SCMs are that they can be placed within existing infrastructure or under parking lots, and thus do not take up land that may be used for other purposes. They make excellent choices for retrofit situations. For filters, there is a wealth of experience from the water treatment community on their operations. For all manufactured devices there are several testing protocols that have been set up to validate the performance of the manufactured devices (the sufficiency of which is discussed in Box 5-9). Weaknesses of these devices include their cost and maintenance requirements. Regular maintenance and inspection at a high level are required to remove captured pollutants, to replace mulch, or to rake and remove the surface layer to prevent clogging. In some cases specialized equipment (vacuum trucks) is required to remove built-up sediment. Although the underground placement of these devices has many benefits, it makes it easy to neglect their maintenance because there are no signs of reduced performance on the surface. Because these devices are manufactured, the unit construction cost is usually higher than for other SCMs. Finally, the numerous testing protocols are confusing and prevent more widespread applications.

The chief uncertainty with these SCMs is due to the lack of certification of some manufactured devices. There is also concern about which pollutants are removed by which class of device. For example, hydrodynamic devices and sand filters do not address dissolved nutrients, and in some cases convert suspended pollutants to their dissolved form. Both issues are related to the false perception that a single SCM must be found that will comprehensively treat stormwater. Such pressures often put vendors in a position of trying to certify that their devices can remove all pollutants. Most often, these devices can serve effectively as part of a treatment train, and should be valued for their incremental contributions to water quality treatment. For example, a filter that removes sediment upstream of a bioinfiltration SCM can greatly prolong the life of the infiltration device.

Aquatic Buffers and Managed Floodplains

Aquatic buffers, sometimes also known as stream buffers or riparian buffers, involve reserving a vegetated zone adjacent to streams, shorelines, or wetlands as part of development regulations or as an ordinance. In most regions of the country, the buffer is managed as forest, although in arid or semi-arid

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BOX 5-9
Insufficient Testing of Proprietary Stormwater Control Measures

Manufacturers of proprietary SCMs offer a service that can save municipalities time and money. Time is saved by the ability of the manufactures to quickly select a model matching the needs of the site. A city can minimize the cost of buying the product by requiring the different manufacturers to submit bids for the site. All the benefits of the service will have no meaning, however, if the cities cannot trust the performance claims of the different products. Because the United States does not have, at this time, a national program to verify the performance of proprietary SCMs, interested municipalities face a high amount of uncertainty when they select a product. Money could be wasted on products that might have the lowest bid, but do not achieve the water quality goals of the city or state.

The EPA's Environmental Technology Verification (ETV) program was created to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The Wet Weather Flow Technologies Pilot was established as part of the ETV program to verify commercially available technologies used in the abatement and control of urban stormwater runoff, combined sewer overflows, and sanitary sewer overflows. Ten proprietary SCMs were tested under the ETV program (see Figure 5-47), and the results of the monitoring are available on the National Sanitation Foundation International website. Unfortunately, the funding for the ETV program was discontinued before all the stormwater products could be tested. Without a national testing program some states have taken a more regional approach to verifying the performance of proprietary practices, while most states do not have any type of verification or approval program.

The Washington Department of Ecology has supported a testing protocol called Technology Assessment Protocol–Ecology that describes a process for evaluating and reporting on the performance and appropriate uses of emerging SCMs. California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia have sponsored a testing program called Technology Acceptance and Reciprocity Partnership (TARP), and a number of products are being tested in the field. The State of Wisconsin has prepared a draft technical standard (1006) describing methods for predicting the site-specific reduction efficiency of proprietary sedimentation devices. To meet the criteria in the standard the manufacturers can either use a model to predict the performance of the practice or complete a laboratory protocol designed to develop efficiency curves for each product. Although none of these state or federal verification efforts have produced enough information to sufficiently reduce the uncertainty in selection and sizing of proprietary SCMs, many proprietary practices are being installed around the country, because of the perceived advantage of the service being provided by the manufacturers and the sometimes overly optimistic performance claims.

All those involved in stormwater management, including the manufacturers, will have a much better chance of implementing a cost-effective stormwater program in their cities if the barriers to a national testing program for proprietary SCMs are eliminated. Two of the barriers to the ETV program were high cost and the transferability of the results. Also, the ETV testing did not produce results that could be used in developing efficiency curves for the product. A new national testing program could reduce the cost by using laboratory testing instead of field testing. Each manufacturer would only have to do one series of tests in the lab and the results would be applicable to the entire country. The laboratory

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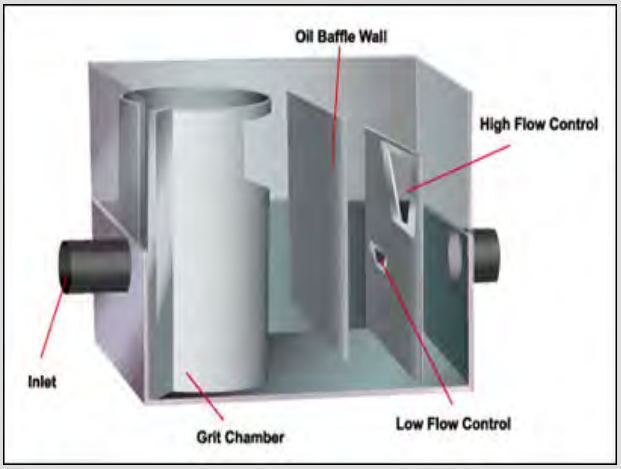
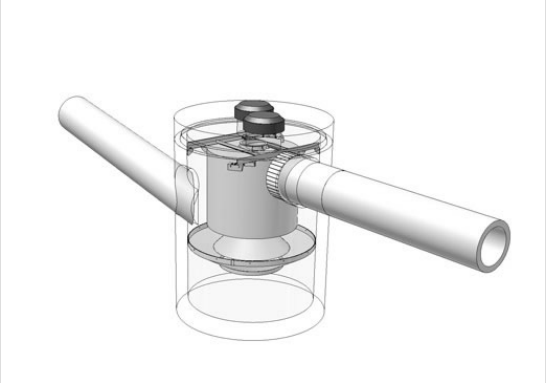
BOX 5-9 Continued

protocol in the Wisconsin Technical Standard 1006 provides a good example of what should be included to evaluate each practice over a range of particle sizes and flows. These types of laboratory data could also be used to produce efficiency curves for each practice. It would be relatively easy for state and local agencies to review the benefits of each installation if the efficiency curves were incorporated into urban runoff models, such as WinSLAMM or P8.



Stormwater 360 Hydrodynamic Separator. SOURCE: EPA (2005c).



Downstream Defender. SOURCE: Available online at http://epa.gov/Region1/assistance/ ceitts/stormwater/techs/downstreamdefender.html

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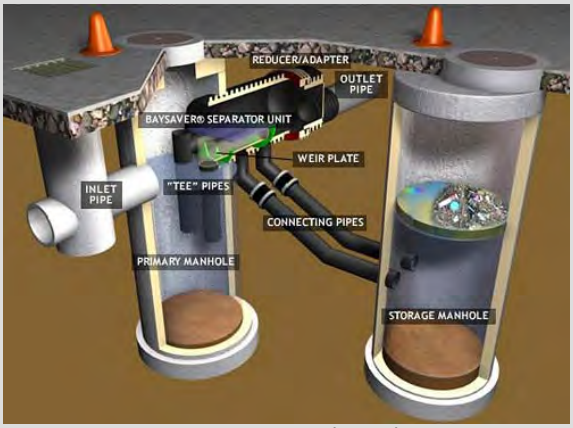
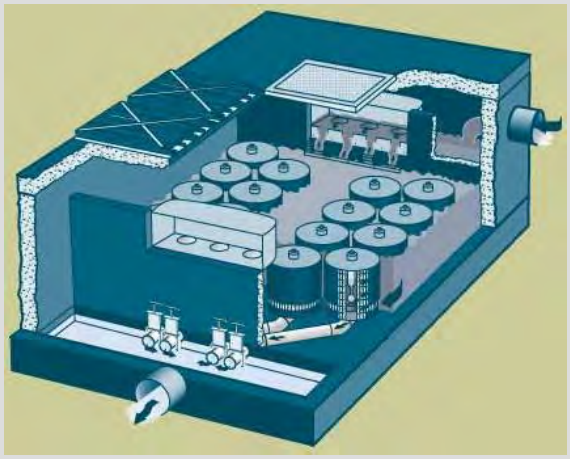


Bay Seperator. SOURCE: EPA (2005a).



Stormfilter. SOURCE: EPA (2005b).

FIGURE 5-47 Proprietary Manufactured Devices tested by the ETV Program.

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regions it may be managed as prairie, chapparal, or other cover. When properly designed, buffers can both reduce runoff volumes and provide water quality treatment to stormwater.

The performance of urban stream buffers cannot be predicted from studies of buffers installed to remove sediment and nutrients from agricultural areas (Lowrance and Sheridan, 2005). Agricultural buffers have been reported to have high sediment and nutrient removal because they intercept sheet flow or shallow groundwater flow in the riparian zone. By contrast, urban stream buffers often receive concentrated surface runoff or may even have a storm-drain pipe that short-circuits the buffer and directly discharges into the stream. Consequently, the pollutant removal capability of urban stream buffers is limited, unless they are specifically designed to distribute and treat stormwater runoff (NRC, 2000). This involves the use of level spreaders, grass filters, and berms to transform concentrated flows into sheet flow (Hathaway and Hunt, 2006). Such designed urban stream buffers have been applied widely in the Neuse River basin to reduce urban stormwater nutrient inputs to this nitrogen-sensitive waterbody.

The primary benefit of buffers is to help maintain aquatic biodiversity within the stream. Numerous researchers have evaluated the relative impact of riparian forest cover and impervious cover on stream geomorphology, aquatic insects, fish assemblages, and various indexes of biotic integrity. As a group, the studies suggest that indicator values for urban stream health increase when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Goetz et al., 2003; Wang et al., 2003b; McBride and Booth, 2005; Moore and Palmer, 2005). The width of the buffer is also important for enhancing its stream protection benefits, and it ranges from 25 to 200 feet depending on stream order, protection objectives, and community ordinances. At the present time, there are no data to support an optimum width for water quality purposes. The beneficial impact of riparian forest cover is less detectable when watershed impervious cover exceeds 15 percent, at which point degradation by stormwater runoff overwhelms the benefits of the riparian forest (Roy et al., 2005, 2006; Walsh et al., 2007).

Maintenance, inspection, and compliance for buffers can be a problem. In most communities, urban stream buffers are simply a line on a map and are not managed in any significant way after construction is over. As such, urban stream buffers are prone to residential encroachment and clearing, and to colonization by invasive plants. Another important practice is to protect, preserve, or otherwise manage the ultimate 100-year floodplain so that vulnerable property and infrastructure are not damaged during extreme floods. Federal Emergency Management Agency (FEMA), state, and local requirements often restrict or control development on land within the floodway or floodplain. In larger streams, the floodway and aquatic buffer can be integrated together to achieve multiple social objectives.

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Stream Rehabilitation

While not traditionally considered an SCM, certain stream rehabilitation practices or approaches can be effective at recreating stream physical habitat and ecosystem function lost during urbanization. When combined with effective SCMs in upland areas, stream rehabilitation practices can be an important component of a larger strategy to address stormwater. From the standpoint of mitigating stormwater impacts, four types of urban stream rehabilitation are common:

- Practices that stabilize streambanks and/or prevent channel incision/enlargement can reduce downstream delivery of sediments and attached nutrients (see Figure 5-48). Although the magnitude of sediment delivery from urban-induced stream-channel enlargement is well documented, there are very few published data to quantify the potential reduction in sediment or nutrients from subsequent channel stabilization.

- Streams can be hydrologically reconnected to their floodplains by building up the profile of incised urban streams using grade controls so that the channel and floodplain interact to a greater degree. Urban stream reaches that have been so rehabilitated have increased nutrient uptake and processing rates, and in particular increased denitrification rates, compared to degraded urban streams prior to treatment (Bukavecas, 2007; Kaushal et al., 2008). This suggests that urban stream rehabilitation may be one of many elements that can be considered to help decrease loads in nutrient-sensitive watersheds.

- Practices that enhance in-stream habitat for aquatic life can improve the expected level of stream biodiversity. However, Konrad (2003) notes that improvement of biological diversity of urban streams should still be considered an experiment, since it is not always clear what hydrologic, water quality, or habitat stressors are limiting. Larson et al. (2001) found that physical habitat improvements can result in no biological improvement at all. In addition, many of the biological processes in urban stream ecosystems remain poorly understood, such as carbon processing and nutrient uptake.

- Some stream rehabilitation practices can indirectly increase stream biodiversity (such as riparian reforestation, which could reduce stream temperatures, and the removal of barriers to fish migration).

It should be noted that the majority of urban stream rehabilitation projects undertaken in the United States are designed for purposes other than mitigating the impacts of stormwater or enhancing stream biodiversity or ecosystem function (Bernhardt et al., 2005). Most stream rehabilitation projects have a much narrower design focus, and are intended to protect threatened infrastructure,

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FIGURE 5-48 Three photographs illustrate stream rehabilitation in Denver. The top picture is a creek that has eroded in its bed due to urbanization. The middle picture shows a portion of the stabilized creek immediately after construction. Check structures, which keep the creek from cutting its bed, are visible in the middle distance. The bottom image shows the creek just upstream of one of the check structures two years after stabilization. The thickets of willows established themselves naturally. The only revegetation performed was to seed the area for erosion control. SOURCE: Courtesy of Wenk Associates.

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naturalize the stream corridor, achieve a stable channel, or maintain local bank stability (Schueler and Brown, 2004). Improvements in either biological health or the quality of stormwater runoff have rarely been documented.

Unique design models and methods are required for urban streams, compared to their natural or rural counterparts, given the profound changes in hydrologic and sediment regime and stream–floodplain interaction that they experience (Konrad, 2003). While a great deal of design guidance on urban stream rehabilitation has been released in recent years (FISRWG, 2000; Doll and Jennings, 2003; Schueler and Brown, 2004), most of the available guidance has not yet been tailored to produce specific outcomes for stormwater mitigation, such as reduced sediment delivery, increased nutrient processing, or enhanced stream biodiversity. Indeed, several researchers have noted that many urban stream rehabilitation projects fail to achieve even their narrow design objectives, for a wide range of reasons (Bernhardt and Palmer, 2007; Sudduth et al., 2007). This is not surprising given that urban stream rehabilitation is relatively new and rarely addresses the full range of in-stream alteration generated by watershed-scale changes. This shortfall suggests that much more research and testing are needed to ensure urban stream habilitation can meet its promise as an emerging SCM.

Municipal Housekeeping (Street Sweeping and Storm-Drain Cleanouts)

Phase II NPDES stormwater permits specifically require municipal good housekeeping as one of the six minimum management measures for MS4s. Although EPA has not presented definitive guidance on what constitutes “good housekeeping”, CWP (2008) outlines ten municipal operations where housekeeping actions can improve the quality of stormwater, including the following:

- municipal hotspot facility management,
- municipal construction project management,
- road maintenance,
- street sweeping,
- storm-drain maintenance,
- stormwater hotline response,
- landscape and park maintenance ,
- SCM maintenance, and
- employee training.

The overarching theme is that good housekeeping practices at municipal operations provide source treatment of pollutants before they enter the storm-drain system. The most frequently applied practices are street sweeping (Figure 5-49) and sediment cleanouts of sumps and storm-drain inlets. Most communities

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FIGURE 5-49 Vacuum street sweeper at Villanova University. SOURCE: Robert Traver, Villanova University.

conduct both operations at some frequency for safety and aesthetic reasons, although not specifically for the sake of improving stormwater quality (Law et al., 2008).

Numerous performance monitoring studies have been conducted to evaluate the effect of street sweeping on the concentration of stormwater pollutants in downstream storm-drain pipes (see Pitt, 1979; Bender and Terstriep, 1994; Brinkman and Tobin, 2001; Zarrielo et al., 2002; Chang et al., 2005; USGS, 2005; Law et al., 2008). The basic finding is that regular street sweeping has a low or limited impact on stormwater quality, depending on street conditions, sweeping frequency, sweeper technology, operator training, and on-street parking. Sweeping will always have a limited removal capability because rainfall events frequently wash off pollutants before the sweeper passes through, and only some surfaces are accessible to the sweeper, thus excluding sidewalk, driveways, and landscaped areas. Frequent sweeping (i.e., weekly or monthly) has a moderate capability to remove sediment, trash and debris, coarse solids, and organic matter.

Fewer studies have been conducted on the pollutant removal capability of frequent sediment cleanout of storm-drain inlets, most in regions with arid climates (Lager et al., 1977; Mineart and Singh, 1994; Morgan et al., 2005). These studies have shown some moderate pollutant removal if cleanouts are done on a monthly or quarterly basis. Most communities, however, report that they clean out storm drains on an annual basis or in response to problems or drainage complaints (Law, 2006).

Frequent sweeping and cleanouts conducted on the dirtiest streets and storm

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drains appear to be the most effective way to include these operations in the stormwater treatment train. However, given the uncertainty associated with the expected pollutant removal for these practices, street sweeping and storm-drain cleanout cannot be relied on as the sole SCMs for an urban area.

Illicit Discharge Detection and Elimination

MS4 communities must develop a program to detect and eliminate illicit discharges to their storm-drain system as a stormwater NPDES permit condition. Illicit discharges can involve illegal cross-connections of sewage or washwater into the storm-drain system or various intermittent or transitory discharges due to spills, leaks, dumping, or other activities that introduce pollutants into the storm-drain system during dry weather. National guidance on the methods to find and fix illicit discharges was developed by Brown et al. (2004). Local illicit discharge detection and elimination (IDDE) programs represent an ongoing and perpetual effort to monitor the network of pipes and ditches to prevent pollution discharges.

The water quality significance of illicit discharges has been difficult to define since they occur episodically in different parts of a municipal storm drain system. Field experience in conducting outfall surveys does indicate that illicit discharges may be present at 2 to 5 percent of all outfalls at any given time. Given that pollutants are being introduced into the receiving water during dry weather, illicit discharges may have an amplified effect on water quality and biological diversity.

Many communities indicate that they employ a citizen hotline to report illicit discharges and other water quality problems (Brown et al., 2004), which sharply increases the number of illicit discharge problems observed.

Stormwater Education

Like IDDE, stormwater education is one of the six minimum management measures that MS4 communities must address in their stormwater NPDES permits. Stormwater education involves municipal efforts to make sure individuals understand how their daily actions can positively or negatively influence water quality and work to change specific behaviors linked to specific pollutants of concern (Schueler, 2001c). Targeted behaviors include lawn fertilization, littering, car fluid recycling, car washing, pesticide use, septic system maintenance, and pet waste pickup. Communities may utilize a wide variety of messages to make the public aware of the behavior and more desirable alternatives through radio, television, newspaper ads, flyers, workshops, or door-to-door outreach. Several communities have performed before-and-after surveys to assess both the penetration rate for these campaigns and their ability to induce changes in actual behaviors. Significant changes in behaviors have been recorded (see Schueler,

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2002), although few studies are available to link specific stormwater quality improvements to the educational campaigns (but see Turner, 2005; CASQA, 2007).

Residential Stewardship

This SCM involves municipal programs to enhance residential stewardship to improve stormwater quality. Residents can undertake a wide range of activities and practices that can reduce the volume or quality of runoff produced on their property or in their neighborhood as a whole. This may include installing rain barrels or rain gardens, planting trees, xeriscaping, downspout disconnection, storm-drain marking, household hazardous waste pickups, and yard waste composting (CWP, 2005). This expands on stormwater education in that a municipality provides a convenient delivery service to enable residents to engage in positive watershed behavior. The effectiveness of residential stewardship is enhanced when carrots are provided to encourage the desired behavior, such as subsidies, recognition, discounts, and technical assistance (CWP, 2005). Consequently, communities need to develop a targeted program to educate residents and help them engage in the desired behavior.

SCM Performance Monitoring and Modeling

Stormwater is characterized by widely fluctuating flows. In addition, inflow pollutant concentrations vary over the course of a storm and can be a function of time since the last storm, watershed, size and intensity of rainfall, season, amount of imperviousness, pollutant of interest, and so forth. This variability of the inflow to SCMs along with the very nature of SCMs makes performance monitoring a complex task. Most SCMs are built to manage stormwater, not to enable flow and water quality monitoring. Furthermore, they are incorporated into the collection system and spread throughout developments. Measurement of multiple inflows, outflows, evapotranspiration, and infiltration are simply not feasible for most sites. Many factors, such as temperature and climate, play a role in how well SCMs function. Infiltration rates can vary by an order of magnitude as a function of temperature (Braga et al., 2007; Emerson and Traver, 2008), such that a reading in late summer might be twice that of a winter reading. Determining performance can be further complicated because, e.g., at the start of a storm a detention basin could still be partially full from a previous storm, and removal rates for wetlands are a function of the growing season, not to mention snowmelt events.

Monitoring of SCMs is usually performed for one of two purposes: functionality or more intensive performance monitoring. Monitoring of functionality is primarily to establish that the SCM is functioning as designed. Performance monitoring is focused on determining what level of performance is achieved by

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the SCM.

Functionality Monitoring

Functionality monitoring, in a broad sense, involves checking to see whether the SCM is functioning and screening it for potential problems. Both the federal and several state industrial and construction stormwater general permits have standard requirements for visual inspections following a major storm event. Visual observations of an SCM by themselves do not provide information on runoff reduction or pollutant removal, but rather only that the device is functioning as designed. Adding some grab samples for laboratory analysis can act as a screening tool to determine if a more complex analysis is required.

The first step of functionality monitoring for any SCM is to examine the physical condition of the device (piping, pervious surfaces, outlet structure, etc.). Visual inspection of sediments, eroded berms, clogged outlets, and other problems are good indications of the SCM's functionality (see Figure 5-50). For infiltration devices, visiting after a storm event will show whether or not the device is functioning. A simple staff gauge (Figure 5-51) or a stilling well in pervious pavement can be used to measure the amount of water-level change over several days to estimate infiltration rates. Minnesota suggests the use of fire equipment or hydrants to fill infiltration sites with a set volume of water to measure the rate of infiltration. For sites that are designed to capture a set volume, for example a green roof, a visit could be coordinated with a rainfall event of the appropriate size to determine whether there is overflow during the event. If so, then clearly further investigation is required.



FIGURE 5-50 Rusted outlet structure. SOURCE: Reprinted, with permission, from Emerson. Copyright by Clay Emerson.

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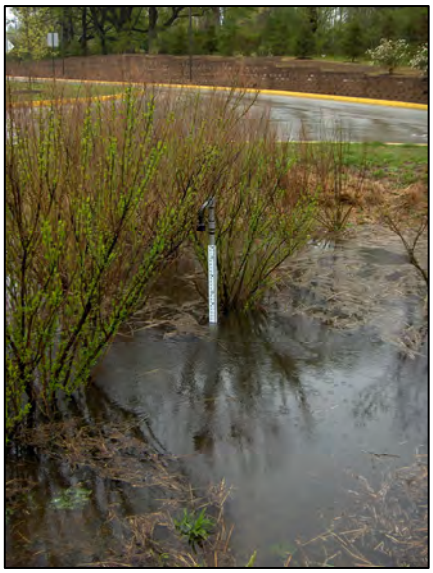

FIGURE 5-51 Staff gauge attached to ultrasonic sensor after a storm. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

For extended detention and stormwater wetlands, the depth of water during an event is an indicator of how well the SCM is functioning. Usually high-water marks are easy to determine due to debris or mud marks on the banks or the structures. If the size of the storm event is known, the depths can be compared to what was expected for the structure. Other indicators of problems would include erosion downstream of the SCM, algal blooms, invasive species, poor water clarity, and odor.

For water quality and manufactured devices, visual inspections after a storm event can determine whether the SCM is functioning properly. Standing water over a sand or other media filter 48 hours after a storm is a sign of problems. Odor and lack of flow clarity could be a sign of filter breakthrough or other problems. For manufactured devices, literature about the device should specify inspection and maintenance procedures.

Monitoring of nonstructural SCMs is almost exclusively limited to visual observation due to the difficulty in applying numerical value to their benefits. Visual inspection can identify eroded stream buffers, additional paved areas, or denuded conservation areas (see Figure 5-52).

Performance Monitoring

Performance monitoring is an extremely intensive effort to determine the performance of an SCM over either an individual storm event or over a series of

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FIGURE 5-52 Wooded conservation area stripped of trees. Note pile of sawdust. SOURCE: Robert Traver, Villanova University.

storms. It requires integration of flow and water quality data creating both a hydrograph and a polutograph for a storm event as shown in Figure 5-53. The creation of these graphs requires continuous monitoring of the hydrology of the site and multiple water quality samples of the SCM inflow and outflow, the vadose zone, and groundwater. Event mean concentrations can then be determined from these data. There should be clear criteria for the number and type of storms to be sampled and for the conditions preceding a storm. For example, for most SCMs it would be improper to sample a second storm event in series, as the inflow may be free of pollutants and the soil moisture filled, resulting in a poor or negative performance. (Extended detention basins are an exception because the outflow during a storm event may include inflows from previous events.) The size of the sampled storm is also important. If the water quality goal is focused on smaller events, the 100-year storm would not give a proper picture of the performance because the occurrence is so rare that it is not a water quality priority.

For runoff-volume-reduction SCMs, performance monitoring can be extremely difficult because these systems are spread over the project site. The monitoring program must consider multiple-size storms because these SCMs are designed to remove perhaps the first inch of runoff. Therefore, for storms of less than an inch, there is no surface water release, so the treatment is 100

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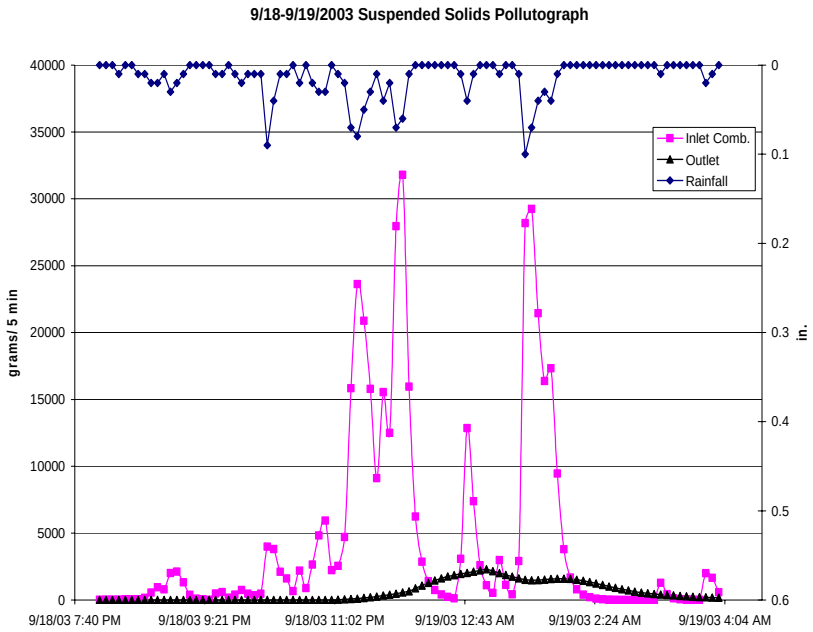

FIGURE 5-53 Example polutograph that displays inflow and outflow TSS during a storm event from the Villanova wetland stormwater SCM. SOURCE: Reprinted, with permission, Rea and Traver (2005). Copyright 2005 by the American Society of Civil Engineers.

percent effective for surface discharges. During larger events, a bioretention SCM or green roof may export pollutants. When viewed over the entire spectrum of storms, these devices are an outstanding success; however, this may not be evident during a hurricane.

Through the use of manufactured weirs (Figure 5-54), it is possible to develop flow-depth criteria based on hydraulic principles for surface flows entering or leaving the SCM. Where this is not practical, various manufacturers have Doppler velocity sensors that, combined with geometry and depth, provide a reasonable continuous record of flow. Measurement of depth within a device can be accomplished through use of pressure transducers, bubblers, float gauges, and ultrasonic sensors. Other common measures would include rainfall and temperature. One advantage of these data recording systems is that they can be connected to water quality probes and automated samplers to provide a flow-weighted sample of the event for subsequent laboratory analysis. Field calibration and monitoring of these systems is required.

Groundwater sampling for infiltration SCMs is a challenge. Although the rate of change in water depth can indicate volume moving into the soil mantle, it is difficult to establish whether this flow is evapotranspirated or ends up as baseflow or deep groundwater input. Sampling in the vadose zone can be established

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FIGURE 5-54 Weir flow used to measure flow rate. SOURCE: Robert Traver, Villanova University.

through the use of lysimeters that, through a vacuum, draw out water from the soil matrix. Soil moisture probes can give a rough estimation of the soil moisture content, and weighing lysimeters can establish evapotranspiration rates. Finally groundwater wells can be used to establish the effect of the SCM on the groundwater depth and quality during and after storm events.

Performance monitoring of extended detention SCMs is difficult because the inflows and outflows are variable and may extend over multiple days. Hydrologic monitoring can be accomplished using weirs (Figure 5-54), flow meters, and level detectors. The new generation of temperature, dissolved oxygen, and conductivity probes allows for automated monitoring. (It should be noted that in many cases the conductivity probes are observing chlorides, which are not generally removed by SCMs.) In many cases monitoring of the downstream stream-channel geomorphology and stream habitat may be more useful than performance monitoring when assessing the effect of the SCM.

The performance monitoring of treatment devices is straightforward and involves determining the pollutant mass inflows and outflows. Performance monitoring of manufactured SCMs has been established through several protocols. An example is TARP, used by multiple states (*http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/).* This requires the manufacturer to test their units according to a set protocol of lab or field experiments to set performance criteria. Several TARP member and other states have published revised

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protocols for their use. These and other similar criteria are evolving and the subject of considerable effort by industry organizations that include the American Society of Civil Engineers.

Finally, much needs to be done to determine the performance of nonstructural SCMs, for which little to no monitoring data are available (see Table 5-2). Currently most practitioners expand upon current hydrologic modeling techniques to simulate these techniques. For example, disconnection of impervious surfaces is often modeled by adding the runoff from the roof or parking area as distributed "rainfall" on the pervious area. Experiments and long-term monitoring are needed for these SCMs.

More information on SCM monitoring is available through the International Stormwater BMP Database (*http://www.bmpdatabase.org*).

Modeling of SCM performance

Modeling of SCMs is required to understand their individual performance and their effect on the overall watershed. The dispersed nature of their implementation, the wide variety of possible SCM types and goals, and the wide range of rainfall events they are designed for makes modeling of SCMs extremely challenging. For example, to model multiple SCMs on a single site may require simulation of many hydrologic and environmental processes for each SCM in series. Modeling these effects over large watersheds by simulating each SCM is not only impractical, but the noise in the modeling may make the simulation results suspect. Thus, it is critical to understand the model's purpose, limitations, and applicability.

As discussed in Chapter 4, one approach to simulating SCM performance is through mathematical representation of the unit processes. The large volumes of data needed for process-based models generally restrict their use to smaller-scale modeling. For flow this would start with the hydrograph entering the SCM and include infiltration, evapotranspiration, routing through the system, or whatever flow paths were applicable. The environmental processes that would need to be represented could include settling, adsorption, biological transformation, and soil physics. Currently there are no environmental process models that work across the range of SCMs. Rather, the state of art is to use general removal efficiencies from publications such as the International Stormwater BMP Database (http://www.bmpdatabase.org) and the Center for Watershed Protection's National Pollutant Removal Database (CWP, 2000b, 2007b). Unfortunately, this approach has many limitations. The percent removal used on a site and storm basis does not include storm intensity, period between the storms, land use, temperature, management practices, whether other SCMs are upstream, and so forth. It also should be noted that percent removals are a surface water statistic and do not address groundwater issues or include any biogeochemistry.

Mechanistic simulation of the hydrologic processes within an SCM is much advanced compared to environmental simulation, but from a modeling scale it is

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still evolving. Indeed, models such as the Prince George's County Decision Support System are greatly improved in that the hydrologic simulation of the SCM includes infiltration, but they still do not incorporate the more rigorous soil physics and groundwater interactions. Some models, such as the Stormwater Management Model (SWMM), have the capability to incorporate mechanistic descriptions of the hydrologic processes occurring inside an SCM.

At larger scales, simulation of SCMs is done primarily using lumped models that do not explicitly represent the unit processes but rather the overall effects. For example, the goal may be to model the removal of 2 cm of rainfall from every storm from bioinfiltration SCMs. Thus, all that would be needed is how many SCMs are present and their configuration and what their capabilities are within your watershed. What is critical for these models is to represent the interrelated processes correctly and to include seasonal effects. Again, the pollutant removal capability of the SCM is represented with removal efficiencies derived from publications.

Regardless of the scale of the model, or the extent to which it is mechanistic or not, nonstructural SCMs are a challenge. Limiting impervious surface or maintenance of forest cover have been modeled because they can be represented as the maintenance of certain land uses. However, aquatic buffers, disconnected impervious surfaces, stormwater education, municipal housekeeping, and most other nonstructural SCMs are problematic. Another challenge from a watershed perspective is determining what volume of pollutants comes from streambank erosion during elevated flows versus from nonpoint source pollution. Most hydrologic models do not include or represent in-stream processes.

In order to move forward with modeling of SCMs, it will be necessary to better understand the unit processes of the different SCMs, and how they differ for hydrology versus transformations. Research is needed to gather performance numbers for the nonstructural SCMs. Until such information is available, it will be virtually impossible to predict that an individual SCM can accomplish a certain level of treatment and thus prevent a nearby receiving water from violating its water quality standard.

DESIGNING SYSTEMS OF STORMWATER CONTROL MEASURES ON A WATERSHED SCALE

Most communities have traditionally relied on stormwater management approaches that result in the design and installation of SCMs on a site-by-site basis. This has created a large number of individual stormwater systems and SCMs that are widely distributed and have become a substantial part of the contemporary urban and suburban landscape. Typically, traditional stormwater infrastructure was designed on a subdivision basis to reduce peak storm flow rates to predevelopment levels for large flood events (> 10-year return period). The problem with the traditional approach is that (1) the majority of storms throughout the year are small and therefore pass through the detention facilities

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uncontrolled, (2) the criterion of reducing storm flow does not address the need for reducing total storm volume, and (3) the facilities are not designed to work as a system on a watershed scale. In many cases, the site-by-site approach has exacerbated downstream flooding and channel erosion problems as a watershed is gradually built out. For example, McCuen (1979) and Emerson et al. (2005) showed that an unplanned system of site-based SCMs can actually increase flooding on a watershed scale owing to the effect of many facilities discharging into a receiving waterbody in an uncoordinated fashion—causing the very flooding problem the individual basins were built to solve.

With the relatively recent recognition of unacceptable downstream impacts and the regulation of urban stormwater quality has come a rethinking of the design of traditional stormwater systems. It is becoming rapidly understood that stormwater management should occur on a watershed scale to prevent flow control problems from occurring or reducing the chances that they might become worse. In this context, the "watershed scale" refers to the small local watershed to which the individual site drains (i.e., a few square miles within a single municipality). Together, the developer, designer, plan reviewer, owners, and the municipality jointly install and operate a linked and shared system of distributed practices across multiple sites that achieve small watershed objectives. Many metropolitan areas around the country have institutions, such as the Southeast Wisconsin Regional Planning Commission and the Milwaukee Metropolitan Sewage District, that are doing stormwater master planning to reduce flooding, bank erosion, and water quality problems on a watershed scale.

Designing stormwater management on a watershed scale creates the opportunity to evaluate a system of SCMs and maximize overall effectiveness based on multiple criteria, such as the incremental costs to development beyond traditional stormwater infrastructure, the limitations imposed on land area required for site planning, the effectiveness at improving water quality or attenuating discharges, and aesthetics. Because the benefits that accrue with improved water quality are generally not realized by those entities required to implement SCMs, greater value must be created beyond the functional aspects of the facility if there is to be wide acceptance of SCMs as part of the urban landscape. Stormwater systems designed on a watershed basis are more likely to be seen as a multi-functional resource that can contribute to the overall quality of the urban environment. Potential even exists to make the stormwater system a primary component of the civic framework of the community—elements of the public realm that serve to enhance a community's quality of life like public spaces and parks. For example, in central Minneapolis, redevelopment of a 100-acre area called Heritage Park as a mixed-density residential neighborhood was organized around two parks linked by a parkway that served dual functions of recreation and stormwater management.

Key elements of the watershed approach to designing systems of SCMs are discussed in detail below. They include the following:

1. Forecasting the current and future development types.

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2. Forecasting the scale of current and future development.
3. Choosing among on-site, distributed SCMs and larger, consolidated SCMs.
4. Defining stressors of concern.
5. Determining goals for the receiving water.
6. Noting the physical constraints.
7. Developing SCM guidance and performance criteria for the local watershed.
8. Establishing a trading system.
9. Ensuring the safe performance of the drainage network, streams, and floodplains.
10. Establishing community objectives for the publically owned elements of stormwater infrastructure.
11. Establishing a maintenance plan.

Forecasting the Current and Future Development Types

Forecasting the type of current and future development within the local watershed will guide or shape how individual practices and SCMs are generally assembled at each individual site. The development types that are generally thought of include Greenfield development (small and large scales), redevelopment within established communities and on Brownfield sites, and retrofitting of existing urban areas. These development types range roughly from lower density to higher density impervious cover. Box 5-10 explains how the type of development can dictate stormwater management, discussing two main categories—*Greenfield* development and *redevelopment* of existing areas. The former refers to development that changes pristine or agricultural land to urban or suburban land uses, frequently low-density residential housing. Redevelopment refers to changing from an existing urban land use to another, usually of higher density, such as from single-family housing to multi-family housing. Finally, *retrofitting* as used in this report is not a development type but rather the upgrading of stormwater management within an existing land use to meet higher standards.

Table 5-7 shows which SCMs are best suited for Greenfield development (particularly low-density residential), redevelopment of urban areas, and intense industrial redevelopment. The last category is broken out because the suite of SCMs needed is substantially different than for urban redevelopment. Each type of development has a different footprint, impervious cover, open space, land cost, and existing stormwater infrastructure. Consequently, SCMs that are ideally suited for one type of development may be impractical or infeasible for another. One of the main points to be made is that there are more options during Greenfield development than during redevelopment because of existing infrastructure, limited land area, and higher costs in the latter case.

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BOX 5-10
Development Types and their Relationship to the Stormwater System

Development falls into two basic types. Greenfield development requires new infrastructure designed according to contemporary design standards for roads, utilities, and related infrastructure. Redevelopment refers to developed areas undergoing land-use change. In contrast to Greenfields, infrastructure in previously developed areas is often in poor condition, was not built to current design standards, and is inadequate for the new land uses proposed. The stormwater management scenarios common to these types of development are described below.

Greenfield Development

At the largest scale, Greenfield development refers to planned communities at the developing edge of metropolitan areas. Communities of this type often vary from several hundred acres to very large projects that encompassed tens of thousands of acres requiring buildout over decades. They often include the trunk or primary stormwater system as well as open stream and river corridors. The most progressive communities of this type incorporate a significant portion of the area to stormwater systems that exist as surface elements. Such stormwater system elements are typically at the subwatershed scale and provide for consolidated conveyance, detention, and water quality treatment. These elements of the infrastructure can be multi-functional in nature, providing for wildlife habitat, trail corridors, and open-space amenities.

Greenfield development can also occur on a small scale—neighborhoods or individual sites within newly developing areas that are served by the secondary public and tertiary stormwater systems. This smaller-scale, incremental expansion of existing urban patterns is a more typical way for cities to grow. A more limited range of SCMs are available on smaller projects of this type, including LID practices.

Redevelopment of Existing Areas

Redevelopment within established communities is typically at the scale of individual sites and occasionally the scale of a small district. The area is usually served by private, on-site systems that convey larger storm events into preexisting stormwater systems that were developed decades ago, either in historic city centers or in “first ring,” post-World War II suburbs adjacent to historic city centers. Redevelopment in these areas is typically much denser than the original use. The resulting increase in impervious area, and typically the inadequacy of existing stormwater infrastructure serving the site often results in significant development costs for on-site detention and water quality treatment. Elaborate vaults or related structures, or land area that could be utilized for development, must often be committed to on-site stormwater management to comply with current stormwater regulations.

Brownfields are redevelopments of industrial and often contaminated property at the scale of an individual site, neighborhood, or district. Secondary public systems and private stormwater systems on individual sites typically serve these areas. In many cases, especially in outdated industrial areas, little or no stormwater infrastructure exists, or it is so inadequate as to require replacement. Water quality treatment on contaminated sites may also be necessary. For these reasons, stormwater management in such developments presents special challenges. As an example, the most common methods of remediation of contaminated sites involve capping of contaminated soils or treatment of contaminants in situ, especially where removal of contaminated soils from a site is cost prohibitive. Given that contaminants are still often in place on redeveloped Brownfield sites and must not be disturbed, certain SCMs such as infiltration of stormwater into site soils, or excavation for stormwater piping and other utilities, present special challenges.

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TABLE 5-7 Applicability of Stormwater Control Measures by Type of Development

Stormwater Control Measure	Low-Density Greenfield Residential	Urban Redevelopment	Intense Industrial Redevelopment
Product Substitution	○	●	●
Watershed and Land-Use Planning	■	■	○
Conservation of Natural Areas	■	♦	○
Impervious Cover Minimization	■	♦	♦
Earthwork Minimization	■	♦	♦
Erosion and Sediment Control	■	■	■
Reforestation and Soil Conservation	■	●	●
Pollution Prevention SCMs	♦	●	■
Runoff Volume Reduction—Rainwater Harvesting	■	■	●
Runoff Reduction—Vegetated	■	○	●
Runoff Reduction—Subsurface	■	○	♦
Peak Reduction and Runoff Treatment	■	♦	○
Runoff Treatment	●	●	■
Aquatic Buffers and Managed Floodplains	●	♦	○
Stream Rehabilitation	○	♦	♦
Municipal Housekeeping	○	○	NA
IDDE	○	○	○
Stormwater Education	●	●	●
Residential Stewardship	■	●	NA

NOTE: ■, always; ●, often; ○, sometimes; ♦, rarely; NA, not applicable.

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Forecasting the Scale of Current and Future Development

The choice of what SCMs to use depends on the area that needs to be serviced. It turns out that some SCMs work best over a few acres, whereas others require several dozen acres or more; some are highly effective only for the smallest sites, while others work best at the stream corridor or subwatershed level. Table 5-1 includes a column that is related the scale at which individual SCMs can be applied ("where" column). The SCMs mainly applied at the site scale include runoff volume reduction—rainwater harvesting, runoff treatment like filtering, and pollution prevention SCMs for hotspots. As one goes up in scale, SCMs like runoff volume reduction—vegetated and subsurface, earthwork minimization, and erosion and sediment control take on more of a role. At the largest scales, watershed and land-use planning, conservation of natural areas, reforestation and soil conservation, peak flow reduction, buffers and managed floodplains, stream rehabilitation, municipal housekeeping, IDDE, stormwater education, and residential stewardship play a more important role. Some SCMs are useful at all scales, such as product substitution and impervious cover minimization.

Choosing Among On-Site, Distributed SCMs and Larger, Consolidated SCMs

There are distinct advantages and disadvantages to consider when choosing to use a system of larger, consolidated SCMs versus smaller-scale, on-site SCMs that go beyond their ability to achieve water quality or urban stream health. Smaller, on-site facilities that serve to meet the requirements for residential, commercial, and office developments tend to be privately owned. Typically, flows are directed to porous landscape detention areas or similar SCMs, such that volume and pollutants in stormwater are removed at or near their source. Quite often, these SCMs are relegated to the perimeter project, incorporated into detention ponds, or, at best, developed as landscape infiltration and parking islands and buffers. On-site infiltration of frequent storm events can also reduce the erosive impacts of stormwater volumes on downstream receiving waters. Maintenance is performed by the individual landowner, which is both an advantage because the responsibility and costs for cleanup of pollutants generated by individual properties are equitably distributed, and a disadvantage because ongoing maintenance incurs a significant expense on the part of individual property owners and enforcement of properties not in compliance with required maintenance is difficult. On the negative side, individual SCMs often require additional land, which increases development costs and can encourage sprawl. Monitoring of thousands of SCMs in perpetuity in a typical city creates a significant ongoing public expense, and special training and staffing may be required to maintain SCM effectiveness (especially for subgrade or in-building vaults used in ultra-urban environments). Finally, given that as much as 30 per-

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cent of the urban landscape is comprised of public streets and rights-of-way, there are limited opportunities to treat runoff from streets through individual on-site private SCMs. (Notable exceptions are subsurface runoff-volume-reduction SCMs like permeable pavement that require no additional land and promote full development density within a given land parcel because they use the soil areas below roads and the development site for infiltration.)

In contrast, publicly owned, consolidated SCMs are usually constructed as part of larger Greenfield and infill development projects in areas where there is little or no existing infrastructure. This type of facility—usually an infiltration basin, detention basin, wet/dry pond, or stormwater wetland—tends to be significantly larger, serving multiple individual properties. Ownership is usually by the municipality, but may be a privately managed, quasi-public special district. There must be adequate land available to accommodate the facility and a means of up-front financing to construct the facility. An equitable means of allocating costs for ongoing maintenance must also be identified. However, the advantage of these facilities is that consolidation requires less overall land area, and treatment of public streets and rights-of-way can be addressed. Monitoring and maintenance are typically the responsibility of one organization, allowing for effective ongoing operations to maintain the original function of the facility. If that entity is public, this ensures that the facility will be maintained in perpetuity, allowing for the potential to permanently reduce stormwater volumes and for reduction in the size of downstream stormwater infrastructure. Because consolidated facilities are typically larger than on-site SCMs, mechanized maintenance equipment allows for greater efficiency and lower costs. Finally, consolidated SCMs have great potential for multifunctional uses because wildlife habitat, recreational, and open-space amenities can be integrated to their design. Box 5-11 describes sites of various scales where either consolidated or distributed SCMs were chosen.

Defining Stressors of Concern

The primary pollutants or stressors of concern (and the primary source areas or stormwater hotspots within the watershed likely to produce them) should be carefully defined for the watershed. Although this community decision is made only infrequently, it is critical to ensuring that SCMs are designed to prevent or reduce the maximum load of the pollutants of greatest concern. This choice may be guided by regional water quality priorities (such as nutrient reduction in the Chesapeake Bay or Neuse River watersheds) or may be an outgrowth of the total maximum daily load process where there is known water quality impairment or a listed pollutant. The choice of a pollutant of concern is paramount, since individual SCMs have been shown to have highly variable capabilities to prevent or reduce specific pollutants (see WERF, 2006; ASCE, 2007; CWP, 2007b). In some cases, the capability of SCMs to reduce a specific pollutant may be uncertain or unknown.

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BOX 5-11
Examples of Communities Using Consolidated versus Distributed SCMs

Stapleton Airport New Community

This is a mixed-use, mixed-density New Urbanist community that has been under development for the past 15 years on the 4,500-acre former Stapleton Airport site in central Denver. As shown in Figures 5-55 and 5-56, the stormwater system emphasizes surface conveyance and treatment on individual sites, as well as in consolidated regional facilities.

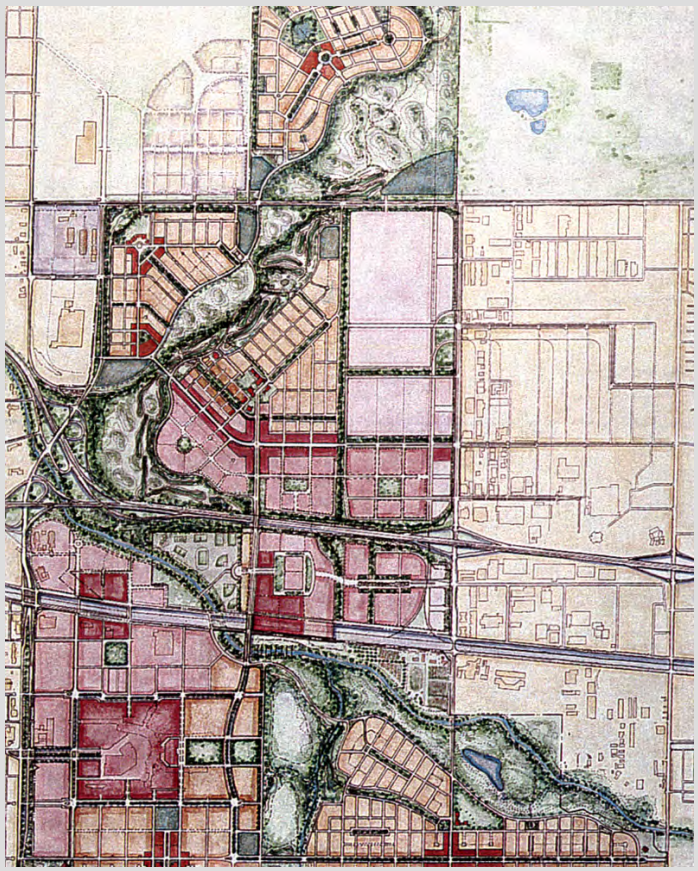

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FIGURE 5-55 The community plan, shown on the left, is organized around two day lighted creeks, formerly buried under airport runways, and a series of secondary conveyances which provide recreational open space within neighborhoods. The image above illustrates one of the multi-functional creek corridors. Consolidated stormwater treatment areas and surface conveyances define more traditional park recreation and play areas. SOURCE: Courtesy of the Stapleton Redevelopment Foundation.



FIGURE 5-56 A consolidated treatment area adjacent to one of several neighborhoods that have been constructed as part of the project's build-out. SOURCE: Courtesy of Wenk Associates.

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BOX 5-11 Continued

Heritage Park Neighborhood Redevelopment

A failed public housing project adjacent to downtown Minneapolis, Minnesota, has been replaced by a mixed-density residential neighborhood. Over 1,200 rental, affordable, and market-rate single- and multi-family housing units have been provided in the 100-acre project area. The neighborhood is organized around two neighborhood parks and a parkway that serve dual functions as neighborhood recreation space and as surface stormwater conveyance and a consolidated treatment system (see Figure 5-57). Water quality treatment is being provided for a combined area of over 660 acres that includes the 100-acre project area and over 500 acres of adjacent neighborhoods. Existing stormwater pipes have been routed through treatment areas with treatment levels ranging from 50 to 85 percent TSS removal, depending on the available land area.



FIGURE 5-57 View of a sediment trap and porous landscape detention area in the central parkway spine of Heritage Park. The sediment trap in the center left of the photo was designed for ease of maintenance access by city crews with standard city maintenance equipment. SOURCE: Courtesy of the SRF Consulting Group, Inc.

The High Point Neighborhood

This Seattle project is the largest example of the city's Natural Drainage Systems Project and it illustrates the incorporation of individual SCMs into street rights-of-way as well as a consolidated facility. The on-site, distributed SCMs in this 600-acre neighborhood are swales, permeable pavement, and disconnected downspouts. A large detention pond services the entire region that is much smaller than it would have been had the other SCMs not been built. Both types of SCMs are shown in Figure 5-58.

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FIGURE 5-58 Natural drainage system methods have been applied to a 34-block, 1,600-unit mixed-income housing redevelopment project called High Point. Shown on top, vegetated swales, porous concrete sidewalks, and frontyard rain gardens convey and treat stormwater on-site. Below is the detention pond for the development. SOURCE: top, William Wenk, Wenk Associates, and bottom, Laura Ehlers, National Research Council.

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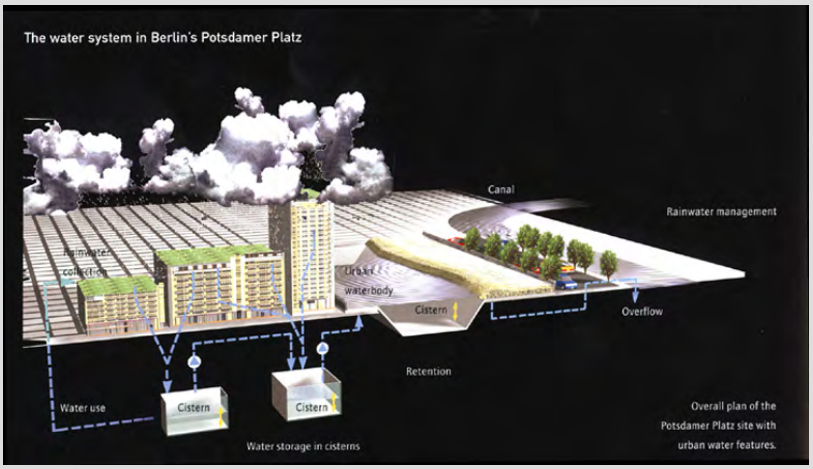
BOX 5-11 Continued

Pottsdammer Platz

This project, in the heart of Berlin, Germany, illustrates the potential for stormwater treatment in the densest urban environments by incorporating treatment into building systems and architectural pools that are the centerpiece of a series of urban plazas. As shown in Figure 5-59, on-site, individual SCMs are used to collect stormwater and use it for sanitary purposes.



FIGURE 5-59 As shown to the left and below, stormwater is collected and stored on-site in a series of vaults. Water is circulated through a series of biofiltration areas and used for toilets and other mechanical systems in the building complex. Large storms overflow into an adjacent canal. SOURCE: Reprinted, with permission, from Herbert Dreiseitl, Dieter Grau (2001). Copyright 2001 by Birkhäuser Publishing Ltd.



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Menomonee Valley Redevelopment, Wisconsin

The 140-acre redevelopment of abandoned railyards illustrates how a Brownfield site within an existing floodplain can be redeveloped using both on-site and consolidated treatment. As shown in Figure 5-60, consolidated treatment is incorporated into park areas which provide recreation for adjacent neighborhoods and serve as a centerpiece for a developing light industrial area that provides jobs to surrounding neighborhoods. Treatment on individual privately owned parcels is limited to the removal of larger sediments and debris only, making more land available for development. The volume of water that, by regulation, must be captured and treated on individual sites is conveyed through a conventional subsurface system for treatment in park areas.



FIGURE 5-60 Illustrations show consolidated treatment areas in proposed parks. The top image illustrates the fair weather condition, the center image the water quality capture volume, and the bottom image the 100-year storm event. Construction was completed in spring 2007. SOURCE: Courtesy of Wenk Associates.

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Determining Goals for the Receiving Waters

It is important to set biological and public health goals for the receiving water that are achievable given the ultimate impervious cover intended for the local watershed (see the Impervious Cover Model in Box 3-10). If the receiving water is too sensitive to meet these goals, one should consider adjustments to zoning and development codes to reduce the amount of impervious cover. The biological goals may involve a keystone species, such as salmon or trout, a desired state of biological integrity in a stream, or a maximum level of eutrophication in a lake. In other communities, stormwater goals may be driven by the need to protect a sole-source drinking water supply (e.g., New York watersheds) or to maintain water contact recreation at a beach, lake, or river. Once again, the watershed goals that are selected have a strong influence on the assembly of SCMs needed to meet them, since individual SCMs vary greatly in their ability to achieve different biological or public health outcomes.

Noting the Physical Constraints

The specific physical constraints of the watershed terrain and the development pattern will influence the selection and assembly of SCMs. The application of SCMs must be customized in every watershed to reflect its unique terrain, such as karst, high water tables, low or high slopes, freeze–thaw depth, soil types, and underlying geology. Each SCM has different restrictions or constraints associated with these terrain factors. Consequently, the SCM prescription changes as one moves from one physiographic region to another (e.g., the flat coastal plain, the rolling Piedmont, the ridge and valley, and mountainous headwaters).

Developing SCM Guidance and Performance Criteria for the Local Watershed

Based on the foregoing factors, the community should establish specific sizing, selection, and design requirements for SCMs. These SCM performance criteria may be established in a local, regional, or state stormwater design manual, or by reference in a local watershed plan. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how SCM guidance can be customized to protect specific types of receiving waters (e.g., high-quality lakes, trout streams, drinking water reservoirs, and impaired waters). In general, the watershed- or receiving water-based criteria are more specific and detailed than would be found in a regional or statewide stormwater manual. For example, the local stormwater guidance criteria may be more prescriptive with respect to runoff reduction and SCM sizing requirements, outline a preferred sequence for SCMs, and indicate where SCMs should (or should not) be located

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in the watershed. Like the identification of stressors or pollutants of concerns, this step is rarely taken under current paradigms of stormwater management.

Establishing a Trading System

A stormwater trading or offset system is critical to situations when on-site SCMs are not feasible or desirable in the watershed. Communities may choose to establish some kind of stormwater trading or mitigation system in the event that full compliance is not possible due to physical constraints or because it is more cost effective or equitable to achieve pollutant reduction elsewhere in the local watershed. The most common example is providing an offset fee based on the cost to remove an equivalent amount of pollutants (such as phosphorus in the Maryland Critical Area—MD DNR, 2003). This kind of trading can provide for greater cost equity between low-cost Greenfield sites and higher-cost ultra-urban sites.

Ensuring the Safe and Effective Performance of the Drainage Network, Streams, and Floodplains

The urban water system is not solely designed to manage the quality of runoff. It also must be capable of safely handling flooding from extreme storms to protect life and property. Consequently, communities need to ensure that their stormwater infrastructure can prevent increased flooding caused by development (and possibly exacerbated future climate change). In addition, many SCMs must be designed to safely pass extreme storms when they do occur. This usually requires a watershed approach to stormwater management to ensure that quality and quantity control are integrated together, with an emphasis on the connection and effective use of conveyance channels, streams, riparian buffers, and floodplains.

Establishing Community Objectives for the Publicly Owned Elements of Stormwater Infrastructure

The stormwater infrastructure in a community normally occupies a considerable surface area of the landscape once all the SCMs, drainage easements, buffers, and floodplains are added together. Consequently, communities may require that individual SCM elements are designed to achieve multiple objectives, such as landscaping, parks, recreation, greenways, trails, habitat, sustainability, and other community amenities (as discussed extensively above). In other cases, communities may want to ensure that SCMs do not cause safety or vector problems and that they look attractive. The best way to maximize community benefits is to provide clear guidance in local SCM criteria at the site

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level and to ensure that local watershed plans provide an overall context for their implementation.

Establishing an Inspection and Maintenance Plan

The long-term performance of any SCM is fundamentally linked to the frequency of inspections and maintenance. As a result, NPDES stormwater permit conditions for industrial, construction, and municipal permittees specify that pollution prevention, construction, and post-construction SCMs be adequately maintained. MS4 communities are also required under NPDES stormwater permits to track, inspect, and ensure the maintenance of the collective system of SCMs and stormwater infrastructure within their jurisdiction. In larger communities, this can involve hundreds or even thousands of individual SCMs located on either public or private property. In these situations, communities need to devise a workable model that will be used to operate, inspect, and maintain the stormwater infrastructure across their local watershed. Communities have the lead responsibility in their MS4 permits to assure that SCMs are maintained properly to ensure their continued function and performance over time. They can elect to assign the responsibility to the public sector, the private sector (e.g., property owners and homeowners association), or a hybrid of the two, but under their MS4 permits they have ultimate responsibility to ensure that SCM maintenance actually occurs. This entails assigning legal and financial responsibilities to the owners of each SCM element in the watershed, as well as maintaining a tracking and enforcement system to ensure compliance.

Summary

Taking all of the elements above into consideration, the emerging goal of stormwater management is to mimic, as much as possible, the hydrological and water quality processes of natural systems as rain travels from the roof to the stream through combined application of a series of practices throughout the entire development site and extending to the stream corridor. The series of SCMs incrementally reduces the volume of stormwater on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure required.

There is no single SCM prescription that can be applied to each kind of development; rather, a combination of interacting practices must be used for full and effective treatment. For a low-density residential Greenfield setting, a combination of SCMs that might be implemented is illustrated in Table 5-8. There are many successful examples of SCMs in this context and at different scales. By contrast, Tables 5-9 and 5-10 outline how the general “roof-to-stream” stormwater approach is adapted for intense industrial operations and urban redevelopment sites, respectively. As can be seen, these development situations require a differ combination of SCMs and practices to address the unique design

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TABLE 5-8 From the Roof to the Stream: SCMs in a Residential Greenfield

SCM	What it Is	What it Replaces	How it Works
Land-Use Planning	Early site assessment	Doing SWM design after site layout	Map and plan submitted at earliest stage of development review showing environmental, drainage, and soil features
Conservation of Natural Areas	Maximize forest canopy	Mass clearing	Preservation of priority forests and reforestation of turf areas to intercept rainfall
Earthwork Minimization	Conserve soils and contours	Mass grading and soil compaction	Construction practices to conserve soil structure and only disturb a small site footprint
Impervious Cover Minimization	Better site design	Large streets, lots and cul-de-sacs	Narrower streets, permeable driveways, clustering lots, and other actions to reduce site IC
Runoff Volume Reduction—Rainwater Harvesting	Utilize rooftop runoff	Direct connected roof leaders	A series of practices to capture, disconnect, store, infiltrate, or harvest rooftop runoff
Runoff Volume Reduction—Vegetated	Frontyard bioretention	Positive drainage from roof to road	Grading frontyard to treat roof, lawn, and driveway runoff using shallow bioretention
	Dry swales	Curb/gutter and storm drain pipes	Shallow, well-drained bioretention swales located in the street right-of-way
Peak Reduction and Runoff Treatment	Linear wetlands	Large detention ponds	Long, multi-cell, forested wetlands located in the stormwater conveyance system
Aquatic Buffers and Managed Floodplains	Stream buffer management	Unmanaged stream buffers	Active reforestation of buffers and restoration of degraded streams

Note: SCMs are applied in a series, although all of the above may not be needed at a given residential site. This “roof-to-stream” approach works best for low- to medium-density residential development.

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TABLE 5-9 From the Roof to the Outfall: SCMs in an Industrial Context

SCM Category	What it Is	What it Replaces	How it Works
Pollution Prevention	Drainage mapping	No map	Analysis of the locations and connections of the stormwater and wastewater infrastructure from the site
	Hotspot site Investigation	Visual inspection	Systematic assessment of runoff problems and pollution prevention opportunities at the site
	Rooftop management	Uncontrolled rooftop runoff	Use of alternative roof surfaces or coatings to reduce metal runoff, and disconnection of roof runoff for stormwater treatment
	Exterior maintenance practices	Routine plant maintenance	Special practices to reduce discharges during painting, powerwashing, cleaning, sealcoating and sandplasting
	Extending roofs for no exposure	Exposed hotspot operations	Extending covers over susceptible loading/unloading, fueling, outdoor storage, and waste management operations
	Vehicular pollution prevention	Uncontrolled vehicle operations	Pollution prevention practices applied to vehicle repair, washing, fueling, and parking operations
	Outdoor pollution prevention practices	Outdoor materials storage	Prevent rainwater from contact with potential pollutants by covering, secondary containment, or diversion from storm-drain system
	Waste management practices	Exposed dumpster or waste streams	Improved dumpster location, management, and treatment to prevent contact with rainwater or runoff
	Spill control plan and response	No plan	Develop and test response to spills to the storm-drain system, train employees, and have spill control kits available on-site
	Greenscaping	Routine landscape and turf maintenance	Reduce use of pesticides, fertilization, and irrigation in pervious areas, and conversion of turf to forest
	Employee stewardship	Lack of storm-water awareness	Regular ongoing training of employees on stormwater problems and pollution prevention practices
	Site housekeeping and stormwater maintenance	Dirty site and unmaintained infrastructure	Regular sweeping, storm-drain cleanouts, litter pickup, and maintenance of stormwater infrastructure
Runoff Treatment	Stormwater retrofitting	No stormwater treatment	Filtering retrofits to remove pollutants from most severe hotspot areas
IDDE	Outfall analysis	No monitoring	Monitoring of outfall quality to measure effectiveness

Note: While many SCMs are used at each individual industrial site, the exact combination depends on the specific configuration, operations, and footprint of each site.

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TABLE 5-10 From the Roof to the Street: SCMs in a Redevelopment Context

SCM Category	What it Is	What it Replaces	How it Works
Impervious Cover Minimization	Site design to prevent pollution	Conventional site design	Designing redevelopment footprint to restore natural area remnants, minimize needless impervious cover, and reduce hotspot potential
Runoff Volume Reduction—Rainwater Harvesting and Vegetated	Treatment on the roof	Traditional rooftops	Use of green rooftops to reduce runoff generated from roof surfaces
	Rooftop runoff treatment	Directly connected roof leaders	Use of rain tanks, cisterns, and rooftop disconnection to capture, store, and treat runoff
	Runoff treatment in landscaping	Traditional landscaping	Use of foundation planters and bioretention areas to treat runoff from parking lots and rooftops
Soil Conservation and Reforestation	Runoff reduction in pervious areas	Impervious or compacted soils	Reducing runoff from compacted soils through tilling and compost amendments, and in some cases, removal of unneeded impervious cover
	Increase urban tree canopy	Turf or landscaping	Providing adequate rooting volume to develop mature tree canopy to intercept rainfall
Runoff Reduction—Subsurface	Increase permeability of impervious cover	Hard asphalt or concrete	Use of permeable pavers, porous concrete, and similar products to decrease runoff generation from parking lots and other hard surfaces.
Runoff Reduction—Vegetated	Runoff treatment in the street	Sidewalks, curb and gutter, and storm drains	Use of expanded tree pits, dry swales and street bioretention cells to further treat runoff in the street or its right-of-way
Runoff Treatment	Underground treatment	Catch basins and storm-drain pipes	Use of underground sand filters and other practices to treat hotspot runoff quality at the site
Municipal Housekeeping	Street cleaning	Unswept streets	Targeted street cleaning on priority streets to remove trash and gross solids
Watershed Planning	Off-site stormwater treatment or mitigation	On-site waivers	Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met on-site

Note: SCMs are applied in a series, although all of the above may not be needed at a given redevelopment site.

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challenges of dense urban environments. The tables are meant to be illustrative of certain situations; other scenarios, such as commercial development, would likely require additional tables.

In summary, a watershed approach for organizing site-based stormwater decisions is generally superior to making site-based decisions in isolation. Communities that adopt the preceding watershed elements not only can maximize the performance of the entire system of SCMs to meet local watershed objectives, but also can maximize other urban functions, reduce total costs, and reduce future maintenance burdens.

COST, FINANCE OPTIONS, AND INCENTIVES

Municipal Stormwater Financing

To be financially sustainable, stormwater programs must develop a stable long-term funding source. The activities common to most municipal stormwater programs (such as education, development design review, inspection, and enforcement) are funded through general tax revenues, most commonly property taxes and sales taxes (NAFSMA, 2006), which is problematic for several reasons. First, stormwater management financed through general tax receipts does not link or attempt to link financial obligation with services received. The absence of such links can reduce the ability of a municipality to adequately plan and meet basic stormwater management obligations. Second, when funded through general tax revenues, stormwater programs must compete with other municipal programs and funding obligations. Finally, in programs funded by general tax revenue, responsibilities for stormwater management tend to be distributed into the work responsibilities of existing and multiple departments (e.g., public works, planning, etc.). One recent survey conducted in the Charles River watershed in Massachusetts found that three-quarters of local stormwater management programs did not have staff dedicated exclusively for stormwater management (Charles River Watershed Association, 2007).

Increasingly, many municipalities are establishing stormwater utilities to manage stormwater (Kaspersen, 2000). Most stormwater utilities are created as a separate organizational entity with a dedicated, self-sustaining source of funding. The typical stormwater utility generates the large majority of revenue through user fees (Florida Stormwater Association, 2003; Black and Veatch, 2005; NAFSMA, 2006). User fees are established and set so as to have a close nexus to the cost of providing the service and, thus, are most commonly based on the amount of impervious surface, frequently measured in terms of equivalent residential unit. For example, an average single-family residence may create 3,000 square feet of impervious surface (roof and driveway area). A per-unit charge is then assigned to this “equivalent runoff unit.” To simplify program

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administration, utilities typically assign a flat rate for residential properties (customer class average) (NAFSMA, 2006). Nonresidential properties are then charged individually based on the total amount of impervious surface (square feet or equivalent runoff units) of the parcel. Fees are sometimes also based on gross area (total area of a parcel) or some combination of gross area and a development intensity measure (Duncan, 2004; NAFSMA, 2006).

Municipalities have the legal authority to create stormwater utilities in most states (Lehner et al., 1999). In addition to creating the utility, a municipality will generally establish the utility rate structure in a separate ordinance. Separating the ordinances allows the municipality flexibility to change the rate structure without revising the ordinance governing the entire utility (Lehner et al., 1999). While municipalities generally have the authority to collect fees, some states have legal restrictions on the ability of local governments to levy taxes (Lehner et al., 1999; NAFSMA, 2006). The legal distinction between a tax and a fee is the most common legal challenge to a stormwater utility. For example, stormwater fees have been subject to litigation in at least 17 states (NAFSMA, 2006). To avoid legal challenges, care must be taken to meet a number of legal tests that distinguish a fee for a specific service and a general tax.

Stormwater utilities typically bill monthly, and fees range widely. A recent survey of U.S. stormwater utilities reported that fees for residential households range from $1 to $14 per month, but a typical residential household rate is in the range of $3 to $6 (Black and Veatch, 2005). Despite the dedicated funding source, the majority of stormwater utilities responding to a recent survey (55 percent) indicated that current funding levels were either inadequate or just adequate to meet their most urgent needs (Black and Veatch, 2005).

Both municipal and state programs can finance administrative programming costs through stormwater permitting fees. Municipal stormwater programs can use separate fees to finance inspection activities. For instance, inspection fees can be charged to cover the costs of ensuring that SCMs are adequately planned, installed, or maintained (Debo and Reese, 2003). Stormwater management programs can also ensure adequate funding for installation and maintenance of SCMs by requiring responsible parties to post financial assurances. Performance bonds, letters of credit, and cash escrow are all examples of financial assurances that require up-front financial payments to ensure that longer-term actions or activities are successfully carried out. North Carolina's model stormwater ordinance recommends that the amount of a maintenance performance security (bond, cash escrow, etc.) be based on the present value of an annuity based on both inspection costs and operation and maintenance costs (Whisnant, 2007).

In addition to fees or taxes, exactions such as impact fees can also be used as a way to finance municipal stormwater infrastructure investments (Debo and Reese, 2003). An impact fee is a one-time charge levied on new development. The fee is based on the costs to finance the infrastructure needed to service the new development. The ability to levy impact fees varies between states. Municipalities that use impact fees are also required to show a close nexus between the size of the fee and the level of benefits provided by the fee; a failure to do so

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exposes local government to law suits (Keller, 2003). Compared to other funding sources, impact fees also exhibit greater variability in revenue flows because the amount of funds collected is dependent on development growth.

Bonds and grants can supplement the funding sources identified above. Bonds and loans tend to smooth payments over time for large up-front stormwater investments. For example, state and federal loan programs (state revolving funds) provide long-term, low-interest loans to local governments or capital investments (Keller, 2003). In addition, grant opportunities are sometimes available from state and federal sources to help pay for specific elements of local stormwater management programs.

Municipalities require funds to meet federal and state stormwater requirements. Understanding of the municipal costs incurred by implementing stormwater regulations under the Phase I and II stormwater rules, however, is incomplete (GAO, 2007). Of the six minimum measures of a municipal stormwater program (public education, public involvement, illicit discharge detection and elimination, construction site runoff control, post-construction stormwater management, and pollution prevention/good housekeeping—see Chapter 2), a recent study of six California municipalities found that pollution prevention activities (primarily street sweeping) accounted for over 60 percent of all municipal stormwater management costs in these communities (Currier et al., 2005). Annual per-household costs ranged from $18 to $46.

Stormwater Cost Review

Conceptually, the costs of providing SCMs are all opportunity costs (EPA, 2000). Opportunity costs are the value of alternatives (next best) given up by society to achieve a particular outcome. In the case of stormwater control, opportunity costs include direct costs necessary to control and treat runoff such as capital and construction costs and the present value of annual operation and maintenance costs. Initial installation costs should also include the value of foregone opportunities on the land used for stormwater control, typically measured as land acquisition (land price).

Costs also include public and private resources incurred in the administration of the stormwater management program. Private-sector costs might include time and administrative costs associated with permitting programs. Public costs include agency monitoring and enforcement costs.

Opportunity costs also include other values that might be given up as a consequence of stormwater management. For example, the creation of a wet pond in a residential area might be opposed because of perceived safety, aesthetic, or nuisance concerns (undesirable insect or animal species). In this case, the diminished satisfaction of nearby property owners is an opportunity cost associated with the wet pond. On the other hand, if SCMs are considered a neighborhood amenity (e.g., a constructed wetland in a park setting), opportunity costs may decrease. In addition, costs of a given practice may be reduced by reducing

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costs elsewhere. For example, increasing on-site infiltration rates can reduce off-site storage costs by reducing the volume and slowing the release of runoff.

In general the cost of SCMs is incompletely understood and significant gaps exist in the literature. More systematic research has been conducted on the cost of conventional stormwater SCMs (wet ponds, detention basins, etc.), with less research applied to more recent, smaller-scale, on-site infiltration practices. Cost research is challenging given that stormwater treatment exhibits considerable site-specific variation resulting from different soil, topography, climatic conditions, local economic conditions, and regulatory requirements (Lambe et al., 2005).

The literature on stormwater costs tend to be oriented around construction costs of particular types of SCMs (Wiegand et al., 1986; SWRPC, 1991; Brown and Schueler, 1997; Heaney et al., 2002; Sample et al., 2003; Wossink and Hunt, 2003; Caltrans, 2004; Narayanan and Pitt, 2006; DeWoody, 2007). In many of these studies, construction cost functions are estimated statistically based on a sample of recently installed SCMs and the observed total construction costs. Observed costs are then related statistically to characteristics that influence cost such as practice size. Other studies estimate costs by identifying the individual components of a construction project (pipes, excavation, materials, labor, etc.), estimating unit costs of each component, and then summing all project components. These studies generally find that construction costs decrease on a per-unit basis as the overall size (expressed in volume or drainage area) of the SCM increases (Lambe et al., 2005). These within-practice economies of scale are found across certain SCMs including wet ponds, detention ponds, and constructed wetlands. Several empirical studies, however, failed to find evidence of economies of scale for bioretention practices (Brown and Schueler, 1997; Wossink and Hunt, 2003).

Increasing attention has been paid to small-scale practices, including efforts to increase infiltration and retain water through such means as green roofs, permeable pavements, rain barrels, and rain gardens (under the label of LID). The costs of these practices are less well studied compared to the other stormwater practices identified above. In general, per-unit construction and design costs exceed larger-scale SCMs (Low Impact Development Center, 2007). Higher construction costs, however, may be offset to various degrees by reducing the investments in stormwater conveyance and storage infrastructure (i.e., less storage volume is needed) (CWP, 1998a, 2000a; Low Impact Development Center, 2007). Others have suggested that per-unit costs to reduce runoff may be less for these small-scale distributed practices because of higher infiltration rates and retention rates (MacMullan and Reich, 2007).

Compared to construction costs, less is known about the operation and maintenance costs of SCMs (Wossink and Hunt, 2003; Lambe et al., 2005; MacMullan and Reich, 2007). Most stormwater practices are not maintenance free and can create financial and long-term management obligations for responsible parties (Hager, 2003). Cost-estimation programs and procedures have been developed to estimate operation and maintenance costs as well as construction

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costs (SWRPC, 1991; Lambe et al., 2005; Narayanan and Pitt, 2006), but examination of observed maintenance costs is less common. Based on estimates from Wossink and Hunt (2003), the total present value of maintenance costs over 20 years can range from 15 to 70 percent of total capital construction costs for wet ponds and constructed wetlands and appear generally consistent with percentages reported in EPA (1999). Operation and maintenance costs were also reported to be a substantial percentage of construction costs of infiltration pits and bioretention areas in Southern California (DeWoody, 2007). Others estimate that over the life of many SCMs, maintenance costs may equal construction costs (CWP, 2000a). In general, maintenance costs tend to decrease as a percentage of total SCM cost as the total size of the SCM increases (Wossink and Hunt, 2003).

Very few quantifiable estimates are available for public and private regulatory compliance costs. Compliance costs could include both initial permitting costs (labor and time delays) of gaining regulatory approval for a particular stormwater design to post-construction compliance costs (administration, inspection monitoring, and enforcement). Compliance monitoring is a particular concern if a stormwater management program relies on widespread use of small-scale distributed on-site practices (Hager, 2003). Unlike larger-scale or regional stormwater facilities that might be located on public lands or on private lands with an active stormwater management plan, a multitude of smaller SCMs would increase monitoring and inspection times by increasing the number of SCMs. Furthermore, municipal governments may be reluctant to undertake enforcement actions against citizens with SCMs located on private land.

Land costs tend to be site specific and exhibit a great deal of spatial variation. Some types of SCMs, such as constructed wetlands, are more land intensive than others. In highly urban areas, land costs may be the single biggest cost outlay of land-intensive SCMs (Wossink and Hunt, 2003).

In general, cost analyses generally find that the cost to treat a given acreage or volume of water is less for regional SCMs than for smaller-scale SCMs (Brown and Schueler, 1997; EPA, 1999; Wossink and Hunt, 2003). For example, considering maintenance, capital construction, and land costs, recent estimates for North Carolina indicate that annual costs for wet ponds and constructed wetlands range between $100 and $3,000 per treated acre (typically less than $1,000). Per-acre annual costs for bioretention and sand filters typically ranged between $300 and $3,500, and between $4,500 and 8,500, respectively. However, if SCMs face space constraints, bioretention areas can become more cost effective. Furthermore, other classes of small, on-site practices, such as grass swales and filter strips, can sometimes be implemented for relatively low cost.

There are exceptions to the general conclusion that larger-scale stormwater practices tend to be less costly on a per-unit basis than more numerous and distributed on-site practices. For instance, in Sun Valley, California, a recent study indicates that installing small distributed practices (infiltration practices, porous pavement, rain gardens) was more cost effective than centralized approaches for

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a retrofit program (Cutter et al., 2008). In this particular setting, the difference tended to revolve around the high land costs in the urbanized setting. Small-scale practices can be placed on low-valued land or integrated into existing landscaping, reducing land costs. Centralized stormwater facilities require substantial purchases of high-priced urban properties. Similarly, small distributed practices (porous pavement, green roofs, rain gardens, and constructed wetlands) can also provide a more cost-effective approach to reducing combined sewer overflow (CSO) discharges in a highly urban setting than large structural CSO controls (storage tanks) (Montalto et al., 2007).

SCMs are now a part of most development processes and consequently will increase the cost of the development. Randolph et al. (2006) report on the cost of complying with stormwater and sediment and erosion control regulations for six developments in the Washington, D.C., metropolitan area. These costs include primarily stormwater facility construction and land costs. The findings from these case studies indicate that stormwater and erosion and sediment control comprised about 60 percent of all environmental-related compliance costs for the residential developments studied and added about $5,000 to the average price of a home. Nationwide, stormwater and erosion and sediment controls are estimated to add $1,500 to $9,000 to the cost of a new residential dwelling unit (Randolph et al., 2006).

As a means to control targeted chemical constituents, SCMs may be an expensive control option relative to other control alternatives. For example, nutrients from anthropocentric sources are an increasing water quality concern for many fresh and marine waters. Some states (e.g., Virginia, Maryland, and North Carolina) require stormwater programs to achieve specific nutrient (nitrogen or phosphorus) stormwater standards. The construction, maintenance, and land costs of reducing nitrogen discharge from residential developments using bioretention areas, wet ponds, constructed wetlands, or sand filters range from $60 to $2,500 per pound (Aultman, 2007). These control costs can be an order of magnitude higher than nitrogen control costs from point sources or agricultural nonpoint sources. The high per-pound removal costs are due in part to the relatively low mass load of nutrients carried in stormwater runoff. These estimates, however, assume that all costs are allocated exclusively to nitrogen removal. The high per-pound removal costs from the control of single pollutants highlight the importance of achieving ancillary and offsetting benefits associated with stormwater control (e.g., removal of other pollutants of concern, stream-channel protection from volume reduction, and enhancement of neighborhood amenities).

It should also be noted that installing SCMs in an existing built environment tends to be significantly more expensive than new construction. Construction costs for retrofitted extended detention ponds, wet ponds, and constructed wetlands were estimated to be two to seven times more costly than new SCMs (Schueler et al., 2007). Retrofit costs can be higher for a variety of reasons, including the need to upgrade existing infrastructure (culverts, drainage channels, etc.) to meet contemporary engineering and regulatory requirements. Retrofitting a single existing residential city block in Seattle with a new stormwater

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drainage system that included reduced street widths, biofiltration practices, and enhanced vegetation cost an estimated $850,000 (see Box 5-5; Seattle Public Utilities, 2007). Estimates suggested that the costs might have been even higher using more conventional stormwater piping/drainage systems (Chris May, personal communication, August 2007; EPA, 2007).

As discussed earlier in the chapter, stormwater runoff can be reduced and managed through better site design to reduce impervious cover. Low- to medium-density developments can reduce impervious cover through cluster development patterns that preserve open space and reduce lot sizes. Impervious surfaces and infiltration rates could be altered by any number of site-design characteristics such as reduction in street widths, reduction in the number of cul-de-sacs, and different setback requirements (CWP, 2000a). Finally, impervious surface per capita could be substantially reduced by increasing the population per dwelling unit.

Quantifying the cost of many of these design features is more challenging, and the literature is much less developed or conclusive than the literature on conventional SCM costs. Many design features described above (clustering, reduced setbacks, narrower streets, less curb and gutter) can significantly lower construction and infrastructure costs (CWP, 2001; EPA, 2007). Such features may reduce the capital cost of subdivision development by 10 to 33 percent (CWP, 2000a).

On the other hand, the evidence is unclear whether consumers are willing to pay for these design features. If consumers prefer features typically associated with conventional developments (large suburban lot, for example), then some aspects of alternative development designs/patterns could impose an opportunity cost on builders and buyers alike in the form of reduced housing value. For example, most statistical studies in the U.S. housing market find that consumers prefer homes with larger lots and are willing to pay premiums for homes located on cul-de-sacs, presumably for privacy and safety reasons (Dubin, 1998; Fina and Shabman, 1999; Song and Knapp, 2003). These effects, however, might be partly or completely offset by the higher value consumers might place on the proximity of open space to their homes (Palmquist, 1980; Cheshire and Sheppard, 1995; Qiu et al., 2006). Anecdotal evidence indicates that residents feel that Seattle's Street Edge Alternative program (the natural drainage system retrofit program that combines swales, bioretention and reduced impervious surfaces) increased their property values (City of Seattle, undated). Studies that have attempted to assess the net change in costs are limited, but some evidence suggests that the amenity values of lower-impact designs may match or outweigh the disamentities (Song and Knapp, 2003).

Incentives for Stormwater Management

The dominant policy approach to controlling effluent discharge under the Clean Water Act is through the application of technology-based effluent stan-

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dards or the requirements to install particular technologies or practices. Some note that this general policy approach may not provide the regulated community with (1) incentives to invest in pollution prevention activities beyond what is required in the standard or with (2) sufficient opportunities or flexibility to lower overall compliance costs (Parikh et al., 2005).

A loosely grouped set of policies, called here "incentive-based,"[1] aim to create financial incentives to manage effluent or volume discharge. Such policies tend to be classified into two groups: price- and quantity-based mechanisms (Stavins, 2000; Parikh et al., 2005). Price-based mechanisms are created when government creates a charge (tax, fee, etc.) or subsidy (payment) on an outcome that government wants to either discourage or encourage. Ideally, the price would be placed on a target outcome (effluents discharged, volume of water released, etc.) and not on the means to achieve that outcome end (such as a tax or subsidy to adopt specific technologies or practices).[2] Quantity-based policies require government to establish some binding limit or cap on an outcome (e.g., mass load of effluent, volume of runoff, etc.) for an identified group of dischargers, but then allow the regulated parties to "trade" responsibilities for meeting that limit or cap. The opportunity to trade creates the financial incentive. The trading concept is discussed in greater detail in Chapter 6, while this section focuses on price-based incentives.

Some stormwater utilities offer reductions in stormwater fees to landowners who voluntarily undertake activities to reduce runoff from their parcels (Doll and Lindsey, 1999; Keller, 2003). The reduction in tax obligations, called credits, can be interpreted as a financial subsidy or payment for implementing onsite runoff controls. Credit payments are typically made based on the volume of water detained. For example, as part of Portland, Oregon's Clean River Rewards program, residents and commercial property owners can reduce their stormwater utility fee by as much as 35 percent by reducing stormwater runoff from existing developed properties (Portland Bureau of Environmental Services, 2008a). Residential and commercial property owners are given a number of ways to reduce runoff to receive this financial benefit. In addition, Portland has a downspout disconnection program that aims to reduce discharge into CSOs in targeted areas in the city. Property owners may be reimbursed up to $53 per eligible downspout (Portland Bureau of Environmental Services, 2008b).

Alternatively, stormwater utilities could (where allowed) also use fee revenue to provide private incentives for stormwater control through a competitive

[1] These policies are sometimes called "market-based" policies, but that term will not be used here because many of the incentive-based policies discussed fail to contain features characteristic of a market system.

[2] The literature on what level to set the price (tax or subsidy) is vast, complex, and controversial. Parikh et al. (2005) seem to wander into this debate (perhaps unwittingly) by making a distinction between taxes based on some optimality rule (marginal damage costs equal to marginal control costs) and those based on some other sort of decision rule. Without getting into the specifics of this debate here, this discussion will simply assert more generally that price-based incentive policies structure taxes and subsidies to induce desirable behavioral change (rather than simply to raise revenue).

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bidding process. Such a bidding process ("reverse auction") would request proposals for stormwater reduction projects and fund projects that reduce volume at the least cost. Proposed investments that can meet the program objectives at the lowest per unit cost would receive payments. Such a program creates private incentives to search for low-cost stormwater investments by creating a price for runoff volume reduction. The bidding program could also be used to identify cost-effective stormwater investments in areas targeted for enhanced levels of restoration. A bidding program has been proposed as a way to lower overall costs of a stormwater program in Southern California (Cutter et al., 2008). Revenue to fund such a competitive bid program could come from a variety of sources including stormwater utility fees or fees paid into an in lieu fee program.

Finally, impact fees on new developments can be structured in a way to create incentives to reduce stormwater runoff volumes. Charges based on runoff volume (or a surrogate measure like impervious surface) can provide an incentive for developers to reduce the volume of new runoff created.

CHALLENGES TO IMPLEMENTATION OF WATERSHED-BASED MANAGEMENT AND STORMWATER CONTROL MEASURES

The implementation of SCMs has seen variable success. Environmental awareness, threats to potable water sources or to habitat for threatened and endangered species, problems with combined sewer overflows, and other environmental factors have caused cities such as Portland, Oregon; Seattle, Washington; Chicago, Illinois; and Austin, Texas to aggressively pursue widespread implementation of a broad range of SCMs. In contrast, other cities have been slow to implement recommended practices, for many reasons. This is particularly true for nonstructural SCMs, despite their popularity among planners and regulators for the past two decades. A host of real and perceived concerns about individual nonstructural SCMs are often raised regarding development costs, market acceptance, fire safety, emergency access, traffic and parking congestion, basement seepage, pedestrian safety, backyard flooding, nuisance conditions, maintenance, and winter snow removal operations. While most of these concerns are unfounded, they contribute to a culture of inertia when it comes to code change (CWP, 1998a, 2000a). As a result, some nonstructural SCMs are discouraged or even prohibited by local development codes. Very few communities make the consideration of nonstructural practices a required element of stormwater plan review, nor do they require that they be considered early in the site layout and design process when their effectiveness would be maximized. Finally, many engineers and planners feel they can fully comply with existing stormwater criteria without resorting to nonstructural SCMs.

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Cost Issues

There are numerous cost issues that have proven to be significant barriers to the use of innovative SCMs. Special construction techniques required for the proper design and function of SCMs, specially formulated manufactured soils, expensive subsurface vaults, and increased land area requirements as a result of increased stormwater storage requirements can significantly increase site development costs. For smaller projects in highly urbanized areas where land costs are high, there can be a disproportionately large expense to comply with stormwater regulations, causing developers to seek, and often receive, exemption from requirements.

Sediment removal and related maintenance activities required to ensure the proper ongoing functioning of SCMs are activities that are not a part of normal building maintenance. Data on maintenance costs of SCMs on privately owned facilities are limited, and management companies responsible for commercial and office building maintenance have yet to provide SCM maintenance as part of their services.

Additional costs are incurred when development review periods by public agencies get extended because of an increased level of design review required to evaluate the compliance of SCMs with city ordinances. Additional review increases development costs and extends the design process. Even with specialized training for city staff to evaluate SCM submittals, deviation from the most basic type of SCM design seems to require extended review and documentation.

Cost concerns are partly responsible for the markedly slow implementation of the stormwater program. The federal deadlines for permit coverage have long passed; in fact more than 14 years have lapsed for medium and large municipalities. A good part of the delay can be explained by the resistance of states and local governments to the unknown cost burden. Cities contend that the permit requirements are unreasonable, expensive, and unrealistic to achieve. Many local government officials view some permit provisions such as LID or better site design as intrusion into the land-use authority of local governments.

As discussed in Chapter 2, the U.S. Congress provided no start-up or upgrade financial assistance, unlike what it did for municipally owned and operated wastewater treatment plants after the promulgation of the NPDES permit program under the Clean Water Act in 1972. Local governments have been reluctant to tax residents or create stormwater utilities. States like California and Michigan even have laws that require voter approval in order for local governments to assess new fees. Thus, to implement the NPDES stormwater program, states have had to largely rely on stormwater permit fees collected to support a skeletal to modest staff for program oversight. In Denver, and presumably in other cities, there is no reduction in stormwater fees when impervious area is reduced because of construction of on-site SCMs. This amounts to a disincentive to do the “right thing.” Meanwhile, the overall federal budget for the NPDES program, including stormwater, has been declining.

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Long-Term Maintenance of Stormwater Control Measures

One of the weakest parts of most stormwater management programs is the lack of information about, and funding to support, the long-term maintenance of SCMs. If SCMs are not inspected and maintained on a regular basis, the stormwater management program is likely to fail. This also negatively impacts the design process—if there is no inspection program oand no accountability for maintenance, the designer has no incentive to build better, more maintenance-friendly SCMs. Finally, without an accurate assessment of the maintenance needs of an SCM, land owners and other responsible parties cannot anticipate their total costs over the lifetime of the device.

Almost all SCMs require active long-term maintenance in order to continue to provide volume and water quality benefits (Hoyt and Brown, 2005; Hunt and Lord, 2006b). Furthermore, a typical municipality may contain hundreds or thousands of individual SCMs within its jurisdiction. Thus, the long-term obligations for maintenance are considerable. For example, the annual maintenance cost of 100 medium-sized wet ponds (one-half acre to 2 acres) is estimated to be a quarter of a million dollars (Hunt and Lord, 2006c). Currently, the majority of municipal stormwater programs do not have adequate plans or resources in place for the long-term maintenance of SCMs (GAO, 2007).

A number of issues confront the long-term maintenance of SCMs. First, legal and financial responsibility for maintenance must be assigned. Historically stormwater ownership and responsibility have been poorly defined and implemented (Reese and Presler, 2005). If a party is an industrial facility that is required to obtain a permit, then responsibility for maintaining SCMs rests with the permittee. Other instances are more ambiguous. For residential developments, the responsibility for long-term maintenance could be assigned to the developer (e.g., establishing long-term financial accounts for maintenance), individual landowners, homeowners associations, or the municipality itself. Some cities, like Austin and Seattle, assume responsibility for long-term maintenance of SCMs in residential areas. Concerns over assigning responsibility to individual residential landowners or homeowners associations include insufficient technical and financial resources to conduct consistent maintenance and a lack of inspection to require maintenance. A recent survey of municipal stormwater programs found that less than one-third perform regular maintenance on stormwater detention ponds or water quality SCMs in general residential areas (Reese and Presler, 2005). To ensure that adequate maintenance will occur, municipalities can require performance securities (performance bonds, escrow accounts, letter of credit, etc.) that ensure adequate funds are available for maintenance and repair in the event of failure to maintain the SCM by the responsible party.

An effective maintenance program also requires a system to inventory and track SCMs, inspection/monitoring, and enforcement against noncompliance. The large number of SCMs to track and manage creates management challenges. Municipal stormwater programs must administer their regulatory programs, perform inspection and enforcement activities, and maintain SCMs in public

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lands/rights-of-way and sometimes in residential areas. Municipal programs often do not have adequate staff to ensure that these maintenance responsibilities are adequately carried out. The lack of adequate staff for inspection and an inadequate system for prioritizing inspections have been repeatedly pointed out (Duke and Beswick, 1997; Duke, 2007; GAO, 2007).

Tracking and monitoring costs may also create disincentives for municipalities to adopt smaller-scale SCMs. Residential-scale rain gardens, porous driveways, rain barrels, and grass swales all have the potential to increase the cost and complexity of compliance monitoring because of the multitude of small infiltration devices that are located on private property as opposed to having fewer SCMs located in public rights-of-way or public lands. Small-scale distributed SCMs located on private property raise concerns of municipal willingness to inspect and enforce against noncompliance. Indeed, some municipalities have banned innovative SCMs like pervious pavement because the municipalities have no means to ensure their maintenance and continued operation.

Finally, there is concern that there is inadequate funding to maintain the growing number of SCMs on the landscape. The long-term funding obligation for maintenance has been difficult to assess (GAO, 2007), partly because many stormwater programs frequently do not have adequate accounting practices to define capital value and depreciation, maintenance, operation, or management programs (Reese and Presler, 2005). The problem is compounded because the long-term maintenance cost associated with various types of SCMs is not well understood. Additional research and information are needed on the costs of maintaining the performance of SCMs as experienced in the field (rather than ex ante estimates based on design plans). Research into long-term maintenance costs should include not only routine operation and maintenance costs but also costs for inspection and enforcement and remediation costs associated with SCM performance failures. Such research is critical to understanding the long-term cost obligation that is being assumed by municipal stormwater programs that are responsible for managing a growing number of SCMs.

At the present time, the maintenance schedule for many of the proprietary and non-proprietary SCMs is poorly defined. It will vary with the type of drainage area and the activities that are occurring within it and with the efficiency of the SCM. (For example, the city of Austin, Texas, has determined that the average lifespan of their sand filters ranges from 5 to 15 years, but can be as little as one year if there is construction in the drainage area.) In order to establish a maintenance schedule, an assessment protocol needs to be adopted by municipalities. The protocol, which is specific to the type of SCM, could consist of the following: each year municipalities would be required to collect data from a subset of their SCMs on public and private property, and then over a period of years these data could be used to determine maintenance schedules, predict performance based on age and sediment loading, and identify failed systems. A measurement of the depth of deposited sediment might be the only test needed for settling devices, such as hydrodynamic devices and wet detention ponds. Two levels of analysis could be performed for infiltration devices—one based

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on simple visual observations and the other using an instrument to check infiltration rates. These assessment methods for infiltration devices have been tested at the University of Minnesota (Gulliver and Anderson, 2007). Without an assessment protocol for SCMs, the chances for poor maintenance and outright failure are greatly increased, it is difficult if not impossible to determine the actual performance of an SCM, and there will be insufficient data to reduce the uncertainty in future SCM design.

Lack of Design Guidance on Important SCMs and Lack of Training

Progress in implementing SCMs is often handicapped by the lack of local or national design guidance on important SCMs, and by the lack of training among the many players in the land development community (planners, designers, plan reviewers, public works staff, regulators, and contractors) on how to properly implement them on the ground. For example, design guidance is lacking or just emerging for many of the non-traditional SCMs, such as conservation of natural areas, earthwork minimization, product substitution, reforestation, soil restoration, impervious cover reduction, municipal housekeeping, stormwater education, and residential stewardship. Some LID techniques are better covered, such as the standards for pervious concrete from the American Concrete Institute and the National Ready Mixed Concrete Association. Design guidance for traditional SCMs such as erosion and sediment control may exist but is often incomplete, outdated, or lacking key implementation details to ensure proper on-the-ground implementation. In other cases, design guidance is available, but has not been disseminated to the full population of Phase II MS4 communities. For example, in an unpublished survey of state manuals used to develop national post-construction stormwater guidance, Hirschman and Kosco (2008) found that less than 25 percent provided sizing criteria, detailed engineering design specifications, or maintenance criteria. Nationwide guidance on SCM design and implementation may not be advisable or applicable to all physiographic, climatic, and ecoregions of the country. Rather, EPA and the states should encourage the development of regional design guidance that can be readily adapted and adopted by municipal and industrial permittees. Improvement of SCM design guidance should incorporate more direct consideration of the parameters of concern, how they move across the landscape, and the issues in receiving waters—a strategy both espoused in this report (page 351) and in recent publications on this topic (Strecker et al., 2005, 2007).

The second key issue relates to how to train and possibly certify the hundreds of thousands of individuals that are responsible for land development and stormwater infrastructure at the local and state level. New stormwater methods and practices cannot be effectively implemented until local planners, engineers, and landscape architects fully understand them and are confident on how to apply them to real-world sites. Currently, stormwater design is not a major com-

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ponent of the already crowded curriculum of undergraduate or graduate planning engineering or landscape architecture programs. Most stormwater professionals acquire their skills on the job. Given the rapid development of new stormwater technologies, there is a critical need for implementation of regional or statewide training programs to ensure that stormwater professionals are equipped with the latest knowledge and skills. The training programs should ultimately lead to formal certification for stormwater designers, inspectors, and plan reviewers.

Different Standards in Different Jurisdictions That Are Within the Same Watershed

Governmental and watershed boundaries rarely coincide, with the result that most watersheds are made up of many municipal bodies regulating stormwater management. Unfortunately in most cases there is no overarching stormwater regulatory structure that is based upon a watershed analysis. This can result in many unfortunate conflicts, where approval of a stormwater facility does not affect the community issuing the permit. It is often said that the most effective stormwater management for an area high in the watershed is to speed the water downstream, thus saving the upstream community but severely damaging the downstream rivers. While this may be an exaggeration, the problems downstream are less of a concern to the upper watershed communities, and downstream communities may not be able to solve their water issues without help from the upstream communities.

Often neighboring communities' plans or the methods or data used do not coincide. For example, often out-of-date rainfall distributions, methods, or standards are required in the code that do not apply to the newer focus on smaller storms and volume reduction. If methods that include Modified Rational or TR-55 are used, it is difficult if not impossible to show the benefits in peak flow reduction gained through volume reduction devices. Also, some municipalities may require curb and piping and not allow swales, impending the implementation of a cost-effective design. Finally, it is difficult to observe a measureable impact of SCMs when they are guided by a patchwork of regulations. One community may require removal of the first inch of runoff, and another may require the reduction of the 25-year, post-construction peak to the 10-year pre-construction level.

Water Rights that Conflict with Stormwater Management

In the West, water is considered real property, governed by state law and regional water compacts. Landowners in urban areas rarely own surface water rights and are typically prohibited from "beneficial use" of that water, which affects how SCMs are chosen. For example, current practices in Colorado typically allow stormwater to be infiltrated within a short period of time on-site

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without violation of water laws. However, storage of and/or pumping this water for broader distribution is considered to be a beneficial use and is therefore prohibited. Moreover, as discussed in Chapter 2, SCMs that manage stormwater by driving the water underground with a bored, drilled, or driven shaft or a hole dug deeper than its widest surface dimension are typically considered to be "injection wells," requiring a federal permit and regular monitoring under the Safe Drinking Water Act.

Some states prohibit infiltration because of concerns over long-term groundwater pollution. In California, which does not have a uniform policy for groundwater management and groundwater rights, authority over groundwater quality management falls to several regional and local agencies. For example, the Upper Los Angeles River Area (ULARA) has a court-appointed Watermaster to manage the complex appropriation of its groundwater to user cities and agencies. The ULARA has clashed with the City of Los Angeles regarding rights to all of the water that normally recharges the Los Angeles River via runoff from precipitation. In 2000, the ULARA Watermaster expressed a concern with certain permit provisions of the Los Angeles County MS4 Permit for New Development/ Redevelopment that promoted infiltration, stating that the MS4 permit interfered with the adjudicated right of the City of Los Angeles to manage groundwater.

Urban Development and Sprawl

The continued expansion of urban areas is inevitable given population increases worldwide and the transition from agricultural to industrial economies. Given that urbanization of almost any magnitude—even less than 10 percent impervious area—has been demonstrated to have an impact on in-stream water quality, a central question to be addressed is how water quality can be maintained as cities grow, without having negative impacts on social and economic systems. Ideally, SCMs would perform their water quality function, contribute to the livability of cities, and enhance their economic and social potentials.

Low-density, auto-oriented urban development, commonly known as sprawl, has been the predominant pattern of development in the United States, and increasingly worldwide, since World War II. It has been widely criticized for its inefficient use of land, its high use of natural resources, and its high energy costs—all of which are associated with the required auto-oriented travel. Additionally, ongoing economic costs related to the provision of widely dispersed services and social impacts of a breakdown in community life have been identified (Bruegmann, 2005). Sprawl and the impacts on in-stream water quality that result from urbanization have been an inevitable consequence of improved economic conditions. In the United States, sprawl constitutes the vast majority of development occurring today because a majority of the population is attracted to the benefits of a suburban lifestyle, government has subsidized roads and highways at the expense of public transit, and local zoning often limits de-

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velopment density.

There has been a great deal of innovation in city planning and design in the past decade that encourages greater density and a return to urban living. New types of zoning, New Urbanism, Smart Growth, and related innovations in urban planning and design have been developed in parallel with environmental regulations at local to national levels (see Chapter 2). They acknowledge the importance of protecting natural resources to maintain quality of life and have established water quality as an important consideration in city building.

It is not clear that current stormwater regulations can be effectively implemented over the broad range of development patterns that characterize contemporary cities or if they inadvertently favor one type of development over another. For example, on-site SMCs are often recommended as the preferred means of stormwater management, although they tend to encourage lower-density development patterns. And while they are easily implemented and regulated given the incremental, site-by-site development that is typical of most urban growth, monitoring and maintenance can be expensive and difficult for both the individual property owner and the regulating authority. In highly urbanized areas, they are often relegated to subsurface systems that are expensive and that, to be effective, require high levels of maintenance.

In newly developing areas, cluster development should be encouraged whenever possible, according to the Smart Growth principles of narrower streets, reduced setbacks, and related approaches to reduce the amount of impervious area required and land consumed. Furthermore, an interconnected series of on-site and consolidated SCMs can reduce subsurface stormwater piping requirements. Most planned communities have dedicated park and open-space areas that can constitute 25 percent or more of a development's total land area, making it feasible to easily accommodate consolidated SCMs (typically 8 to 10 percent of impervious area) within multi-functional open space and park lands. Cost efficiencies such as a 30 percent reduction in infrastructure costs (Duaney Plater-Zyberk & Company, 2006) can be realized through Smart Growth development techniques. Clustered housing surrounded by open space, laced with trails, has appreciated in value at a higher rate than conventionally designed subdivisions (Crompton, 2007).

In order to encourage infill or redevelopment over sprawl patterns of development, innovative zoning and other practices will be needed to prevent stormwater management from becoming onerous. For example, incentive zoning or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Innovations in governance and finance can also be used to incorporate consolidated SCMs into urban environments. For example, the City of Denver, in updating its Comprehensive Plan, designated certain underdeveloped corridors and districts in the city as "areas of change" where it hoped to encourage large-scale infill redevelopment. Given the scale of redevelopment, it would be feasible to establish special maintenance districts, allowing the development of consolidated SCMs that have multiple functions. To fund land purchase and facility design and construction, cash in lieu of pay-

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ments could be made.

Safety and Aesthetic Concerns

Vector-borne diseases, especially West Nile virus, are a concern when SCMs such as extended detention basins, constructed wetlands, and rain barrels are proposed. Furthermore, other SCMs that are poorly designed, improperly constructed, or inadequately maintained may retain water and provide an ideal breeding ground for mosquitoes, increasing the potential for disease transmission to humans and wildlife. Kwan et al. (2005) found that water-retaining SCMs increase the availability of breeding habitats for disease vectors and provide opportunistic species an extended breeding season. State Health Departments generally recommend that SCMs be designed to drain fully in 72 hours, which is the minimum time required for a mosquito to complete its life cycle under optimum conditions. In SCMs where there is permanent standing water, such as stormwater wetlands, there is the possibility of introducing biota that might prey on mosquitoes. Municipalities may have to consider the added cost of vector control and public health when implementing stormwater quality management programs.

With larger consolidated and regional extended detention facilities, concerns about the safety of children who may be attracted to such SCMs and ensuing liability must be considered. These SCMs need to be fenced off or otherwise designed appropriately to reduce the risk of drowning.

One aspect of stormwater management that is infrequently considered is the aesthetic appeal, or lack thereof, of SCMs. The visual qualities of SCMs are important because they are a growing part of the urban landscape setting. Although it can be assumed that landscapes that are carefully tended are often preferred over other types of landscapes, it depends substantially on one's point of view. For example, an engineer may consider a particular SCM that is functioning as expected to be beautiful in the sense that its engineering function has been realized, even though there is sediment buildup, algae, or other products of a properly functioning SCM visible. Similarly, a biologist or ecologist evaluating an ecologically healthy SCM in an urban context might find it to be beautiful because of its biological or ecological diversity, whereas another individual who evaluates the same SCM finds it to be "weedy." SCMs can be viewed as a means of restoring a degraded landscape to a state that might have existed before urban development. The desire to "return to nature" is a seductive idea that suggests naturalistic SCMs that may have very little to do with an original landscape, given the dramatic changes in hydrology that are inevitable with urban streams. Each of these widely varied views of SCMs may be appropriate depending on the context and the viewer.

A goal of stormwater management should be to make SCMs desirable and attractive to a broader audience, thereby increasing their potential for long-term effectiveness. For example, the Portland convention center rain gardens demon-

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strate how native and non-native wetland plantings can be carefully composed as a landscape composition and also provide for stormwater treatment. If context and aesthetics of a chosen SCM are poorly matched, there is a high probability that the SCM will be eliminated or its function compromised because of modifications that make its landscape qualities more appropriate for its context.

CONCLUSIONS AND RECOMMENDATIONS

SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. However, in very few cases has the performance of SCMs been mechanistically linked to the guaranteed sustainment at the watershed level of receiving water quality, in-stream habitat, or stream geomorphology. Many studies demonstrate that degradation in rivers is directly related to impervious surfaces in the contributing watershed, and it is clear that SCMs, particularly combinations of SMCs, can reduce the runoff volume, erosive flows, and pollutant loadings coming from such surfaces. However, none of these measures perfectly mimic natural conditions, such that the accumulation of these SCMs in a watershed may not protect the most sensitive beneficial aquatic life uses in a state. Furthermore, the implementation of SCMs at the watershed scale has been too inconsistent and too recent to observe an actual cause-and-effect relationship between SCMs and receiving waters. The following specific conclusions and recommendations about stormwater control measures are made.

Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds. SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.

Nonstructural SCMs such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.

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SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the "first flush" of contaminants. SCMs designed to remove this class of storms from surface runoff (runoff-volume-reduction SCMs—rainwater harvesting, vegetated, and subsurface) can also address larger watershed flooding issues.

Performance characteristics are starting to be established for most structural and some nonstructural SCMs, but additional research is needed on the relevant hydrologic and water quality processes within SCMs across different climates and soil conditions. Typical data such as long-term load reduction efficiencies and pollutant effluent concentrations can be found in the International Stormwater BMP Database. However, understanding the processes involved in each SCM is in its infancy, making modeling of these SCMs difficult. Seasonal differences, the time between storms, and other factors all affect pollutant loadings emanating from SCMs. Research is needed that moves away from the use of percent removal and toward better simulation of SCM performance. Hydrologic models of SCMs that incorporate soil physics (moisture, wetting fronts) and groundwater processes are only now becoming available. Research is particularly important for nonstructural SCMs, which in many cases are more effective, have longer life spans, and require less maintenance than structural SCMs. EPA should be a leader in SCM research, both directly by improving its internal modeling efforts and by funding state efforts to monitor and report back on the success of SCMs in the field.

Research is needed to determine the effectiveness of suites of SCMs at the watershed scale. In parallel with learning more about how to quantify the unit processes of both structural and nonstructural practices, research is needed to develop surrogates or guidelines for modeling SCMs in lumped watershed models. Design formulas and criteria for the most commonly used SCMs, such as wet ponds and grass swales, are based on extensive laboratory and/or field testing. There are limited data for other SCMs, such as bioretention and proprietary filters. Whereas it is important to continue to do rigorous evaluations of individual SCMs, there is also a role for more simple methods to gain an approximate idea about how SCMs are performing. The scale factor is a problem for watershed managers and modelers, and there is a need to provide guidance on how to simulate a watershed of SCMs, without modeling thousands of individual sites.

Improved guidance for the design and selection of SMCs is needed to improve their implementation. Progress in implementing SCMs is often

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handicapped by the lack of design guidance, particularly for many of the non-traditional SCMs. Existing design guidance is often incomplete, outdated, or lacking key details to ensure proper on-the-ground implementation. In other cases, SCM design guidance has not been disseminated to the full population of MS4 communities. Nationwide guidance on SCM design and implementation may not be advisable or applicable to all physiographic, climatic, and ecoregions of the country. Rather, EPA and the states should encourage the development of regional design guidance that can be readily adapted and adopted by municipal and industrial permittees. As our understanding of the relevant hydrologic, environmental, and biological processes increases, SCM design guidance should be improved to incorporate more direct consideration of the parameters of concern, how they move across the landscape, and the issues in receiving waters.

The retrofitting of urban areas presents both unique opportunities and challenges. Promoting growth in these areas is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, it is more complex than Greenfields development because of the need to upgrade existing infrastructure, the limited availability and affordability of land, and the complications caused by rezoning. These sites may be contaminated, requiring cleanup before redevelopment can occur. Both innovative zoning and development incentives, along with the selection of SCMs that work well in the urban setting, are needed to achieve fair and effective stormwater management in these areas. For example, incentive or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Publicly owned, consolidated SCMs should be strongly considered as there may be insufficient land to have small, on-site systems. The performance and maintenance of the former can be overseen more effectively by a local government entity. The types of SCMs that are used in consolidated facilities—particularly detention basins, wet/dry ponds, and stormwater wetlands—perform multiple functions, such as prevention of streambank erosion, flood control, and large-scale habitat provision.

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6
Innovative Stormwater Management and Regulatory Permitting

There are numerous innovative regulatory strategies that could be used to improve EPA's stormwater program. This chapter first outlines a substantial departure from the status quo, namely, basing all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries. Watershed-based permitting is not a new concept, but it has been attempted in only a few communities. Development of the new permitting paradigm is followed by more modest and easily implemented recommendations for improving the stormwater program, from a new plan for monitoring industrial sites to encouraging greater use of quantitative measures of the maximum extent practicable requirement. The recommendations in the latter half of the chapter do not preclude adoption of watershed-based permitting at some future date, and indeed they lay the groundwork in the near term for an eventual shift to watershed-based permitting.

WATERSHED PERMITTING FRAMEWORK FOR MANAGING STORMWATER

At its initial meeting in January 2007, the committee heard opinions that collectively pointed in a new direction for managing and regulating stormwater that would differ from the end-of-pipe approach traditionally applied by regulatory agencies under the National Pollutant Discharge Elimination System (NPDES) permits and be based instead on a watershed framework. Indeed, the U.S. Environmental Protection Agency (EPA) has already given substantial thought to watershed permitting and issued a Watershed-Based NPDES Permitting Policy Statement (EPA, 2003a) that defined watershed-based permitting as an approach that produces NPDES permits that are issued to point sources on a geographic or watershed basis. It went on to declare that, "The utility of this tool relies heavily on a detailed, integrated, and inclusive watershed planning process. Watershed planning includes monitoring and assessment activities that generate the data necessary for clear watershed goals to be established and permits to be designed to specifically address the goals."

In the statement, EPA listed a number of important benefits of watershed permitting:

- More environmentally effective results;
- Ability to emphasize measuring the effectiveness of targeted actions on improvements in water quality;

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- Greater opportunities for trading and other market-based approaches;
- Reduced cost of improving the quality of the nation's waters;
- More effective implementation of watershed plans, including total maximum daily loads (TMDLs); and
- Other ancillary benefits beyond those that have been achieved under the Clean Water Act (e.g., integrating CWA and Safe Drinking Water Act [SDWA] programs).

Subsequent to the policy statement, EPA published two guidance documents that lay out a general process for a designated state that wishes to set up any type of permit or permits under CWA auspices on a watershed basis (EPA, 2003b, 2007a). It also outlined a number of case studies illustrating various kinds of permits that contain some watershed-based elements. Box 6-1 describes in greater detail the more recent report (EPA, 2007a) and its 11 "options" for watershed-based permitting. Unfortunately, the EPA guidance is lacking in its description of what constitutes watershed-based permitting, who would be covered under such a permit, and how it would replace the current program for municipalities and industries discharging stormwater under an individual or general NPDES permit. Few examples are given, some of which are not even watershed-based, with most of the examples involving grouping municipal wastewater treatment works under a single permit with no reference to stormwater. Most of the 11 options are removed from the fundamental concept of watershed-based permitting. Finally, the guidance fails to elaborate on the policy statement goal to make water quality standards watershed-based. The committee concluded that, although the EPA documents lay some groundwork for watershed-based permitting—especially the ideas of integrated municipal permits, water quality trading, and monitoring consortia—the sum total of EPA's analysis does not define a framework for moving toward true watershed-based permitting. The guidance attends to few of the details associated with such a program and it has made no attempt to envision how such a system could be extended to the states and the municipal and industrial stormwater permittees. This chapter attempts to overcome these shortcomings by presenting a more comprehensive description of watershed-based permitting for stormwater dischargers.

The approach proposed in this chapter fits within the general framework outlined by EPA but goes much further. First, it is intended to replace the present structure, instead of being an adjunct to it, and to be uniformly applied nationwide. The proposal adopts the goal orientation of the policy statement and then extends it to root watershed management and permitting in comprehensive objectives representing the ability of waters to actually support designated beneficial uses. The proposal builds primarily around the integrated municipal permit concept in the policy statement and technical guidance. Like EPA's outline, the committee emphasizes measuring the effectiveness of actions in bringing improvements, but goes on from there to recommend a set of monitoring activi-

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BOX 6-1
EPA's Current Guidance on Watershed-Based Permitting

Rather than explicitly define watershed based permitting, the EPA's recent guidance (EPA, 2007a) groups a large number of activities as having elements of watershed-based permitting, and defines how each might be utilized by a community. They are

- NPDES permitting development on a watershed basis,
- Water quality trading,
- Wet weather integration,
- Indicator development for watershed-based stormwater management,
- TMDL development and implementation,
- Monitoring consortium,
- Permit synchronization,
- Statewide rotating basin planning,
- State-approved watershed management plan development,
- Section 319 planning, and
- Source water protection planning.

Taking these topics in order, the first option is generally similar to that in EPA (2003a,b), but with some more detail on possible permitting forms. "Coordinated individual permits" implies that individual permits would be made similar and set with respect to one another and to a holistic watershed goal. The nature of such permits is not fully described, and there are no examples given. An "integrated municipal permit," also presented in the earlier policy statement, would place the disparate individual NPDES permits in a municipality (e.g., wastewater plants, combined sewer overflows, municipal separate storm sewer systems [MS4s]) under one permit. However, such a permit is not necessarily watershed-based. Finally, the "multi-source permit" could go in numerous directions, none of which are described in detail. In one concept, all current individual permittees who discharge a common pollutant into a watershed would come under one new individual permit that regulates that pollutant, while keeping the existing individual permits intact for other purposes. The Neuse River Consortium is given as an example. Alternatively, a multi-source permit could cover all dischargers of a particular type now falling under one individual permit that regulates all of their pollutants (no examples are given). In yet another application, this permit could be a general permit, and it would be identical to the existing general permits, except that it would be organized along watershed boundaries. As above, it could be refined on the basis of pollutant or discharger type.

The other ten options are more distant from the fundamental concept of watershed-based permitting. The water quality trading description is minimal, though it does mention a new EPA document that gives guidance to permittees for trading. Wet weather integration, the third topic, can mean any number of things, from creating a single permit to cover all discharges of pollutants during wet weather in a municipality, as described above for "coordinated individual permits," to just having all the managers of the systems get together and strategize. Although a stated goal is to reduce the amount of water in the sewer system after a storm, this integration is not particularly well defined in the document, nor is it well differentiated from other activities that would normally occur under an MS4 permit.

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BOX 6-1 Continued

Indicator development for watershed-based stormwater management refers to identifying indicators that are better than one or a few pollutants at characterizing the degree of impairment wrought by stormwater. Stormwater runoff volume is one indicator being developed by Vermont, and percent impervious surface is another. As discussed in Chapter 2, some states have long used biological indicators that integrate the effects of many pollutants as well as physical stresses such as elevated flow velocities. Indicators can be used as TMDL targets or as goals in NPDES permits. Identifying and adopting indicators is, essentially, a prerequisite to implementing some of the other options listed above.

Regarding the next topic on the list, the option of TMDL development is obvious, since the TMDL program is by definition watershed based. If it can be made the highest priority, and if stormwater is a contributor, then the implementation plan can be an excellent way to combat stormwater pollution on a watershed basis. Reducing the contribution of the pollutant from a stormwater source can involve water quality trading, better enforcement of existing permits, or creating new watershed-based permits. Hence, again, there is considerable overlap with the previously discussed options.

Developing a monitoring consortium is an option that works when sufficient data are not available to do much else. The concept mainly refers to monitoring of ambient waters. The activity is shared among partners (e.g., all wastewater plants in a region), with the goal of collecting and analyzing enough data to improve management decisions on a watershed basis, instead of for a single plant.

The following topic, permit synchronization, refers to having all permits within a watershed expire and be renewed simultaneously. This approach could be helpful for streamlining administrative, monitoring, and management tasks associated with maintaining the permits. Some states have operated in this way, whereas others have decided not to. It is one way to coordinate permits in cases where other types of watershed-based permitting would not work. Similarly, the statewide rotating basin approach, used by many states, relies on a five-year cycle. The state is divided into major watersheds, and each watershed is in a different stage of the cycle every year. It is a way to distribute the workload such that there is never a year when, for example, every watershed would require monitoring. Since it is a statewide program, how it relates to a watershed-based permitting situation is not at all clear.

ties designed to support active adaptive management to achieve objectives, aswell as to assess compliance. Credit trading, indicator development, the rotating basin approach, and monitoring should be part of management and permitting programs within watersheds, and ideas are advanced to develop these and other elements.

In addition to building on the work of EPA, the proposed approach tackles many of the impediments to effective watershed management identified in the National Research Council (NRC) treatise on watershed management (NRC, 1999). That report noted that watershed approaches are easiest to implement at the local level; thus, the approach developed in this chapter is a bottom-up process in which programmatic responsibility lies mainly with municipalities. Because the natural boundaries of watersheds rarely coincide with political jurisdictions, watersheds as geographic areas are less useful for political, institutional, and funding purposes, such that initiatives and organizations directed at watershed management should be flexible. The proposed approach recognizes this reality and makes numerous suggestions for pilot testing, funding, and institutional arrangements that will facilitate success. Finally, NRC (1999) notes the

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With regard to the next topic, there has been a great deal of watershed planning around the nation and tremendous variety in form and comprehensiveness. Plans generally contain some information on the state of the watershed, goals for the watershed, and activities to meet those goals. Development of such plans in areas that do not have them could facilitate watershed-based permitting by providing much needed information about conditions, sources of pollutants, and methods to reduce pollution. According to EPA, a watershed plan may or may not indicate the need for watershed-based permitting.

The Section 319 Program refers to voluntary efforts to reduce pollution from nonpoint sources. The program in and of itself is not relevant to NPDES permits, since it deals strictly with activities that are not regulated. However, these activities could be traded with more traditional stormwater practices as part of a watershed-based effort to reduce overall pollution reaching waterbodies. Many watershed plans must consider guidance for the 319 program in order to get funding for their management activities.

If the watershed in question contains a drinking water source (either surface water or groundwater), then a good source water protection plan can have a significant impact on NPDES permitting in a watershed. Information collected during the assessment phase of source water protection could be used to help inform watershed-based permitting. Also, NPDES permits could be rewritten taking into account the proximity of discharges to source water intakes.

Following its coverage of the 11 options, EPA (2007a) gives a hypothetical example of picking six of the options to develop permitting for a watershed. It discusses how the options might be prioritized, but in a very qualitative manner, according to considerations such as availability of funding and personnel, stakeholder desires, environmental impacts, and sequencing of events. Chapter 1 of the report ends with a list of performance goals that might apply to the 11 options.

Chapter 2 further explains the multi-source watershed-based permit, discussing, for example, who would be covered by it, who would administer it, and how credit trading fits in. The chapter has a lot of practical, although quite intuitive, information about how to write such a permit. Much of the decision making is left to the permit writer. There are discussions of effluent limitations, monitoring requirements, reporting and record keeping, special conditions, and public notice. Chapter 3 follows by presenting case studies, although fewer than appeared in 2003 and not all truly watershed based.

need to "develop practical procedures for considering risk and uncertainty in real world decision-making in order to advance watershed management." The proposed revised monitoring system presented later in this chapter is designed to provide information in the face of ongoing uncertainty, i.e., adaptive management in a permitting context.

Watershed Management and Permitting Issues

There are many implications of redirecting the stormwater management and regulatory system from a site-by-site, SCM-by-SCM approach to an emphasis on attainment of beneficial uses throughout a watershed. Most fundamentally, the program's focus would shift to a primary concentration on broad goals in terms of, for example, achieving a targeted condition in a biological indicator associated with aquatic ecosystem beneficial uses or no net increase in elevated

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flow duration. Application of site-specific stormwater control measures (SCMs) would no longer constitute presumptive evidence of permit compliance, as is often the case in permits now, although it would still be an essential means to meeting goals. Achieving those goals, however, would form the compliance criteria.

In recognition of the demonstrated negative effects of watershed hydrologic modification on the attainment of beneficial uses, the proposal steps beyond the generally prevailing practice by embracing water quantity as a concern along with water quality. The inclusion of hydrology is consistent with the CWA on several grounds. First, elevated runoff peak flow rates and volumes increase erosive shear stress on stream beds and banks and directly contribute particulate pollutants to the flow (such as suspended and settleable solids, as well as nutrients and other contaminants bound to the soil material). Conversely, reduced dry-weather flows often occur in urban streams as a result of lost groundwater recharge and tend to concentrate pollutants and, hence, worsen their biological effects. Moreover, pollutant mass loading is the product of concentration and flow volume, and thus increased wet-weather surface runoff directly augments the cumulative burden on receiving waters. Finally, regulatory precedent for incorporating hydrology exists, as demonstrated by Vermont's stormwater program (LaFlamme, 2007).

At this time, stormwater management and regulation are divorced from the management and regulation of municipal and industrial wastewater. A true watershed-based approach would incorporate the full range of municipal and industrial sources, including (1) public streets and highways; (2) municipal stormwater drainage systems; (3) municipal separate and combined wastewater collection, conveyance, and treatment systems; (4) industrial stormwater and process wastewater discharges; (5) private residential and commercial property; and (6) construction sites. These many sources represent an array of uncoordinated permits under the current system and a strong challenge to developing a watershed-based approach. As pointed out in Chapter 2, multi-source considerations are an implicit facet of TMDL assessments, wherein states must consider both point and nonpoint sources. EPA (2003b) identified, among other possible permit types, an Integrated Municipal NPDES Permit, which would bundle all requirements for a municipality (e.g., stormwater, combined sewer overflows, biosolids, pretreatment) into a single permit. The Tualatin River watershed in Oregon has faced this challenge, at least in part, through an innovative watershed permit that combines both wastewater treatment and stormwater, brings in management of agricultural contributions to thermal pollution, and allows for pollutant trading among sources (see Box 6-2). It appears that the various participating parties did not use their energies in trying to allocate blame but instead determined the most effective and efficient ways of improving conditions. For example, the municipal permittees willingly offered incentives to agricultural landowners to plant riparian shade trees as an alternative to more expensive means of reducing stream temperatures under their direct control. Indeed, with agriculture not being regulated by the Clean Water Act, watershed permitting

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BOX 6-2
Watershed-Based Permitting in Oregon

Clean Water Services is a wastewater and stormwater utility that covers a special service district of 12 cities and unincorporated areas in urban Washington County, Oregon. It was originally chartered in the 1970s as the Unified Sewerage Agency to consolidate the management of 26 "package" wastewater treatment facilities. Its responsibilities expanded to stormwater management in the early 1990s and it now serves nearly 500,000 customers. There are four wastewater treatment plants (WWTPs) in the district, with a dry weather capacity of 71 million gallons per day (MGD). During low-flow months, the discharge from these plants can account for 50 percent of the water in the Tualatin River. The district also own rights to one-quarter of the stored water in Hagg Lake. The land use in the watershed is about one-third urban, one-third agriculture, and one-third forest.

In 2001, the region was faced with TMDLs on the Tualatin River or its tributaries for total phosphorus, ammonia, temperature, bacteria, and dissolved oxygen. By 2002, the area was also dealing with four expired NPDES permits and one expired MS4 permit (all of which had been administratively extended), approval of a second TMDL, and an Endangered Species Act (ESA) listing. The region decided that it wanted to try to integrate all of these programs using a watershed-based regulatory framework. This would include a TMDL implementation mechanism, an ESA response plan, and integrated water resources management (meaning that water quantity, water quality, and habitat considerations would be made at the same time). Prior to integration, water quality was covered by the TMDL and NPDES programs, but these programs did not cover water quantity and habitat issues. The ESA listing addressed the habitat issues, but it was done totally independently of the TMDLs and NPDES permits.

Thus, the region applied for an integrated municipal NPDES permit that bundles all NPDES permit requirements for a municipality into a single permit, including publicly owned treatment works (POTWs), pretreatment, stormwater, sanitary sewer overflows, and biosolids. Initially, it encompassed the four WWTP permits, the one MS4 permit, and the industrial and construction stormwater permits. The hope was that this would streamline multiple permits and capture administrative and programmatic efficiencies; provide a mechanism for implementing more cost-effective technologies and management practices including water quality credit trading; integrate watershed management across federal statutes such as the CWA, SDWA, and ESA; and encourage early and meaningful collaboration and cooperation among key stakeholders.

This case study was successful because a single entity—Clean Water Services—was already in charge of what would have otherwise been a group of individual permittees. Furthermore, all the NPDES permits had expired and the TMDL had just been issued, providing a window of opportunity. The state regulatory agency was very willing, and EPA provided a $75,000 grant. Finally, there was a robust water quality database and modeling performed for the area because of the previous TMDL work. The watershed-based permit, the first in the nation, was issued February 26, 2004. Among its unique elements are an intergovernmental agreement companion document signed by the Oregon Department of Environmental Quality (DEQ), water quality credit trading, and consolidation of reporting requirements. The water quality trading is one of the most interesting elements, and several variations have been attempted. Biological oxygen demand (BOD) and NH_3 have been traded both intra-facility and inter-facility.

The temperature TMDL on the Tualatin River is a particularly interesting example of trading because it helped to bring agriculture into the process, where it would otherwise not have been involved. Along the length of the river, there are portions that exceed the temperature standard. A TMDL allocation was calculated that would lower temperatures by the

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BOX 6-2 Continued

same amount everywhere, such that there would be no point along the river that would be in exceedance. Options for reducing temperature include reducing the influent wastewater temperature (which is hard to do), reducing the total WWTP discharge to the Tualatin River (which is not practical), mechanically cooling or refrigerating WWTP discharge (which would require more energy), or trading the heat load via flow augmentation and increased shading (which is what was attempted).

Clean Water Services choose to utilize a market-based, watershed approach to meet the Tualatin temperature TMDL. It was market-based because it had financial incentives for certain groups to participate, it was cost-effective, and it provided ancillary ecosystem services. It was a watershed-based approach because it capitalized on the total assimilative capacity of the basin. What was done was to (1) provide cooling and in-stream flow augmentation by releasing water from Hagg Lake Reservoir, and (2) trade riparian stream surface shading improvement credits. They also reused WWTP effluent in lieu of irrigation withdrawals. For the riparian shading, they developed an "enhanced" CREP program to increase the financial incentives to rural landowners (with Clean Water Services paying the difference over existing federal and state programs). Clean Water Services also made incentive payments to the Soil and Water Conservation District to hire people to act as agents of Clean Water Services. Oregon DEQ's Shadalator model was used to quantify thermal credits for riparian planting projects, which required that information be collected at 100-foot increments along the stream on elevation, aspect, wetted width, Nordfjord-Sogn Detachment Zone, channel incision, and plant type and planting corridor width. To summarize, over the five-year term of the permit, Clean Water Services will release 30 cfs/d of stored water from Hagg Lake each July and August and shade roughly 35 miles of tributary riparian area (they have already planted 34 miles of riparian buffer). This plan involved an element of risk taking, since the actions of unregulated parties (such as farmers) have suddenly become the responsibility of Clean Water Services.

and initiatives of this type represent the best, and perhaps only, mechanism for ameliorating negative effects of agricultural runoff that, left unattended, would undo gains in managing urban runoff. The Neuse River case study, discussed later in this chapter, is another example of bringing agricultural contributions to aquatic degradation under control, along with urban sources, through a watershed-based approach.

Significant disadvantages of the current system of separate permits for municipal, construction, and industrial activities are (1) the permits attack the problem on a piecemeal basis, (2) they are hard to coordinate because they expire at different times, (3) they are not designed to allow for long-term operation of SCMs, and (4) they do not cover all discharges. A solution to these problems would be to integrate all discharge permitting under municipal authority, as is proposed here. The lead permittee and co-permittees would bear ultimate responsibility for meeting watershed goals and would regulate all public and private discharges within their jurisdictions to attain them. Municipalities are the natural focus for this role because they are the center of land-use decisions throughout the nation.

Municipalities must be provided with substantially greater resources than they have now to take on this increased responsibility. Beyond funding, regula-

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tory responsibilities must be realigned to some degree. The norm now is for states to administer industrial permits directly and generally attend to all aspects of permit management. However, states, more often than not, are unable because of resource limitations to give permittees much attention in the form of inspection and feedback to ensure compliance. At the same time, some states, explicitly or implicitly, expect municipal permittees to set up programs to meet water quality standards in the waters to which all land uses under their jurisdictions discharge.[1] It only makes sense in this situation to have designated states (or EPA for the others) specify criteria for industrial and construction permits but revise regulations to empower and support municipal co-permittees in compliance-related activities. This paradigm is not unprecedented in environmental permitting, as under the Clean Air Act, states develop state implementation plans for implementation by local entities. For this new arrangement to work, states would have to be comfortable that municipalities could handle the responsibility and be able to exercise the added authority granted. The committee's opinion is that municipalities generally do have the capability, working together as co-permittees with a large-jurisdiction lead permittee and with guidance and support from states.

It bears noting at the outset that the proposed new program would not reduce the present system's reliance on general permits. Whereas a general permit now can be issued to a group of municipalities having differing circumstances, under the new system a permit could just as well be formulated in the same way for a group of varying watersheds. General industrial and construction permits would be just as prevalent too.

Toward Watershed-Based Permitting

Watershed-based permitting is taken in this report to mean regulated allowance of discharges of water and wastes borne by those discharges to waters of the United States, with due consideration of (1) the implications of those discharges for preservation or improvement of prevailing ecological conditions in the watershed's aquatic systems, (2) cooperation among political jurisdictions sharing a watershed, and (3) coordinated regulation and management of all discharges having the potential to modify the hydrology and water quality of the watershed's receiving waters.

[1] For example, the second Draft Ventura County [California] Municipal Separate Storm Sewer System Permit states (under Findings D. Permit Coverage), "Provisions of this Order apply to the urbanized areas of the municipalities, areas undergoing urbanization and areas which the Regional Water Board Executive Officer determines are discharging storm water that causes or contributes to a violation of a water quality standard … ." The permit further states (under Part 2—Receiving Water Limitations), "1. Discharges from the MS4 that cause or contribute to a violation of water quality standards are prohibited. … 3. … This Order shall be implemented to achieve compliance with receiving water limitations. If exceedence(s) of water quality objectives or water quality standards persist … the Permittee shall assure compliance with discharge prohibitions and receiving water limitations … ."

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Determining Watershed Scale for Permitting

A fundamental question that must be answered at the outset of any move to watershed permitting is, What is a watershed? Hydrologically, a watershed is the rain catchment area draining to a point of interest. Hence, the question comes down to, Where should the point of interest be located to define watersheds for permitting purposes? If placed close to the initial sources of surface runoff (e.g., on each first-order stream just above its confluence with another first-order stream), attention would be very specifically directed. However, there would be little flexibility to devise solutions for the greatest good. For example, trading of the commodities runoff quantity and quality would be very restricted. If on the other hand the point of interest is placed far downstream, thus defining a very large watershed, a welter of issues, and probably also of involved jurisdictions, would overly confuse the management and regulatory task.

The U.S. Geological Survey (USGS) delineates watersheds in the United States using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloging units. These hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). USGS identifies each hydrologic unit by a unique hydrologic unit code (HUC) consisting of 2 to 16 digits based on the four levels of classification in the hydrologic unit system. Watersheds thus delineated are typically of the order a few square kilometers in area. This system is now being linked to the National Hydrography Dataset (NHD) and the National Land Cover Dataset to produce NHDPlus, an integrated suite of application-ready geospatial datasets.

The USGS system provides a starting point. Ultimately, though, what constitutes a watershed will best be answered with reference to specific biogeophysical conditions and problems and by personnel at relatively close hand (i.e., state or regional oversight agency staff). A general guideline might be the catchment area of a waterbody influenced by a set of similar subwatersheds. Similar subbasins would presumably be amenable to similar solutions and trading off reduced efforts in some places for compensating additional efforts elsewhere, as well as to analysis and monitoring on a representative basis, instead of exhaustively throughout. Often, a watershed defined in this way would flow into another watershed and influence it. Thus, there would have to be coordination among managers and regulators of interacting watersheds. It would be common for several watersheds ranging from relatively small to large in scale to be nested. Each would have its management team, and a committee drawn from those teams should be formed to coordinate goals and actions.

A prerequisite to moving toward watershed permitting, then, is for states or regions within states to delineate watersheds. California took this step early in the NPDES stormwater permitting process and offers a model in this respect, as well as in encompassing all jurisdictions coordinated by a lead permittee. First, the state organized its California EPA regional water boards on a watershed ba-

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sis. Furthermore, since 1992 it has been common in California to establish one jurisdiction as the lead permittee (e.g., Los Angeles County in the Los Angeles region, Orange County in the Santa Ana Region, and San Diego County in the San Diego Region) and all of the politically separate cities as co-permittees. The lead permittee has typically been the jurisdiction most widely distributed geographically in the region and large enough to develop compliance mechanisms and coordinate their implementation among all participants. Box 6-3 describes the approach taken to delineating management units within the Chesapeake Bay watershed, which comprises parts of Pennsylvania, Maryland, Virginia, and the District of Columbia. The case study illustrates well the approach advocated here of focusing on the outcome in the receiving water and considering all aspects of land and water resources management that determine that outcome.

Steps Toward Watershed-Based Permitting

Once a watershed is defined, a further question arises regarding how much and what part of its territory to cover formally under permit conditions. Under the present system substantial development occurring outside Phase I or Phase II municipal jurisdictions is escaping coverage. Failing to control relatively high levels of development both outside a permitted jurisdiction and upstream of more lightly developed areas within a permitted area is particularly contrary to the watershed approach. Areas having a more urban than rural character are already essentially treated as urban in water supply and sewer planning, and the same should occur in the area of stormwater management. Accordingly, the permit should extend to any area in the watershed, even if outside Phase I or II jurisdictions, zoned or otherwise projected for development at an urban scale (e.g., more than one dwelling per acre). States do have authority under the CWA to designate any area for Phase II coverage based on projected growth or the presence of impact sources. They should be required to do so for nationwide uniformity and best protection of water resources.

It is essential to clarify that watershed-based permitting as formulated in this chapter differs sharply from what has been termed watershed (or basin) planning. According to EPA, watershed planning "identifies broad goals and objectives, describes environmental problems, outlines specific alternatives for restoration and protection, and documents where, how, and by whom these action alternatives will be evaluated, selected, and implemented" (*http://www.epa.gov/watertrain/planning/planning7.htm*). Drawing up such a plan is a time-consuming process, which has often become an end in itself, instead of a means to an end. Completing a full watershed plan, as usually construed, should not be a prerequisite to watershed-based permitting. Rather, the anticipated process would spring much more from comprehensive, advanced scientific and technical analysis of the water resources to be managed and their contributing catchment areas than from a planning framework.

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BOX 6-3
Watershed Delineation for the Chesapeake Bay

The "Tributary Strategy Team" approach of the Chesapeake Bay Watershed provides a specific example of a watershed-scale approach to implementation of water quality control measures. Some background on this longstanding program is first provided, before turning to how watersheds were delineated. In 1983, the states of Virginia, Maryland, and Pennsylvania; the District of Columbia; and EPA signed an agreement to form the Chesapeake Bay Program with a goal to restore and protect the bay, which was suffering from nutrient overenrichment, severely reduced submerged aquatic vegetation, and contamination by toxics. In 1987 the program established a target of a 40 percent reduction in the amount of nutrients entering the Bay by 2000. In 1992 the bay program partners agreed to continue the 40 percent reduction goal beyond 2000 by allocating nutrient reduction targets to the bay's tributaries. In Chesapeake 2000, the most recent version of the Chesapeake Bay agreement, the nutrient reduction goals were reaffirmed, and an additional goal of sediment reduction was established. New York, Delaware, and West Virginia, locations of the bay's headwaters, also became involved in nutrient and sediment reduction. Cap load allocations for nutrients (nitrogen and phosphorus) and sediment to be reached by 2010 were agreed upon by the states. The states began developing 36 voluntary watershed-based tributary strategies to meet the state cap load allocations covering the entire 64,000-square-mile Chesapeake Bay watershed.

Watershed-based tributary strategies are developed in cooperation with local watershed stakeholders. For rural areas, where stakeholders include farmers, nutrient strategies include promotion of management practices such as maintaining cover crops on recently harvested cropland to reduce soil erosion, reduction in nitrogen applications, conservation tillage, and establishment of riparian buffers. For urban-area stakeholders such as homeowners and municipalities, tributary strategies include practices such as enhanced nutrient removal at WWTPs, low-impact development (LID) practices, erosion and sediment control practices, and septic system upgrades.

The first cut at delineating the watershed, which was based on hydrography and topography, defined the eight major areas draining to the Chesapeake Bay: six major basins (Susquehanna, Potomac, York, James, Rappahannock, and Patuxent) plus smaller areas not draining to a major river on the Eastern and Western Shores of the bay in Maryland. These subdivisions are disparate with respect to size (the Susquehanna can engulf almost the entire other seven), but direct drainage to the bay was the criterion at this level.

The next cut was made at state borders. For example, the Susquehanna traverses three states and was subdivided at the New York–Pennsylvania and Pennsylvania–Maryland political boundaries. Further cuts were subsequently made within some states. The criteria for these cuts varied from state to state, but generally involved a combination of smaller political jurisdictions (e.g., county, township), subwatershed basin borders, and other local considerations, such as local interest and investment (e.g., watershed associations).

The resulting delineations are highly variable in size but apparently satisfactory to the local parties who decided on the areas. They represent individual "tributary strategy areas" but are also nested within the larger eight designations and involve interjurisdictional and interstate coordination where a subbasin is divided by a political boundary. Although the example of the Chesapeake Bay is at a very large scale, the principles of watershed delineation it illuminates apply at all scales.

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Effective watershed-based permitting as outlined in this report is composed of:

- Centralizing responsibility and authority for implementation with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees;
- Adopting a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses within the watershed's component waterbodies;
- Assessing waterbodies that are not providing designated beneficial uses in order to set goals aimed at recovering these uses;
- Defining careful, complete, and clear specific objectives to be achieved through management and permitting;
- Comprehensive impact source analysis as a foundation for targeting solutions;
- Determining the most effective ways to isolate, to the extent possible, receiving waterbodies from exposure to those impact sources;
- Developing and appropriately allocating funding sources to enable the lead permittee and partners to implement effectively;
- Developing a monitoring program composed of direct measures to assess compliance and progress toward achieving objectives and diagnosing reasons for the ability or failure to meet objectives, in support of active adaptive management; and
- Developing a market system of trading credits as a tool available to municipal co-permittees to achieve watershed objectives, even if solutions cannot be uniformly applied.

The system proposed herein is a significant departure from the road traveled in the 20 years since CWA amendments began to bring stormwater under direct regulation. This reorganization is necessary because of the failure of the present system to achieve widespread and relatively uniform compliance (see Chapter 2) and, ultimately, to protect the nation's water resources from degradation by municipal, industrial, and construction runoff. The workload associated with adopting this approach will be considerable and will take some time to complete. The structure of the new program should be fully in place within five years, which is considered to be a reasonable period to complete the work. It could be fully implemented throughout the nation within ten years. However, interim measures toward its fulfillment should occur sooner, within one to two years. Such measures should be applied to each land-use and impact-source category (i.e., existing residential and commercial development, existing industry, new development, redevelopment, construction sites). For example, measures such as an effective impervious area limit or a requirement to maintain predevelopment recharge to the subsurface zone could make early progress in man-

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aging new development, and lead toward the ultimate, objective-based management and permitting strategy for that category. Advanced source control performance standards would be appropriate interim measures for existing development.

One innovative approach to watershed-based management that can ease the burden of the proposed new system is the rotating basin approach. As described by EPA (2007a), this option entails delineating state watershed boundaries and grouping the watersheds into basin management units, usually by the state water pollution control agency. Next, states implement a watershed management process on a rotating schedule, which is usually composed of five activities: (1) data collection and monitoring, (2) assessment, (3) strategy development, (4) basin plan review, and (5) implementation. Over time, different waterbodies are intensively studied as part of the rotation. Data collected can be used to support a number of different reporting and planning requirements, including a finding of attainment of water quality standards, a determination of impairment, or possible delisting if the waterbody is found not to be impaired. Florida offers a good example of the rotating basin approach. The Florida Department of Environmental Protection has defined five levels of intensity, or phases, each taking about one year to complete, and it has divided the state into 30 areas based on HUCs. At any one time six areas are in each phase before rotating to a subsequent phase. This division of effort would help alleviate the burden of moving to a new system of watershed-based permitting by programming the work over a period of years. It could certainly be organized on a priority basis, in which the watersheds of greatest interest for whatever reason (e.g., having the highest resource values, being most subject to new impacts) would get attention first.

An Objective-Based Framework

The proposed framework for watershed-based management and regulation of stormwater relies on broad goals to retain and recover aquatic resource beneficial uses, backed by specific objectives (e.g., water quality criteria) that must be achieved if the goals are to be fulfilled. Meeting the objectives and overarching goals is intended to become the basis for determining permit compliance, instead of the current reliance on implementation of SCMs as presumptive evidence of compliance.

The broad goals of retaining and recovering beneficial uses are entirely consistent with the antidegradation clause of the CWA. Antidegradation means that the current level of water quality shall be maintained and protected, unless waters exceed levels necessary for maintaining their beneficial uses *and* the state finds that allowing lower water quality is necessary to accommodate important economic or social development. In accordance with the antidegradation clause, a major pillar of the proposed concept is the goal of preventing degradation from the existing state of biological health, whatever it may be, to a lower state. Thus, fully and nearly pristine watersheds are to remain so and, at a minimum,

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partially or highly impaired ones are to suffer no further impairment. Beyond this minimum, impaired waters should be assessed to determine if feasible actions can be taken to recover lost designated beneficial uses or at least improve degraded uses.

As discussed in Chapter 2, beneficial uses relate to the social and ecological services offered, or intended to be offered, by waterbodies. For example, California has 20 categories of beneficial uses embracing water supply for various domestic, agricultural, and industrial purposes; provision of public recreation; and support of aquatic life and terrestrial wildlife (CalEPA, Central Coast Regional Water Board Basin Plan). That beneficial uses are usually assigned at the state level by waterbody classes or specific waterbodies would not change under the proposed permitting program revision. Most waters have several beneficial uses encompassing some water supply and ecological functions and, perhaps, some form of recreation. Unlike most current stormwater programs where attainment of beneficial uses is only implicit, these goals would become explicit in the altered system and officially promulgated by the authority operating the permit program (a designated state, in most cases, or EPA). The permitting authority would then partner with municipal permittees to determine the conditions that must be brought to bear to attain beneficial uses, set objectives or criteria to establish those conditions, and follow through with the tasks to accomplish objectives.

The proposed framework's reliance on achieving objectives that reflect the cumulative aquatic resource effects of contributing watershed conditions suggests the following related concepts:

- In whatever manner watershed boundaries are set, the full extent of the watershed from headwaters onward should be considered in defining objectives. This is important even where watershed scale and boundaries are based on local and/or regional hydrogeomorphic circumstances and their associated management and regulatory needs. Watersheds can and often will be defined and nested at different scales (e.g., streams tributary to a lake, a river flowing into an estuary or marine bay).

- The scale of objectives must be consistent with the scale and recognized beneficial uses of the watershed(s) in question; for example, sustaining salmonid fish spawning could be the basis for a stream objective, while retaining an oligotrophic state could be the essential objective for a lake to which the stream is tributary.

- Whenever beneficial uses pertain to living organisms (aquatic life or humans), representing the vast majority of all cases, objectives should be largely in biological terms. That is not to say that supplementary objectives cannot be stated otherwise (e.g., in terms of flow characteristics, chemical water quality constituents, or habitat attributes), but the ultimate direct thrust of the program

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should be toward the biota.

- Objectives must be carefully chosen to represent attributes of importance from a resource standpoint, limited in number for feasibility of tracking achievement, and defined in a way that achievement can be measured. For example, nitrogen is generally the nutrient limiting algal growth in saline systems and in excess it stimulates growth that can reduce dissolve oxygen, killing fish and other aerobic organisms. In this case the most productive objectives would probably target reduction of nitrogen concentration and mass flux and maintenance of dissolved oxygen. For waterbodies designated for contact recreation, fecal coliform indicators (although not directly pathogenic when waterborne) have proven to be an effective means of assessing condition and should continue to form the basis for objectives to protect contact recreation until research produces superior measures. If drinking water supply is a designated beneficial use of a lake, it will better serve that function in a lower than a higher state of eutrophication, which can be managed, according to a long limnological research record, by restricting water column chlorophyll *a* as an objective. Where the beneficial use is fish protection and propagation, biological criteria might include (1) maintenance of a specific population size of a resident fish species when that species' population can be assayed conveniently; (2) maintenance of a numerical index (e.g., benthic index of biotic integrity) when a fish species of ultimate interest cannot be assessed so conveniently but is known or reasonably hypothesized to be associated with the index; or (3) a related parameter, such as eelgrass beds, which are important fish nursery areas in estuarine waters, such that areal coverage by these beds would be an appropriate objective to track over time. An intermittent waterbody could have biological criteria related to, for example, fish migration or amphibian reproduction.

- The achievement of objectives, or lack thereof, is the basis for follow-up and prescription of remedies in an active adaptive management mode; that is, falling short of objectives would trigger a search for reasons throughout the watershed, followed by identification of actions necessary and sufficient to remedy the shortfall, assessment of their ability to reach objectives, and the cost of doing so. In the course of this assessment it may be concluded that the objective itself is faulty and should be restated, replaced, or discarded.

Basing the watershed framework principally on biological objectives grows out of the CWA's fundamental charge to protect the biological (as well as physical and chemical) integrity of the nation's waters. The tie between specific physical and chemical conditions and the sustenance of aquatic biological communities is not well established through an extensive, well-verified body of research. Moreover, living organisms consuming or living in water are subject to a vast multitude of simultaneous physical and chemical agents having the potential to harm them individually and interactively. There are no realistic prospects

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for research to determine the levels of these numerous agents that must be maintained to support beneficial uses. Therefore, their integrative effects must be determined using measures of biological populations or communities of interest.

By and large, state water quality standards as now promulgated would not serve the proposed objective-based system well. They are usually not phrased in biological terms or with respect to hydrologic variables now known to have instrumental negative effects on aquatic organisms, but instead mostly as concentrations of selected chemical elements or compounds. However, there is no prohibition of biological or hydrologic standards in the law. The recommended emphasis is consistent with and informed by the tiered aquatic life uses system applied by some states and illustrated for Ohio in Box 2-1. The use of such systems must expand greatly to support the recommended framework. An opportunity to do so exists through the triennial review already required for each state's water quality standards.

Certain special considerations affect the development and use of objectives as the device to carry forward watershed-based stormwater management and regulation. First, other elements of the CWA beyond the stormwater program and other laws may very well be involved in a watershed (see Chapter 2). Municipal and industrial wastewater discharges will often be contributors along with stormwater. Aquatic organisms may be listed as threatened or endangered under the federal ESA or state authority. Both objectives and the management and regulatory program designed to achieve objectives should reflect any such circumstances.

Instituting the proposed permitting program will require converting the TMDL program to one more suitable for its purposes and structure. The TMDL program is watershed based and hence offers some precedent and experience applicable to the new system. However, for the most part, it has operated only on waters declared to be impaired for specific pollutants, and it relies on management of specific physical and chemical water quality variables. Furthermore, in its current mode it takes no account of potential future impact sources. The TMDL program should be replaced with one adapted to the objective-based framework proposed here. This new program should apply to all waters assigned objectives, "impaired" or not, and formulate limits in whatever terms are best to achieve objectives. Hence, although the program would expand in coverage area, the efficient tailoring of objectives directly to beneficial uses could compensate for the expansion by targeting fewer variables. Finally, the new program should look to the future as well as the present by encompassing the anticipated impacts of prospective landscape changes.

The nature of a program to replace TMDLs can be glimpsed from a few attempts to move in the anticipated direction even under the existing structure. For example, Connecticut collected data directly linking impervious cover to poor stream health in Eagleville Brook (Connecticut Department of Environmental Protection, 2007). The stream's TMDL was developed using watershed impervious cover as a surrogate parameter for a mix of pollutants conveyed by stormwater. The intention is to reduce effective imperviousness by disconnect-

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ing impervious areas, installing unspecified SCMs, minimizing additional disturbance, and enhancing in-stream and riparian habitat. Flow was used as a surrogate for stormwater pollution in the Potash Brook, Vermont TMDL (Vermont DEC, 2006). In this waterbody, the impairment was based on biological indices that were then related to a hydrologic condition believed to be necessary to achieve the Vermont criteria for aquatic life. The TMDL will be implemented via the use of runoff-volume-reduction SCMs throughout the watershed.

Impact Sources

The CWA provides for regulating, as specific land-use types, only designated industrial categories, with construction sites disturbing one acre or more considered to be one of those categories. Otherwise, it gives authority to regulate municipal jurisdictions operating separate storm sewer systems. Generally speaking, these jurisdictions encompass, in addition to the industrial categories, the full range of urban land-use types, such as single- and multiple-family residential, various kinds and scales of commercial activity, institutional, and parks and other open space. All of these land uses and the activities conducted on them are, to one degree or another, sources of the agents that physically and chemically modify aquatic systems to the detriment of their biological health. Hence, most of the impact sources to which these aquatic systems are subject are not directly regulated under CWA authority as are industrial sources, but instead are indirectly regulated through the municipal program. Also, as already discussed, the situation is further complicated by the presence of municipal and industrial wastewater sources along with landscape sources contributing flow and pollutants to receiving waters via stormwater discharges.

The watershed-based framework envisioned here relies on municipalities led by a principal permittee. Thus, a fundamental task that municipal permittees charged with operating under a watershed-based permit must do is to find industries and construction sites in the watershed that have not filed for permit coverage and bring them under regulation. Furthermore, municipal co-permittees, with leadership by a watershed lead permittee, must classify industries and construction sites within their borders according to risk and accordingly prioritize them for inspection and monitoring (methods for doing this are discussed later in the chapter). Municipal permittees must have better tools than they have had in the past to assess the various impact sources and formulate strategies to manage them that have a reasonably high probability of fulfilling objectives. The present state of practice and research findings offers some directions for choosing or more completely developing these tools. However, by no means are all the necessary elements available, and substantial new basic and applied research must be performed.

From the literature come several possibilities to improve source analysis in the complex urban environment. Some examples of apparent promise, drawn from Clark et al. (2006) include the following:

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- Nirel and Revaclier (1999) used the ratio of dissolved rubidium (Rb) to strontium (Sr) to identify and quantify the impact of sewage effluents on river quality in Switzerland. Rubidium was present in larger quantities than strontium in feces and urine, making the ratio of these two elements an effective tracer that does not vary with river flow for a given water quality condition. Using the ratio alone produced the same conclusions regarding impact as measuring a host of physicochemical water quality variables. The researchers estimated that the Rb:Sr ratio must be lower than 0.007 if biological diversity is to be maintained, which could be the basis of an objective to manage river water quality. Although this case pertains to municipal wastewater and the technique works best in waters with a naturally low Rb:Sr ratio (e.g., calcareous regions), it success points out a potential avenue of research to simplify stormwater management on the basis of quantitative objectives related to biological integrity.

- Cosgrove (2002) described the approach used in New Jersey to characterize the relative contribution of point and nonpoint sources of pollutants in the Raritan River Basin. Twenty-one surface water sampling locations within the watershed were monitored four to five times per year from 1991 to 1997. These data were evaluated by comparing the median concentration at each sampling location with land-use statistics. Cumulative probability curves were also developed for each pollutant to demonstrate the probability that the concentration at a given location would be below a certain level (e.g., a stream standard). These probability curves were useful in determining the risk that a given location would violate a particular standard. The concentration data, coupled with continuous flow monitoring records, were utilized to determine the total load for each constituent. Regression analysis was used to develop a relationship between the total in-stream loads and flow. Such an analysis provided an indication of municipal or industrial discharge versus diffuse-source-dominated locations. Pollutant loads could then be converted to yield (load per unit area) to normalize the results for comparison from one station to another. The "screening level" methodology uses only existing data and, not requiring advanced modeling techniques, can be used to understand where to focus more rigorous modeling techniques.

- Maimone (2002) presented the overall approach that was used to screen and evaluate potential pollutant sources within the Schuylkill River watershed as part of the Schuylkill River Source Water Assessment Partnership. The partnership performed source water assessments of 42 public water supply intakes for the Pennsylvania Department of Environmental Protection. The watershed encompasses over 1,900 square miles with more than 3,000 potential point sources of contamination. In addition, runoff from diverse land uses such as urban and agriculture had to be characterized using the Stormwater Management Model. For all 42 surface water intakes, potential point sources were identified using existing databases. The list was first passed through a series of Geographic In-

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formation System-based "screening" sieves to limit the sources to only those considered to be high priority (including proximity and travel time from source to intake). Ten categories were identified that cover the range of the most important contaminants that might be found within the watershed, and a representative or surrogate chemical was identified whose properties were used to stand in for the category. Beyond the geographic screening, a more sophisticated screening was needed to limit the number of sites, using a decision support computer software program called EVAMIX. The greatest benefit of EVAMIX, compared to other software, is that it allows mixed criteria evaluation, qualitative and quantitative, to be considered concurrently. EVAMIX produced source rankings representing an organized and consistent use of both the objective data and the subjective priorities of decision makers.

- Hetling et al. (2003) investigated the effect of water quality management efforts on wastewater discharges to the Hudson River (from Troy, New York to the New York City Harbor) from 1900 to 2000. The paper demonstrated a methodology for estimating historic loadings where data are not available. Under these circumstances, estimated historic sewered and treated populations and per capita values were used to calculate wastewater flow and loadings for 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen, and total phosphorus. The analysis showed that dispersed landscape sources have become the most significant contributors of the first two contaminants to the river, while municipal wastewater plants remain the largest sources of nutrients. The methodology presented in this paper could be used by co-permittees to estimate present-day sources of various types and contribute to moving toward a comprehensive permit incorporating multiple sources.

- Zeng and Rasmussen (2005) used multivariate statistics to characterize water quality in a lake and its tributaries. Tributary water was composed of three components. Factor analysis demonstrated that stormwater runoff was the predominant cause of elevation of a group of water quality variables in a factor including TSS, the measurement of which is a convenient surrogate for all variables in the factor. Similarly, municipal and industrial discharges could be characterized by total dissolved solids, and groundwater by alkalinity plus soluble reactive phosphorus. These sources can thus be distinguished through measurement of just four common water quality variables. Reducing the number of analytes reduces laboratory costs and allows resources to be freed up for other purposes. Cluster analyses performed on the data indicated that further savings could be realized by sampling just one among several stations in a cluster and sampling at just one point in time over a period of relatively stable water quality (e.g., a relatively dry period).

A key research need associated with applying the proposed framework is assessment of these and other mechanisms for sorting out the contributions of

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the variety of impact sources in the urban environment. Leading this effort would be a natural role for EPA.

Impact Reduction Strategies

The philosophical basis for impact reduction under a modified permitting system centered on a lead municipal permittee and associated co-permittees is to avoid, as far as possible, exposing receiving waters to impact sources or to otherwise minimize that exposure. The concept embraces both water quantity and quality impact sources and specifically raises the former category to the same level of scrutiny as traditionally applied to water quality sources. Furthermore, the endpoints upon which success and compliance would be judged are directly related to achievement of beneficial uses. This approach to impact reduction, where the direct focus is on reducing the loss of aquatic ecosystem functioning supportive of beneficial uses, fundamentally contrasts with the currently prevailing system. What are primary concerns in the existing system (e.g., discharge concentrations of certain chemical and physical substances, technological strategies from a menu of practices) are still prospectively important, but only as a means toward realizing functional objectives, not as endpoints themselves. To be sure, attaining beneficial uses will require wise choices among tools to decrease discharges and contaminant emissions. However, the ultimate proof will always be in biological outcomes.

As made clear in Chapters 3 and 4, linkages among myriad stressing agents, impact receptors, and specific mitigating abilities of technological fixes are poorly understood and not easily understandable. The proposed new paradigm acknowledges that the linkages are not established among the voluminous elements in an exceptionally complex system ranging from impact sources, through environmental transport and fate mechanisms, to ecosystem health. However, it is intuitively and theoretically clear that minimizing the generation of impacts in the first place and slowing their progression into aquatic environments can break the chain of landscape alteration that leads to increased runoff and pollutant production, modifies aquatic habitat, and ultimately causes deterioration of the biological community. Landscapes can be managed in a preventive, integrated fashion that deals with the many undifferentiated agents of impact and avoids, or at least reduces, the damage. Although the application of these theories may not automatically and quickly stem biological losses, the powerful mechanism of adaptive management, if correctly applied, can be used to make course corrections toward meeting the defined objectives.

An earlier National Research Council (NRC) committee examined the scientific basis of EPA's TMDL program and recommended "adaptive implementation" (AI) to water quality standards (NRC, 2001a). That committee drew AI directly from the concept of adaptive management for decision making under uncertainty, introduced by Holling and Chambers (1973) and Holling (1978) and described it as an iterative process in which TMDL objectives and the imple-

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mentation plans to meet those objectives are regularly reassessed during the ongoing implementation of controls. Shabman et al. (2007) and Freedman et al. (2008) subsequently extended and refined the applicability of AI for promoting water quality improvement both within and outside of the TMDL program. In that broader context, AI fits well with the framework put forward here. Indeed, the proposed revised monitoring system presented later in this chapter is designed to provide information to support adaptive management in a permitting context.

The Stages of Urbanization and Their Effects on Strategy

In waterbodies that are not in attainment of designated uses, it is likely that the physical stresses and pollutants responsible for the loss of beneficial uses will have to be decreased, especially as human occupancy of watersheds increases. Reducing stresses, in turn, entails mitigative management actions at every life stage of urban development: (1) during construction when disturbing soils and introducing other contaminants associated with building; (2) after new developments on Greenfields are established and through all the years of their existence; (3) when any already developed property is redeveloped; and (4) through retrofitting static existing development. Most management heretofore has concentrated on the first two of those life stages.

The proposed approach recognizes three broad stages of urban development requiring different strategies: new development, redevelopment, and existing development. *New development* means building on land either never before covered with human structures or in prior agricultural or silvicultural use relatively lightly developed with structures and pavements (i.e., Greenfields development). *Redevelopment* refers to fully or partially rebuilding on a site already in urban land use; there are significant opportunities for bringing protective measures to these areas where none previously existed. The term *existing development* means built urban land not changing through redevelopment; retrofitting these areas will require that permittees operate creatively.

What is meant by redevelopment requires some elaboration. Regulations already in force typically provide some threshold above which stormwater management requirements are specified for the redeveloped site. For example, the third Draft Ventura County Municipal Separate Storm Sewer System Permit defines “significant redevelopment” as land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site. The permit goes on to state that where redevelopment results in an alteration to more than 50 percent of the impervious surfaces of a previously existing development, and the existing development was not subject to postdevelopment stormwater quality control requirements, the entire site becomes subject to application of the same controls required for new development. Where the alteration affects 50 percent or less of the impervious surfaces, only the modified portion is subject to these controls.

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All urban areas are redeveloped at some rate, generally slowly (e.g., roughly one or at most a few percent *per annum*) but still providing an opportunity to ameliorate aquatic resource problems over time. Extending stormwater requirements to redeveloping property also gradually "levels the playing field" with new developments subject to the requirements. As pointed out in Chapter 2, some jurisdictions offer exemptions from stormwater management requirements to stimulate desired economic activities or realize social benefits. Such exemptions should be considered very carefully with respect to firm criteria designed to weigh the relative socioeconomic and environmental benefits, to prevent abuses, to gauge just how instrumental the exemption is to gaining the socioeconomic benefits, and to compensate through a trading mechanism as necessary to achieve set aquatic resource objectives.

It is important to mention that not only residential and commercial properties are redeveloped, but also streets and highways are periodically rebuilt. Highways have been documented to have stormwater runoff higher than other urban land uses in the concentrations and mass loadings of solids, metals, and some forms of nutrients (Burton and Pitt, 2002; Pitt et al., 2004; Shaver et al., 2007). Redevelopment of transportation corridors must be taken as an opportunity to install SCMs effective in reducing these pollutants.

Opportunities to apply SCMs are obviously greatest at the new development stage, somewhat less but still present in redevelopment, but most limited when land use is not changing (i.e., existing development). Still, it is extremely important to utilize all readily available opportunities and develop others in static urban areas, because compromised beneficial uses are a function of the development in place, not what has yet to occur. Often, possibly even most of the time, to meet watershed objectives it will be necessary to retrofit a substantial amount of the existing development with SCMs. To further progress in this overlooked but crucial area, the Center for Watershed Protection issued a practical Urban Stormwater Retrofit Practices manual (Schueler et al., 2007).

Practices for Impact Reduction

As described in Chapter 5, in the past 15 to 20 years stormwater management has passed through several stages. First, it was thought that the key to success was to match postdevelopment with predevelopment peak flow rates, while also reducing a few common pollutants (usually TSS) by a set percentage. Finding this to require large ponds but still not forestalling impacts, stormwater managers next deduced that runoff volumes and high discharge durations would also have to decrease. Almost simultaneously, although not necessarily in concert, the idea of LID arose to offer a way to achieve actual avoidance or at least minimization of discharge quantity and pollutant increases reaching far above predevelopment levels. For purposes of this discussion, the SCMs associated with LID along with others are named Aquatic Resources Conservation Design (ARCD). First, this term signifies that the principles and many of the methods

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apply not only to building on previously undeveloped sites, but also to redeveloping and retrofitting existing development. Second, incorporating aquatic resources conservation in the title is a direct reminder of the central reason for improving stormwater regulation and management. ARCD goes beyond LID to encompass many of the SCMs discussed in Chapter 5, in particular those that decrease surface runoff peak flow rates, volumes, and elevated flow durations caused by urbanization, and those that avoid or at least minimize the introduction of pollutants to any surface runoff produced. This concentration reduction, together with runoff volume decrease, cuts the cumulative mass loadings (mass per unit time) of pollutants entering receiving waters over time. The SCM categories from Table 5-1 that qualify as ARCD include:

- Product Substitution,
- Watershed and Land-Use Planning,
- Conservation of Natural Areas,
- Impervious Cover Minimization,
- Earthwork Minimization,
- Reforestation and Soil Conservation,
- Runoff Volume Reduction—Rainwater Harvesting, Vegetated, and Subsurface,
- Aquatic Buffers and Managed Floodplains, and
- Illicit Discharge Detection and Elimination.

The menu of ARCD practices begins with conserving, as much as possible, existing trees, other vegetation, and soils, as well as natural drainage features (e.g., depressions, dispersed sheet flows, swales). Clustering development to affect less land is a fundamental practice advancing this goal. Conserving natural features would further entail performing construction in such a way that vegetation and soils are not needlessly disturbed and soils are not compacted by heavy equipment. Using less of polluting materials, isolating contaminating materials and activities from contacting rainfall or runoff, and reducing the introduction of irrigation and other non-stormwater flows into storm drain systems are essential. Many ARCD practices fall into the category of minimizing impervious areas through decreasing building footprints and restricting the widths of streets and other pavements to the minimums necessary. Water can be harvested from impervious surfaces, especially roofs, and put to use for irrigation and gray water system supply. Harvesting is feasible at the small scale using rain barrels and at larger scales using larger collection cisterns and piping systems. Relatively low traffic areas can be constructed with permeable surfaces such as porous asphalt, open-graded Portland cement concrete, coarse granular materials, concrete or plastic unit pavers, or plastic grid systems. Another important category of ARCD practices involves draining runoff from roofs and pavements onto pervious areas, where all or much can infiltrate or evaporate in many situations.

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If these practices are used, but excess runoff still discharges from a site, ARCD offers an array of techniques to reduce the quantity through infiltration and evapotranspiration and improve the quality of any remaining runoff. These practices include (1) bioretention cells, which provide short-term ponded and soil storage until all or much of the water goes into the deeper soil or the atmosphere; (2) swales, in which water flows at some depth and velocity; (3) filter strips, broad surfaces receiving sheet flows; (4) infiltration trenches, where temporary storage is in below-ground gravel or rock media; and (5) vegetated ("green") roofs, which offer energy as well stormwater management benefits. Natural soils sometimes do not provide sufficient short-term storage and hydraulic conductivity for effective surface runoff reduction because of their composition but, unless they are very coarse sands or fine clays, can usually be amended with organic compost to serve well.

ARCD practices should be selected and applied as close to sources as possible to stem runoff and pollutant production near the point of potential generation. However, these practices must also work well together and, in many cases, must be supplemented with strategies operating farther downstream. For example, the City of Seattle, in its "natural drainage system" retrofit initiative, built serial bioretention cells flanking relatively flat streets that subsequently drain to "cascades" of vegetated stepped pools created by weirs, along more sloping streets. The upstream components are highly effective in attenuating most or even all runoff. Flowing at higher velocities, the cascades do not perform at such a high level, although under favorable conditions they can still infiltrate or evapotranspire the majority of the incoming runoff (Horner et al., 2001, 2002, 2004; Chapman, 2006; Horner and Chapman, 2007). Their role is to reduce runoff from sources not served by bioretention systems as well as capture pollutants through mechanisms mediated by the vegetation and soils. The success of Seattle's natural drainage systems demonstrates that well-designed SCMs can mimic natural landscapes hydrologically, and thereby avoid raising discharge quantities above predevelopment levels.

In some situations ARCD practices will not be feasible, at least not entirely, and the SCMs conventionally used now and in the recent past (e.g., retention/detention basins, biofiltration without soil enhancement, and sand filters) should be integrated into the overall system to realize the highest management potential.

The proposed watershed-based program emphasizing ARCD practices would convey significant benefits beyond greatly improved stormwater management. ARCD techniques overall would advance water conservation, and infiltrative practices would increase recharge of the groundwater resource. ARCD practices can be made attractive and thereby improve neighborhood aesthetics and property values. Retention of more natural vegetation would both save wildlife habitat and provide recreational opportunities. Municipalities could use the program in their general urban improvement initiatives, giving incentives to property owners to contribute to goals in that area while also complying with their stormwater permit.

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Municipal Permittee Roles in Implementing Strategies

Municipal permittees sharing a watershed will have key roles in promoting ARCD under the proposed new system. First, the lead permittee and its partners would be called upon to perform detailed scientifically and technically based watershed analysis as the program's foundation. The City of San Diego (2007) offers a model by which permittees could operate with its Strategic Plan for Watershed Activity Implementation. The plan consists of:

- Activity location prioritization—locations prioritized for action based on pollutant loading potential;
- Implementation strategy and activity prioritization—tiered approach identifying activities directed at meeting watershed goals over a five-year period;
- Potential watershed activities—general list of activities required and potentially required to meet goals as guidance for planning and budgeting;
- Watershed activity maps—specified locations for activities; and
- Framework for assessment monitoring—a plan for development of the monitoring and reporting program.

Municipal permittees would be required under general state regulations to make ARCD techniques top priorities for implementation in approving new developments and redevelopments, to be used unless they are formally and convincingly demonstrated to be infeasible. In that situation permit approval would still require full water quantity and quality management using conventional practices. Beyond regulation, municipalities would be called upon to give private property owners attractive incentives to select ARCD methods and support to implement them. Furthermore, they should supplement on-site ARCD installations with municipally created, more centralized facilities in subwatersheds.

Other municipal roles in the proposed program revolve around the prominence of soil infiltration as a mechanism in ARCD. Successful use of infiltration requires achieving soil hydraulic conductivity sufficient to drain the runoff collector quickly enough to provide capacity for subsequent storms and avoid nuisance conditions, while not so rapid that contaminants would reach groundwater. One important task for municipal co-permittees will be defining watershed soils and hydrogeological conditions to permit proper siting and design of infiltrative facilities. A great deal of soils information already exists in any community but must be assembled and interpreted to assist stormwater managers. U.S. Department of Agriculture soil surveys, while a start, are often insufficiently site-specific to characterize the subsurface accurately at a point on the landscape. More localized data available to municipalities come from years of recorded well logs, soil borings, and percolation test results. Municipalities should tap these records to define, to their best ability, soil types, hydraulic conductivities, and seasonal groundwater positions. Although abundant and valu-

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able, these data are unlikely to be sufficient to define subsurface attributes across a watershed. Thus, municipalities should collect additional data (soil borings, soils analyses, and percolation tests) to obtain a good level of assurance of the prospects for infiltrative ARCD.

Part of the task for municipalities will be overcoming opposition to infiltration if it is unjustified. Some opponents discourage infiltration based on coarse soil survey data that may not apply at all at a locality, or they fail to take into account that the well-established ARCD practice of soil amendment, generally with organic compost, can improve the characteristics of somewhat marginal soils sufficiently to function well during infiltration. While such amendment cannot increase hydraulic conductivity sufficiently in restrictive clay soils, the technique has proven to effectuate substantial infiltration and attendant reduction in runoff volumes and peak flow rates in Seattle's natural drainage systems, discussed above. These systems lie on variable soils, including formations categorized by the Natural Resources Conservation Service (2007) as being in hydrologic group C. This group generally has somewhat restricted saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters (20 inches) of between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). Furthermore, additional runoff reduction often occurs through evapotranspiration, which is enhanced by the vegetation in ARCD systems.

Another objection sometimes raised to infiltrating stormwater is its perceived potential to compromise groundwater quality. Whether or not that potential is very great depends upon a number of variables: rate of infiltration, ability of the soil type to extract and retain contaminants, distance of travel to groundwater, and any contaminated layers through which the water passes. It is unlikely that urban stormwater, with its prevailing pollutant concentrations, will threaten groundwater if it travels at a moderate rate, through soils of medium or fine textures without contaminant deposits, to groundwater at least several meters below the surface. To ensure that groundwater is not compromised when surface water is routed through infiltrative practices, municipalities must establish where appropriate conditions do and do not exist and spot infiltration opportunities accordingly. Records of past waste disposal, leaks, and spills must be consulted to clean up or stay away from contaminated zones. There are alternatives even if documented soils or groundwater limitations rule out infiltrative practices. Much can be accomplished to reduce the quantities of contaminated urban runoff discharged to receiving waters through impervious surface reduction, water harvesting, and green roofs.

One additional problem to infiltrating stormwater runoff exists in some relatively dry areas and must be countered by municipalities. Overirrigation of lawns and landscape plantings has already increased infiltration well over the predevelopment amount and raised groundwater tables, sometimes to problematic levels. This unnecessary use of irrigation not only wastes potable water, often scarce in such areas, but reduces capacity to infiltrate stormwater without further water table rise. Municipalities should set up effective programs to con-

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serve water and simultaneously increase stormwater infiltration capacity.

A final element of an integrated management and permitting program under municipal control is use of capacity in the sanitary sewer and municipal wastewater treatment systems to treat some stormwater. This initiative must be pursued very carefully. One reason for care is that municipal treatment works have historically been overburdened with stormwater flows in combined sewers and have not yet broken free of that burden through sewer separation programs. A second reason is that municipal sewage treatment plants are generally designed to remove particulates and decompose organic wastes and not to capture the array of pollutants in stormwater, many dissolved or associated with the finest and most difficult to capture particles. Toxic contaminants can damage microbes and upset biological treatment plants. Nonetheless, capacity exists in many WWTPs to treat stormwater. The delivery of pollutants the plant was not designed to handle can be managed by pretreatment requirements, applied to industrial stormwater dischargers particularly. Dry weather flows, consisting mostly of excess irrigation runoff, can be diverted to treatment plants to prevent at least some of the nutrient and pesticide contamination that otherwise would flow to receiving waters. Additional capacity to treat stormwater can be gained by repairing defective municipal wastewater pipes that allow groundwater entry.

Special Considerations for Construction and Industrial Land Uses

All of the principles discussed above apply to industrial and construction sites as well: minimize the quantity of surface runoff and pollutants generated in the first place, or act to minimize what is exported off the site. Unfortunately, construction site stormwater now is managed all too often using sediment barriers (e.g., silt fences and gravel bags) and sedimentation ponds, none of which are very effective in preventing sediment transport. Much better procedures would involve improved construction site planning and management, backed up by effective erosion controls, preventing soil loss in the first place, which might be thought of as ARCD for the construction phase of development. Just as ARCD for the finished site would seek to avoid discharge volume and pollutant mass loading increase above predevelopment levels, the goal of improved construction would be to avoid or severely limit the release of eroded sediments and other pollutants from the construction site. Chapter 5 discusses construction-phase stormwater management in more detail.

Other industrial sites are faced with some additional challenges. First, industrial sites usually have less landscaping potentially available for land-based treatments. Their discharges are often more contaminated and carry greater risk to groundwater. On the other hand, industrial operations are amenable to a variety of source control options that can completely break the contact between pollutants and rainfall and runoff. Moving operations indoors or roofing outdoor material handling and processing areas can transform a high-risk situation to a

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no-risk one. It is recommended that industrial permits strongly emphasize source control (e.g., pollution prevention) as the first priority and the remaining ARCD measures as secondary options (as outlined in Table 5-9). Together these measures would attempt to avoid, or minimize to the extent possible, any discharge of stormwater that has contacted industrial sources.

It is likely that the remaining discharges that emanate from an industrial site will often require treatment and, if relatively highly contaminated, very efficient treatment to meet watershed objectives. Some industrial stormwater runoff carries pollutant concentrations that are orders of magnitude higher than now prevailing water quality standards. In these cases meeting watershed objectives may require providing active treatment, which refers to applying specifically engineered physicochemical mechanisms to reduce pollutant concentrations to reliably low levels (as opposed to the passive forms of treatment usually given stormwater, such as ponds, biofiltration, and sand filters). Examples now in the early stages of application to stormwater include chemical coagulation and precipitation, ion exchange, electrocoagulation, and filtration enhanced in various ways. These practices are undeniably more expensive than source controls and other ARCD options and traditional passive treatments. If they must be used at all, it is to the advantage of all parties that costs be lowered by decreasing contaminated waste stream throughput rates to the absolute minimum.

Administrative and Funding Arrangements

A number of practical, logistical considerations pertain to converting to the permitting and regulatory system discussed above. These considerations include:

- What design and performance standards should be placed on the management systems?
- What administrative vehicles offer the best prospects for success?
- What funding arrangements are necessary to support the revised permitting and management system?

Design and Performance Standards

It has already been asserted under the discussion of objectives above that ultimate performance standards should be based on results in the aquatic systems under protection. The report further advocates promulgating these standards primarily in terms of biological health (for protection of human health, aquatic life, or both), supplemented by measures of conditions well known to influence biological health quite directly, such as hydrologic variables. It was further proposed that active adaptive management be applied in relation to the degree of

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achievement of water resource objectives. However, it would not be wise to standardize entirely on this level and leave all questions of the means to the end to individual permittees. Certain design-level standards would also be appropriate. An example is provided by the recently issued draft municipal permit for Ventura County, California. In that permit, application of low-impact methods to new development and redevelopment is specified to hold the effective impervious area to 5 percent of the total contributing catchment. While technical experts may disagree on the precise number, the point is that adopting such a standard gives a straightforward design requirement on an evidentiary basis. Results in the receiving waters would still be tracked and used in active adaptive management if necessary, but effective application of the design standard would provide some level of initial assurance that the aquatic health standards can be met.

Forging Institutional Partnerships

At the heart of the proposal for a new system of regulating discharges to the nation's waters is issuing permits to groups of municipalities in a watershed operating as co-permittees under a lead permittee. Furthermore, the proposal envisions these municipal permittees assuming responsibility for and implementing the permits for all public and private dischargers in their jurisdictions. These admittedly sweeping changes in the way waters have been managed almost everywhere in the nation raise serious issues of acquiescence to the new arrangements, compatibility, and devising a sufficient and stable funding base. This section draws from the small number of examples where arrangements like those proposed here have been attempted.

The Los Angeles County Municipal Storm Water Permit offers a case study in how to aggregate municipalities in a co-permittee system while still allowing prospective members latitude should they perceive their own interests to deviate, even considering the advantages of group action. The permit, first issued in 1990, presently covers five watersheds and 86 municipal permittees. During the process of reissuing the 1996 permit, the City of Long Beach challenged the provisions of the Los Angeles County MS4 permit. The city was given the option of applying for its own individual permit, which it did. Long Beach was issued its own individual MS4 permit in 1999 with provisions similar to the Los Angeles County MS4 permit. As another example, a small coastal municipality (Hermosa Beach) covered by the Los Angeles County Municipal Storm Water Permit investigated the possibility of withdrawing from the county permit in 2000 to be reclassified as a Phase II municipality. Just as with Long Beach, Hermosa Beach was given the option of applying for an individual permit as a Phase I MS4, but in the end Hermosa Beach elected to remain within the areawide permit. Although this report strongly encourages cooperative participation of municipalities as co-permittees, it does not mandate it. Rather, the flexibility illustrated above should be retained in the proposed new permitting pro-

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gram. What matters for compliance with the CWA is that a municipality manage discharges in a manner at least equivalent to other permittees in the watershed.

Stephenson and Shabman (2005) gave thought to the dilemma of entities who may not naturally work well together being asked to cooperatively solve a problem that all have had a share in creating. They argued that new organizational forms that consolidate multiple regulated entities under a single organizational umbrella could be used to coordinate and manage jointly the collective obligations of a group of regulated parties at lower costs to members. Private and public regulated entities alike could benefit from participation in these new organizations. Such cooperative organizations could offer participating parties financial incentives and decision-making flexibility through credit trading programs.

Two larger-scale compliance associations exist in the Neuse and Tar-Pamlico river basins in North Carolina (Stephenson and Shabman, 2005). In both programs the state was concerned about nutrient enrichment of estuary waters and imposed an aggregate cap on industrial and municipal wastewater dischargers equivalent to a 30 percent reduction in nitrogen loads. In both programs, the state granted individual point source dischargers a choice: (1) accept new requirements to control nitrogen through individual NPDES permits or (2) form and join a discharger association. The rigidities associated with individual NPDES permits provided enough incentive for most point source dischargers to opt for the second choice. Compliance associations were then created and issued permits.

The Neuse River rules cover nonpoint agricultural sources as well as point discharges. Counties are responsible for reducing nutrient loads, and farmers must either join county associations that apply different strategies or individually contribute to meeting objectives by setting aside 50- to 100-foot buffers along all streams.

North Carolina requires compliance associations to meet a single mass load cap. In the Tar-Pamlico case, the legal requirement to meet the cap was established by an enforceable contractual agreement signed by the association and the state. In the Neuse program, a single “group compliance permit” was issued to the association. Both legal mechanisms established financial penalties for the two associations if aggregate discharges of the group exceed the association cap. A key advantage of the association is similar to that of a formal effluent trading program—granting dischargers flexibility to decide how best to meet the aggregate load cap. To date, the associations have managed to keep nitrogen loads considerably below their respective caps. Compliance costs have also fallen below original projections. Further, there is some evidence that the association concept is producing incentives for strong cooperative behavior that did not exist prior to implementation.

The case studies presented here illustrate ways in which both public and private entities subject to regulation can exercise options for operating autonomously should they not wish to incorporate with a group, while still contributing

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to the achievement of watershed objectives. The case studies suggest that most dischargers conclude in the end that group membership offers considerable advantages.

Funding Considerations

The existing stormwater permit program is characterized, in most of the nation, by municipal Phase I and now Phase II permittees operating mostly alone. In contrast the new system envisions coalitions of permittees that share a watershed operating in concert, under the coordination and leadership of a principal permittee. The present structure tends to bring about duplication in effort and staff, whereas cooperation should stimulate efficiencies that could defray at least part or even much of the extra local costs associated with new responsibilities for municipal permittees.

As explored in the preceding section, municipalities may not necessarily wish to join in co-permittee arrangements; and mechanisms are proposed to allow them to operate individually, as long as watershed objectives are met. However, the state could encourage participation through financial inducements, for example, by estimating the resources needed to meet the requirements of each watershed permit and pointing out to permittees how shared resources can save each contributor money. The state should also set preferences and better terms for grants in the favor of municipalities who join together.

To the questions of administrative vehicles and funding arrangements, stormwater utilities are the preferred mechanism, and regulations should support creating stormwater utilities. It should be added that, with watershed-based permitting as proposed here, utilities should also be regionalized on a watershed basis. A utility draws funds from the entities served in direct relation to the cost of providing the services, here management of the quantity and quality of stormwater discharged to natural waterbodies. These funds must be dedicated to that purpose and that purpose only, and cannot be redirected to general agency coffers or for any unrelated use.

Not only are more funds from more reliable sources needed, but monies should be redirected in ways differing from their allocation under the current system. It was proposed earlier that a lead municipal permittee, working with other municipal co-permittees, be given responsibility for coordinating permitting and management of municipal, industrial, and construction stormwater permits, and even permits involving other sources, such as industrial process and municipal wastewaters. Those entities would hence be doing work now devolving to individual private developers and industrial plants and other public authorities. They would need to attract the revenue from those other bodies in proportion to the added work taken on. A utility structure would provide a well-tested means of carrying out this reallocation.

Stormwater utility fees are generally assessed according to a simple formula, such as a flat rate for all single-unit dwellings and in proportion to imper-

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vious area for commercial property. Some municipalities have investigated charging more directly according to the estimated quantity and quality of stormwater discharged into the public drainage system. Municipal permittees may choose to formulate such a system, but the development process itself is not a trivial task and, being based on general (and usually quite simple) hydrologic and water quality models, can generate considerable arguments from rate payers. Going through this process is probably not necessary or even advisable for most municipal permittees, who will have many new functions should the proposed system be adopted. Instead, they should concentrate on implementing a fee structure based on a simple formula like the one above and then capture additional revenues for special functions that they will take over from industrial and construction permittees.

As discussed previously, in the proposed program municipal co-permittees, with leadership by a watershed lead permittee, will be asked to classify industries and construction sites within their borders according to risk and accordingly prioritize them for inspection and monitoring. It is proposed in the section on Measures of Achievement, below, that inspection include reviewing and approving industrial and construction site stormwater pollution prevention plans (SWPPPs). While many municipalities now inspect construction sites for stormwater compliance and some inspect industries, this work will increase significantly in the new system, and SWPPP review and approval will be a completely new element. Moreover, municipalities would perform some industrial monitoring now conducted by the industries themselves and may monitor high-risk construction sites. These special functions would require different institutional arrangements and substantial new revenue that could not be fairly charged to all rate payers. There are several possible sources for these funds. One way would be to increase industrial and construction permit fees and direct large proportions to municipalities to support inspection and monitoring. The permitting authority (designated state or EPA) would still hold ultimate authority, and municipalities could refer industrial and construction permittees found during inspection to be out of compliance to the permitting authority for enforcement. Another means would be to form consortia of industries of similar type and assess fees directly applicable to inspection and monitoring. For example, scrapyards under the jurisdiction of the California EPA Los Angeles Regional Water Board formed a monitoring consortium under which sample collection by a qualified contractor rotates among the members, with funding by all. While the members operate this system, it could be adapted to operation by municipal co-permittees.

A second-level funding concern is, once revenues are generated, how should they be put to use? It is very important that funds largely be devoted directly to the tasks at hand regarding the achievement of objectives instead of into excessive administrative and bureaucratic structure. These tasks are scientific and technical and are highly oriented toward what is actually going on in the drainage systems and their receiving waters. Thus, the majority of funds should be directed to making scientific and technical judgments based on obser-

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vations and monitoring results obtained in the field (see the discussion below).

Measures of Achievement

Critique of the Current Monitoring System

No area exemplifies the differences between the present and proposed new stormwater permitting and monitoring systems more than the measures used to gauge achievement. The current monitoring system is characterized by scattered and uncoordinated measurements of discharges from Phase I MS4s and some industries, and some visual observations of construction sites. The system proposed to take its place would emphasize monitoring of receiving water biological conditions as a data source for prescribing management adaptations to meet specified biological objectives. The discussion here first critiques the prevailing system to construct part of the rationale for changing it. It then proceeds to outline a recommended monitoring structure to replace it.

To expand very briefly on the point that the present system is scattered and uncoordinated, monitoring under all three stormwater permits is according to minimum requirements not founded in any particular objective or question. It therefore produces data that cannot be applied to any question that may be of importance to guide management programs, and it is entirely unrelated to the effects being produced in the receiving waters. Phase I municipal permit holders are generally required to monitor some storms at some discharges for no stated purposes but to report periodically to the permitting agency (Phase II municipalities have no monitoring requirements, although they may represent the major or even only impact sources in a given watershed). The usual model for industries across the nation is to collect a few discharge grab samples a year and send the results to the permitting authority, plus occasionally to make observations for obvious signs of pollution (e.g., oil sheen, odor). Construction site monitoring is less standardized and often involves no water quality monitoring at all. Again, no permittee under any of the three programs is obligated according to national standards to check the effects of its discharges on receiving waters. Since the individual effects of any discharger are often not distinguishable from any other, the scattershot system would usually not be able to discern responsibility for negative effects in the receiving water ecosystem.

Input to the committee conveyed the strong sense that monitoring as it is being done is nearly useless, burdensome, and producing data that are not being utilized. For example, the City of Philadelphia conducts substantial amounts of wet weather monitoring, which is very expensive, but it can barely monitor for TSS in many of its heavily impacted streams (Crockett, 2007). The resources to monitor for the more exotic pollutants do not exist. Smaller municipal permittees without the resources and sophistication of a big-city program have difficulty performing even the most basic monitoring. City water managers believe

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that the traditional stormwater program places too much emphasis on monitoring of individual chemicals rather than looking at ecological results (Crockett, 2007).

Industry representatives have also described several problems they see in industrial stormwater monitoring as it is performed now (Bromberg, 2007; Longsworth, 2007; Smith, 2007). One concerns the high degree of variability, from the methods used to what is actually measured (Stenstrom and Lee, 2005; Lee et al., 2007). Opponents have been quite critical of the benchmarks to which industrial monitoring data are compared, believing that the benchmarks have no basis in direct measurements associating stormwater with impacts. Some have suggested replacing monitoring with an annual stormwater documentation report to the permitting authority. It seems that industry personnel disrespect the current monitoring framework for some good reasons and feel it conveys a burden for little purpose. There was some implication that industry would be receptive to measures offering more meaningful information in place of poorly conceived monitoring requirements (Bromberg, 2007; Longsworth, 2007; Smith, 2007).

Proposed Revised Monitoring System

A structure in several tiers is proposed as a monitoring system to serve the watershed-based permitting and management framework.

Progress Evaluation Tier. This tier would represent the ultimate basis for judgment on whether the objectives adopted for the watershed are being met. Because these objectives would mainly be expressed in terms related to direct support of beneficial uses, so too would monitoring in the Progress Evaluation Tier principally emphasize direct measurements of ecological health. The preferred model for this evaluation would be the paired watershed approach, which is based on the classic method of scientific experimentation and was developed for water resource management investigations by EPA (Clausen and Spooner, 1993). Ideally, conditions in the waterbody under evaluation would be compared to conditions in the same waterbody before imposition of a permit and management scheme (before versus after comparison), as well as to conditions in a similar waterbody not subject to human-induced changes (affected system versus reference system comparison). At least one of these comparisons must be made if both cannot. If the objectives involve improving conditions, and not just avoiding more degradation, the reference should represent that state to which the objective points.

This function has traditionally been the province of the permitting authority (i.e., the designated state or EPA). In the new program, the function is assigned to municipal permittees, guided by the lead permittee, to conduct or contract, but with a substantial contribution by the permitting authority in the form of material support and guidance. The primary vehicle envisioned to perform the pro-

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gress assessment is a well-qualified monitoring consortium serving the watershed, and perhaps other watersheds in the vicinity. Case studies below present examples of successful joint ventures in monitoring that can serve as models. The proposal is based on the belief that monitoring should be more manageable and effective at the watershed compared to the state level and, furthermore, that utilizing a consortium approach should make it feasible for a coalition of municipal co-permittee partners to commission monitoring.

Findings of objective shortfall would trigger development of active adaptive management strategies. Generally, an assessment should be conducted to determine what additional measures should be put in place in regulating new development and redevelopment, as well as increasing coverage of existing developments with retrofits.

Diagnostic Tier. The second tier would be designed to provide the municipal permittees with the necessary information to formulate active adaptive management strategies, and they would be responsible for this second tier as well as the first. The Diagnostic Tier would be composed of assessment of information from the Compliance Reporting Tier, plus some specific field monitoring to determine the main reasons for ability or failure to meet objectives. Some highly directed monitoring of receiving water conditions could determine the need to improve management of water quantity, water quality, or both. A tool like the Vermont flow-duration curves is an example of a potentially useful device for diagnostic purposes. To allow the use of such a tool, it is important that continuous flow recorders be installed on key streams in the watershed. The techniques described in the Impact Sources section above, once they are further developed, would also be useful in Diagnostic Tier monitoring.

An important dimension of this tier would be prioritized inspection and monitoring of potentially high-risk industrial and construction sites. In addition, data submitted by the industrial and construction permittees according to the Compliance Reporting Tier would assist in targeting dischargers to bring about the necessary improvements in water quantity and/or quality management.

Compliance Reporting Tier. It is proposed that the first step in compliance reporting be submission of SWPPPs by all construction and industrial permittees (plus municipal corporation yards as an industrial-like activity) to the jurisdictional municipal permittee for review and approval. It is further proposed that the industrial permittees and municipal corporation yards be relieved of sample collection, *if* they develop SWPPPs making maximum possible use of ARCD practices, supplemented by active treatment as necessary, and the municipal permittee approves the SWPPP. Construction sites would be given a similar sampling dispensation if they develop an approved SWPPP along the lines of Box 5-3.

Otherwise, the permittees would be required to perform scientifically valid sampling and analysis and report results to the watershed co-permittees. This more comprehensive and meaningful monitoring would increase the burden al-

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ready felt by permittees and create a strong incentive to apply excellent SCMs. This burden could be relieved to a degree through participation with other similar dischargers in the watershed in a monitoring coalition. As an example, in North Carolina coalitions of wastewater dischargers are working with the state Division of Water Quality (DWQ) to create and manage coalition-led watershed monitoring programs that operate in conjunction with DWQ's ambient chemistry and biological programs (Atkins et al., 2007). Lee et al. (2007), after an assessment of industrial stormwater and other monitoring data, concluded that selecting a subset of permittees from each monitored category would yield better results at lower overall cost compared to monitoring at every location. This strategy would permit the use of more advanced sampling techniques, such as flow-weighted composite samplers instead of grab sampling, to estimate representative loads from each category with improved accuracy and reduced variability.

All permittees would still make observations of the SCMs and discharges and keep records. The final proposed step in compliance reporting is an annual report covering observations, SCM operation and maintenance, SWPPP modifications, and monitoring results (if any), to be sworn as to correctness, notarized, and submitted to the lead municipal permittee. The Massachusetts Environmental Results Program (April and Greiner, 2000) offers a possible model for compliance reporting and verification. This program uses annual self-certification to shift the compliance assurance burden onto facilities. Senior-level company officials certify annually that they are, and will continue to be, in compliance with all applicable air, water, and hazardous waste management performance standards. The state regulatory agency reviews the certifications, conducts both random and targeted inspections, and performs enforcement when necessary.

Research Tier. The final tier would be outside the permit system and exist to develop broad mechanistic understanding of stormwater impacts and SCM functioning important to assist permittees in reaching their objectives. EPA and state agencies designated to operate the permit system would have charge of this tier. These agencies would develop projects and contract with universities and other qualified research organizations on a competitive basis to carry out the research.

Instructive Case Studies for the Proposed Revised Monitoring System

Many municipalities, even large ones, would be challenged and burdened by taking on comprehensive watershed monitoring. The Southern California Coastal Water Research Project Authority (SCCWRP, http://www.sccwrp.org) offers an excellent model of how co-permittees in a watershed or an even broader area could organize to diffuse these challenges and burdens. SCCWRP

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is a joint-powers agency, one that is formed when several government bodies have a common mission that can be better addressed by pooling resources and knowledge. In SCCWRP's case, the common mission is to gather the necessary scientific information so that member agencies can effectively and cost-efficiently protect the Southern California marine environment. Key goals adopted by SCCWRP are defining the mechanisms by which aquatic biota are potentially affected by anthropogenic inputs and fostering communication among scientists and managers. Comprised of a multidisciplinary staff, SCCWRP encompasses units specializing in analytical chemistry, benthic ecology, fish biology, watershed conditions, toxicology, and emerging research.

SCCWRP's current mission stems from the results of a 1990 NRC review of marine environmental monitoring programs in the Southern California Bight (NRC, 1990). It was determined that although $17 million was being spent annually on marine monitoring, it was not possible to provide an integrated assessment of the status of the Southern California coastal marine environment. Most monitoring was associated with NPDES permit requirements and directed toward addressing questions about site-specific discharge sources. As a result, most monitoring in the bight was restricted to an area covering less than 5 percent of the bight's overall watershed, making it difficult to draw conclusions about the system as a whole. The limited spatial extent of monitoring was also found to limit the quality of local-scale assessments, since the boundaries of most monitoring programs did not match the spatial and temporal boundaries of the important physical and biological processes in the bight.

NRC (1990) further found that there was a lack of coordination among existing programs, with substantial differences in the parameters measured among programs, preventing integration of data. Even when the same parameters were examined, they were often measured with different methodologies or with different (or unknown) levels of quality assurance. Moreover, the NRC found that even when the same parameters were measured in the same way, substantial differences in data storage systems among monitoring programs limited access to the data for more comprehensive assessment. To avoid repetition of these shortcomings, the SCCWRP example should be given very thorough consideration as a template for the Progress Evaluation, Diagnostic, and Research Tiers in the proposed revised monitoring program.

The San Gabriel River Regional Monitoring Program (SGRRMP, *http://www.lasgrwc.org/SGRRMP.html*) is a watershed-scale counterpart to the larger-scale regional monitoring efforts in Southern California. The SGRRMP incorporates local and site-specific issues within a broader watershed-scale perspective. The program exists to improve overall monitoring cost effectiveness, reduce redundancies within and between existing monitoring programs, target monitoring efforts to contaminants of concern, and adjust monitoring locations and sampling frequencies to better respond to management priorities in the San Gabriel River watershed. Five core questions provide the structure for the regional program:

- What is the environmental health of streams in the overall watershed?

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- Are the conditions at areas of unique importance getting better or worse?
- Are receiving waters near discharges meeting water quality objectives?
- Are local fish safe to eat?
- Is body-contact recreation safe?

The workgroup convened to establish the program recommended monitoring designs to answer the core questions effectively and efficiently. The resulting program is a multilevel monitoring framework that combines probabilistic and targeted sampling for water quality, toxicity, and bioassessment and habitat condition.

The City of Austin, Texas, has more than 20 years of stormwater monitoring experience and offers additional guidance on designing and implementing watershed monitoring programs (City of Austin, 2006). Austin performs detailed periodic synoptic sampling in the watersheds it manages to track trends in stormwater quantity and quality. The city uses the results to evaluate the impacts of land development on stormwater quantity and pollution, establishing statistical relationships between measures of these conditions and the amount of impervious cover. Trend assessment over time leads to recommended changes to the City of Austin Environmental Criteria Manual as needed.

Creating Flexibility and Incentives Within a Watershed Approach

A watershed-based permitting approach to stormwater management focuses attention on watershed objectives and endpoints. To be able to achieve these goals, observable performance measures beyond the success of an individual SCM need to be identified that are consistent and necessary to meet designated uses. These might include watershed-level numeric limits on the amount of a particular pollutant allowed to enter a waterbody (e.g., pounds of phosphorus) or various measures of allowable volume of discharge. A watershed focus shifts attention away from specific SCM performance and site-specific technological requirements to achieving a larger watershed goal. As a consequence, there is considerable management flexibility in deciding how these goals will be achieved. Indeed, this flexibility was cited by the NRC (1999) as a prerequisite to successful watershed management.

One way of exercising this flexibility is to create an "incentive-based" or "market-based" approach to choose how watershed goals are met. It is recognized throughout the environmental management field that entities subject to regulation do not necessarily have equal opportunities and qualifications to comply sufficiently to sustain resources. To compensate for this, the market-based approach allows individual discretion to select how effluent (or runoff volume) will be controlled (choice of technology, processes, or practices) and where they will be controlled (on site or off site). That is, any discharger legiti-

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mately unable to meet discharge quantity and quality allocations would be able to finance offsets elsewhere to achieve the watershed goals. An important element and challenge is to couple this decision-making flexibility with personal (typically financial) incentives so that people willingly make choices supportive of the watershed objectives. Broadly stated, the idea is to create financial reasons and decision-making opportunities to lower compliance costs and create or implement new effluent/volume control options (Shabman and Stephenson, 2007).

Because incentive-based policies require a shift in emphasis from technologies and practices to outcomes (e.g., volume or quantity of effluents), the municipal manager would not be responsible for deciding what SCM will be implemented in specific areas or hand picking specific practices to promote. Rather the stormwater program manager's responsibilities shift to establishing watershed goals, developing metrics to measure outcomes and performance, and performing necessary inspection and enforcement activities.

Effluent trading, sometimes called "water-quality trading," is one type of incentive-based policy. In an ideal form, effluent trading requires government to establish a binding aggregate limit or cap on an outcome (e.g., mass load of effluent, volume of runoff) for an identified group of dischargers. The cap or aggregate allowable discharge is set to support and achieve a socially determined environmental goal. Because it is fixed, the cap provides the public assurances that environmental objectives will be achieved in the face of a growing and changing economy. The total allowable discharge is then divided into discrete and transferable units, called allowances, and either distributed or auctioned to existing dischargers. All dischargers must own sufficient allowances to cover their discharges. For instance, any new or expanding source must first purchase allowances (and hence effluent or volume reductions) from another source before legally discharging. The requirement to hold allowances on the condition to discharge and the positive allowance price creates financial incentives for pollution prevention. Dischargers holding allowances rather than reducing discharge face forgone revenues that could have been achieved from the sale of allowances. Conversely, expanding dischargers have incentives to invest in pollution prevention in order to avoid the cost of purchasing additional allowances.

In the context of the revised permit system advocated here, achievement of objectives (generally of a biological nature) will require some combination of strategies such as no net increases in hydrologic parameters (e.g., peak flow rates, durations, volumes), water pollutants, forest cover loss, and effective impervious area. If one entity is unable to contribute adequately to meeting its share of compliance, then it must obtain the necessary credit by buying it from another similar entity that is able to contribute more than its designated share. Ideally, all sources of a waterbody's problems, not only stormwater, would come under the trading system.

Implementing the market system requires development of a resource-based currency, a nontrivial exercise but one for which models are available in other

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fields, especially air emissions. For example, emission trading has been a critical element of the nation's strategy to limit sulfur dioxide and nitrogen oxide emissions (Ellerman et al., 2000). Carbon trading is a cornerstone policy in the European Union effort to limit greenhouse gas emissions. The EPA promotes the use of trading to help achieve the goals of the CWA and has issued several policy statements and recently published guidance on how trading programs can be grafted within existing NPDES permitting programs (EPA, 2003a, 2007b).

However, compared to the air program, experience and success with trading in the water program have been limited (Shabman et al., 2002). Furthermore, programs labeled trading have been implemented in a multitude of ways in the nation's water quality program (Woodward et al., 2002; Stephenson et al., 2005; Shabman and Stephenson, 2007). In many instances, trading programs are case-specific and isolated "trades" that do not fundamentally change the choice and incentives facing dischargers in a conventional permitting system. The extent to which trading policies can be effectively employed on a watershed scale is limited not only by the physical differences between air and water mediums, but also by the unique legal structure of the CWA (Stephenson et al., 1999). For example, the CWA is oriented around imposing technology-based performance requirements on specific subset of discharge sources. Individual NPDES permits require sources to achieve these agency-identified levels of performance and may specify how performance is achieved. The statute also places limits and disincentives on the degree to which permit agencies can deviate from these limits (e.g., "antibacksliding").

Thus, the focus of the NPDES permitting system has been on individual source control and technologies, unlike the air program, which has a stronger statutory orientation around achieving broader air quality goals (ambient air quality standards). The orientation of the NPDES program limits the flexibility and incentives for regulated parties that might make market-oriented trading possible. It turns out that some of the more successful applications of trading in the water program have occurred because of permitting innovations that effectively avoid some of these rigidities (see discussion of North Carolina point source control program on the Neuse River, above).

Trading programs of various types have been proposed or suggested for stormwater (Thurston et al., 2003; Parikh et al., 2006). Although conceptual models of a comprehensive trading program based on the total volume of allowable water to be discharged have been proposed, no working examples have yet to be implemented. More limited versions of trading programs, however, have been developed. These programs provide compliance flexibility for new sources of stormwater runoff. In some locations, new developments face a requirement to provide a specific level of volume or effluent control from the parcel to be developed. The regulated entity is typically obligated to meet this requirement with the applications of on-site SCMs. Trading programs create opportunities for regulated entities to meet their regulatory requirement off site (off the parcel to be developed), called here an offset. In some trading programs, the off-site controls can be accomplished by the creation of an in lieu fee program. Such

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programs typically occur for dischargers that are not required to hold or obtain individual NPDES permits.

In lieu fee programs offer some opportunity for regulated parties to make a financial payment (fee) to a local government entity in lieu of implementing on-site controls. The fees are collected and used to implement stormwater controls in other areas of the watershed. Controlling runoff at a regional level rather than through the construction of many small on-site controls may be more cost-effective given the economies of scale associated with some SCMs (see Chapter 5 pages 362–363). The option for off-site controls also allows the stormwater program to direct investments in stormwater control to specifically targeted areas of the watershed.

Examples of in lieu fee programs include Santa Monica, California, the Neuse River Basin in North Carolina, and Williamsburg, Virginia. Santa Monica's program requires new and redevelopment projects to treat a specific volume of runoff. The program first requires the regulated entity to take all feasible steps to meet the requirement through the implementation of on-site infiltration practices. If the regulated party can demonstrate why it is economically and physically infeasible to install any type of infiltration or treatment SCM, the regulated party can pay a fee based on the volume of water that needs to be controlled (the total mitigation volume is the volume that would have been attenuated via an SCM). The fee set by Santa Monica is $18/gallon of total required mitigation volume. The $18 reflects the cost of constructing an SCM and maintaining it over 40 years (DeWoody, 2007). Presumably these fees are used to construct infiltration measures elsewhere.

The Neuse River Program requires all new land development to meet a nitrogen export standard of 3.6 pounds per acre per year (North Carolina Division of Water Quality, 1999). The water quality goal for the Neuse basin is to reduce mass nitrogen loads by 30 percent in order to improve water quality in the estuary. The export standard was set to achieve a 30 percent reduction from the average nitrogen load from lands prior to development. Developers have the option to meet this export standard either through the application of on-site SCMs or by paying a fee into a state-administered Riparian Buffer Restoration Fund (see 15A North Carolina Administrative Code 02B .0240), which would be used to reduce nitrogen loads elsewhere in the basin. Developer discretion, however, is not unlimited. Under no circumstances may developers discharge more than an estimated 6.0 pounds per acre per year from a residential site.

The Williamsburg program has an in lieu fee program for total phosphorus loads created by new development (Frie et al., 1996; Stephenson et al., 1998). For every new development, the increase in total phosphorus load from stormwater runoff from impervious surfaces is estimated. Developers have the choice to meet the phosphorus load reduction requirement through the application of on-site controls or by paying a fee to the city. The fee is set at $5,000/lb of phosphorus, with the fees earmarked to the construction of regional stormwater facilities or for the preservation of open space within the city. The presence of a fee option could also provide incentives for developers to implement source

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reduction practices.

The above programs differ in some important ways. For example, the Santa Monica program requires regulated entities to undergo a "sequencing" process that places regulatory preference on on-site controls before being able to use the fee option. The Williamsburg program allows regulated entities the option to select between constructing on-site controls and paying the fee without a regulatory preference for on-site controls. Sequencing rules tend to limit control options and thus the cost-effectiveness of these types of programs.

In lieu fee programs are distinguished from other offset programs in that it is the responsibility of the local government (or more generally, any designated fee service provider such as a nongovernmental organization) to provide the off-site SCMs. In lieu fee programs, common in the U.S. wetlands program, face a number of implementation and design challenges (Shabman and Scodari, 2004). For example, enforcement sometimes becomes a concern because the local stormwater management agency responsible for constructing and maintaining the SCMs is also responsible for monitoring and enforcement. These dual responsibilities create potential conflicts of interest; if an off-site mitigation project fails, there maybe no apparent overseeing agency to enforce corrective actions. The lack of transparency in accounting to determine whether the offset projects provide enough compensation is also sometimes a challenge. Finally, the ability to fully offset the volume of effluent discharge from a new development is contingent on collecting enough revenue from the fee to pay for the construction and maintenance of offsite SCMs. The delay between impacts and compensation and lack of full public cost accounting complicate the challenges of setting an appropriate fee.

Ensuring that in lieu fee programs provide the necessary mitigation could be accomplished in a number of ways. For example, an oversight agency may be designated to establish tracking and reporting requirements and monitor in lieu fee program performance. Or, the potential conflicts of interest inherent in the lieu fee program design could be avoided by separating the provision of the off-site mitigation service from the monitoring and enforcement. It is possible to imagine that the private sector, rather than an in lieu fee administrator, could provide off-site stormwater reduction services to those subject to the stormwater control requirements. In this case, the private sector would provide stormwater detention/retention services above and beyond what is required by law. These private service providers would receive stormwater runoff credits for these investments ("above baseline") that could be sold to developers who might wish to meet their control obligations in ways other than on-site controls. In essence, the role of searching, designing, and constructing offsite SCMs would be transferred to the private-sector stormwater credit providers. The local stormwater managers, however, would retain full authority to monitor, verify, and enforce to ensure that these offsets are successfully implemented.

The flexibility provided by in lieu fee and trading programs requires that pollutant loads or runoff volume created at one site be reduced at another site. Thus, a design issue confronting these types of programs is the consideration of

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the spatial extent in which offsetting activities can occur. The extent of the spatial range of offsetting activities in turn will depend partly on the nature and type of service being offset. For example, in the Neuse example nitrogen is a regional, basinwide concern with minimal localized effects. In such cases, the offsetting activities might be allowed basinwide (after adjusting for nitrogen attenuation through the basin). In other situations where localized concerns maybe a greater concern (say from localized flooding), the flexibility offered by such programs may be more limited. However, such spatial flexibility might also be a way to implement and achieve watershed planning objectives. For example, development may be encouraged in high-impact areas, and offsetting fees could be used to protect and enhance water quality objectives in other areas.

This last point deserves further explanation. Although this chapter advocates that biological conditions in waterbodies should be maintained or improved, there are many urban areas where local waterbodies cannot achieve the same designated uses as less developed areas. If a goal-setting entity chose to do so, beneficial uses for waters in these areas could be set at levels that acknowledge this highly altered condition, such that these streams would not be expected to achieve the same biological condition as streams outside the urban core (see Chapter 5 pages 364-366). This might be done to encourage development in high impact areas; San Jose, CA, provides an example (see Chapter 2). In that city's stormwater program, in urban areas where on-site control is either technically impossible (due to soil or space constraints) or prohibitively costly, the developers can meet the post-construction treatment standard by providing volume control either through participation in a regional stormwater project or by providing equivalent projects off site (e.g., stream restoration).

It is also possible to design a stormwater offset program that allows the different functions of stormwater management to be separated to achieve watershed objectives. For example, management of peak flow serves mostly to prevent localized flooding while more stringent volume control maybe required to protect stream channels and aquatic life. Control of peak flow might be required on site or within a narrow geographic region. In areas targeted for development, however, the volume control needed for channel protection might be transferred off site and into areas where watershed planning has identified the need for higher levels of stream channel protection or enhancement (more stringent water quality standards). A similar watershed approach based on functional assessment was recommended for wetland compensation (NRC, 2001b).

Regulatory and Legal Implications of Proposed Watershed-Based Permitting Framework for Managing Stormwater

EPA, the states, and municipal permittees would all have tasks to perform to transform the framework set forth in this report to a fully developed and functioning program. These efforts would be rewarded with a program that is rooted

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in science, transparent in its aims, fairer for all than the current program, and better for the aquatic environment. This section of the report outlines the tasks necessary to carry the proposal forward to full development.

EPA should seek significant congressional funding to support the states and municipalities in undertaking this new program, in the nature of the support distributed to upgrade municipal WWTPs after the 1972 passage of the Federal Water Pollution Control Act. Beyond financial support, EPA's tasks emphasize broad policy formulation, regulatory modifications and adaptations necessary to initiate the new program, and guidance to the states and permittees. The principal adaptation needed in the regulatory arena involves converting the current TMDL program to a form suitable for the new system. Guidance would be needed in a number of crucial areas, and it is EPA's natural role to develop it.

States (or EPA for states without delegated authority) would have broad responsibilities to translate policies and federal regulations into their own regulatory and management systems. A key task in this regard would be to recast water quality standards into objectives most directly supporting sustenance and improvement of beneficial uses. States already have considerable background for performing this task through their present definitions of beneficial uses, the Section 303(d) process for assessing waterbody compliance with water quality standards, and the triennial review of those standards. However, the added prominence of biological aspects of beneficial uses and associated objectives will require additional analysis. Other prominent state tasks will involve defining the watersheds subject to permits, forming bodies of co-permittees associated with the watersheds, and appointing the lead permittee. Many other state tasks entail cooperative work with the permittees to support and assist them in funding and conducting their activities.

Many aspects of the municipal permittees' roles in implementing strategies were explored above in a section titled accordingly. That section especially focused on activities to advance the use of ARCD methods. More broadly, the permittees will be coordinators of all permits pertaining to the watershed's aquatic resources, collectively pointed toward meeting objectives that the permittees adopt under state oversight. Other categories of tasks assigned to the municipalities under the proposed system include monitoring, in the contexts of both inspections and sampling performed through a consortium, and enforcement actions and program adaptations to promote progress toward achieving objectives. Box 6-4 provides a listing of anticipated tasks for the municipal permittees as well as the states and EPA.

A Pilot Program as a Stepping Stone

The shift of responsibility for stormwater regulation to municipalities under the watershed-based approach may lead to some surprises in implementation and enforcement. Primarily because of this, EPA is well advised to institute a pilot

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BOX 6-4
Government Agencies Roles during the Operation of a Watershed-Based Permitting System

EPA

1. Petition Congress for significant funding support for states and municipal permittees, and develop a program of fairly distributing funds based on environmental and financial needs at the watershed level.
2. Initiate regulatory modifications and clarifications necessary to establish the system.
3. Set policies for watershed permitting based on this report's recommendations.
4. Adapt TMDL program for use in the new program.
5. Produce guidance to assist the states and municipal permittees in the areas of:
   a. Developing a rotating basin approach;
   b. Developing an integrated municipal NPDES permit incorporating the full range of sources;
   c. Developing stormwater utilities and other funding mechanisms;
   d. Using impact source analysis (e.g., using reasonable potential analysis and new research results, industrial and construction site risk assessment);
   e. Using ARCD techniques for new development, redevelopment, and retrofitting;
   f. Developing monitoring consortia;
   g. Developing a credit trading system;
   h. Developing an active adaptive management program

Designated States (or EPA otherwise)

1. Define watersheds for which permits will be issued and set up a rotating basin approach to govern watershed analysis in support of subsequent steps.
2. Formulate and formally adopt goals relative to avoiding any further loss or degradation of designated beneficial uses in each watershed's component waterbodies and recovering lost beneficial uses.
3. Use the results of the existing Section 303(d) process and supplementary work to assess the extent of designated beneficial use achievement in each watershed and set goals for protection and recovery.
4. Match municipal permittees to watersheds and designate a lead permittee for each watershed.
5. Estimate resource needs to fulfill permit requirements in each watershed.
6. Develop a grant program, drawing on EPA and state funds, to support municipal permittees, with incentives for joining co-permittee associations.
7. Identify areas outside the jurisdictions of permitted municipalities that should be brought into the program because of projected development or the existence of problem sources that would compromise the protection and recovery of beneficial uses.
8. Use the triennial review process to modify water quality standards to the objective basis, emphasizing biological outcomes recommended in this report.
9. Revise the TMDL program in accord with the needs of the new program.
10. Set requirements for credit trading systems.
11. Set up an integrated municipal NPDES permit incorporating the full range of sources.
12. Work with municipal permittees to establish specific objectives as the basis for progress assessment.
13. Work with municipalities to develop adaptive management programs responding to progress assessment results.

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14. Write municipal permits incorporating the above elements.
15. Write industrial and construction general or individual permits incorporating the recommendations in this report.
16. Allocate a substantial portion of industrial and construction permit fees to municipal permittees to oversee those sectors.
17. Set requirements for municipalities and private properties to opt out of the defined program without compromising the achievement of objectives.
18. Provide consultation, support, and guidance (adapted from EPA materials or originally produced) to municipal permittees in the areas of:
    a. Developing stormwater utilities and other funding mechanisms;
    b. Using impact source analysis (e.g., industrial and construction site risk assessment);
    c. Using ARCD techniques for new development, redevelopment, and retrofitting;
    d. Developing monitoring consortia;
    e. Developing a credit trading system
19. Perform enforcement actions on non-complying dischargers referred by municipal permittees.
20. Assess performance of municipal permittees and specify corrections, rewards, and penalties accordingly.

Municipal Co-permittees (led by Lead Permittee)

1. Adopt specific objectives as the basis for program progress assessment.
2. Convert ordinances and regulations as needed to implement the modified program.
3. Supplement and reorganize staffing to emphasize progress and compliance assessment as the principal functions of the program.
4. Perform or contract detailed scientifically and technically based watershed analysis as a foundation for permit compliance.
5. Assemble existing data on soils and hydrogeologic properties and supplement with additional data collection as necessary to assess infiltration prospects across the municipality.
6. Create incentives for private property owners to maximize the use of ARCD methods in new development and redevelopment.
7. Build subwatershed-scale, publicly owned ARCD works to supplement on-site management measures and as retrofits.
8. Develop capacity for stormwater management in municipal WWTPs by reducing groundwater inflows to sanitary sewer lines.
9. In areas experiencing excessive infiltration and groundwater table rise resulting from non-stormwater flows, develop capacity for stormwater management through infiltration by formulating water conservation programs.
10. Identify industries and construction sites that are required to apply for permits but have not done so and compel their filing.
11. Establish or enhance existing programs to inspect and oversee industries and construction sites; report non-complying dischargers to the state for enforcement actions.
12. Set up or join a monitoring consortium structured to implement the progress evaluation and diagnostic tiers of the proposed monitoring program.
13. Annually report monitoring results to the permitting authority; submit a comprehensive progress assessment triennially.

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program that provides some experience in municipality-based stormwater regulation before instituting a nationwide program. This pilot program will also allow EPA to work through more predictable impediments to this watershed-based approach. The most obvious impediment arises from the inevitable limits of an urban municipality's responsibility within a larger watershed: substantial growth and accompanying stormwater loading may occur on the outside periphery of a municipality's designated boundaries. If an urban authority lacks legal authority over this future growth, and if this growth contributes significantly to water quality degradation, then a considerable share of the urban stormwater problem could remain poorly addressed. A pilot program should help identify the extent of this jurisdictional slippage and help identify ways to overcome it. Second, it is possible that some municipalities will balk at the added responsibility involved with the watershed-based approach, even with adequate funding. Unless the objective performance standards are rigid, the monitoring requirements substantial, and the rewards for compliance compelling for municipalities that meet the standards, it is quite possible that noncompliance or bare minimal compliance will be the norm. A pilot program provides a less politically charged atmosphere to experiment with the benefits of watershed-based regulation at the local level and to generate local government support for the approach. Finally, because the watershed-based approach necessitates legislative amendments to the CWA, instituting a pilot program in the interim—both to improve the design of a watershed-based program as well as to generate enthusiasm for it—seems a sensible course.

The pilot program should target those local governments that are most eager to redress water quality degradation in their watersheds, but feel stymied by what they perceive as inadequate legal authority and flexibility to make the necessary improvements. Willing municipalities or regional governments would thus opt-in to the program. The pilot program entices these more progressive municipalities to participate by allowing them to serve as the lead authority and providing them with much greater flexibility to determine how to meet their performance-based water quality goals with fewer legal constraints.

Under the pilot program, a municipal government or similar legal authority would apply to EPA or a delegated state to be designated as the lead agency for that portion of the watershed within its legal jurisdiction. In the application itself the municipality would establish—using modeling and ambient data—how it plans at a general level to maintain or exceed its water quality goals (objective performance standards). These goals must be at or above the state water quality goals, or if they are different (i.e., use biological criteria when the state adopts chemical criteria), the municipality must demonstrate how its performance standards will attain the equivalent of the state water quality goals at the downstream edge of the municipality's border. The municipality would also be required to provide assurance of sufficient infrastructure and funding to allow it to develop a water quality plan, implement that plan, issue permits, and enforce the requirements within its boundaries. Finally, municipal plans, once finalized, would need to meet minimum federal procedural requirements. For example,

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the plans must be transparent and provide opportunities for public comment; they must be enforceable; and they must establish monitoring programs that will track whether they in fact meet the objective performance standards. If a municipality fails to meet any of its performance standards by the requisite deadline, the state and EPA would have the option of revoking the municipality's program, and reinstituting federal requirements. Ideally, federal guidance would also be available to municipalities to provide direction on how they might institute a watershed-based plan within their boundaries, while still reserving considerable flexibility to allow them to develop creative and progressive stormwater solutions. For example, municipalities would be encouraged to form stormwater utilities that are financed from point and even nonpoint sources that assist them in establishing rigorous permitting and enforcement of their water quality plan.

Municipalities that voluntarily take on this role as lead authority will be rewarded with few legal constraints on how they meet their performance-based objectives. NPDES permits for major sources will still be required and must meet federal minima (technology-based controls) to avoid possible hot spots surrounding large dischargers, and states would remain listed as the lead permittee for these permits, but the lead municipality or other regional government would be able to propose new, more stringent limits that are presumptively favored in revised NPDES permits. Stormwater permits would also be mandatory, but their substantive requirements would be left wholly within the discretion of the lead municipality. Finally, states and municipalities would *not* be required to comply with all of the federal regulations governing TMDLs (they would make a basic load calculation for pollutants contributing to degraded conditions, 33 U.S.C. § 1313(d), but would not be required to do more). Instead, the watershed-based program would be considered the functional equivalent of TMDLs for at least the municipality's portion of the watershed since the program ensures that water quality objectives are met. Municipalities could even be allowed to set interim goals over a period of a decade or more so that TMDLs need not be achieved in a single permit cycle.

Other than federal minimum standards for major NPDES sources, municipalities would have primary if not exclusive authority to decide what types of sources (including nonpoint) require permits, whether certain land uses might be taxed for stormwater management fees, and whether and how to create trading programs among the contributors to water quality impairments within their watershed. Municipalities would also have legal authority to petition EPA to restrict upstream sources that contribute significantly to water quality degradation in ways that make it difficult for them to reach their goals. Upstream governments or sources could be subject to more rigorous federal or state TMDLs and could be vulnerable to tort and related claims from downstream municipalities.

This added flexibility and authority for municipalities to control water quality problems within their legal jurisdiction—coupled with objective performance standards—should lead to more creative approaches to stormwater management that create significant benefits to the municipality (i.e., more green-space buffers along waterways for recreation) and stronger planning and taxation of new de-

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velopments that otherwise might be uncontrolled. Municipal green space, parks, and a variety of other public goods that both reduce stormwater and enhance the public enjoyment of the surface waters could result from allowing a municipality the freedom to determine how best to regulate sources within its local boundaries. For example, rather than automatically allowing federally approved SCMs that have little aesthetic or recreational qualities, alternative approaches to SCMs that retain their effectiveness but provide other qualities (particularly qualities that draw the public outdoors for recreation or relaxation) are more likely to be encouraged or even required by a municipality that serves as lead over implementation of its water quality program.

Although a national watershed-based approach to stormwater regulation is likely to require legislative amendments, the pilot program may not necessitate additional legislative authorization. It is possible that through regulation, EPA may be able to develop "in lieu of" or "functional equivalent" requirements that allow a rigorous watershed plan to substitute for the bare federal requirements governing stormwater regulation, general permits, and TMDL planning laid out in the CWA. This type of intricate legal analysis, however, is beyond the scope of this document.

Final Thoughts

The watershed-based stormwater permitting program outlined above is ultimately essential if the nation is to be successful in arresting aquatic resource depletion stemming from sources dispersed across the landscape. EPA is called upon to adopt the framework now and set in motion a process to move it toward implementation over the next five to, at most, ten years. This chapter deals with some but not the entire realm of political, legal, regulatory, and logistical issues raised by converting to a fundamentally different system of management and permitting. Ideas are contributed regarding piloting and transitioning toward the new program, altering institutional arrangements to accommodate it, and incentives for effective participation. For watershed-based permitting to take hold, specific actions will have to be undertaken by EPA, state permitting authorities, and municipal permittees during the adoption and transition process.

The proposed program could be implemented by EPA in a number of ways, ranging from making it mandatory without any exception in all states and jurisdictions to leaving it entirely voluntary. The committee recommends neither extreme and believes the best course would be: (1) pilot test and refine the program as described in the report section titled "A Pilot Program as a Stepping Stone;" (2) make the refined program the default to be followed by all designated states (and EPA in others) and all municipal, industrial, and construction permittees, unless a state permitting authority convincingly demonstrates to EPA's satisfaction than an alternative approach will accomplish the program's overall goal of retaining and recovering aquatic resource beneficial uses; (3) develop very significant incentives for states and permittees to participate; and

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(4) require objective demonstration by any state opting for an alternative that it is broadly achieving the goal to at least the same extent as states within the program, with appropriate sanctions for noncompliance.

ENHANCEMENT OF EXISTING PERMITTING BASIS

The current federal stormwater regulatory framework has been in place since 1990, and the point source NPDES program under which it is being implemented has existed since 1972. The U.S. Congress deliberately acted in 1987 to amend the federal CWA with the goal of addressing stormwater pollution because it had been identified as a leading cause of surface water impairments, and regulations were inadequate to address it effectively. The total rethinking of the current framework of regulating stormwater pollution described above may require changes in statute and take a long time to implement. Thus, in addition to the longer-term approach that integrates a watershed-wide planning and permitting strategy into the program, several near-term solutions are also offered, with the objective of improving the current regulatory implementation and which at most might require changes in regulation.

Problems Complying with Both Municipal and General Industrial Permits

The NPDES permitting authority issues (1) separate individual permits or general permits to impose discharge requirements on small, medium, and large MS4s; (2) general permits that require construction activity operators who discharge stormwater to waters of the United States, including those who discharge via MS4s, to implement SCMs; and (3) general permits for operators of stormwater discharges associated with industrial activity who discharge to waters of the United States, including those who discharge via MS4s, to implement SCMs. The MS4 operators in turn are also required under the terms of their MS4 permits to require industries and construction site operators who discharge stormwater via the MS4 to implement controls to reduce pollutants in stormwater discharges to the maximum extent practicable, including those covered under the permitting authority's NPDES general permits. This dual-coverage scheme appears intended to recognize the separation of governmental authorities. Unfortunately, in practice it is duplicative, inefficient, and ineffective in controlling stormwater pollution that enters the MS4 from diffuse and dispersed sources. Particularly in the area of monitoring of water quality, the dual approach seems to have resulted in a lack of prioritization of high-risk industrial sources and the purposeless collection of industrial stormwater monitoring data or the poor use of it to strategically reduce the discharge of stormwater pollutants to the MS4.

The preference of EPA to use general NPDES permits to alleviate the administrative burden associated with permitting more than a 100,000 point

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sources discharging stormwater is understandable. It would have been prudent to have some form of prioritization to select some subset of the whole as high-risk or have a strategy for identifying a subset for individual NPDES permits to better achieve the objective of ensuring compliance with water quality standards on the basis of potential risk. As discussed in Chapter 2, there are no federal guidelines for prioritization (determining what industries are high-risk for stormwater discharges), and the state permitting authorities have largely not prioritized because of the overwhelming burden of administering a very expansive stormwater permitting program.

In the existing permitting scheme, the MS4 operator cannot be faulted for having a reasonable expectation that the permitting authority's general NPDES permits that regulate industrial activities and construction that discharge to the MS4 would require, at a minimum, a sufficient level of identification and implementation of SCMs to facilitate the MS4 operator's compliance with the MS4 permit. However, such controls are not identified by the NPDES permitting authority and rather are left to the choice of the industrial facility and construction site operators. Furthermore, the NPDES permitting authority imposes weak to no discharge sampling requirements on industrial facility and construction activity operators, which greatly impairs the MS4's ability to determine and control the worst regulated stormwater discharges to the MS4. Similarly, the NPDES permitting authority's general permit for construction activity encourages construction facility operators to consider post-construction stormwater controls, but it does not require them, even though the MS4 permit's programmatic measures mandate new development planning and post-construction controls as essential elements of the MS4 program. The lack of integration among stormwater permits and the absence of objective measures of compliance that are quantifiable is a glaring shortcoming in current stormwater permits and renders them difficult to enforce for water quality protection.

The California EPA State Water Board asked an expert panel to evaluate the extent of implementation success of the stormwater program in California and the feasibility of numeric effluent limits in stormwater permits. In its report (CA SWB, 2006), the panel concluded that the flexible approach of allowing a permittee to self-select SCMs for the purpose of controlling stormwater pollution was largely ineffective. The reasons stated were: (1) the SCMs were selected without proper consideration of design, performance, hydraulics, and function; (2) the MS4 permittees were not accountable for the performance of the SCMs; (3) the industrial and construction permittees were not responsible for the performance of the SCMs; and (4) the SCMs were seldom maintained properly except for aesthetic purposes. In other words, the flexibility provided by self-determination, self-evaluation, and self-reporting did not assure that SCMs were being implemented to effectively reduce stormwater pollutants to the MEP. Rather, the flexibility resulted in a lack of coordination of purpose and accountability between the MS4 permittees who owned or operate the MS4 and the industry and construction permittees who discharge to the MS4. Although typically enforcement by the permitting authority would have restored the integrity

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of the stormwater program, that remedy is likely to be ineffective here because the choice of SCMs is left too much to discretion and there are no quantifiable performance or design criteria for water quality purposes.

Integration and Dissemination of Authority

This section offers a near-term alternative solution to the problem cited above that utilizes the existing framework of the NPDES stormwater program. The strategy builds on the authority of MS4s over industry and construction sites to implement an integrated permitting scheme to reduce stormwater pollution into the waters of the United States. Unlike the first section of this chapter, it does not take a watershed approach to protecting water quality, even though the municipal stormwater programs may be more cost-effective if implemented on a watershed scale. It also addresses a significant shortcoming of the current scheme, that is, failure to recognize the enormous staff resources that it would take at the federal and state level for successful implementation in the absence of the leadership of local governments. Further, federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel under the principles of democratic governance, such as in the United States, to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees, who are local governments working for the public good, to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality—an approach here called "integration."

The central concept of integration is to give the MS4s controlling jurisdiction and responsibility over discharges from construction and industry to the MS4 in addition to their responsibility to implement the programmatic minimum measures identified in regulation. This approach would be similar to the current NPDES permitting scheme for publicly owned WWTPs, where a WWTP operator controls the quality of wastewater inputs (industrial waste streams) to make sure that the total output will not exceed water quality standards (see Box 6-5 on the National Pretreatment Program). The WWTP operators establish additional criteria such as local limits, require discharge monitoring of industrial wastes, and conduct inspections to make sure industrial discharges implement adequate wastewater treatment technologies, so that treated effluent from the wastewater treatment can comply with water quality standards to protect receiving waters. The same could be done for stormwater, except here the WWTP is replaced by the MS4, and the other inputs in this case are all industrial and construction discharges of stormwater into the MS4. The criteria by which the outputs of the industries are judged could be either water quality- or technology-based criteria. This arrangement puts the burden on the MS4 to identify high-risk industries because the MS4 is now responsible for the overall output (which could be, for example, the concentration of pollutants in stormwater monitored during

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BOX 6-5
National Pretreatment Program

EPA's NPDES Permitting Program requires that all point source discharges to waters of the United States (i.e., "direct discharges") must be permitted. To address "indirect discharges" from industries to Publicly Owned Treatment Works (POTWs), EPA, through CWA authorities, established the National Pretreatment Program as a component of the NPDES Permitting Program. The National Pretreatment Program requires industrial and commercial dischargers to treat or control pollutants in their wastewater prior to discharge to POTWs.

In 1986, more than one-third of all toxic pollutants entered the nation's waters from POTWs through industrial discharges to public sewers. Certain industrial discharges, such as slug loads, can interfere with the operation of POTWs, leading to the discharge of untreated or inadequately treated wastewater into rivers, lakes, etc. Some pollutants are not compatible with biological wastewater treatment at POTWs and may pass through the treatment plant untreated. This "pass through" of pollutants impacts the surrounding environment, occasionally causing fish kills or other detrimental alterations of the receiving waters. Even when POTWs have the capability to remove toxic pollutants from wastewater, these toxics can end up in the POTW's sewage sludge, which in many places is land-applied to food crops, parks, or golf courses as fertilizer or soil conditioner.

The National Pretreatment Program is unique in that the general pretreatment regulations require all large POTWs (i.e., those designed to treat flows of more than 5 MGD) and smaller POTWs with significant industrial discharges to establish local pretreatment programs. These local programs must enforce all national pretreatment standards (effluent limitations) and requirements, in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW. More than 1,500 POTWs have developed and are implementing local pretreatment programs designed to control discharges from approximately 30,000 significant industrial users.

EPA has supported the pretreatment program through development of more than 30 manuals that provide guidance to EPA, states, POTWs, and industry on various pretreatment program requirements and policy determinations. Through this guidance, the pretreatment program has maintained national consistency in interpretation of the regulations.

The general pretreatment regulations establish responsibilities of federal, state, and local government, industry, and the public to implement pretreatment standards to control pollutants that pass through or interfere with POTW treatment processes or that may contaminate sewage sludge. The general pretreatment regulations apply to all non-domestic sources that introduce pollutants into a POTW. These sources of "indirect discharge" are more commonly referred to as industrial users (IUs). Since IUs can be as simple as an unmanned coin-operated car wash to as complex as an automobile manufacturing plant or a synthetic organic chemical producer, EPA developed four criteria that define a significant industrial user (SIU). Many of the general pretreatment regulations apply to SIUs as opposed to IUs, based on the fact that control of SIUs should provide adequate protection of the POTW.

Unlike other environmental programs that rely on federal or state governments to implement and enforce specific requirements, the Pretreatment Program places the majority of the responsibility on local municipalities**.** Specifically, Section 403.8(a) of the general pretreatment regulations states that any POTW (or combination of treatment plants operated by the same authority) with a total design flow greater than 5 million MGD and smaller POTWs with SIUs must establish a local pretreatment program. As of early 1998, 1,578 POTWs were required to have local programs. Although this represents only about 15 percent of the total treatment plants nationwide, these POTWs account for more than 80 percent (i.e., approximately 30 billion gallons a day) of the national wastewater flow.

Consistent with Section 403.8(f), POTW pretreatment programs must contain the six minimum elements described below (EPA, 1999):

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1. Legal Authority

The POTW must operate pursuant to legal authority enforceable in federal, state, or local courts, which authorizes or enables the POTW to apply and enforce any pretreatment regulations developed pursuant to the CWA. At a minimum, the legal authority must enable the POTW to:

i. deny or condition discharges to the POTW,
ii. require compliance with pretreatment standards and requirements,
iii. control IU discharges through permits, orders, or similar means,
iv. require IU compliance schedules when necessary to meet applicable pretreatment standards and/or requirements and the submission of reports to demonstrate compliance,
v. inspect and monitor IUs,
vi. obtain remedies for IU noncompliance, and
vii. comply with confidentiality requirements.

2. Procedures

The POTW must develop and implement procedures to ensure compliance with pretreatment requirements, including:

i. identify and locate IUs subject to the pretreatment program,
ii. identify the character and volume of pollutants contributed by such users,
iii. notify users of applicable pretreatment standards and requirements,
iv. receive and analyze reports from IUs,
v. sample and analyze IU discharges and evaluate the need for IU slug control plans,
vi. investigate instances of noncompliance, and
vii. comply with public participation requirements.

3. Funding

The POTW must have sufficient resources and qualified personnel to carry out the authorities and procedures specified in its approved pretreatment programs.

4. Local Limits

The POTW must develop local limits or document why those limits are not necessary.

5. Enforcement Response Plan (ERP)

The POTW must develop and implement an ERP that contains detailed procedures indicating how the POTW will investigate and respond to instances of IU noncompliance.

6. List of SIUs

The POTW must prepare, update, and submit to the approval authority a list of all significant industrial users (SIUs).

In addition to the six specific elements, pretreatment program submissions must include:

- A statement from the city solicitor (or the like) declaring the POTW has adequate authority to carry out program requirements;
- Copies of statutes, ordinances, regulations, agreements, or other authorities the POTW relies upon to administer the pretreatment program, including a statement reflecting the endorsement or approval of the bodies responsible for supervising and/or funding the program;

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BOX 6-5 Continued

- A brief description and organizational chart of the organization administering the program; and
- A description of funding levels and manpower available to implement the program.

The objectives of the National Pretreatment Program are achieved by applying and enforcing three types of discharge standards: (1) prohibited discharge standards, (2) categorical standards, and (3) local limits.

Prohibited Discharge Standards

All IUs, whether or not subject to any other national, state, or local pretreatment requirements, are subject to the general and specific prohibitions identified in 40 C.F.R. §§403.5(a) and (b), respectively. General prohibitions forbid the discharge of any pollutant(s) to a POTW that cause pass-through or interference. These prohibited discharge standards are intended to provide general protection for POTWs. Examples of these include prohibitions on discharges of pollutants that can create fire or explosion hazards, cause corrosive structural damage, obstruct flow within the POTW, and interfere with the POTW's biological treatment activity. However, their lack of specific pollutant limitations creates the need for additional controls, namely categorical pretreatment standards and local limits.

Categorical Standards

Categorical pretreatment standards (i.e., categorical standards) are national, uniform, technology-based standards that apply to discharges to POTWs from specific industrial categories (i.e., indirect dischargers) and limit the discharge of specific pollutants. Categorical pretreatment standards for both existing and new sources are promulgated by EPA pursuant to Section 307(b) and (c) of the CWA. Limitations developed for indirect discharges are designed to prevent the discharge of pollutants that could pass through, interfere with, or otherwise be incompatible with POTW operations. The categorical pretreatment standards can be concentration based or mass based. For example, the pretreatment standard for the electrical and electronic component manufacturing industry (40 C.F.R. Part 469, Subparts A-D) are concentration-based daily maximum and monthly average limits that vary by subpart and pollutant parameter.

Local Limits

Prohibited discharge standards are designed to protect against pass-through and interference generally. Categorical pretreatment standards, on the other hand, are designed to ensure that IUs implement technology-based controls to limit the discharge of pollutants. Local limits, however, address the specific needs and concerns of a POTW and its receiving waters**.** Federal regulations at 40 CFR §§403.8(f)(4) and 122.21(j)(4) require control authorities to evaluate the need for local limits and, if necessary, implement and enforce specific limits as part of pretreatment program activities. Local limits are developed for pollutants (e.g., metals, cyanide, BOD_5, TSS, oil and grease, organics) that may cause interference, pass-through, sludge contamination, and/or worker health and safety problems if discharged in excess of the receiving POTW treatment plant's capabilities and/or receiving water quality standards.

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events). If put in this position, municipalities will make intelligent choices and adopt effective strategies to identify which industries and sources to focus upon. Each of these issues is discussed in greater detail below.

Determination of High-Risk Dischargers

At present, the federal stormwater regulations do not specifically identify which sources would be considered high risk given the common pollutants in MS4 stormwater discharges. With the exception of the category of municipal landfills and hazardous waste treatment, storage, and disposal facilities, it does not even state that the other nine categories of industry singled out in the regulations for permitting under the multi-sector industrial stormwater general permit (MSGP) are really high risk. The devolution of this responsibility to the municipality is sensible because the municipality, as the land-use authority, already conducts development review and issues industrial conditional-use permits. The permitting authority would still be responsible for inspecting high-risk state, federal, and other facilities over which the MS4 permittee has no jurisdiction. In addition, the permitting authority would inspect municipal facilities such as airports, ports, landfills, and waste storage facilities to avoid the situation of self-inspection. Methods for ranking industries according to risk are discussed in a subsequent section.

It is likely that some of the designated high-risk facilities would be better regulated by individual stormwater NPDES permits. In particular, good candidates for individual NPDES permits include international ports, airports, and multiphase construction land developments, which are similar (in the potential risk they pose to water quality) to traditional major wastewater facilities such as petroleum refineries and large POTWs.

SCM Design Parameters, Numerical SCM Performance Criteria, and Monitoring

For the integration approach to work, the permitting authority and the MS4 permittee must better delineate SCM design parameters, numerical performance criteria, and default SCMs based on best available technology or water quality standards for the discharge of industrial and construction stormwater. Both the ASCE International Storm Water Database (which is now called the WERF International Storm Water Database because it is maintained by the Water Environment Research Foundation) and the National Stormwater Quality Database (NSQD), which were developed with EPA funding, are comprehensive datasets that can be used to develop numeric technology-based effluent criteria or limits for industrial and construction stormwater discharges. The MS4 can then determine the compliance of industry and construction activity with its requirements by using either some numeric criteria or a suite of SCMs that have been

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presumptively determined as capable of achieving the performance criteria. The EPA MSGP includes a general list of sector-specific SCMs, but these presently have no performance criteria associated with them. It is important that the EPA continue to support both the WERF and the NSQD databases as the repositories of SCM performance and MS4 monitoring data, so that MS4s can use them to establish local limits and update the performance criteria periodically to fully effectuate the iterative approach to ensuring that MS4 discharges eventually will meet water quality standards.

The proposed integration scheme will also facilitate the MS4 permittee's implementation of a purpose-oriented stormwater monitoring program directed toward identifying problematic industrial or construction stormwater discharges or high-risk industrial facility sectors. The current benchmark monitoring conducted by MSGP facilities would be eliminated. Instead, MSGP facilities would have the option of performing scientifically valid stormwater discharge sampling to demonstrate their compliance with performance criteria or to participate in an MS4-led monitoring program by paying in lieu fees to support the cost of the purpose-oriented MS4 monitoring program. The net effect of this alternative is to pool the resources to come up with an optimal sampling strategy to replace what is now a stormwater monitoring strategy that is haphazard and not useful.

MS4 Responsibilities

Under integration, the MS4 permittee would be primarily responsible for the quality of stormwater discharges that exit the MS4 to the waters of the United States. The MS4 permittee would not be responsible for stormwater discharges from federal and state facilities or for facilities that have been issued an individual NPDES permit for stormwater discharges. The MS4 permittee would be responsible for implementing the six minimum program measures, assisting in the oversight and inspection of facilities covered under the MSGP and the construction general permit (CGP), and implementing a strategic water quality monitoring program to identify and control pollutant discharges from high-risk sites. The permitting authority would share any fees collected under the MSGP and CGP with the MS4, and facilities covered by them would have the option to opt-out of self-monitoring and contribute equivalent funds to an MS4-led monitoring program. Similarly, the permitting authority would be expected to support research and special studies that address issues of regional or national significance through partnerships with the MS4 permittees.

Some MS4s may balk at taking on more responsibility for the control of stormwater pollution, as required for integration to succeed. However, there are already several case examples that exist. The State of Oregon requires facilities that discharge industrial stormwater to file a Notice of Intent (NOI) for coverage under the MSGP with both the state and the local MS4 (Campbell, 2007). The state has an agreement with the local MS4s for the inspection of the facilities covered under the MSGP and the sharing of NOI fees. The State of Tennessee

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has a statewide pilot program to partner with local MS4s for the inspection of construction sites that are covered under the CGP.

Analogy to the WWTP Pretreatment Program

It is certainly true that the MS4s are a more challenging point source to regulate for the discharge of pollutants than WWTPs. WWTPs have fewer outfalls discharging to waters of the United States than MS4s, and inputs into them are through discrete rather than diffuse sources as in the case of MS4s. It is thus expected to be more difficult to identify problem stormwater sources and to hold them accountable for discharges in excess of standards. This problem is not insurmountable, however. Watershed and land-use hydrologic models can be developed and refined by strategic sampling of pollutant sources for use by MS4 permittees and regulatory agencies. If EPA and state permitting authorities establish measurable outcomes as expected endpoints of progress, MS4 permittees will make intelligent choices about which measures to implement in order to meet these endpoints. In large part, the lack of progress nationally towards controlling pollutants in stormwater discharges from the MS4s has been due to the absence of national SCM design standards, MS4 discharge performance criteria, and stormwater effluent guidelines. Presently, the MS4 permittees as owners and operators of the MS4 affirmatively approve connections to the conveyance system for rainfall runoff. Historically the issuance of the MS4 connection permit has been based on the sizing of the pipes for the conveyance of flood waters. There are few barriers to including water quality considerations in reauthorizing these connections and adding new ones.

Note that EPA did initially consider using the WWTP pretreatment approach for stormwater discharges by requiring MS4 permittees to be primarily responsible for discharges of stormwater associated with industrial activity through the MS4 (53 Fed. Reg. 49428; December 7, 1988). However, EPA deviated from this approach in issuing its Final Storm Water Rule (55 Fed. Reg. 48006; November 16, 1990). In the absence of regulations that specifically confer authority on MS4 permittees to establish local limits for stormwater discharges to the MS4 from industry and businesses, the EPA should promulgate specific SCMs and performance guidelines with rigorous requirements for self-monitoring and compliance in order to support the integrated framework for controlling stormwater pollution from MS4s.

Potential Legal Barriers

A revised stormwater program that requires MS4s to play a more significant role in enforcement and oversight and that provides greater specificity in permit requirements is not only contemplated, but arguably demanded by Congress in the CWA. Specifically, Congress directs that MS4 permits be conditioned on

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the requirement that the MS4s "shall require controls to reduce the discharge of pollutants to the maximum extent practicable" 42 U.S.C. § 1342(p)(3)(B)(iii). EPA has already conditioned Phase I MS4 permits on the requirement that the municipality establish that it has the legal authority to inspect discharges into the system and take regulatory and enforcement action against excessive or violating sources [40 C.F.R. § 122.26(d)(2)(i)]. Nevertheless, to ensure that MS4s play an even more active role, EPA should include several additional requirements in its implementing regulations. In addition to promulgating more detailed and specific SCM requirements as discussed above, EPA should also require that the Phase I MS4s establish that they possess sufficient funding and staff to effectuate their responsibilities [see, e.g., 40 C.F.R. § 403.8(f)(2) and (3) requiring this showing for the POTW program]. Like the POTW program, states should also be authorized as MS4 permittees when the local governments are unable or unwilling to carry out their mandatory stormwater permit responsibilities [see, e.g., 40 C.F.R. § 403.10(e) providing this authority for the POTW program].

Industrial Program

The industrial stormwater permit program presently incorporates a menu of SCMs that are to be selected by the facility operator, a rudimentary monitoring program that includes visual observations, some water quality sampling for selected parameters for certain types of industries subject to numerical effluent limitations (see Table 2-6) or a set of pollutant-level benchmarks that are to be used as a measure to appropriately revise the SWPPP (see Table 2-5), and annual reporting. Neither SCM performance criteria nor the characteristics of a design storm for water quality purposes have been established. Given the broad discretion that facility operators enjoy as a result, it has been difficult to gauge compliance with the MSGP and initiate enforcement for non-compliance even though industrial stormwater discharges are required to meet effluent limitations (technology- or water quality-based) that reflect water quality standards (Duke and Beswick, 1997; Duke and Augustenborg, 2006; Wagner, 2006). Several ideas to address some of the shortcomings in the implementation of the permitting program for industrial stormwater discharges are offered as *additions* to the concept of MS4 regulatory integration discussed previously. They would substantively improve the current industrial stormwater permitting program even if the integration recommendations were not acted upon.

Criteria for a Water Quality Design Storm and Subsequent SCM Selection

To improve the quality of stormwater discharges from industry, provide for better accountability, and advance the objectives of the CWA, it is important

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first to identify the criteria for a water quality design storm as opposed to one for flood control design, where the objective is to protect human life and real property. It is important that the permitting authority designate the basis for the determination of the water quality design storm, and explicitly state that it would form the criteria for evaluation of compliance with technology-based standards or water quality-based standards. This is essential because the engineering design decisions that determine how much stormwater is to be treated to remove toxic pollutants that pose a risk to human health or aquatic life is more a policy matter than a scientific one (Schiff et al., 2007). While modeling exercises using continuous simulation methods in theory could be performed for every project or subwatershed or region to support planning decisions on how much stormwater needs to be treated for optimum water quality benefits, such a detailed analysis will be too cumbersome and cost-prohibitive for routine planning and implementation purposes. Thus it is recommended that the EPA establish guidelines for the selection of water quality design storms for controlling pollution from MS4 and industrial stormwater discharges. This would not be a new practice for EPA because the agency has previously established design storms for certain industrial sectors when promulgating effluent guidelines (Table 2-6). Conceivably, unlike the technology limiting design storms that are set on rainfall recurrence intervals, the design storm to protect surface water quality and beneficial uses could be different for different eco-regions of the United States.

The water quality design storm, which may be expressed as total rainfall depth, runoff volume, or rainfall intensity, incorporates the concept that extreme rainfall events are rare, and that a few times each year the runoff volume or flow rate from a storm will exceed the design volume or rate capacity of an SCM. Therefore, for the purpose of best available technology and cost-effectiveness, industrial facility operators should not be held accountable for pollutant removal from storms beyond the size for which an SCM is designed.

For MS4 operators, the concept of designing MS4s for both flood control conveyance (capital flood design) and for water quality protection (water quality design) involves a fundamental shift. Whereas flood control engineers design conveyance systems with return frequencies of two years (streets), ten years (detention basins), 50 years, and 100 years (channels), the water quality design storm event is for a return frequency of six months to a year. The water quality design implicitly focuses on treating the first flush of runoff, which contains the highest load and concentration of pollutants and which occurs in the first half to one inch of runoff. In contrast, flood control designs are built to convey tens of inches of runoff.

In addition to issuing the guidelines to support the setting of stormwater criteria for water quality design, it is important that the EPA establish SCM performance criteria based on best technologies and identify the "presumptive technologies" that have been demonstrated to achieve the performance criteria. The water quality design storm and the best available technologies with their associated criteria can then form a basis for technology-based effluent limitations to be included in industrial stormwater permits. If the facility operator elects the iden-

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tified presumptive technology, then compliance monitoring requirements can be scaled down to a minimum to ensure that the treatment systems are being properly maintained. On the other hand, if the operator elects to go with a suite of alternative SCMs, then the monitoring requirements sufficient to demonstrate that the suite of alternative SCMs are in fact achieving the effluent quality of the selected technology can be prescribed. In such a scheme, visual monitoring will serve to ensure that the treatment systems are being properly maintained, and compliance can be reported using the same procedures as required presently for the industrial wastewater permits.

How to Identify a High-Risk Industry

Both the watershed-based permitting approach described previously in this chapter and the integration approach call for municipal permittees, as part of their responsibilities, to identify high-risk industrial stormwater dischargers. This involves identifying the potential sources of concern, evaluating the extent of their potential impacts, and then prioritizing them for attention—a classic risk assessment. Municipalities would generally not be able to give equal and full attention to all sources, nor should they. Unfortunately, what constitutes high risk or any level of risk for industries covered by NPDES stormwater permits has not been defined by EPA, although the states have developed various interpretations (see Appendix C).

Two methodologies for identifying industrial and commercial facilities that are considered high-risk for discharging pollutants in stormwater are presented below. Box 6-6 describes the "intensity of industrial activity" method devised for the City of Jacksonville (Duke, 2007). This method uses telephone queries and a point scale system to visually score each facility based on the intensity of the industrial activities exposed to stormwater, and groups the results into categories A, B, C, or D in increasing order of intensity (Cross and Duke, 2008). The categories are designed to distinguish high-risk facilities from low-risk facilities, and not to make fine distinctions among facilities with similar characteristics. This typology is sufficient to distinguish facilities with little or no potential for discharging pollutants associated with stormwater from facilities that might discharge those pollutants. More than half of the facilities that were subject to Florida's MSGP were determined to be low-risk (Cross and Duke, 2008).

Box 6-7 outlines an empirical methodology used by the County of Los Angeles to rank the risk of industrial facilities for stormwater pollution on the basis of pollution potential P. The pollution potential P was computed as a product of the number of on-site sources, percent imperviousness, pollutant toxicity, degree of exposure, and the number of facilities (Los Angeles County, 2001). Based on this ranking scheme, five top high-risk industries were selected: (1) automobile dismantlers, (2) automobile repair, (3) metal fabrication, (4) motor freight, and (5) automobile dealers. Stormwater discharges from six facilities in each category were characterized over a two-year period, and the effectiveness of SCMs

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BOX 6-6
Risk Assessment for Industrial Dischargers of Stormwater

The City of Jacksonville has had very good success in determining what industries pose the highest stormwater risks by starting with businesses having the Standard Industrial Classification (SIC) codes designated for permit coverage but using multiple lists of potential sources and cross checking them to target inspections and other interventions where they will have the best effect. Other clues to sources of interest include other environmental permits (e.g., wastewater NPDES permits, permits for discharge to sanitary sewer), tax records, records of fire code inspections, building permit filings, planning agency proceedings, contacts with business associations, marketing information put out by companies, Resource Conservation and Recovery Act hazardous waste reports, and telephone and field surveys.

Duke (2007) proposed a 0- to 8-point scoring scheme (shown below) to rate the intensity of industrial activities exposed to stormwater. The system is based on the relative amount of exposure to precipitation and runoff by industrial materials, processes, wastes, and vehicles. Once municipalities gather the data and then classify their industries accordingly, they would have a very useful tool to program inspections and monitoring emphasizing the industries most risking their success in achieving established objectives. A similar system could and should be developed for construction sites.

0 points
- Small bulk waste, e.g., covered dumpster: area <100 m^2
- Hazardous waste: containers not exposed to precipitation

1 point
- Outdoor vehicle use: 1-2 vehicles, outdoors occasionally/never, not used in precipitation
- Vehicle washing outdoors, 1-2 vehicles, rarely or occasionally done

2 points
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors occasionally/never, used in precipitation
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors every day, not used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors occasionally/never, not used in precipitation
- Vehicle maintenance or re-fueling, 1-2 vehicles, rarely or occasionally done, outside
- Vehicle washing outdoors, 1-2 vehicles, regularly done
- Vehicles washing outdoors, 3 vehicles, rarely or occasionally done

4 points
- Storage of materials or products: area < 100m^2 and/or < five 55-gallon drums
- Fixed outdoor equipment: 1-2 small or large item(s)
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors every day, used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors occasionally/never, used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors every day, not used in precipitation
- Uncovered shipping/receiving area: 1-2 docks
- Vehicle maintenance or re-fueling outdoors, 1-2 vehicles, regularly done
- Vehicle maintenance or re-fueling outdoors, vehicles, rarely or occasionally done
- Plant yard, rail lines, access roads: 1,000 ft^2
- Small process equipment, e.g., compressors, generators: exposed to precipitation

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BOX 6-6 Continued

6 points
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors every day, used in precipitation
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors occasionally, used in precipitation
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors every day, not used in precipitation
- Vehicle maintenance or re-fueling outdoors, 3 vehicles, regularly done
- Plant yard, rail lines, access roads: 1,000 ft^2

8 points
- Storage of materials or products: area 100^2 and/or five 55-gallon drums
- Boneyard of scrap, disused equipment, similar
- Hazardous waste: containers exposed to precipitation
- Fixed outdoor equipment: small or 2 large items
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors every day, used in precipitation
- Uncovered shipping/receiving area: 3 docks
- Plant yard, rail lines, access roads: 5,000 ft^2
- Manufacturing activities, e.g., cutting, painting, coating materials: exposed to precipitation

SOURCE: Duke (2007).

was assessed at a subset of them. However, the monitoring was minimal, and so much of the prioritization was based on best professional judgment about pollutant discharges.

Industrial Stormwater Discharge Monitoring

Monitoring data from Phase I MS4s have been compiled in the NSQD for several years, making possible a number of important findings about the quality of municipal stormwater (see Chapter 3). Although industry that occurs within MS4s is technically included in the NSQD, the data are lumped together and not sector specific. There is no comparable, reliable source of data specifically on industrial discharges, even though EPA requires benchmark monitoring for MSGP industrial permittees. The intent was that industrial facility operators would use benchmark exceedances as action levels to improve SCMs, but this self-directed approach has been largely a failure. Many industrial facilities reported repeated exceedances of benchmark values without action, and others have failed to report any monitoring data at all. In addition, the representativeness of single grab samples taken to characterize the discharge and less-than-rigorous sample collection and quality assurance procedures have resulted in monitoring data that are not very useful. One of the only analyses of benchmark monitoring data ever done evaluated California's program between 1992 and 2001 (see Box 4-2; Stenstrom and Lee, 2005; Lee et al., 2007). The study showed no relationship between facility type and stormwater discharge quality. The cited reasons for the poor relationship included variability in sampling parameters, sampling time, and sampling strategy—that is, poor data.

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BOX 6-7
Los Angeles County Critical Facilities Monitoring Data

One of the few sources of data on industrial stormwater discharges comes from the County of Los Angeles. A stepwise process was used to identify the highest-risk industrial/commercial facilities, which were then monitored to measure the quality of their stormwater discharges and to evaluate the effectiveness of SCMs. The initial list of candidate facilities was identified from their relative numbers and the extent of their outdoor activities. This list was then refined using an empirical equation for pollutant potential P:

$$P = Q \times R \times T \times E \times N$$

where

Loading (*Q*) is the number of sources at a site and the likelihood of release;
Imperviousness (*R*) of a site is the percent of paved area;
Pollutant toxicity (*T*) denotes the number of toxic pollutants and the inherent toxicity of the mix;
An exposure factor (*E*) signifies if activities are exposed to rainfall; and
The Number (*N*) represents the total number of sites in the county.

Each variable was assigned a qualitative number from 1 to 10, with 10 representing the worst condition.

Based on this equation, five top "critical source" industries were determined: (1) automobile dismantlers; (2) automobile repair; (3) metal fabrication; (4) motor freight; and (5) automobile dealers. Six facilities from each of these categories were monitored during five storms a year for two years. The stormwater discharge samples were analyzed for general conventional pollutants, heavy metals, bacteria, and semi-volatile organic compounds. Half of the facilities were then fitted with SCMs, which were monitored to evaluate their effectiveness.

The highest median values were observed for total zinc (approx. 450 µg/L), dissolved zinc (approx. 360 µg/L), total copper (approx. 240 µg/L), and dissolved copper (approx. 110 µg/L) in stormwater discharges from fabricated metal sites. However, levels for total and dissolved zinc did not appear to be significantly different among the industry types. SCMs in the form of good housekeeping and spill containment measures were installed at half of the sites. For total and dissolved zinc, the median concentration lowered or stayed nearly the same with the implementation of SCMs at the auto dismantling, auto repair, and fabricated metals industries (i.e., in none of the circumstances was the difference significant). For total and dissolved copper, however, where the fabricated metal industry had displayed the highest median concentrations, levels were significantly reduced with the implementation of SCMs. The auto dismantling and auto repair businesses showed no significant differences in copper after the implementation of SCMs.

SOURCE: Los Angeles County (2001).

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In the past, it has been proposed to EPA that it fund a project that would systematically collect the benchmark monitoring data across the nation, as has been done for MS4s, but these suggestions have been rejected. To get better data from specific industrial sectors, it is recommended that a small subset of industrial users and sectors be selected for composite sampling in a program directed by the MS4. Alternatively, making a trained team responsible for monitoring of small-business industrial dischargers would reduce, if not eliminate, current problems with quality assurance.

Monitoring of industrial stormwater discharges could be streamlined by considering the adoption of a Reasonable Potential Analysis (RPA), which is already part of the existing practice in developing limits for NPDES wastewater permits (EPA, 1991). The RPA is a procedure that uses statistical distribution assumptions in association with a limited number of wastewater discharge quality measurements to determine the likelihood that a receiving water quality standard would be violated, which assists the permitting authority in determining what permit limitations should be set to protect receiving water quality. The effluent data from any treatment system may be described using standard descriptive statistics such as the mean concentration and the coefficient of variation. Using a statistical distribution such as the lognormal, an entire distribution of values can be projected from limited data; limits on pollutant concentrations in discharge can then be set at a specified probability of occurrence so that the receiving water is protected. An RPA for stormwater pollutants may be particularly relevant in developing performance criteria for SCMs for facilities discharging stormwater within the integrated framework of MS4 permitting. Also, MS4 permittees could use the method to reduce the number of pollutants that high-risk industries would be required to monitor in order to demonstrate to the municipality that they are not the source of pollutants in MS4 discharges that are impairing surface waters.

Construction Program

The recommendations for stormwater discharges associated with construction activity are very similar to those offered for stormwater discharges associated with industrial activity. The integration with the MS4 program is less of a challenge because municipalities have always had primacy on land development planning and construction activity. Most municipalities have had requirements for soil erosion and sediment control plans on construction sites that precede the federal stormwater regulations. EPA regulations already allow permitting authorities to approve Phase I and Phase II MS4 permittee oversight of CGP construction sites under the qualifying local program provision (40 C.F.R. 122.44(s)) (Grumbles, 2006). The weakness in the implementation of this provision currently is the absence of rigorous SCM performance criteria guidelines for MS4s permittees to meet in order to be deemed as qualifying.

The construction stormwater general permit program requires the develop-

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ment and implementation of an SWPPP. The SWPPP, which must be prepared before construction begins, focuses on two major requirements: (1) describing the site adequately and identifying the sources of pollution to stormwater discharges associated with construction activity on site and (2) identifying and implementing appropriate measures to reduce pollutants in stormwater discharges to ensure compliance with the terms and conditions of this permit. The SWPPP must describe the sequence of major stormwater control activities and the kinds of SCMs that will be in place, and it must identify interim and permanent stabilization practices, including a schedule of their implementation. There is an expectation that the construction site operator will use good site planning, preserve mature vegetation, and properly stage major earth-disturbing activities to avoid sediment loss and prevent erosion. Post-construction stormwater controls need to be considered, but are not required. Construction site operators are required to visually inspect the construction site weekly and perform a walk through before predicted storm events. No annual reports are required, but records must be kept for a period of three years after permit coverage has been terminated. There are no SCM performance criteria, other than a suggestion that most SCMs should be able to achieve 80 percent TSS removal. As with industry, it is difficult to gauge compliance with the CGP except when inadequate SCMs result in a massive discharge of sediment from a construction site.

The pollutant parameters that are of concern in stormwater discharges from construction activity are TSS, settleable solids, turbidity, and nutrients from erosion; pH from concrete and stucco; and a wide range of metallic and organic pollutants from construction materials, processes, wastes, and vehicles and other motorized equipment. The permitting authority, in addition to guidelines for the water quality design storm, must establish SCM performance criteria for stormwater discharges associated with construction activity. The construction site operator should be given the option of implementing SCMs that are the presumptive technology, or equivalent SCMs that can achieve the performance criteria. For example, the recommended SCMs in Box 5-3 could serve as the presumptive construction SCMs on a typical construction site that is less than 50 acres in size. If the operator elects to go with a suite of alternative SCMs, then adequate monitoring must be performed to demonstrate that the alternative SCMs are in fact achieving the performance criteria. In addition, the CGP presently does not mandate or require that post-construction SCMs be integrated with the MS4 permittee requirements under its New Development/Redevelopment Program requirements. The proper planning for and implementation of SCMs that will help mitigate stormwater pollution from planned future use of the site will be critical to protecting water quality. Thus the post-construction requirements of the CGP should be strengthened and better integrated with the new development/redevelopment requirements of the MS4 permits.

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Municipal Program

Several key enhancements to the MS4 permitting program are needed to ensure that resources are targeted to achieve the greatest on-the-ground implementation of SCMs to make incremental progress in meeting water quality standards. Six specific issues are discussed below; their implementation will require greater collaboration and flexibility among regulators and permitted parties. These recommendations are suggested for communities that are not ready for the integrated watershed approach proposed in the prior section, and represent a bridge toward building internal capacity to implement them.

Numeric Expression of "Maximum Extent Practicable"

The ambiguity of the term "maximum extent practicable" (MEP) has been a major impediment to achieving meaningful water quality results in the MS4 program. The EPA should develop numerical expressions of MEP in the next round of permit renewals that can be measured and tracked. A national numeric benchmark should be avoided; states should focus on regional benchmarks that are tied to their water quality problems. Four examples of methods to define MEP in a numeric manner are provided below: the first three are applied at a regional or state level, whereas the last (impervious cover-based TMDLs) offers more flexibility to be applied at individual sites.

Establish Municipal Action Levels. This approach relies on the use of a national database of stormwater runoff quality to establish reasonable expectations for outfall monitoring in highly developed watersheds. The NSQD (Pitt et al., 2004) allows users to statistically establish action levels based on regional or national event mean concentrations developed for pollutants of concern. The action level would be set to define unacceptable levels of stormwater quality (e.g., two standard deviations from the median statistic, for simplicity). Municipalities would then routinely monitor runoff quality from major outfalls. Where an MS4 outfall to surface waters consistently exceeds the action level, municipalities would need to demonstrate that they have been implementing the stormwater program measures to reduce the discharge of pollutants to the maximum extent practicable. The MS4 permittees can demonstrate the rigor of their efforts by documenting the level of implementation through measures of program effectiveness, failure of which will lead to an inference of noncompliance and potential enforcement by the permitting authority.

Site-Based Runoff and/or Pollutant Load Limits. This approach is primarily used for watersheds that are experiencing rapid development; it establishes numeric targets or performance standards for pollutant or runoff reduction that must be met on individual development sites. The numeric targets may involve specific pollutant load limits or runoff reduction volumes. For example,

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Virginia DCR (2007) and Hirschman et al. (2008) established a statewide computational method to ensure that SCMs are sized, designed, and sequenced to comply with specific nutrient-based load and runoff reduction limits. The nutrient load limits of 0.28 lb/acre/yr for total phosphorus and 2.68 lb/acre/yr for total nitrogen were computed using the Chesapeake Bay Model for Virginia tributaries to the bay. The design process also requires the computation of runoff reduction volumes achieved to promote the use of nonstructural SCMs. The basic concept is that new development on non-urban land must not exceed the average annual nutrient load and runoff volume for non-urban land using effective SCMs in the watershed. This blended site-based runoff and load limit approach has been advocated by the Office of Inspector General (2007) and Schueler (2008a) and is under active consideration by several other Chesapeake Bay states.

Wenger et al. (2008) reports on a no-net-hydrologic-increase strategy to protect endangered fish species in the northern Georgia Piedmont that sets specific on-site runoff reduction requirements for a range of land uses and design storm events. A similar approach has been incorporated into the recently enacted Energy Independence and Security Act of 2007 that contains provisions that require that the "sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

The challenge of defining MEP as a runoff reduction or pollutant load limit is that considerable scientific and engineering analysis is needed to establish the performance standards, evaluate SCM capability to meet them, and devise a workable computational approach that links them together at both the site and watershed levels. In addition, care must be taken to define an appropriate baseline to represent predevelopment conditions that does not unduly penalize redevelopment projects or make it impossible to comply with limits at new development sites after maximum effort to apply multiple SCMs is made.

Turbidity Limits for Construction Sites. Numeric enforcement criteria can be used to define what constitutes an egregious water quality violation at construction sites and provide a technical criterion to measure the effectiveness of erosion and sediment control practices. Currently, most states and localities do not specify either numeric enforcement criteria or a monitoring requirement within their CGP (see the survey data contained in Appendix C).

A maximum turbidity limit would establish definitive criteria as to what constitutes a direct sediment control violation and trigger an assessment for remediation and prevention actions. For example, local erosion and sediment control ordinances could establish a numeric turbidity limit of 75 Nephelometric Turbidity Units (NTU) as an instantaneous maximum for rainfall events less than an inch (or a 25 NTU monthly average) and would prohibit visible sedi-

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ment in water discharged from upland construction sites. While the exact turbidity limit would need to be derived on a regional basis to reflect geology, soils, and receiving water sensitivity, research conducted in the Puget Sound of Washington indicates that turbidity limits in the 25 to 75 NTU can be consistently achieved at most highway construction sites using current erosion and sediment control technology that is properly maintained (Horner et al., 1990). If turbidity limits are exceeded, a detailed assessment of site conditions and follow-up remediation actions would be required. If turbidity limits continue to be exceeded, penalties and enforcement actions would be imposed. Enforcement of turbidity limits could be performed either by state, local, or third party erosion and sediment control inspectors, or—under appropriate protocols, training, and documentation—by citizens or watershed groups.

Impervious Cover Limits and IC-based TMDLs. MS4s that discharge into TMDL watersheds also require more quantitative expression of how MEP will be defined to reduce pollutant loads to meet water quality standards. Maine, Vermont, and Connecticut have recently issued TMDLs that are based on impervious cover rather than individual pollutants of concern (Bellucci, 2007). In such a TMDL, impervious cover is used as a surrogate for increased runoff and pollutant loads as a way to simplify the urban TMDL implementation process. Impervious cover-based TMDLs have been issued for small subwatersheds that have biological stream impairments associated with stormwater runoff but no specific pollutant listed as causing the impairment (in most cases, these subwatersheds are classified as impacted according to the Impervious Cover Model [ICM]—see Box 3-10). A specific subwatershed threshold is set for effective impervious cover, which means impervious cover reductions are required through removal of impervious cover, greater stormwater treatment for new development, offsets through stormwater retrofits, or other means.

Traditional pollutant-based TMDLs would continue to be appropriate for "non-supporting" and "urban drainage" subwatersheds, although they could be modified to focus compliance monitoring on priority urban source areas or subwatersheds that produce the greatest pollutant loads. Although EPA (2002) indicates that this analysis does not extend to demonstrating that changes will occur in receiving waters, it does outline a rigorous process for evaluating pollutant discharges and SCM performance. More recent EPA guidance (2007c) recommends that MS4s conduct a four-step analysis, which is distilled to its essence below:

Step 1: Estimate loads for pollutant of concern for the watershed.

Step 2: Provide a specific list of SCMs that will be applied in the listed watershed.

Step 3: Estimate the pollutant removal capability of the individual SCMs applied.

Step 4: Compute aggregate watershed pollutant reduction achieved by the MS4.

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Although this is not a particularly new interpretation of addressing stormwater loads in watersheds listed as impaired and/or having written TMDLs, it is exceptionally uncommon for individual MS4s to document the link between their stormwater discharges and water quality standard exceedances, as modified by the system of SCMs that they used to reduce these pollutants. As of 2007, EPA could only document 17 TMDLs that addressed stormwater discharges using this sequential analysis. EPA and states need to provide more specific guidance for MS4s to comply with TMDLs in their permit applications and annual reports.

Focus MS4 Permit Implementation at the Subwatershed Level

Chapter 5 noted the importance of the watershed context for making better local stormwater decisions. This context can be formally incorporated into local MS4 permits by focusing implementation on a subwatershed basis, using the ICM, as described in Box 3-10 and outlined in Table 6-1. When urban streams are classified by the ICM, this basic subwatershed planning process can be used to establish realistic water quality and biodiversity goals for individual classes of subwatersheds, as shown in Table 6-2. As can be seen, goals for water and habitat quality become less stringent as impervious cover increases within the subwatershed. This subwatershed approach provides stormwater managers with more specific, measurable, and attainable implementation strategies than the one-size-fits-all approach that is still enshrined in current wet-weather management regulations.

Some examples of how to customize stormwater strategies for different subwatersheds are described in Table 6-3. This approach enables MS4s to utilize the full range of watershed planning, engineering, economic, and regulatory tools that can manage the intensity, location, and impact of impervious cover on receiving waters. In addition, the application of multiple tools in a given subwatershed class helps provide the maximum level of protection or restoration for an individual subwatershed when impervious cover is forecast to increase due to future growth and development. The conceptual management approach shown in Table 6-3 is meant to show how urban stream classification can be used to guide stormwater decisions on a subwatershed basis. The first column of the table lists some key stormwater management issues that lend themselves to a subwatershed approach and are explained in greater detail below.

Linkage with Local Land-Use Planning and Zoning. Given the critical relation between land use and the generation of stormwater, communities should ensure that their planning tools (e.g., comprehensive plans, zoning, and watershed planning) are appropriately aligned with the intended management classification for each subwatershed. For example, it is reasonable to encourage redevelopment, infill, and other forms of development intensification within non-

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TABLE 6-1 Components of Subwatershed-Based Stormwater Management

1. Define interim water quality and stormwater goals (i.e., pollutants of concern, biodiversity targets) and the primary stormwater source areas and hotspots that cause them.
2. Delineate subwatersheds within community boundaries.
3. Measure current and future impervious cover within individual subwatersheds.
4. Establish the initial subwatershed management classification using the ICM.
5. Undertake field monitoring to confirm or modify individual subwatershed classifications.
6. Develop specific stormwater strategies within each subwatershed classification that will guide or shape how individual practices and SCMs are generally assembled at each individual site.
7. Undertakes restoration investigations to verify restoration potential in priority subwatersheds.
8. Agree on the specific implementation measures that will be completed within the permit cycle. Evaluate the extent to which each of the six minimum management practices can be applied in each subwatershed to meet municipal objectives.
9. Agree on the maintenance model that will be used to operate or maintain the stormwater infrastructure, assign legal and financial responsibilities to the owners of each element of the system, and develop a tracking and enforcement system to ensure compliance.
10. Define the trading or offset system that will be used to achieve objectives elsewhere in the local watershed objectives in the event that full compliance cannot be achieved due to physical constraints (e.g., indexed fee-in-lieu to finance municipal retrofits).
11. Establish sentinel monitoring stations in subwatersheds to measure progress towards goals.
12. Revise subwatershed management plans in the subsequent NPDES permitting cycle based on monitoring data.

supporting or urban drainage subwatersheds, whereas down-zoning, site-based IC caps, and other density-limiting planning measures are best applied to sensitive subwatersheds.

Stormwater Treatment and Runoff Reduction MEP. Subwatershed classification allows managers to define achievable numerical benchmarks to define treatment in terms of the maximum extent practicable. Thus, a greater level of treatment is required for less-developed subwatersheds and a reduced level of treatment is applied for more intensely developed subwatersheds. This is most frequently expressed in terms of a rainfall depth associated with a given design storm. Designers are required to treat and/or reduce runoff for all storm events up to the designated storm event. This flexibility recognizes the greater difficulty and cost involved in providing the same level of treatment in an in-

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TABLE 6-2 Expectations for Different Urban Subwatershed Classes

Lightly Impacted Subwatersheds (1 to 5% IC)	• Consistently attain scores for specific indicators for hydrology, biodiversity, and geomorphology that are comparable to streams whose entire subwatersheds are fully protected in a natural state (e.g., national parks). Should provide for healthy reproduction of trout, salmon, or other keystone fish species.
Moderately Impacted Subwatersheds (6 to 10% IC)	• Consistently attain scores for specific stream indicators that are comparable to the highest 10 percent of streams in a population of rural watersheds in order to maintain or restore ecological structure, function, and diversity of the streams. The "good to excellent" indicator scores for this category of subwatersheds will be the benchmark against which the relative quality of more developed subwatersheds will be measured.
Heavily Impacted Subwatersheds (11 to 25% IC)	• Consistently attain good stream quality indicator scores to ensure enough stream function to adequately protect downstream receiving waters from degradation. • Function is defined in terms of flood storage, in-stream nutrient processing, biological corridors, stable stream channels, and other factors.
Non-Supporting Subwatersheds (26 to 60% IC)	• Consistently attain "fair to good" stream quality indicator scores. • Meet bacteria standards during dry weather and trash limits during wet weather. • Maintain existing stream corridor to allow for safe passage of fish and floodwaters.
Urban Drainage Subwatersheds (61 to 100% IC)	• Maintain "good" water quality conditions in downstream receiving waters. • Consistently attain "fair" water quality scores during wet weather and "good" water scores during dry weather. • Provide clean "plumbing" in upland land uses such that discharges of sewage and toxics do not occur.

Note: the objectives presume some portion of the subwatershed has already been developed, thereby limiting attainment of objectives. If a subwatershed is not yet developed, managers should shift expectations up one category (e.g., urban drainage should behave like non-supporting). Also, the specific ranges of IC that define each management category should always be derived from local or regional monitoring data. Note that the ranges in IC shown to define a subwatershed management category are illustrative and will vary regionally.

tensely developed subwatershed, as well as the fact that less treatment is needed to maintain stream condition in a highly urban subwatershed.

The other key element of defining MEP is to specify how much of the treatment volume must be achieved through runoff reduction. The runoff reduction volume has emerged as the primary performance benchmark to maintain predevelopment runoff conditions at a site after it is developed. In its simplest terms, this means achieving the same predevelopment runoff coefficient for each storm up to a defined storm event through a combination of canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration, or evapotranspiration (Schueler, 2008b). Once again, the physical feasibility and need to provide treatment through runoff reduction becomes progressively harder as subwatershed impervious cover increases.

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TABLE 6-3 Examples of Customizing Stormwater Strategies on a Subwatershed Basis

Stormwater Management Issue	Lightly Impacted Subwatershed (1 to 5% IC)	Moderately Impacted Subwatershed (6 to 10% IC)	Impacted (IC 11 to 25%)	Non-Supporting (IC 26 to 60%)	Urban Drainage (61% + IC)
Linkage with Local Land-Use Planning and Zoning	Utilize extensive land conservation and acquisition to preserve natural land cover	Implement site-based or watershed-based IC caps and maximize conservation of natural areas	Reduce the IC created for each zoning category by changing local codes and ordinances	Encourage redevelopment, development intensification and mass transit to decrease per-capita IC utilization in the urban landscape. Develop watershed restoration plans to maintain or enhance existing aquatic resources.	
Site-based Stormwater Reduction and Treatment Limits	Allow no net increase in runoff volume, velocity and duration up to the five-year design storm	Treat runoff from two-year design storm, using SCMs to achieve 100% runoff reduction		Treat runoff from the one-year design storm, using SCMs to achieve at least 75% runoff reduction	
Site-Based IC Fees	None	Establish Excess IC fee for projects that exceed IC for zoning category		Allow IC mitigation fee	
Subwatershed Trading	Receiving Area for Conservation Easements	Receiving Area for Restoration Projects and/or Retrofit		Receiving or Sending Area for Retrofit	Sending Area for Restoration Projects
Stormwater Monitoring Approach	Measure in-stream metrics of biotic integrity		Track subwatershed IC and measure SCM performance	Check outfalls and measure SCM performance	Check stormwater quality against municipal actions levels at outfalls
TMDL Approach	Protect using antidegradation provisions of the CWA	Use IC-based TMDLs that use flow or IC as a surrogate for traditional pollutants		Use pollutant TMDLs to identify problem subwatersheds	Use pollutant TMDLs to identify priority source areas
Dry Weather Water Quality	Perform in-stream grab sampling of water quality at sentinel stations	Check for failing septic systems	Screen outfalls for illicit discharges	Perform dry weather sampling in streams and outfall screening	Perform dry weather sampling in receiving waters
Addressing Existing Development	Protect or conserve natural areas, enhance riparian cover, assess road crossings, and ensure farm, forest, and pasture best practices are used		Perform stream repairs, riparian reforestation, and residential stewardship	Perform storage retrofits and stream repairs	Use pollution source controls and municipal housekeeping

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Site-Based IC Fees. Several economic strategies can be used to promote equity and efficiency when it comes to managing stormwater in different kinds of subwatersheds. In lower-density subwatersheds, an excess impervious cover fee can be charged to individual sites that exceed a maximum threshold for impervious cover for their zoning category. Similarly, an impervious cover mitigation fee can be levied at individual development sites in more intensely developed subwatersheds when on-site compliance is not possible or it is more cost-effective to provide an equivalent amount of treatment elsewhere in the watershed. The type of fee and the frequency that is used is expected to be closely related to the subwatershed classification.

Subwatershed Trading. The degree of impervious cover in a subwatershed also has a strong influence on the feasibility, cost, and appropriateness of restoration projects. Consequently, any revenues collected from various site IC fees can be traded among subwatersheds to arrive at the least-cost, effective solutions. In general, the most intensely developed subwatersheds are sending areas and the more lightly developed subwatersheds are used as receiving areas for such projects.

Stormwater Monitoring Approach. Subwatershed classification can also be used to define the type and objectives for stormwater monitoring to track compliance over time. For example, in sensitive subwatersheds, it may be advisable to routinely measure in-stream metrics of biological integrity to ensure stream quality is being maintained or enhanced. As impervious cover increases, stormwater managers may want to shift toward tracking of subwatershed impervious cover and actual performance monitoring of select SCMs to establish their effectiveness (e.g., impacted subwatersheds). At even higher levels of impervious cover, streams are transformed into urban drainage, and monitoring becomes more focused on identifying individual stormwater outfalls with the worst quality during storm conditions.

TMDL Approach. Subwatershed classification may also serve as a useful tool to decide how to apply TMDLs to impaired waters, or how to ensure that healthy waters are not degraded by future land development. For example, most lightly developed subwatersheds will seldom be subject to a TMDL, or if so, urban stormwater is often only a minor component in the final waste load allocation. Antidegradation provisions of the CWA are often the best means to protect the quality of these healthy waters before they are degraded by future land development. By contrast, impaired watersheds appear to be the best candidates to apply impervious cover-based TMDLs, as described earlier in this section. As subwatershed impervious cover increases, more traditional pollutant-based TMDLs are warranted, with a focus on problem subwatersheds for non-supporting streams and priority source areas for urban drainage.

Dry Weather Water Quality. The type, severity, and sources of illicit dis-

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charges often differ among different subwatershed classifications, which can have a strong influence on the kind of dry weather detective work needed to isolate them. For example, in lightly developed subwatersheds, failing septic systems are often the most illicit discharges, which prompts assessments at the lot or ditch level. The storm-drain network and potential discharge source areas becomes progressively more complex as subwatershed impervious cover increases. Consequently, illicit-discharge assessments shift toward outfall screening, catchment analysis, and individual source analysis.

Addressing Existing Development. The need for, type of, and feasibility for restoration efforts shift as subwatershed impervious cover increases. In general, lightly developed watersheds have the greatest land area available for retrofits and restoration projects in the stream corridor. Consequently, unique restoration strategies are developed for different subwatershed classifications (Schueler, 2004).

Require More Quantitative Evaluation of MS4 Programs

The next round of permit renewals should contain explicit conditions to define and measure outcomes from the six minimum management measures that constitute a Phase II MS4 program. Measurable program evaluation is critical to develop, implement, and adapt effective local stormwater programs, and has been consistently requested in permits and application guidance. To date, however, only a small fraction of MS4 communities have provided measurable outcomes with regard to aggregate pollutant reduction achieved by their municipal stormwater programs.

CASQA (2007) defines a six-level pyramid to assess program effectiveness, beginning with documenting activities, raising awareness, changing behaviors, reducing loads from sources, improving runoff quality, and ultimately leading to protection of receiving water quality (see Figure 6-1).

At the current time, most MS4s are struggling simply to organize or document their program activities (i.e., the first level), and few have moved up the pyramid to provide a quantitative link between program activities and water quality improvements. The framework and methods to evaluate program effectiveness for each of the six minimum management measures has been outlined by CASQA (2007). Regulators are encouraged to work with permitted municipalities to define increasingly more specific quantitative measures of program performance in each succeeding permit cycle.

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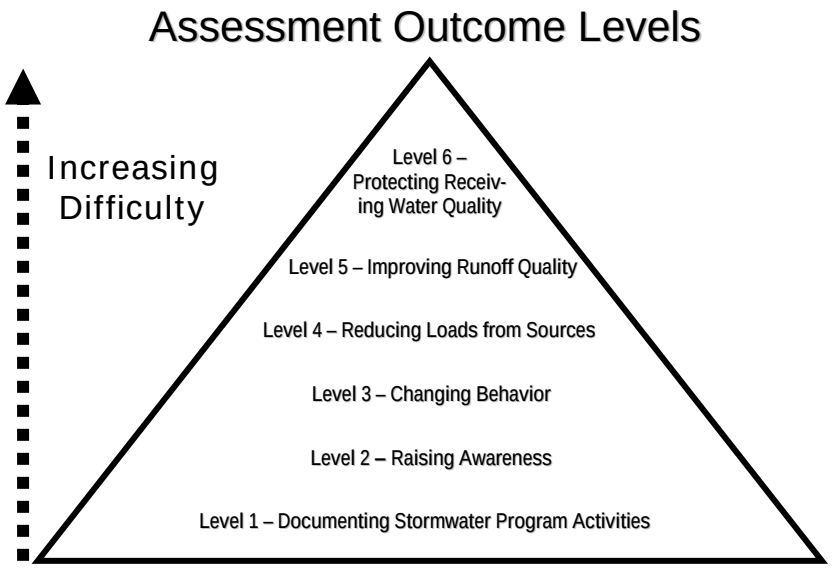

FIGURE 6-1 Pyramid of Assessment Outcome Levels for an MS4. SOURCE: CASQA (2007).

Shift Monitoring Requirements to Measure the Performance of Stormwater Control Measures

The lack of monitoring requirements in the Phase II stormwater program makes it virtually impossible to measure or track actual pollutant load or runoff volume reductions achieved. While the existing Phase I outfall monitoring requirements have improved our understanding of urban stormwater runoff quality, they are also insufficient to link program effort to receiving water quality. It is recommended that both Phase I and II MS4s shift to a more collaborative monitoring effort to link management efforts to receiving water quality, as described below:

- If a review of past Phase 1 MS4s stormwater outfall monitoring indicates no violations of the Municipal Action Limits, then their current outfall monitoring efforts can be replaced by pooled annual financial contributions to a regional stormwater monitoring collaborative or authority to conduct basic research on the performance and longevity of range of SCMs employed in the community.

- If some subwatersheds exceed Municipal Action Levels, outfall monitoring should be continued at these locations, as well as additional source area sampling in the problem subwatershed to define the sources of the stormwater

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pollutant of concern.

- Phase II MS4s should be encouraged to make incremental financial contributions to a state or regional stormwater monitoring research collaborative to conduct basic research on SCM performance and longevity. Although the committee knows of no examples where this has been accomplished, this pooling of financial resources by multiple MS4s should produce more useful scientific data to support municipal programs than could be produced by individual MS4s alone. Phase II communities that do not participate in the research collaborative would be required to perform their own outfall and/or SCM performance monitoring, at the discretion of the state or federal permitting authority.

- All MS4s should be required to indicate in their annual reports and permit renewal applications how they incorporated research findings into their existing stormwater programs, ordinances, and design manuals.

CONCLUSIONS AND RECOMMENDATIONS

The watershed-based permitting program outlined in the first part of this chapter is ultimately essential if the nation is to be successful in arresting aquatic resource depletion stemming from sources dispersed across the landscape. Smaller-scale changes to the EPA stormwater program are also possible. These include integration of industrial and construction permittees into municipal permits ("integration"), as well as a number of individual changes to the current industrial, construction, and municipal programs.

Improvements to the stormwater permitting program can be made in a tiered manner. Thus, individual recommendations specific to advancing one part of the municipal, industrial, or construction stormwater programs could be implemented immediately and with limited additional funds. "Integration" will need additional funding to provide incentives and to establish partnerships between municipal permittees and their associated industries. Finally, the watershed-based permitting approach will likely take up to ten years to implement. The following conclusions and recommendations about these options are made:

The greatest improvement to the EPA's Stormwater Program would be to convert the current piecemeal system into a watershed-based permitting system. The proposed system would encompass coordinated regulation and management of all discharges (wastewater, stormwater, and other diffuse sources), existing and anticipated from future growth, having the potential to modify the hydrology and water quality of the watershed's receiving waters.

The committee proposes centralizing responsibility and authority for implementation of watershed-based permits with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees,

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with enhanced authority and funding commensurate with increased responsibility. Permitting authorities would adopt a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses in the watershed's component waterbodies and additional goals in some cases aimed at recovering lost beneficial uses. The framework envisions the permitting authorities and municipal co-permittees working cooperatively to define careful, complete, and clear specific objectives aimed at meeting goals.

Permittees, with support from the permitting authority, would then move to comprehensive scientific and technically based watershed analysis as a foundation for targeting solutions. The most effective solutions are expected to lie in isolating, to the extent possible, receiving waterbodies from exposure to those impact sources. In particular, low-impact design methods, termed Aquatic Resources Conservation Design in this report, should be employed to the full extent feasible and backed by conventional SCMs when necessary. This report also outlines a monitoring program structured to assess progress toward meeting objectives and the overlying goals, diagnosing reasons for any lack of progress, and determining compliance by dischargers. The new concept further includes market-based trading of credits among dischargers to achieve overall compliance in the most efficient manner and adaptive management to program additional actions if monitoring demonstrates failure to achieve objectives.

Integration of the three permitting types, such that construction and industrial sites come under the jurisdiction of their associated municipalities, would greatly improve many deficient aspects of the stormwater program. Federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality. The National Pretreatment Program, EPA's successful treatment program for municipal and industrial wastewater sources, could serve as a model for integration.

Short of adopting watershed-based permitting or integration, a variety of other smaller-scale changes to the EPA stormwater program could be made now, as outlined below.

EPA should issue guidance for MS4, MSGP, and CGP permittees on what constitutes a design storm for water quality purposes. Precipitation events occur across a spectrum from small, more frequent storms to larger and more extreme storms, with the latter being a more typical focus of guidance manuals to date. Permittees need guidance from regional EPA offices on what water quality considerations to design SCMs for beyond issues such as safety of human life and property. In creating the guidance there should be a good faith

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effort to integrate water quality requirements with existing stormwater quantity requirements.

EPA should issue guidance for MS4 permittees on methods to identify high-risk industrial facilities for program prioritization such as inspections. Two visual methods for establishing rankings that have been field tested are provided in the chapter. Some of these high-risk industrial facilities and construction sites may be better covered by individual NPDES stormwater permits rather than the MSGP or the CGP, and if so would fall directly under the permitting authority and not be part of MS4 integration.

EPA should support the compilation and collection of quality *industrial* stormwater effluent data and SCM effluent quality data in a national database. This database can then serve as a source for the agency to develop technology-based effluent guidelines for stormwater discharges from industrial sectors and high-risk facilities.

EPA should develop numerical expressions to represent the MS4 standard of Maximum Extent Practicable. This could involve establishing municipal action levels based on expected outfall pollutant concentrations from the National Stormwater Quality Database, developing site-based runoff and pollutant load limits, and setting turbidity limits for construction sites. Such numerical expressions would create improved accountability, bring about consistency, and result in implementation actions that will lead to measurable reductions in stormwater pollutants in MS4 discharges.

Communities should use an urban stream classification system, such as a regionally adapted version of the Impervious Cover Model, to establish realistic water quality and biodiversity goals for individual classes of subwatersheds. The goals for water and habitat quality should become less stringent as impervious cover increases within the subwatershed. This should not become an excuse to work less diligently to improve the most degraded waterways—only to recognize that equivalent, or even greater, efforts to improve water quality conditions will achieve progressively less ambitious results in more highly urbanized watersheds. This approach would provide stormwater managers with more specific, measurable, and attainable implementation strategies than the one-size-fits-all approach that is promoted in current wet weather management regulations.

Better monitoring of MS4s to determine outcomes is needed. Only a small fraction of MS4 communities have provided measurable outcomes with regard to aggregate flow and pollutant reduction achieved by their municipal stormwater programs. A framework and methods to evaluate program effectiveness for each of the six minimum management measures have been outlined by CASQA (2007) and should be adopted. In addition, the lack of monitoring

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requirements in the Phase II stormwater program makes it virtually impossible to measure or track actual pollutant load or runoff volume reductions achieved. It is recommended that both Phase I and II MS4s shift to a more collaborative monitoring paradigm to link management efforts to receiving water quality.

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Watershed-based permitting will require additional resources and regulatory program support. Such an approach shifts more attention to ambient outcomes as well as expanded permitting coverage. Additional resources for program implementation could come from shifting existing programmatic resources. For example, some state permitting resources may be shifted away from existing point source programs toward stormwater permitting. Strategic planning and prioritization could shift the distribution of federal and state grant and loan programs to encourage and support more watershed-based stormwater permitting programs. However, securing new levels of public funds will likely be required. All levels of government must recognize that additional resources may be required from citizens and businesses (in the form of taxes, fees, etc.) in order to operate a more comprehensive and effective stormwater permitting program.

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Appendixes

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Appendix A
Acronyms

BAC	best attainable conditions
BAT	best available technology
BCG	Biological Condition Gradient
BCT	best control technology
BOD	biochemical oxygen demand
CAFO	concentrated animal feeding operation
CBWM	Chesapeake Bay Watershed Model
CCI	Census of Construction Industries
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGP	Construction General Permit
CN	Curve Number
COD	chemical oxygen demand
COV	coefficient of variability
CWA	Clean Water Act
DHSVM	Distributed Hydrology, Soil, and Vegetation Model
EIA	effective impervious area
EMC	event mean concentration
ERP	Enforcement Response Plan
ETV	Environmental Technology Verification Program
EWH	exceptional warmwater habitat
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GIS	Geographic Information System
GWLF	General Watershed Loading Function
HRU	Hydrologic Response Unit
HSPF	Hydrologic Simulation Program–Fortran
HUC	hydrologic unit code
ICM	Impervious Cover Model
KCRTS	King County Runoff Time Series
LDC	least disturbed conditions
LEED	Leadership in Energy and Environmental Design
LID	low-impact development
MDC	minimally disturbed conditions
MEP	maximum extent practicable
MGD	million gallons per day
MSGP	multi-sector industrial stormwater general permit
MTBE	methyl tert-butyl ether
NCSI	Normalized Channel Stabilization Index
NOI	Notice of Intent

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NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NRI	National Resource Inventory
NSQD	National Stormwater Quality Database
NTU	Nephelometric Turbidity Unit
NURP	National Urban Runoff Program
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
POTW	publicly owned treatment works
PUD	planned unit development
RCRA	Resource Conservation and Recovery Act
RPA	Reasonable Potential Analysis
SBUH	Santa Barbara Unit Hydrograph
SCCWRP	Southern California Coastal Water Research Project Authority
SCM	stormwater control measure
SIC	Standard Industrial Classification
SLAMM	Source Loading and Management Model
SMDR	Soil Moisture Distributed and Routing
SWAT	Soil and Water Assessment Tool
SWMM	Stormwater Management Model
SWPPP	stormwater pollution prevention plan
TALU	tiered aquatic life use
TARP	Technology Acceptance and Reciprocity Partnership
TIA	total impervious area
TKN	total Kjedahl nitrogen
TMDL	total maximum daily load
TND	traditional neighborhood development
TOD	transit-oriented development
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UAA	Use Attainability Analysis
UDC	unified development code
ULARA	Upper Los Angeles River Area
USLE	Universal Soil Loss Equation
WERF	Water Environment Research Foundation
WQA	Water Quality Act
WQS	water quality standard
WWH	warmwater habitat
WWHM	Western Washington Hydrologic Model
WWTP	wastewater treatment plant

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Appendix B
Glossary

Antidegradation: Policies which ensure protection of water quality from a particular waterbody where the water quality exceeds levels necessary to protect fish and wildlife propagation and recreation on and in the water. This also includes special protection of waters designated as outstanding natural resource waters. Antidegradation plans are adopted by each state to minimize adverse effects on water.

Best Management Practice (BMP): Physical, structural, and/or managerial practices that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. The term is synonymous with Stormwater Control Measure (SCM).

Biofiltration: The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff flows over and through vegetated areas.

Bioinfiltration: A particular SCM that is like bioretention but has more infiltration, and thus would be categorized as an infiltration process.

Bioretention: A stormwater management practice that utilizes shallow storage, landscaping, and soils to control and treat urban stormwater runoff by collecting it in shallow depressions before filtering through a fabricated planting soil media. This SCM is often categorized under “filtration” although it has additional functions.

Buffer: The zone contiguous with a sensitive area that is required for the continued maintenance, function, and structural stability of the sensitive area. The critical functions of a riparian buffer (those associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, overflow during high-water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries over time due to hydrologic or climatic effects. The critical functions of terrestrial buffers include protection of slope stability, attenuation of surface water flows from stormwater runoff and precipitation, and erosion control.

> **Stream buffers** are zones of variable width that are located along both sides of a stream and are designed to provide a protective natural area along a stream corridor.

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Combined Sewer Overflow (CSO): A discharge of untreated wastewater from a combined sewer system at a point prior to the headworks of a publicly owned treatment works. CSOs generally occur during wet weather (rainfall or snowmelt). During periods of wet weather, these systems become overloaded, bypass treatment works, and discharge directly to receiving waters.

Combined Sewer System: A wastewater collection system that conveys sanitary wastewaters (domestic, commercial, and industrial wastewaters) and stormwater through a single pipe to a publicly owned treatment works for treatment prior to discharge to surface waters.

Constructed Wetland: A wetland that is created on a site that previously was not a wetland. This wetland is designed specifically to remove pollutants from stormwater runoff.

Created Wetland: A wetland that is created on a site that previously was not a wetland. This wetland is created to replace wetlands that were unavoidably destroyed during design and construction of a project. This wetland cannot be used for treatment of stormwater runoff.

Detention: The temporary storage of stormwater runoff in an SCM with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Detention Facility/Structure: An above- or below-ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater, and the facility is designed to not create a permanent pool of water.

Drainage: Refers to the collection, conveyance, containment, and/or discharge of surface and stormwater runoff.

Drainage Area: That area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge line.

Drainage Basin: A geographic and hydrologic subunit of a watershed.

Dry Pond: A facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels. Synonymous with detention basin, it is intended to be dry between storms.

Effluent Limitation: Any restriction imposed by the EPA director on quantities, discharge rates, and concentrations of pollutants that are discharged from

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point sources into waters of the United States, the waters of the contiguous zone, or the ocean.

Effluent Limitation Guidelines: A regulation published by the EPA Administrator under Section 304(b) of the Clean Water Act that establishes national technology-based effluent requirements for a specific industrial category.

Exfiltration: The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration SCM into the soil.

Extended Detention: A stormwater design feature that provides for the gradual release of a volume of water in order to increase settling of pollutants and protect downstream channels from frequent storm events. When combined with a pond, the settling time is increased by 24 hours.

Filter Strip: A strip of permanent vegetation above ponds, diversions, and other structures to retard the flow of runoff, causing deposition of transported material and thereby reducing sedimentation. As an SCM, it refers to riparian buffers, which run adjacent to waterbodies and intercept overland flow and shallow subsurface flow (both of which are usually sheet flow rather than a distinct influent pipe). The term is borrowed from the agricultural world.

Flood Frequency: The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the n-year flood as being the flood that will, over a long period, be equaled or exceeded on the average once every n years.

Frequency of Storm (Design Storm Frequency): The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows which occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

General Permit: A single permit issued to a large number of dischargers of pollutants in stormwater. General permits are issued by the permitting authority, and interested parties then submit a Notice of Intent (NOI) to be covered. The permit must identify the area of coverage, the sources covered, and the process for obtaining coverage. Once the permit is issued, a permittee may submit an NOI and receive coverage within a very short time frame.

Grab Sample: A sample which is taken from a stream on a one-time basis without consideration of the flow rate of the stream and without consideration of time.

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Hotspot: An area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydrograph: A graph of runoff rate, inflow rate, or discharge rate, past a specific point as a function of time.

Hydroperiod: A seasonal occurrence of flooding and/or soil saturation; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph: A graph of measured precipitation depth (or intensity) at a precipitation gauge as a function of time.

Impervious Surface or Impervious Cover: A hard surface area which either prevents or retards the entry of water into the soil. Common impervious surfaces include roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled surfaces.

Infiltration: The downward movement of water from the surface to the subsoil.

Infiltration Facility: A drainage facility designed to use the hydrologic process of runoff soaking into the ground, commonly referred to as percolation, to dispose of stormwater.

Infiltration Pond: A facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

Level Spreader: A temporary SCM used to spread stormwater runoff uniformly over the ground surface as sheet flow. The purpose of level spreaders is to prevent concentrated, erosive flows from occurring. Levels spreaders will commonly be used at the upstream end of wider biofilters to ensure sheet flow into the biofilter.

Municipal Separate Storm Sewer System: A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned by a state, city, town, or other public body that is designed or used for collecting or conveying stormwater, which is not a combined sewer and which is not part of a publicly owned treatment works.

National Pollutant Discharge Elimination System: A provision of the Clean Water Act that prohibits the discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or, where delegated, a

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tribal government on an Indian reservation. The permit applies to point sources of pollutants to ensure that their pollutant discharges do not exceed specified effluent standards. The effluent standards in most permits are based on the best available pollution technology or the equivalent.

Nonpoint Source: Diffuse pollution source, but with a regulatory connotation; a source without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater. Some common nonpoint sources are agriculture, forestry, mining, dams, channels, land disposal, and saltwater intrusion.

Nonstructural SCM: Stormwater control measure that uses natural measures to reduce pollution levels, does not require extensive construction efforts, and/or promotes pollutant reduction by eliminating the pollutant source.

Peak Discharge Rate: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Point Source: Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fixture, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged.

Pollutant: A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment. Dredged soil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended), heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water (EPA, 2008).

Polutograph: A graph of pollutant loading rate (mass per unit time) as a function of time.

Predevelopment Conditions: Those conditions that existed at a site just prior to the development in question, which are not necessarily pristine conditions.

Pretreatment: The removal of material such as gross solids, grot, grease, and scum from flows prior to physical, biological, and chemical treatment processes to improve treatability. The reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a publicly owned treatment works [40 C.F.R. § 403.3(q)]. Pretreatment may include screening, grit removal, stormwater, and oil separators. With re-

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spect to stormwater, it refers to techniques employed in stormwater SCMs to help trap coarse materials and other pollutants before they enter the SCM.

Recharge: The flow of groundwater from the infiltration of stormwater runoff.

Recharge Volume: The portion of the water quality volume used to maintain groundwater recharge rates at development sites.

Retention: The process of collecting and holding stormwater runoff with no surface outflow. Also, the amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

Retention/Detention Facility: A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold stormwater runoff for a short period of time and then release it to the stormwater management system.

Runoff: The term is often used in two senses. For a given precipitation event, direct *storm runoff* refers to the rainfall (minus losses) that is shed by the landscape to a receiving waterbody. In an area of 100 percent imperviousness, the runoff equals the rainfall. Over greater time and space scales, *surface water runoff* refers to streamflow passing through the outlet of a watershed, including base flow from groundwater that has entered the stream channel.

Soil Stabilization: The use of measures such as rock lining, vegetation, or other engineering structure to prevent the movement of soil when loads are applied to the soil.

Source Control: A type of SCM that is intended to prevent pollutants from entering stormwater. A few examples of source control are erosion control practices, maintenance of stormwater facilities, constructing roofs over storage and working areas, and directing wash water and similar discharges to the sanitary sewer or a dead end sump.

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility. According to 40 C.F.R. § 122.26(b)(13), this includes stormwater runoff, snow melt runoff, and surface runoff and drainage.

Stormwater Control Measure (SCM): Physical, structural, and/or managerial measures that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. Also, a permit condition used in place

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of or in conjunction with effluent limitations to prevent or control the discharge of pollutants. This may include a schedule of activities, prohibition of practices, maintenance procedures, or other management practices. SCMs may include, but are not limited to, treatment requirements; operating procedures; practices to control plant site runoff, spillage, leaks, sludge, or waste disposal; or drainage from raw material storage.

Stormwater Drainage System: Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat, or filter stormwater.

Stormwater Facility: A constructed component of a stormwater drainage system, designed or constructed to perform a particular function or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention basins, retention basins, constructed wetlands, infiltration devices, catch basins, oil/water separators, sediment basins, and modular pavement.

Structural SCMs: Devices which are constructed to provide temporary storage and treatment of stormwater runoff.

Swale: A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths of less than one foot.

> **Biofilter (**same as a **Biofiltration Swale):** A sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to SCMs designed for that purpose.
>
> **Dry Swale**: An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media. It has an underdrain.
>
> **Wet Swale:** An open drainage channel or depression, explicitly designed to retain water or intercept groundwater for water quality treatment.

Technology-Based Effluent Limit: A permit limit for a pollutant that is based on the capability of a treatment method to reduce the pollutant to a certain concentration.

Time of Concentration: The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

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Total Maximum Daily Load (TMDL): The amount, or load, of a specific pollutant that a waterbody can assimilate and still meet the water quality standard for its designated use. For impaired waters the TMDL reduces the overall load by allocating the load among current pollutant loads (from point and nonpoint sources), background or natural loads, a margin of safety, and sometimes an allocation for future growth.

Volumetric Runoff Coefficient (R_v): The value that is applied to a given rainfall volume to yield a corresponding runoff volume based on the percent impervious cover in a drainage basin.

Water Quality-Based Effluent Limit (WQBEL): A value determined by selecting the most stringent of the effluent limits calculated using all applicable water quality criteria (e.g., aquatic life, human health, and wildlife) for a specific point source to a specific receiving water for a given pollutant.

Water Quality SCM: An SCM specifically designed for pollutant removal.

Water Quantity SCM: An SCM specifically designed to reduce the peak rate of stormwater runoff.

Water Quality Volume (W_{qv}): The volume needed to capture and treat 90 percent of the average annual stormwater runoff volume equal to 1 inch times the volumetric runoff coefficient (R_v) times the site area.

Wetlands: Those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. This includes wetlands created, restored, or enhanced as part of a mitigation procedure. This does not include constructed wetlands or the following surface waters of the state intentionally constructed from sites that are not wetlands: irrigation and drainage ditches, grass-lined swales, canals, agricultural detention facilities, farm ponds, and landscape amenities.

Wet Pond: A facility that treats stormwater for water quality by utilizing a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration. Synonymous with a retention basin.

SOURCES: Most of the definitions are from EPA (2003), "BMP Design Considerations," 600/R-03/103, or EPA (2008), "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," EPA 841-B-08-002.

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Appendix C
Summary of Responses from State Stormwater Coordinators

On February 21, 2007, on behalf of the committee, Jenny Molloy of EPA's Office of Wastewater Management sent the following questions to a group of state stormwater program managers and received six responses (found in Tables C-1 and C-2).

1. For industrial and/or construction: do you have information on non-filers, i.e., folks who should have submitted NOIs, but did not? If so, how old are these data, and how do they compare to overall numbers of those with permit coverage? How did you find and/or estimate the number of non-filers?

2. Also for industrial and/or construction: do you have information on compliance rates? Yes, this is a really broad question, but something along the lines of: based on inspections (or monitoring data, or whatever metric you use), have you made any determinations on numbers of facilities out of compliance, or alternatively, in compliance? If so, define what you mean by compliance (paper violations, SWPPP/BMP inadequacies, water quality standards violations, etc.).

TABLE C-1 Nonfilers

State	Information on Industrial Non-Filers	Estimate Percent Non-Filers as of Total	Basis of Estimate	Period of Estimate	Comment
CA	Yes	50 percent of heavy industry statewide 69 percent Of industry within City of Los Angeles	Study—CA Water Board, 1999; Duke and Shaver, 1999. Study—Swamikannu et al., 2001	1995–1998 1998–2000	
MN	No				Study in progress
OH	No				Plan outreach to business
OR	No				Do not compile data
VT	Yes	88–90 percent of industry	Mass mailing	2006	No response from 2,400 of 3,000 mailings
WI	No				

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TABLE C-2 Compliance

State	Information on Compliance Rates	Estimate of Covered Facilities Non-Compliant	Basis of Estimate	Period of Estimate	Comment
CA	Yes (Construction)	40 percent deficient in paperwork; 30 percent with inadequate E&S controls	MS4 construction audit in Los Angeles and Ventura counties, and large CGP construction sites	2002, 2004, and 2005	Prioritized large CGP sites for inspection
	Yes (Industrial)	60 percent poor housekeeping practices; 40 percent incomplete SWPPPs	Transportation sector, plastics manufacturing inspections in Los Angeles County	2005 and 2007	
NH	No				Inspect in response to complaints
OH	No				Inspect construction sites as a priority
OR	No				Do not compile data
VT	No				Plan to inspect for compliance
WV	Yes (Industrial)	66 percent failed to submit report	Monitoring report submittal tracking	2007	Mailed deficiency notices
WI	Yes (Construction)	38 percent with minor and 43 percent with major violations	A subsample of 1 percent of CGP sites	2007	Perform inspections annually; no central database tracking

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In September 2007, the NRC Committee on Reducing Stormwater Discharge Contributions to Water Pollution sent the following survey to 50 state stormwater program managers. Responses were received from 18 states, including at least one from every EPA region. The blank survey is shown below, and Tables C-3 through C-9 contain the states' responses.

The NRC committee members will greatly appreciate receiving the following information from State Stormwater Coordinators. Please complete both sides of this form and return to Xavier Swamikannu, CalEPA, Los Angeles Regional Water Board, xswamikannu@waterboards.ca.gov or Fax: (213) 576-6625.

State:
Name of information provider:

Please summarize your State's Stormwater Permit Program

	Municipal Permit	Industrial General Permit	Construction General Permit
What are the monitoring requirements?			
How is compliance demonstrated (monitoring or other activity)?			
To whom is the SWPPP submitted?			
Can an MS4 perform an inspection of an industry within its boundary?			
What industries are considered "high-risk"?			
Do BMP manuals exist for implementation guidance?			
No. of dedicated staff or FTEs			

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Does your State Storm Water BMP Manual contain the following, and what are they?

WQ sizing criteria	
Recharge criteria	
Channel protection criteria	
Overbank flood criteria	
Extreme flows	
Acceptable BMP list	
Detailed engineering specs for BMPs	
Soil and erosion control requirements (unless this is left to the local government)	

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TABLE C-3 Monitoring Requirements

State	Municipal	Industrial	Construction
Alabama	Monitoring requirements are specific to the Phase I MS4. MS4 Phase II permit does not require monitoring.	Monitoring is specific to the General Permit type and associated discharge. Alabama has 18 NPDES Industrial Stormwater General Permits. http://www.adem.state.al.us/genpermits.htm	Monitoring is required under specific conditions, but in general compliance with the permit does not require monitoring. ADEM Admin. Code Chapter 335-6-12 is attached.
California	Monitoring requirements are specific to the Phase 1 MS4 permits. MS4 Phase II permit monitoring is discretionary.	2 wet weather sampling events per year – 4 basic parameters and other pollutants known to be on site. Quarterly visual monitoring.	Visual monitoring before, during, and after rain events. Analytical monitoring for discharges to sediment-impaired waterbodies.
Connecticut	Sample six outfalls once a year. Twelve chemical parameters.	Sample all outfalls once a year. Ten chemical parameters plus aquatic toxicity.	None, yet. Soon to modify permit to sample for turbidity.
Georgia	Dry weather outfall screening.	Standard monitoring from the EPA MSGP. Additional monitoring for the pollutant of concern for industries that may be causing or contributing to stream impairment.	Monitoring is required for a qualifying rain event (0.5 inch) once after clearing and grubbing, and once after mass grading.
Hawaii	Visual and water chemistry sampling.	Visual and water chemistry sampling.	Visual
Maine	None	No benchmark monitoring, only effluent limitations. Additional monitoring upon request based on discharges, complaints, audits, or inspections	None
Minnesota	The Phase I MS4 permits for Minneapolis and St. Paul require monitoring. MS4 Phase II permit does not require monitoring.	The current state MSGP does not have monitoring requirements. The proposed next term draft permit would require at least 4 stormwater monitoring events per year.	The current state CGP does not require monitoring. The proposed next term draft permit is not expected to include monitoring.

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TABLE C-3 Continued

State	Municipal	Industrial	Construction
Nebraska	Stormwater monitoring required on different use sites. BMP monitoring.	None. Monitoring can be required by the director through permit.	None. Monitoring can be required by the director through permit.
Nevada	Required for storm events that produce runoff.	None	None
New York	Ad hoc	Similar to monitoring in the EPA MSGP.	None. Self-inspection.
Ohio	Phase I MS4 permits require some chemical and biological monitoring. Phase II MS4 permit does not require mandatory monitoring, although recommended as part of IDDE program.	Similar to monitoring in the EPA MSGP, except annually. No priority chemical monitoring required.	For the state CGP, no chemical monitoring. For special watershed CGPs associated with TMDLs, TSS monitoring required.
Oklahoma	Phase 1 MS4s permits require dry weather monitoring, floatables monitoring, and watershed characterization monitoring, including biological assessments.	Quarterly visual monitoring and annual analytical monitoring.	None
Oregon	Monitoring requirements are specific to the Phase I MS4. The Phase II MS4 permit does not require monitoring, though some permittees do monitor on their own accord. The average frequency is 2-4 times a year.	Industrial facilities required to sample their stormwater discharge 4 times per year. Also required to conduct visual monitoring of their discharge on a monthly basis when discharge is present. Mining sites in addition are subject to the same requirements as in the state CGP since sediment is the main pollutant of concern.	None. However, permittees discharging stormwater to waters listed specifically for turbidity/sedimentation on the most recent 303(d) list or that have a TMDL for turbidity/sedimentation have the option of either monitoring for turbidity or implementing additional BMPs.

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State	Municipal	Industrial	Construction
Vermont	None other than the development of an IDDE program and follow-up until elimination occurs	Benchmark monitoring for individual sectors, quarterly for the first year. Visual inspection 4 times per year. Effluent limitations (if applicable) once per year.	None at present. Turbidity monitoring for moderate-risk projects included in draft CGP.
Virginia	Monitoring requirements are specific to the Phase I MS4 permit. The Phase II MS4 permit does not require monitoring.	Benchmark and effluent limitation (the same as EPA's 2000 MSGP), except we only require one sample per year for benchmark samples.	None
Washington	Monitoring requirements are specific to the Phase I MS4, *Outfall conveyance system monitoring*. Selected outfalls for representative land uses are monitored intensively for a wide range of chemical constituents including toxicity. *BMP effectiveness monitoring*. Selected stormwater BMPs are monitored to determine performance and how effective the designs are. The Phase II MS4 permit does not require monitoring, except as required under the IDDE program or for a TMDL.	Industry required to sample for turbidity, pH, zinc, and petroleum oil and grease. If exceeds zinc benchmark, then also need to monitor for total copper, total lead, and hardness. There are additional monitoring requirements for different industry categories. For discharges to impaired 303(d) waters monitor required for the pollutants for which the waterbody is impaired.	All state CGP sites are required to do weekly monitoring for turbidity and pH. If benchmark exceeded, specific actions/responses are triggered. For sites which discharge to waters impaired by phosphorous, turbidity, fine sediments, or high pH, monitoring required for these parameters additionally.
West Virginia	NA	Benchmark monitoring. Sector specific.	None
Wyoming	None	Benchmark monitoring for timber, metal mining, concrete and gypsum, junkyards and recycling. Effluent limitation monitoring for coal piles, concrete manufacture, and asphalt emulsion.	None

NOTE: NA, not answered

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TABLE C-4 How is Compliance Demonstrated?

State	Municipal	Industrial	Construction
Alabama	MS4 Phase I – monitoring and BMPs MS4 Phase II – BMPs	Monitoring reporting and BMP implementation	Inspections. Monitoring; SWPPP implementation during inspection; aerial reconnaissance
California	Annual and monitoring reporting. MS4 audits and inspections.	Annual and monitoring reporting. Inspections.	Annual certifications. Inspections
Connecticut	Annual and monitoring reporting.	Annual and monitoring reporting. Inspections.	Inspections. SWPPP review and implementation for large projects.
Georgia	Annual and monitoring reporting.	Annual and monitoring reporting.	Reporting.
Hawaii	Annual and Monitoring reporting. Inspections.	Annual and monitoring reporting. Inspections.	Inspections. Reporting.
Maine	Annual reporting and municipal audits.	Inspections and audits, at least two per 5-year permit term.	NA
Minnesota		Annual reporting and inspections.	
Nebraska	MS4 audits and annual reporting.	Inspections and SWPPP implementation.	Inspections and SWPPP implementation—complaint only.
Nevada	Annual reporting, MS4 audits, inspections.	Annual reporting, inspections	Inspections.
New York	Annual reporting and MS4 audits.	Annual and monitoring reporting. Inspections.	Inspections and SWPPP implementation.
Ohio	Annual reporting.	SWPPP implementation.	SWPPP implementation.
Oklahoma	Annual reporting. MS4 audits and compliance schedules.	Annual and monitoring reporting. Inspections.	SWPPP implementation and inspections based on complaints received.

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State	Municipal	Industrial	Construction
Oregon	Annual and monitoring reporting.	Annual and monitoring reporting. Action Plan approval.	Inspections and SWPPP implementation.
Vermont	Annual reporting and MS4 audits.	Monitoring reporting.	Inspections, recordkeeping.
Virginia	Registration statement BMP implementation.	Monitoring reporting and inspections.	Inspections. SWPPP and E&S plan implementation.
Washington	Implementation of prescriptive stormwater management program.	Monitoring reporting and inspections.	Inspections and monitoring reporting.
West Virginia	NA	SWPPP implementation and monitoring reporting.	Inspections. SWPPP implementation.
Wyoming	Periodic MS4 audits.	Inspections, monitoring reporting.	Inspections.

NOTE: NA, not answered.

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TABLE C-5 To Whom Is the SWPPP Submitted?

State	Municipal	Industrial	Construction
Alabama	MS4 Phase I – Storm Water Management Program (SWMP) sent to state. Should be available for review at the time of inspection. (SWPPP information should also be provided to the department.) MS4 Phase 2 – SWMP submitted with the Notice of Intent (NOI).	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection. SWPPP required to be submitted under certain circumstance during registration and re-registration.
California	MS4 Phase 1 – SWMP incorporated as prescriptive requirements in the permit. MS4 Phase 2 – SWMP submitted to state with NOI	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.
Connecticut	NA	The SWPPP is submitted to the state only if requested.	The SWPPP is submitted to the state only if requested.
Georgia	The SWMP is submitted to the state.	The SWPPP is submitted to the state only if requested. Otherwise it is kept on-site.	The E&S Control Plan equivalent to the SWPPP is submitted to the Local Issuing Authority. It is also submitted to the state if the project disturbs more than 50 ac, or if there is no LIA.
Hawaii	NA	The SWMP is submitted to the state.	The SWMP is submitted to the state.
Maine	NA	The SWPPP is submitted to the state only if requested.	The E&S Control Plan equivalent to the SWPPP is submitted to the state for review.

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State	Municipal	Industrial	Construction
Minnesota	Phase 1 MS4 - The SWMP is submitted to the state for review and public notice.	The SWPPP is not required to be submitted to the state.	The SWPPP must be must be submitted to the state for review for projects disturbing 50 acres or more, and has a discharge point within 2,000 feet of an impaired or special water listed in the state CGP. A SWPPP must also be submitted for projects proposing to use alternative method(s) for the permanent stormwater management system.
Nebraska	NA	The SWPPP is submitted to the state only if requested.	The SWPPP is submitted to the MS4 permittee and to the state when requested.
Nevada	NA	No submittal to state. The SWPPP must be kept on site.	No submittal to state. The SWPPP must be kept on site.
New York	NA	Some SWPPPs submitted to state (very few).	About 1/6 SWPPPs submitted to state.
Ohio	NA	The SWPPP is submitted to the MS4 permittee and to the state when requested.	The SWPPP is submitted to the state.
Oregon	NA	The SWPPP is submitted to the state on first application and when renewing coverage under the state MSGP.	The SWPPP is submitted to the state on first application and when renewing coverage under the state CGP. Projects that are greater than 5 acres are subject to public notice and comment.

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TABLE C-5 Continued

State	Municipal	Industrial	Construction
Vermont	NA	A copy of the SWPPP is submitted to the state, and the original kept on site.	The E&S Control Plan is submitted to the state. Low-risk projects have a standard assigned E&S Control Plan – "Low Risk Handbook".
Virginia	NA	No submittal to the state. The SWPPP must be kept on-site.	No submittal to the state. The SWPPP must be kept on-site.
Washington	NA	The SWPPP is submitted to the state upon first application only. Otherwise, the SWPPP must be kept on site and must be made available to the state, the MS4 permittee, or the public upon request.	The SWPPP is not submitted to the state. The SWPPP must be kept on site and must be made available to the state, the MS4 permittee or the public upon request.
West Virginia	NA	The SWPPP is submitted to the state upon first application only.	The SWPPP is submitted to the state.
Wyoming	NA	The SWPPP is submitted to the state for facilities >50 ac. Class 1 waters not eligible for coverage under the state MSGP.	The SWPPP is submitted to the state for projects >100 ac or on Class 1 waters.

NOTE: NA, not applicable.

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TABLE C-6 Can an MS4 Inspect Industries Within Its Boundary?

Alabama	Yes, if adequate legal authority exists.
California	Yes. Local agencies inspection to ensure compliance with local stormwater or municipal ordinance.
Connecticut	Yes. Nothing specific. State MSGP requires industries to comply with the stormwater management program of the MS4 in which they are located.
Georgia	Yes
Hawaii	Yes
Maine	Yes
Minnesota	Yes. Capability to do this varies with the MS4.
Nebraska	Yes. Phase 1 MS4s only.
Nevada	Yes
New York	Yes. MS4s can inspect for illicit discharge detection and elimination. Industries can be inspected under local authority, but local inspections are infrequently conducted.
Ohio	Yes. Phase I MS4s can check for MSGP coverage and that a SWPPP exists in conjunction with pretreatment inspections.
Oklahoma	Yes
Oregon	Yes, under various authorities. Pretreatment, industrial stormwater, construction stormwater, etc.
Vermont	Yes. The MS4 can request an inspection but can be denied access.
Virginia	No. No state statute for private property access to inspect for stormwater management. Some do use Fire Marshall's authority through the fire code.
Washington	Yes
West Virginia	NA
Wyoming	Yes. If the MS4 has authority.

NOTE: NA, not answered.

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TABLE C-7 What Industries Are Considered High Risk?

Alabama	Metal foundries.
California	None specified in the state MSGP. Some MS4 permits may specify high-risk industries. Construction activity discharging to sediment-impaired waterbodies are identified as high risk in the state CGP.
Connecticut	None specified in the state MSGP.
Georgia	None specified in the state MSGP. Facilities that may be causing or contributing to stream impairment are high risk.
Hawaii	None specified in the state MSGP
Maine	Auto salvage, scrap metal recycling, boatyards and marinas, concrete and asphalt, batch plants, vehicle maintenance facilities.
Minnesota	None specified in the state MSGP. Heavy industries are considered higher risk.
Nebraska	Ethanol, scrap metal recycling.
Nevada	Waste oil recyclers, auto salvage, aggregate mines, cement plants.
New York	Auto salvage, scrap recycling.
Ohio	None specified in the state MSGP. Individual stormwater permits required for some airports, landfills, sand and gravel operations, and bulk terminals.
Oklahoma	None specified in the state MSGP.
Oregon	None specified in the state MSGP.
Vermont	None specified in the state MSGP. Gravel pits, salvage yards, scrap recycling facilities are considered high risk.
Virginia	None specified in the state MSGP.
Washington	MS4 permit identifies a list of industries and land uses that the permittee must inspect (See Permit appendix 8).
West Virginia	None specified in the state MSGP. Mills and auto salvage yards are considered high risk.
Wyoming	None specified in the state MSGP. Case by case based on proximity to high class waters and industry type.

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TABLE C-8 Do State BMP Manuals Exist for Implementation Guidance?

State	Municipal	Industrial	Construction
Alabama	No. Use EPA materials.	No. Use EPA Materials.	Yes. State E&S Manual. http://swcc.state.al.us/erosion_handbook.htm
California	Yes. CASQA and Caltrans manuals. Not officially adopted.	Yes. CASQA and Caltrans manuals. Not officially adopted	Yes. CASQA and Caltrans manuals. Not officially adopted.
Connecticut	No	No. An SWPPP guidance document is available online.	Yes. E&S Guidelines (2002) and CT Stormwater Quality Manual (2004).
Hawaii	No. Use EPA materials.	No. Use EPA materials.	No. Use EPA materials.
Georgia	Yes. Georgia Stormwater Management Manual.	No. Use EPA materials.	Yes. Manual for Erosion and Sediment Control in Georgia.
Maine	Yes	Yes	Yes
Minnesota	Yes. The Minnesota Stormwater Manual at: http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html Stormwater BMPs – Protecting Water Quality in Urban Areas at: http://www.pca.state.mn.us/water/pubs/sw-bmpmanual.html	No. Plan to develop one.	Yes. Fact sheets and guidance at: http://www.pca.state.mn.us/water/stormwater/stormwater-ms4.html#bmp
Nebraska	No	No	No
Nevada	Yes	Yes	Yes
New York	Yes	Yes. A few state materials.	Yes

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TABLE C-8 Continued

State	Municipal	Industrial	Construction
Ohio	No. Use EPA materials.	No. Use EPA materials.	Yes. http://www.dnr.state.oh.us/water/rainwater/default/tabid/9186/Default.aspx
Oklahoma	No. Use EPA materials.	No. Use EPA materials.	No. Use EPA materials.
Oregon	No	No. Have BMP technical assistance guidance documents.	Yes. Use of Oregon BMP manual is optional.
Vermont	Yes	No	Yes. Standards for designers, a field guide for contractors (2006), and the Low Risk Handbook.
Virginia	Yes. E&S control and stormwater handbooks.	No	Yes. E&S control and stormwater handbooks.
Washington	Yes. Stormwater Management Manual for Western Washington (2005) and Stormwater Management Manual for Eastern Washington (2004)	Yes. http://www.ecy.wa.gov/programs/wq/stormwater/manual.html	Yes. http://www.ecy.wa.gov/programs/wq/stormwater/eastern_manual/index.html
West Virginia	No	No	Yes
Wyoming	No	No. Refer to manuals from other states.	No. Refer to manuals from other states.

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TABLE C-9 Full-Time Staff Dedicated to the Stormwater Program

State	Municipal	Industrial	Construction	Total Statewide
Alabama	1.5	7	25–30	33.5–38.5
California				89
Connecticut				5
Georgia	4.5	2.5	46	53
Hawaii	0.5	1	2	3.5
Maine	0.7	2.5	NA	
Minnesota		4.3	14	36
Nebraska				3
Nevada	1	1.5	3	5.5
New York	7	1	11	19
Ohio				18
Oklahoma				7
Oregon	1	4–5 (shared with construction)	4–5 (shared with industrial)	5–6
Vermont	0.5	2	5	7.5
Virginia	3	8 (shared with other programs)	10	13
Washington	10	17	16	43
West Virginia	NA	1	5	
Wyoming				4

NOTE: NA, not answered.

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Appendix D
Biographical Information for the Committee on Reducing Stormwater Discharge Contributions to Water Pollution

Claire Welty, *Chair*, is the Director of the Center for Urban Environmental Research and Education and Professor of Civil and Environmental Engineering at University of Maryland, Baltimore County (UMBC). Dr. Welty's work has primarily focused on transport processes in aquifers; her current research interest is in watershed-scale urban hydrology, particularly in urban groundwater. Prior to her appointment at UMBC, Dr. Welty was a faculty member at Drexel University for 15 years, where she taught hydrology and also served as Associate Director of the School of Environmental Science, Engineering, and Policy. Dr. Welty is the chair of the National Research Council's (NRC's) Water Science and Technology Board and has previously served on three NRC study committees. She is the Chair-Elect of the Consortium of Universities for the Advancement of Hydrologic Science Inc. Dr. Welty received a B.A. in environmental sciences from the University of Virginia, an M.S. in environmental engineering from the George Washington University, and a Ph.D. in civil and environmental engineering from the Massachusetts Institute of Technology.

Roger T. Bannerman has been an environmental specialist for the Wisconsin Department of Natural Resources for over 30 years. For most of that time he has directed research projects investigating urban runoff. Topics addressed by his studies over the years include the quality of urban streams, identification of problem pollutants in stormwater, toxicity of stormwater pollutants, effectiveness of different stormwater control practices, sources of stormwater pollutants, selection of cost-effective control practices, and benefits of low-impact development. He has applied these results to management plans developed for most urban areas in Wisconsin. This includes the calibration of the urban runoff model called the Source Loading and Management Model. The results of his research projects have been used to develop Wisconsin's new administrative rules that regulate stormwater management. Mr. Bannerman received his B.S. in chemistry from Humboldt State College and an M.S. from the University of Wisconsin in water chemistry.

Derek B. Booth has joint positions as Senior Geologist at Stillwater Sciences, Inc., and Adjunct Professor at the University of Washington where he is senior editor of the international journal *Quaternary Research* and holds faculty appointments in Civil Engineering and Earth & Space Sciences. Prior to this, he was director of the Center for Urban Water Resources Management (and its suc-

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cessor, the Center for Water and Watershed Studies) at the university. He maintains active research into the causes of stream-channel degradation, the effectiveness of stormwater mitigation strategies, and the physical effects of urban development on aquatic systems, with over a dozen publications and a wide range of national and international invited presentations on the topic. Dr. Booth received a B.A. in literature from Hampshire College, a B.A. in geology from the University of California at Berkeley, an M.S. in geology from Stanford University, and a Ph.D. in geological sciences from the University of Washington.

Richard R. Horner is a professor in the Department of Civil and Environment Engineering at the University of Washington, with adjunct appointments in Landscape Architecture and in the College of Forest Resources' Center for Urban Horticulture. He received his Ph.D. from the University of Washington's Department of Civil and Environmental Engineering and previous engineering degrees from the University of Pennsylvania. Dr. Horner splits his time between university research and private practice. In both cases his work concerns how human occupancy of and activities on the landscape affect natural waters, and how negative effects can be reduced. He has been involved in two extended research projects concerning the ecological response of freshwater resources to urban conditions and the urbanization process. The first studied the effect of human activities on freshwater wetlands of the Puget Sound lowlands and led to a comprehensive set of management guidelines to reduce negative effects. A ten-year study involved the analogous investigation of human effects on Puget Sounds' salmon spawning and rearing streams. In addition, he has broad experience in all aspects of stormwater management, having helped design many stormwater programs in Washington, California, and British Columbia. He previously served on the NRC's Committee on the Comparative Costs of Rock Salt and Calcium Magnesium Acetate for Highway Deicing.

Charles R. O'Melia (NAE) is the Abel Wolman Professor of Environmental Engineering and Chair of the Geography and Environmental Engineering Department at the Johns Hopkins University, where he has served on the faculty for over 25 years. Dr. O'Melia's research areas include aquatic chemistry, environmental colloid chemistry, water and wastewater treatment, modeling of natural surface and subsurface waters, and the behavior of colloidal particles. He has served on the advisory board and review committees for the environmental engineering departments of multiple universities. He has served in a range of advising roles to professional societies including the American Water Works Association and Research Foundation, the Water Pollution Control Federation, the American Chemical Society, and the International Water Supply Association. He has served on several NRC committees, including chairing the Steering Committee, Symposium on Science and Regulation, and the Committee on Watershed Management for New York City. He was also a member of the

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NRC Water Science and Technology Board and the Board on Environmental Studies and Toxicology. Dr. O'Melia earned a Ph.D. in Sanitary Engineering from the University of Michigan. In 1989, Dr. O'Melia was elected to the National Academy of Engineering for significant contributions to the theories of coagulation, flocculation, and filtration leading to improved water-treatment practices throughout the world.

Robert E. Pitt is the Cudworth Professor of Urban Water Systems in the Department of Civil, Construction, and Environmental Engineering at the University of Alabama (UA). He is also Director of the UA interdisciplinary Environmental Institute. Dr. Pitt's research concerns the effects, sources, and control of urban runoff, which has resulted in numerous development management plans, stormwater ordinances, and design manuals. Dr. Pitt has also developed and tested procedures to recognize and reduce inappropriate discharges of wastewaters to separate storm drainages. He has investigated the sources and control of stormwater toxicants and examined stormwater effects on groundwater. He has also carried out a number of receiving water impact studies associated with stormwater. These studies have included a variety of field monitoring activities, including water and sediment quality, fish and benthos taxonomic composition, and laboratory toxicity tests. His current research includes developing a nationwide database of national stormwater permit information and conducting comprehensive evaluations of these data. Dr. Pitt received a B.S. in engineering science from Humboldt State University, an M.S. in civil engineering from San Jose State University, and a Ph.D. in civil and environmental engineering from the University of Wisconsin.

Edward T. Rankin is an Environmental Management Associate with Ohio University at the Institute for Local Government Administration and Rural Development (ILGARD) which is the Voinovich School of Leadership and Public Affairs located in Athens, Ohio. He had previously been a Senior Research Associate in the Center for Applied Bioassessment and Biocriteria within the Midwest Biodiversity Institute (MBI). Prior to 2002, he was an aquatic ecologist with Ohio EPA for almost 18 years. Mr. Rankin's research centers around the effects of stormwater and other urban stressors on aquatic life, development and application of stream habitat assessment methodologies, development and application of biological criteria and biological-based chemical criteria for aquatic life, and improving the accuracy of total maximum daily loads for nutrients and sediment. He is particularly interested in the application of research to management of aquatic life issues and has extensive experience with the development of tiered aquatic life uses and use attainability analyses in streams. Mr. Rankin received his B.S. in biology from St. Bonaventure University and his M.S. in zoology from The Ohio State University.

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Thomas R. Schueler founded the Center for Watershed Protection in 1992 as a nonprofit organization dedicated to protecting our nation's streams, lakes and wetlands through improved land management. In 2007, he launched the Chesapeake Stormwater Network, whose mission is to improve on-the-ground implementation of more sustainable stormwater management and environmental site design practices in each of 1,300 communities and seven states in the Chesapeake Bay Watershed. He has conducted extensive research on the pollutant removal performance, cost, and longevity of stormwater control measures, and he has developed guidance for both Phase I and Phase II communities to meet minimum management measures to comply with municipal stormwater permits, including development of a national stormwater monitoring database and national guidance on illicit discharge detection and elimination. Mr. Schueler has written several widely referenced manuals that describe how to apply the tools of watershed protection and restoration, and he is working on a wide range of research projects and watershed applications across the United States. Prior to founding the Center, he worked for ten years at the Metropolitan Washington Council of Governments, where he led the Anacostia Watershed Restoration Team, one of first efforts to comprehensively restore an urban watershed. He received his B.S. in environmental science from the George Washington University.

Kurt Stephenson is an associate professor of Environmental and Natural Resource Economics in the Department of Agricultural and Applied Economics at the Virginia Polytechnic Institute and State University. His professional objective is to better integrate economic perspectives and analysis into decision making related to water resource issues. Particular emphasis is placed on the application of economic analysis to interdisciplinary research of policy issues. The design and implementation of market-based policies to secure environmental objectives is a primary area of study within this context. He is currently involved in determining effective strategies for reducing nutrient loads in the Opequon Watershed in Virginia and West Virginia, including evaluating the cost effectiveness and feasibility of using urban nonpoint source controls (including stormwater management) as an offset to growth in point source loads. He is a member of the Virginia Department of Environmental Quality's Nutrient Trading Technical Advisory Committee and the Academic Advisory Committee. Dr. Stephenson received his B.S. in economics from Radford University, his M.S. in agricultural economics from Virginia Tech, and his Ph.D. in economics from the University of Nebraska.

Xavier Swamikannu is Chief of the Stormwater Permitting Program for the Los Angeles Regional Water Board and the California EPA, where he has worked for nearly 20 years. He has extensive experience with the implementation of municipal and industrial stormwater programs in Southern California, including the evaluation of pollutant discharges, determining the effectiveness of stormwater control measures in treating stormwater runoff,

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developing performance criteria and better understanding of their costs. He has participated on EPA's General Permits and Total Maximum Daily Load Work Groups and he has served on many state and regional technical advisory committees concerned with stormwater regulations. He was recognized by the California Water Boards in 2007 for his national leadership in the stormwater program, and by the California State Senate for his service on the technical advisory committee of the Santa Monica Bay Restoration Commission. Dr. Swamikannu received his B.S. in natural and chemical sciences from St. Joseph's College in Bangalore, India, his M.S. in environmental sciences from Texas Christian University, and his Ph.D. in environmental science and engineering from the University of California, Los Angeles.

Robert G. Traver is a professor of Civil and Environmental Engineering at Villanova University and the Director of the Villanova Urban Stormwater Partnership. He conducts research on topics that include modeling of stream hydraulics, urban hydrology, water quality, and measures to mitigate stormwater effects of urbanization. Most recently he has created a Stormwater Best Management Practice Demonstration and Research Park on the Villanova Campus. Dr. Traver is also involved with the implementation of stormwater policy. He has participated in a team study to review the effects of Pennsylvania's water regulation from a watershed sustainability viewpoint, acted as a reviewer for Pennsylvania's 1995 Best Management Practice Handbook, and has served as Chair for the 1998, 1999, 2001, 2003, and 2005 Pennsylvania Stormwater Management Symposiums held at Villanova. More recently he was selected to serve on the American Society of Civil Engineers' External Review Panel of the Corps investigation of Hurricane Katrina. Dr. Traver is a retired LTC in the Army Reserves and a veteran of Operation Desert Storm. He received his B.S. in civil engineering from the Virginia Military Institute, his M.S. in civil engineering from Villanova, and his Ph.D. in civil engineering from Pennsylvania State University.

Wendy E. Wagner is the Joe A. Worsham Centennial Professor at the University of Texas School of Law. Before joining the UT faculty, she was a professor at Case Western Reserve University School of Law and a visiting professor at Columbia Law School and the Vanderbilt School of Law. Wagner's research focuses on the interface between science and environmental law, and her articles have appeared in numerous journals, including the Columbia, Cornell, Duke, Georgetown, Illinois, Texas, Wisconsin, and Yale Law Reviews. She has published on the practical problems with EPA's current approach to stormwater regulation. She has also written several articles on the challenges of regulating media like stormwater, on restoring polluted waters with public values, on the legal aspects of the regulatory use of environmental modeling, and on technology-based standards. Ms. Wagner received a master's degree in environmental studies from the Yale School of Forestry and

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Environmental Studies and a law degree from Yale Law School. She clerked for the Honorable Judge Albert Engel, Chief Judge of the U.S. Court of Appeals for the 6th Circuit.

William E. Wenk is founder and president of Wenk Associates, Inc., a Denver-based landscape architectural firm. He is also an Adjunct Associate Professor of Landscape Architecture at the University of Colorado in Denver. For over 20 years, he has been influential in the restoration and redevelopment of urban river and stream corridors, the transformation of derelict urban land, and the design of public parks and open spaces. Mr. Wenk was the Principal Urban Designer for the Menomonee River Valley Redevelopment, an award-winning "green infrastructure" redevelopment in Milwaukee that integrated a network of parks and open spaces through stormwater infrastructure, regional and local trails, and a restored river corridor into a proposed 130-acre mixed-use and light industrial development. Other projects of his include the Prairie Trail Community Master Plan in Ankeny, Iowa (a surface stormwater system designed to provide flood control and water quality for a new 1000-acre mixed-use community), and the Stapleton Airport Parks and Open Space Redevelopment (a surface stormwater drainage design for the 4,500-acre redevelopment), as well as the Stapleton Water Quality Guidelines book to guide planners and developers on how to integrate stormwater best management practices into redevelopment. Mr. Wenk received a B.S.L.A. and M.L.A. from Michigan State University and the University of Oregon, respectively.

Laura J. Ehlers is a senior staff officer for the Water Science and Technology Board of the National Research Council. Since joining the NRC in 1997, she has served as the study director for eleven committees, including the Committee to Review the New York City Watershed Management Strategy, the Committee on Bioavailability of Contaminants in Soils and Sediment, the Committee on Assessment of Water Resources Research, and the Committee on Public Water Supply Distribution Systems: Assessing and Reducing Risks. Ehlers has periodically consulted for EPA's Office of Research Development regarding their water quality research programs. She received her B.S. from the California Institute of Technology, majoring in biology and engineering and applied science. She earned both an M.S.E. and a Ph.D. in environmental engineering at the Johns Hopkins University. Her dissertation, entitled RP4 Plasmid Transfer among Strains of *Pseudomonas* in a Biofilm, was awarded the 1998 Parsons Engineering/Association of Environmental Engineering Professors award for best doctoral thesis.

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POLLUTION CONTROL HEARINGS BOARD
STATE OF WASHINGTON

PUGET SOUNDKEEPER ALLIANCE; PEOPLE FOR PUGET SOUND; PIERCE COUNTY PUBLIC WORKS AND UTILITIES DEPARTMENT; CITY OF TACOMA; PORT OF SEATTLE; SNOHOMISH COUNTY; CLARK COUNTY; PACIFICORP; and PUGET SOUND ENERGY, Appellants, v. STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY, Respondent, CITY OF SEATTLE; KING COUNTY; PORT OF TACOMA; PACIFICORP; PUGET SOUND ENERGY; STATE OF WASHINGTON, DEPARTMENT OF TRANSPORTATION, Intervenors.	FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDER **PHASE I** PCHB NOS. 07-021, 07-026, 07-027 07-028, 07-029, 0-030, 07-037

These consolidated appeals involve the regulation of stormwater discharges from municipal storm sewer systems under a National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit (State Waste Permit). In these appeals, multiple parties challenge the validity of the Department of Ecology's (Ecology) 2007 Phase I Municipal Stormwater General Permit (Phase I Permit). This permit was issued pursuant to the

Federal Water Pollution Control Act, commonly known as the "Clean Water Act" (CWA), 33 U.S.C. § 1251 *et seq.* and the state Water Pollution Control Act, (WPCA), Chapter 90.48 RCW.

The Pollution Control Hearings Board (Board) held a multiple day hearing between April 29, 2008 and May 8, 2008. Attorneys Todd True and Jan Hasselman represented Appellants Puget Soundkeeper Alliance and People for Puget Sound (PSA). Attorney Tad H. Shimazu represented Appellant Pierce County. Assistant City Attorney Doug Mosich represented Appellant City of Tacoma. Attorneys Susan Ridgley and Tanya Barnett represented Appellant Port of Seattle. Catherine A. Drews and Elizabeth E. Anderson, Deputy Prosecuting Attorneys, represented Appellant Snohomish County. E. Bronson Potter, Senior Deputy Prosecuting Attorney and Rodney Swanson, Clark County Department of Public Works represented Appellant Clark County. Attorneys Loren R. Dunn and Blake Mark-Dias represented Appellants Pacificorp and Puget Sound Energy (Utilities). Ronald L. Lavigne, Senior Counsel, and Thomas J. Young, Assistant Attorney General represented Respondent Ecology. Assistant City Attorney Theresa R. Wagner represented Intervenor City of Seattle. Senior Deputy Prosecuting Attorney Joseph B. Rochelle and Deputy Prosecutor Verna P. Bromley represented Intervenor King County. Attorney Carolyn Lake represented Intervenor Port of Tacoma. Stephen Klasinski, Assistant Attorney General represented Intervenor Washington State Department of Transportation (WSDOT).

Chair, Kathleen D. Mix, William H. Lynch, and Andrea McNamara Doyle comprised the Board. Administrative Appeals Judge Kay M. Brown, presided for the Board. Randi Hamilton

and Kim L. Otis of Gene Barker and Associates of Olympia, Washington provided court reporting services.

PROCEDURAL BACKGROUND

On January 17, 2007, Ecology issued the Phase I Permit for discharges from large and medium municipal separate storm sewer systems (called MS4s). The Phase I Permit went into effect on February 16, 2007.

PSA, Pierce County, City of Tacoma, Port of Seattle, Snohomish County, Clark County, and the Utilities appealed the Phase I Permit.[1] The Board conducted pre-hearing conferences, and entered pre-hearing orders for the Phase I Appeal. The parties raised multiple issues. The Board addressed many of these issues in a separate summary judgment order[2] and has resolved others through orders on summary judgment and after a hearing on the merits related to the Permit's Special Condition S4.[3] The parties also withdrew some of the issues. This decision resolves the remaining issues, which include the following:[4]

C. Special Condition 8 re: Monitoring (challenged only by Clark and Pierce County)[5]

[1] City of Pacific (PCHB No. 07-031), Whatcom County (PCHB No. 07-032), and Sammamish Plateau Water & Sewer District (PCHB No. 07-024) filed additional appeals, but they are not part of this consolidated action.
[2] See Order on Dispositive Motions (Phase I Municipal Stormwater Permit), issued on April 7, 2008.
[3] See Order on Dispositive Motions: Condition S4, issued on April 2, 2008 and Findings of Fact, Conclusions of Law and Order, Condition S4, issued on August 7, 2008.
[4] The numbering of these issues was retained from the numbering system used in the Third Pre-Hearing Order issued on December 11, 2007.
[5] All of the permittee appellants initially raised issues related to the S8 monitoring provisions. These issues were resolved through an agreement between Ecology and all of the permittee appellants except Clark and Pierce County. *See* Ex. Ecy 11 (Phase I). The agreement also resolves issues raised by Snohomish County related to Special Condition S7.

1. Whether the requirements imposed in Special Condition S8 are lawful, practicable, reasonable, and/or designed to achieve the goals of the statutory municipal stormwater permit program?

3. Whether the monitoring requirements imposed in Special Condition S8 are overly broad, overly prescriptive, and cost-ineffective so that requiring implementation of such requirements as written is unlawful, impracticable, and/or unreasonable?

E. Issues Specific to the Ports of Seattle and Tacoma

5. Whether the requirement in Special Condition S6.E.7 to prepare and implement SWPPP(s) for "all Port-owned lands," regardless of their capacity to generate pollutants or other site-specific characteristics, is unlawful, unreasonable, unjust, or invalid?

F. Joint Environmental Legal Issues

1. Low-Impact Development:

a. Does the permit fail to require maximum on site dispersion and infiltration of stormwater, through the use of "low impact development" techniques, basin planning, and other appropriate technologies, and if so, does that failure unlawfully cause or contribute to violations of water quality standards?

b. Does the permit fail to require maximum onsite dispersion and infiltration of stormwater, through the use of "low impact development" techniques, basin planning, and other appropriate technologies, and if so, does that failure unlawfully allow permittees to discharge pollutants that have not been treated with all known available and reasonable methods of treatment ("AKART"), and/or fail to reduce the discharge of pollutants to the maximum extent practicable ("MEP")?

2. Existing Development:

a. Does the absence of any standard and/or technology requirements for reducing stormwater discharges from existing development and existing stormwater systems unlawfully cause or contribute to violations of water quality standards?

b. Does the absence of any standard and/or technology requirements for reducing stormwater discharges from existing development and existing stormwater systems unlawfully allow permittees to discharge pollutants that have not been treated with AKART, and/or fail to reduce the discharge of pollutants to MEP?

3. Monitoring: Is the monitoring required under Permit Condition S.8 unlawful because it is inadequate to determine whether: (i) the permittee is in compliance with water quality standards; (ii) discharges are causing or contributing to violations of water quality standards; or (iii) discharges are being treated with AKART and/or MEP?[6]

4. Water Quality Standards Violations:

   a. Does the Phase I permit fail to ensure that discharges will not cause or contribute to violations of water quality standards?[7]

5. Compliance:

   a. Does the permit unlawfully provide for compliance with permit terms on a schedule that is indefinite and unenforceable, not as expeditious as possible, and/or in excess of statutory deadlines?
   b. Does the permit unlawfully allow a permittee to create and implement permit requirements without Ecology's oversight or involvement?

Based on pre-filed testimony, multiple days of sworn testimony of witnesses, extensive exhibits submitted into the record, and argument from counsel representing the numerous parties that participated in these consolidated appeals, and having fully considered the record, the Board enters the following decision:

[6] PSA is not challenging the monitoring provisions of the permit. This issue is brought by the Utilities only.
[7] This issue also includes the issue originally stated as S4.6: Does the prohibition on violations of water quality standards contained in Permit Condition S4 unlawfully or unreasonably conflict with the other provisions of the permit?

SUMMARY OF THE DECISION

The Board concludes that the monitoring program established in Special Condition S8 and required of all permittees is a valid exercise of Ecology's technical expertise and discretion. (Issues C.1 and 3, and F.5). The Board upholds the permit term requiring that Stormwater Pollution Prevention Plans (SWPPPs) be prepared on all port-owned lands, but directs that Ecology modify the condition to exempt environmental mitigation sites owned by the Port of Tacoma from the SWPPP preparation requirement. (Issue E.5). The Board concludes that the Phase I Permit fails to require that the municipalities control stormwater discharges to the maximum extent practicable, and does not require application of all known, available, and reasonable methods to prevent and control pollution, because it fails to require more extensive use of low impact development (LID) techniques. (Issue F.1.b). To remedy this problem, the Board directs Ecology to make specific changes to some provisions in the permit, and also remands the permit with direction to Ecology to require the permittees to develop methods for use of low impact development at parcel and subdivision levels in their jurisdictions. The Board concludes that permittees must provide information in their annual report to Ecology on the extent to which basin planning is being undertaken or should be considered in their jurisdiction in order to assist with future phases of the permit. The areas identified should be relatively undeveloped where new development is occurring, and from which discharges may impact aquatic resources. The Board concludes that the structural stormwater control program provisions of the permit, as drafted, constitute impermissible self regulation. (Issues F.2 and F.5.b). To remedy this deficiency, the Board directs modification of the permit to require

permittees to describe the prioritization of their selected structural control projects. The Board affirms the source control program requirements without change. Finally, the Board concludes that PSA and the Utilities failed to prove that any of the conditions of the permit violate the timing requirements of 33 U.S.C. § 1342 (p)(4)(A) (Issue F.5.a).

FINDINGS OF FACT

A. History of Phase I Permit

1.

Ecology developed the current Phase I Permit through an eight year long process. The 2007 Phase I Permit replaced the first municipal stormwater NPDES and State Waste Permits, which were issued in 1995 and expired in July of 2000. *Testimony of Wessel, Moore, Exs. Muni 0002, p. 17, 0006, 0007, 0008, 0009.*

2.

On January 19, 1999, Ecology filed a Notice of Intent to reissue the 1995 permits. *Ex. Muni 0002, p. 6.* Ecology formed an advisory committee, which included representatives from cities, counties, state and federal agencies, environmental groups, and the public, to assist with development of the revised permit. This committee met several times during 1999 and 2000. *Testimony of Wessel, Moore, Exs. Muni 0002, p. 6-7.* The 1995 Phase I Permit closely followed the EPA Phase I Regulations, which allowed the permittees to propose what was contained within their own stormwater programs. Ecology was dissatisfied with this approach and decided that more detailed requirements were needed for the 2007 Phase I Permit. *Testimony of Moore.*

3.

Completion of the new permit was delayed at several junctures as a result of a number of intervening events and shifting priorities, including the federal listing of Puget Sound Chinook Salmon in 1999, the adoption of EPA's Phase II rules, and Ecology's decision to revise the state's Stormwater Management Manuals and develop the first Phase II municipal stormwater permits in tandem with the Phase I permit update. *Testimony of Wessel, Moore, Exs. ECY 6 (Phase I), Muni 0002, p. 7.*

4.

In response to legislative interest in the new federal requirements for municipal stormwater permits, Ecology convened two advisory groups during the summer of 2003: one for Eastern Washington and one for Western Washington. Each advisory group submitted a report of its findings to Ecology in early December, 2003. Ecology developed its own recommendations and published these, together with the recommendations from both advisory groups, in a report to the Legislature dated January, 2004. *Testimony of Moore, Exs. ECY 6 (Phase I), Muni 0002, p. 7.*

5.

Ecology filed a notice of intent to issue the Phase I and Phase II Permits in June of 2004. The agency released the first preliminary draft of the Phase I Permit for public comment in May, 2005, and the first formal draft in February, 2006. *Exs. PSA 018, Muni-0100.* Ecology received and reviewed thousands of pages of public comment, and responded to those comments in a 205 page document when it released the revised, final permit in January, 2007. *Exs. Muni 002, p. 7-*

8, ECY 3 (Phase I). Ecology issued the Phase I permit, in its current form, on January 17, 2007. It became effective on February 16, 2007, and expires on February 15, 2012. *Ex. Muni 001, Testimony of Moore*.

B. Overview of the permit

6.

The Phase I Permit regulates discharges from municipal separate storm sewer systems (MS4s) owned or operated by the following large and medium municipalities statewide: City of Seattle, City of Tacoma, Clark County, King County,[8] Pierce County and Snohomish County.[9] It also allows coverage of "secondary permittees," including the Ports of Seattle and Tacoma, for discharges from other publicly owned or operated municipal separate sewer systems located within the primary permittee cities and counties. Secondary permittees as a group are subject to somewhat different terms under the permit than primary permittees, and the permit also has specific terms applicable only to the Ports of Seattle and Tacoma and not other secondary permittees. The Phase I permit does not cover direct discharges into waters of the state from privately owned stormwater systems, nor does it cover the storm sewers owned and operated by the Washington State Department of Transportation (WSDOT).[10] Unlike traditional NPDES permits, the Phase I permit is a "programmatic permit," meaning it requires the municipal

[8] King County Department of Metropolitan Services (METRO) is covered as a "co-permittee" with the City of Seattle for discharges from outfalls King County owns or operates in the City of Seattle. *Special Condition S1.C., Exs. Muni 0001, p. 1, Muni 0002, p. 21*.

[9] An MS4 consists of all of the conveyances, or systems of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs gutters, ditches manmade channels or storm drains) designed or used for collecting or conveying stormwater. By definition, these systems cannot be combined with sanitary sewer systems. *Exs. Muni 0001, p. 61, 63, Muni 0002, p. 22-24.*

[10] The Phase I permit does not cover the storm sewers owned and operated by the Washington State Department of Transportation (WSDOT). WSDOT's system is covered under an individual permit. *Ex. Muni 0002, p. 19, 21*.

permittees to implement area-wide stormwater management programs rather than establishing benchmarks or other numeric or narrative effluent limits for stormwater discharges from individual outfalls. *Testimony of Moore, Exs. Muni 0001, p. 1, 2, 60-65, Muni 0002, p 20-24.*

7.

The heart of the Phase I Permit requires that permittees implement a Stormwater Management Program (SWMP). Special Condition S5 contains the SWMP requirements for the primary permittees, and Special Condition S6 sets out the SWMP requirements for secondary and co-permittees. The required elements of the SWMP track closely with EPA's Part II Application rules but contain much more detailed minimum performance standards for the municipalities' programs. This approach avoids the need for separate review and approval by Ecology of each SWMP prior to coverage under the Phase I Permit. Instead, a permittee is required to submit the SWMP with the permittee's first year annual report. S5.A. *Testimony of Moore, Wessel; Exs. Muni 0001, p. 6-25; Muni 0002, p. 18, 28-42.*

8.

Ecology views these SWMP requirements, in the aggregate, to represent the MEP standard; that is, permittees who implement all of the program requirements in combination with one another are considered by Ecology to be reducing the discharge of pollutants to the maximum extent practicable, even though it may be possible for a permittee to do more in a specific program element or at a specific outfall if the individual requirements were evaluated in isolation from the rest of the program requirements. *Testimony of Moore.*

9.

Under Special Condition S5 the SWMP must include ten component parts, which are mandatory to the extent allowable under state and federal law. These program components address the following topics, and the minimum requirements for each are set out in S5.C. 1 through 10 of the Phase I Permit: (1) Legal authority; (2) System mapping and documentation; (3) Coordination; (4) Public involvement; (5) Controlling runoff from new development, redevelopment, and construction; (6) Structural stormwater controls (retrofits); (7) Source control for existing development; (8) Illicit connections, illicit discharge detection and elimination; (9) Operations and maintenance; and (10) Education and outreach. *Muni 0001, p. 6-25.*

10.

More specifically, S5.C.1 requires the permittee to demonstrate by the effective date of the Phase I Permit that it has the legal authority to control discharges to and from its MS4s. S5.C.2 requires the permittee to map, by specific dates, prescribed parts of its MS4. S5.C.3 requires the permittee to establish coordination mechanisms to remove barriers to stormwater management created by the need to coordinate efforts both internally within one governmental entity, and externally with jurisdictions that share drainage basins. S5.C.4 requires the permittee to provide ongoing opportunities for public involvement in its stormwater management program. S5.C.5 requires the permittee to develop a program to prevent and control impacts of runoff from new development, redevelopment, and construction activities. S5.C.6 requires the permittee to

include a program to construct structural stormwater controls to prevent or reduce impacts from discharges from its MS4s. This element is applicable to existing development, as well as new development, and addresses impacts that are not already adequately controlled by other required actions under the SWMP. S5.C.7 requires the permittee to include a source control program for existing development that reduces pollutants in runoff from these areas. S5.C.8 requires the permittee to have an ongoing program to detect, remove and prevent illicit connections and illicit discharges, including spills, into its MS4s.[11] S5.C.9 requires the inclusion of a program to regulate maintenance activities and to conduct maintenance activities by the permittee that prevent or reduce stormwater impacts. S5.C.10 requires that the permittee's SWMP include an education program with the goal of reducing or eliminating behaviors and practices that cause or contribute to adverse stormwater impacts. The performance measures associated with S5.C.2 through 10 must be completed within specific time periods. *Testimony of Moore, Wessel, Exs. Muni 0001, p. 6-25, Muni 0002, p. 28-42.*

11.

Special Condition S6 (S6), which is similar but not identical to S5, establishes the components required for SWMPs from secondary permittees. Parts of this condition apply to all secondary permittees (S6.A, B and C), all secondary permittees other than the Ports of Seattle

[11] An illicit connection is any man-made conveyance that is connected to a MS4 without a permit, excluding roof drains and other similar type connections. An illicit discharge is any discharge to a MS4 that is not composed entirely of stormwater except discharges pursuant to a NPDES permit and discharges resulting from fire fighting activities. *Ex. Muni 0001, p. 61.*

and Tacoma (S6.D), and just the Ports of Seattle and Tacoma (S6.E). *Testimony of Moore, Exs. Muni 0001, p. 25-39, Muni 0002, p. 42-47.*

12.

Special Condition S8 (S8) addresses monitoring. It requires the primary permittees and the Ports to develop and implement long-term monitoring programs for the purpose of meeting two of the four monitoring objectives identified in the first round of the Phase I municipal stormwater permits issued in 1995: (1) estimating pollutant concentrations and loads from representative areas or basins; and (2) evaluating the effectiveness of selected Best Management Practices (BMP). The permit does not require monitoring to identify specific sources of pollutants or the degree to which stormwater discharges are impacting selected receiving waters and sediments. *Testimony of Moore, O'Brien, Exs. Muni 0001 p. 40-49; Muni 0002, p. 49-50.*

C. Monitoring provisions in S8

13.

Special Condition S8.C.1 specifies that the primary permittees' and the Ports' monitoring programs must contain three components: 1) stormwater outfall monitoring, which is intended to characterize stormwater runoff quantity and quality at a limited number of locations 2) Targeted stormwater management program effectiveness monitoring, which is intended to improve stormwater management efforts by evaluating at least two stormwater management practices that significantly affect the success of, or confidence in, stormwater controls, and 3) BMP evaluation monitoring, which is intended to evaluate the effectiveness and operation and maintenance requirements of stormwater treatment and hydrologic management BMPs. S8.D, E, and F set out

the requirements for each of the three components. *Testimony of Moore, O'Brien, Exs. Muni 0001, p. 40-49; Muni 0002, p. 49-56.* A Quality Assurance Project Plan (QAPP) must be prepared for each of the components of the monitoring program in accordance with Ecology guidelines and submitted to Ecology for review. Ecology must review and approve the QAPPs for stormwater monitoring conducted under S8.D and F prior to monitoring. *Ex. Muni 0001, p. 40-41.*

14.

The first component of the Special Condition S8 monitoring involves outfall monitoring for the purpose of developing local knowledge of pollutant loads and average event mean concentrations from representative areas drained by MS4s. Developing a baseline of local data is important because some variations are emerging between stormwater characterization data from the Pacific Northwest and other areas around the county and world, with examples of both higher and lower concentration levels present regionally, differing from national averages. To accomplish this objective, the Permit requires permittees to select three sites that represent different land uses and then to monitor a certain percentage of storm events per year for a wide range of constituents and parameters. The permit requires storm events to be sampled using flow-weighted composite storm sampling. S8.D.2.b. The seasonal first-flush must be tested for toxicity. S8.D.2.d. Grab samples from each storm must be taken and tested for total petroleum hydrocarbon and fecal coliform bacteria, and one to three sediment samples must be collected each year at each site and analyzed for a variety of parameters. S8.D.2.e, f. *Testimony of O'Brien, Moore, Ex. Muni 0001, p. 41-45.*

15.

The number of samples is intended to establish a sufficient database from which to discern annual and seasonal loading trends over a long time period. Performing a toxicity test on the "seasonal first-flush storm" provides an annual worst case scenario. Ecology believes this data is necessary to evaluate whether stormwater management programs are making progress towards the goal of reducing pollutants discharged and protecting water quality. The data would also be useful when establishing Water Clean-up Plans (TMDLs) for water bodies not currently achieving water quality standards, and in other efforts to identify sources of toxicant loading to Puget Sound. *Testimony of O'Brien, Ex. Muni 0002, p. 49-53.*

16.

The second component of the S8 required monitoring, described in detail in S8.E, is the targeted stormwater management program effectiveness monitoring. In this section, each permittee must conduct monitoring designed to determine the effectiveness of (1) a targeted action (or narrow suite of actions) from their SWMP, and (2) achieving a targeted environmental outcome. The monitoring must, at a minimum, include stormwater, sediment or receiving water monitoring of physical, chemical and/or biological characteristics, and may also include other kinds of data collection and analysis. Ecology anticipates that the targeted environmental outcomes permittees will chose to evaluate will be measured in the receiving water and, therefore, may involve receiving water monitoring. *Testimony of O'Brien, Moore, Exs. Muni 0001, p. 45-46; Muni 0002, p. 53-54.*

17.

The third component of the S8 monitoring provisions is BMP effectiveness monitoring, the requirements of which are set out in S8.F. The purpose of this third component of the S8 monitoring is to develop local performance data on the effectiveness of specific treatment BMPs in reducing pollutant discharges and the effectiveness of various low impact development (LID) practices in reducing the quantity of runoff. This section requires the primary permittees and Ports to select and monitor two treatment BMPs in use at a minimum of two sites in their jurisdiction. S8.F.2. The permittees are also required to monitor the effectiveness of one flow reduction strategy[12] that is in use or planned for installation in their jurisdiction. S8.F.7. Though many of these treatment BMPs have been in common use for many years, and the 2005 Stormwater Management Manual for Western Washington relies on them as presumptively effective, Ecology has only incomplete information about their actual pollutant removal capabilities. *Testimony of O'Brien, Exs. Muni 0001, p. 46-47; Muni 0002, p. 54-56.*

18.

In the absence of local data, Ecology had relied on an existing national stormwater treatment BMP database, [13]as its primary source of BMPs for the 2005 Stormwater Management Manual for Western Washington (The Manual) *Testimony of O'Brien, Tobiason, Exs. PI 0059, 0060, 0064 and 0065.* The national database is of limited utility, however, in evaluating the

[12] A flow reduction strategy is an approach that reduces the volume of runoff coming off a landscape. Ecology witness Ed O'Brien indicated in his testimony that this referred to the use of low impact development techniques.
[13] The purpose of the database, called the International Stormwater Treatment Database, is to facilitate understanding about how particular BMPs perform database and contains studies from both inside and outside the United States. *Testimony of O'Brien.*

effectiveness of BMPs because the performance of treatment BMPs varies greatly depending on specific design criteria, loading criteria, different rainfall patterns, and the types and sizes of solids to which a site gets exposed. These factors vary widely across the country, and therefore BMP performance data from one area is not always useful for another area. This has been a specific concern for Washington because, until recently, there has been little Washington data in the database. In some instances, this national database lacks also data quality, and relies on an insufficient number of samples at a particular site or from a particular BMP to be statistically useful. So, while there exists national data that allows Ecology to make some general assumptions about how well BMPs perform, Ecology still lacks site-specific, region-specific data to verify that the BMPs perform the way Ecology anticipates they will perform. As a result, Ecology required permittees to evaluate BMP effectiveness in an effort to learn and apply the information in future settings and permit iterations. *Testimony of O'Brien, Tobiason, Kibbey, Exs. PI 0059, 0060, 0064, 0065, Muni 0002, p.* 54-56.

19.

Ecology considered requiring receiving water monitoring in the Phase I Permit, but the municipalities as a group opposed the requirement. The 1995 Phase I Permit identified one monitoring objective as evaluating the degree to which stormwater discharges impact selected receiving waters and sediments, and Ecology concedes this continues to be a valid long-term objective for the municipal stormwater general permits. In the current iteration of the Phase I Permit Ecology decided, however, that receiving water monitoring data would not be the most helpful monitoring data because 1) receiving water monitoring data is more complex data to

obtain, 2) samples can be hard to collect during storms, and 3) it is difficult to tie the receiving water data back to a specific discharger. Ecology agreed with the municipalities that certain receiving waters may receive pollution from multiple upland sources, and monitoring the receiving water would not provide permittees with useful data by which they could develop or tailor their stormwater management programs. Ecology also does not typically require receiving water monitoring under several other general stormwater discharge permits, including the construction and industrial permits, except for certain impaired water bodies where there have been violations of discharge limitations. *Testimony of Moore, O'Brien. Ex. Muni 0002, p. 49.*

20.

The monitoring required by S8 is primarily aimed at developing a uniform baseline of information about the pollutant loading discharging from MS4s, and evaluating the effectiveness of the BMPs that permittees use to control and reduce the pollutants discharging from those systems. Ecology determined this data will be the most useful for establishing what constitutes maximum extent practicable reduction in pollutants from MS4 discharges for future iterations of the municipal stormwater permits. Allowing some municipalities to opt out of these requirements, by substituting different kinds of monitoring, would reduce the robustness of the data set Ecology seeks for establishing this baseline for future permits. *Testimony of Moore, O'Brien.*

21.

Ecology intends to rely on its own monitoring programs, coordinated with and supplemented by other monitoring efforts, to accomplish the receiving water monitoring

objectives identified in the 1995 permit. Ecology received an $800,000 state appropriation to begin work with a collaborative monitoring consortium to identify the elements of a comprehensive receiving water monitoring program, outside of the permit process. Such a monitoring consortium could more fairly distribute the cost of monitoring among all of the entities with an interest in receiving water data and form the basis for effective, region-wide monitoring of receiving water quality in relation to discharge points. Although Ecology is currently organizing the consortium, no water monitoring has been started to date through this program, and inadequate funding currently exists to do so. Outside the consortium, some receiving water monitoring occurs through statewide ambient water quality monitoring and pollutant specific monitoring where a water body is subject to a TMDL. *Testimony of Moore, O'Brien, Wessel*.

D. Pierce and Clark Counties Monitoring Plans

22.

Two primary permittees, Pierce and Clark Counties, already have water quality monitoring programs which differ significantly from the monitoring required in the Phase I Permit. The key difference between both of the counties' programs, and the Phase I Permit monitoring requirements, is that the county programs focus on monitoring in the receiving water environment. However, neither of the County programs monitors the chemical composition or toxicity of stormwater discharges from their MS4, nor relates stormwater management actions to a reduction in the pollutant characteristics of stormwater. *Testimony of Tobiason, O'Brien, Exs. PSA 018, PI 0042.*

23.

Pierce County began working with a consultant in 2004 to develop its monitoring program. The County developed the program based on the proposed monitoring requirements in an early draft of the Phase I permit, which included a receiving water monitoring component, as well as ongoing communications with Ecology personnel. The 2005 draft of the Phase I permit prescribed two of the five monitoring methods that Pierce County incorporated into its monitoring plan. *Ex. PI 0041*. Pierce County published its final program in March, 2007. *Testimony of Tobiason, O'Brien, Ex. PI 0042.*

24.

The overall goal of the Pierce County monitoring program is to implement a comprehensive monitoring program that will provide meaningful data to support the County's efforts to protect receiving waters from stormwater impacts. Although developed primarily in anticipation of the NPDES permit requirements, it also serves other county water quality objectives. In order to accomplish its goal, the program uses a three level receiving water monitoring approach. It includes long term status and trends monitoring, which includes a triad of bioassessments, physical channel characterization, and in-situ bioassays at existing County monitoring sites in selected streams, and may also include flow monitoring where gauges exist. Pierce County includes the sampling of the stream bottom as part of this long-term monitoring in order to determine the presence and health of benthic invertebrates. Monitoring benthic invertebrates provides a good indicator of watershed health because these organisms respond to physical and chemical stresses at the stream bottom. Pierce County applies these monitoring

methods over a five year period to characterize the receiving waters in up to nine watersheds with regards to the receiving waters' physical stability, habitat, biological health, and susceptibility to toxicants in stormwater. This will enable Pierce County to prioritize responses to watersheds that exhibit vulnerability. It also includes targeted development monitoring, which compares upstream and downstream conditions to assess impacts of stormwater discharges on the receiving waters over finite periods before and after specific development. Targeted development monitoring includes continuous turbidity, conductivity and hydraulic stage monitoring and *in-situ* bioassay upstream and downstream of discharges from targeted development, and assessment of physical channel conditions downstream. Some aspects of the County's monitoring program, particularly the real-time data, will also assist the county in detecting spills and illicit discharges. The third level of receiving water monitoring included is a special studies monitoring. This method provides for adaptive management to be employed as needed on a site specific basis to develop cause-effect relationships that lead to focused stormwater management response. As part of this method, chemical analysis may be conducted if other programs indicate a need for such study to determine the cause of a problem discovered through receiving water monitoring. This is the only aspect of the Pierce County Program that provides for the use of chemical analysis. *Testimony of Tobiason, Kibbey, Exs. PI 0042, Ex. PI 0055, PI 0094.*

25.

Clark County, like Pierce County, has its own monitoring plan which is focused on receiving water monitoring. Clark County developed its plan in response to its first

NPDES/State Waste permit which was issued July, 1999 and expired December, 2000.[14] *Muni 0140, Special Condition S5.B.4, p. 7, 8.* Its plan has three elements: a long-term index site project, hydrologic monitoring, and a stormwater needs assessment program. The index site project involves nine stream stations which are influenced by stormwater, and a forested reference site. A suite of stream health characteristics are monitored at each site. Water quality monitoring takes place on a monthly basis. The hydrologic monitoring consists of monitoring stream flow continuously through the use of storm gauges at several locations, including some of the site index locations. The stormwater needs assessment program is a system created to make an assessment of needs for each sub-basin in the county that contains parts of the MS4. Currently, Clark County is in the process of completing reports on 12 urbanizing and rural sub-watersheds. *Testimony of Swanson, Ex. Muni 0140, p. 7-8.*

26.

The monitoring required under the Phase I Permit is fundamentally different than the monitoring contained in the Pierce and Clark County monitoring programs. The Counties' monitoring programs do not routinely look at the chemical content or toxicity of stormwater discharges, nor do they look at the effectiveness of treatment BMPs. *Testimony of O'Brien, Tobiason, Kibbey.*

[14] Clark County was not informed of the need to submit a permit application until January of 1995, because of confusion over whether Clark County met the requirements of the Phase I Permit, i.e. urbanized area with a population greater than 100,000. *Ex. Muni 0141, p. 8.*

27.

Ecology stated that it was extremely important to be able to answer whether our stormwater programs are adequate to protect aquatic resources and uses in its 2004 report to the Legislature. Therefore, Ecology included recommendations that certain types of environmental monitoring be conducted at the local and regional levels, including monitoring of the biological, chemical, and physical health of receiving waters. *Ex. ECY 6 (Phase I), p. 31-32*.

28.

Ecology does not oppose the Counties continuing on with their own monitoring programs in addition to the S8 monitoring. However, it has not allowed Pierce and Clark Counties to substitute their programs for the required S8 monitoring. Ecology witness Edward O'Brien did not rule out the possibility that Ecology could allow Pierce and Clark to substitute their monitoring programs for some parts of the required S8 monitoring. Pierce County witness Heather Kibbey testified that Pierce County could not afford to do both its receiving monitoring program and the required S8 monitoring. *Testimony of O'Brien, Tobiason, Kibbey*.

E. Ports

29.

One of the required elements of the SWMP for all Phase I permittees is the preparation of a stormwater pollution prevention plan (SWPPP). The permit requires all primary permittees to prepare SWPPS for "all heavy equipment maintenance or storage yards, and material storage facilities owned or operated by the Permittee(s)" that are not already covered by another stormwater discharge permit. S5.C.9.b.xi, p. 23, 24. The primary permittees are allowed 24

months to complete the development of their SWPPPs. The secondary permittees, other than the Ports, are required to prepare SWPPPS for "material storage areas, heavy equipment storage areas, and maintenance areas" not covered by another stormwater discharge permit. S6.D.6.a.vi, p. 32. Their SWPPPs must also be completed within three years from the date of permit coverage. *Testimony of Moore, Ex. Muni 0001, p. 23, 24, 32.* In contrast, the Ports' SWPPP preparation requirement, found in S6.E.7, requires the Ports to prepare SWPPPs "all Port-owned lands" that are not covered by another stormwater discharge permit. The Ports are allowed 24 months to develop and implement their SWPPPs. *Ex. Muni 0001, p. 38.*

30.

The Port of Seattle estimates this requirement will involve the preparation of SWPPPs for approximately 44 properties covering approximately 27 percent of its total Seaport acreage (286 acres).[15] Some of these sites include port-controlled and operated facilities with multiple tenants, such as Shilshole Marina and Fisherman's Terminal, and several others consist of tenant-controlled container areas. *Testimony of Guthrie, Exs. PI 0020, 0022.* The Port of Tacoma has identified several port-owned sites that are not covered by other stormwater discharge permits, some of which include buildings and parking lots leased to other businesses, others of which consist of environmental mitigation sites. *Testimony of Graves, Ex. PI 0039.*

31.

The Phase I fact sheet explains Ecology's general thinking regarding SWPPP preparation

[15] By agreement with Ecology, SWPPPs will not be required on "no discharge" properties, which include Port-owned parks and properties with connections to Metro Stormwater Conveyances.

for the primary permittees. It states:

> Ecology has determined that activities at certain sites owned or operated by permittees are potentially similar to activities at sites regulated under the Industrial Stormwater General Permit. For this reason this provision of the permit calls for developing Stormwater Pollution Prevention Plans (SWPPPs) for these sites.
>
> *Ex. Muni 0002, p. 41.*

32.

In the 2005 draft of the Phase I Permit, Ecology required SWPPP preparation for "all Port-owned lands with potential pollutant-generating sources." *Ex. PSA 018, p. 37.* The final permit eliminated the qualifier because Ecology expected that all port-owned lands would be pollutant-generating sources, although Ecology did not consider wetland mitigation areas owned by the Port of Tacoma when it made this decision. *Testimony of Graves, Moore, Exs. PSA 018, p. 37; PI 0022, 0025-0027.*

33.

The Port of Tacoma owns several environmental mitigation sites (i.e. wetlands). Most of these sites probably discharge directly to surface or ground waters of the state, and not to the MS4. For the ones that do discharge to the MS4, there is only a small potential that the discharges would carry pollutants. Therefore, preparation of SWPPPs on these sites is unlikely to result in any corresponding water-quality benefits. *Testimony of Moore, Graves.*

34.

Ecology also explains in the fact sheet its reasons for providing a slightly different

standard for the Ports regarding SWPPP preparation. It states:

> Ecology has determined that special consideration is needed for the Ports of Seattle and Tacoma, distinguishing them from the broader group of Secondary permittees such as diking and drainage districts and public universities. These ports are both located on urban bays with documented water quality and sediment contamination problems that may be linked to stormwater discharges. The infrastructure in both Seattle and Tacoma is fairly old and the MS4s are heavily interconnected between each port and the respective city. Also, both ports lease properties to tenants, of whom many, but not all, are required to have coverage under the Industrial Stormwater General Permit. For these reasons this permit establishes SWMP components that are specific to these two entities.

Ex. Muni 0002, p. 43.

35.

In general, the permit has more requirements for primary permittees SWMPs than it does for the Ports. *Contrast* S5.C. 1 through 10 (establishing 10 components for primary permittees SWMPs) p. 6-25 with S6.E (establishing 7 components for Ports SWMPs) p. 32-39. The source control program for existing development, which is a component of both primary permittees and the Ports SWMPs, also imposes more requirements on the primary permittees than it does the Ports. *Contrast* S5.C.7, p. 13-15, with S6.E.7, p. 38-39. Further, the scope of the primary permittees source control obligation is much wider than that of the Ports, because the primary permittees are dealing with thousands of different sources, compared to a much more limited number for the Ports. Therefore, the Ports will be preparing a much smaller number of SWPPPs than the primary permittees. While Ecology suggests that the Guidance Manual for Preparation of SWPPPs for Industrial Facilities can be used to assist in preparation of Port SWPPPs, it also encourages the use of generic SWPPP provisions for sites grouped by type of activity, such as

parking lots. *Testimony of Moore, Guthrie, Exs. Muni 0001, p. 6-25, 33-39, Muni 0002, p. 44, PI 0021*.

36.

The Port of Seattle expects its tenant businesses to be involved in the preparation of the required SWPPPs because they have the most familiarity with the pollution-generating activities and source control opportunities at the individual sites, but the port, in its role as property manager, will work cooperatively with tenants through its routine compliance assessment process. For example, it has already provided its tenants with templates for preparing the SWPPPs. This process will involve some cost and effort on the part of the tenants, but can also serve as an opportunity for educating and training tenants in issues related to stormwater management. *Testimony of Guthrie*. The Port of Tacoma intends to prepare the SWPPPS for its existing tenant facilities which will require the port to become better informed about the details of its tenant operations and pollutant-generating activities. For new facilities, the Port of Tacoma intends to direct tenants to prepare the SWPPPs. *Testimony of Graves*.

F. Low Impact Development (LID)

37.

The major contention of PSAs' challenge to the Phase I permit is that traditional structural engineered stormwater management practices are inadequate to address the municipal stormwater problem and that the Permit should have also required greater use of Low Impact Development (LID) practices on a broader and more comprehensive scale.

38.

In the Phase I Permit, Ecology chose to regulate stormwater discharges from new development and redevelopment primarily through the imposition of a flow control standard. S5.C.5.b.i. *Ex. Muni 0001, p. 9, Testimony of O'Brien*. The flow control standard generally requires new and redeveloped sites that discharge to surface waters to control the rate at which stormwater is released from their sites so that the discharges do not cause accelerated stream channel erosion. The flow control standard is not a LID concept, because, in contrast to LID techniques, it is based on the premise that there will be discharges of stormwater from particular sites, and it attempts to control the duration and frequency of high stormwater runoff flows. Conventional stormwater management criteria frequently incorporate a post development peak discharge rate for a 2- and 10-year storm event based upon possible property damage due to flooding and stream bank erosion. These are becoming more recognized as insufficient because they do not address the loss of storage volume to provide for groundwater recharge, they do not adequately protect downstream channels from accelerated erosion, and the inspection and maintenance costs are an increasing burden for local governments. The goal of LID, on the other hand, is to minimize or prevent entirely the discharge of stormwater from the site. While utilization of LID techniques may be useful (or even in some cases necessary) to meet the flow control standard on a particular site, the flow control standard does not require the use of LID techniques. *Testimony of O'Brien, Booth, Exs. ECY 4 (Phase I) p. 2-30 through 2-35, Ex. PSA-053, p. 7.*

39.

In order to meet the Permit's flow control standard(s), facilities must be engineered so that discharges are not predicted to exceed the predevelopment flow "durations" for a range of storm events. The Stormwater Management Manual gives detailed design specifications for sizing and constructing detention/retention facilities to meet the flow control standard. The Manual itself recognizes the shortcomings of the use of engineered stormwater conveyance, treatment and detention systems to control stormwater. It states, at page 1-25:

> [These techniques] can reduce the impacts of development to water quality and hydrology. But they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions.

The primary focus of detention standards is on mitigating the worst impacts of large storm events. These standards have little or no effect on small storm events, which can also cause damaging increase in flows. Stated another way, the flow control standard addresses large stormwater flow rates only, which occur only a small percentage of time (1%), and provides only residual control to runoff the remainder of the time. *Testimony of O'Brien, Booth, Ex. ECY 4 (Phase I), p. 1-25, 2-30 through 2-35*.

40.

Another limitation of the flow control standard comes from a significant exception to the requirement to achieve pre-developed discharge rates for basins that have had at least 40 percent total impervious area since 1985. Phase I permit, Appendix 1, p. 25-27, and Manual, Section 2.5.7 Minimum Requirement # 7, pp. 2-33. For sites in these basins, the pre-developed condition

to be matched is the existing land cover. Most areas located within the Seattle city limits, many areas within the City of Tacoma, and some areas in Bellevue and Everett would qualify for this exception. *Testimony of O'Brien, Booth, Exs. ECY 4 (Phase I), p. 2-33, Muni 0001, Appendix 1, p. 25-27.*

41.

The Phase I Permit defines LID as follows:

> stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions.

Ex. Muni 0001, p. 62. Ecology adopted this definition from the Puget Sound Action Team's Low Impact Development Manual (PSAT Manual), which is a technical manual published in 2005 to "provide stormwater managers and site designers with a common understanding of LID goals, objectives, specifications for individual practices, and flow reduction credits that are applicable to the Puget Sound region." *Ex. PSA 050, p.2.*[16] Other definitions of LID offered in testimony at the hearing differ from this definition primarily in the scale of application of LID. Thomas Holz offers an almost identical definition to the one quoted above, but includes application at the watershed scale in addition to the parcel or subdivision scale. *Testimony of Holz, Ex. PSA 050, p.11.*

[16] The advisory committee for the development of the PSAT Manual included Edward O'Brien, Tom Holz, and Derek Booth. These three experts also testified at the Phase I hearing, *Testimony of Moore, Ex. PSA 050, Acknowledgements page and p. 2.*

42.

While specific definitions of LID may vary, the concept of LID is well-established, and the basic BMPs that constitute LID are well-defined. LID techniques emphasize protection of the natural vegetated state, relying on the natural properties of soil and vegetation to remove pollutants. LID techniques seek to mimic natural hydraulic conditions, reducing pollutants that go into stormwater in the first instance, by reducing the amount of stormwater that reaches surface waters. *Testimony of Horner, Booth, Holz.*

43.

LID techniques store, infiltrate and evaporate stormwater where it falls rather than collect and convey it to surface waters off site, and can be implemented at an individual development site level, as well as part of a broader strategy employed at a basin or watershed level. Site-level LID BMPs include, but are not limited to, maintenance of natural vegetation on site; reduction of impervious surfaces; protection of natural drainage patterns, use of minimal excavation foundations such as pin foundation for structures; use of vegetated swales to capture and retain runoff; use of green roofs, and storage and reuse of runoff. At a watershed or landscape scale, LID strategies can include basin planning, watershed-wide limits on imperviousness, and protection of sensitive areas like riparian zones, wetland and steep slopes. *Testimony of Holz, Booth, Ex. PSA 050*.

44.

Although many LID techniques are not new ideas (i.e. grass roofs, rain gardens), LID as a formal stormwater management concept was developed in the late 1980's. *Testimony of Booth,*

Holz. Prince George's County, Maryland, a pioneer in the area of LID in the United States, began working on bioretention or rain gardens during the 1980's, and published a comprehensive LID technical manual and an accompanying volume providing detailed hydrologic analysis and computational procedures in 1999. *Exs. PSA 052 and 053*. Two federal agencies, the U.S. Department of Defense and Department of Housing and Urban Development, adopted LID Manuals in 2003 and 2004. *Exs. PSA 054 and 055*. The Puget Sound Action Team and the Washington State University Pierce County Extension published The PSAT Manual, a 247 page, comprehensive, technical guidance manual for the use of LID in the Puget Sound Area, in January of 2005 with funding provided by the Ecology. *Ex. PSA 050*. The PSAT Manual was intended to provide a menu of treatment options and direction for site design techniques, but it does not attempt to identify a performance standard for any of the included LID strategies. *Testimony of O'Brien*.

45.

The Environmental Protection Agency (EPA) has not required the use of LID in its stormwater rules or EPA permits, but it is increasingly supporting and encouraging the use of LID approaches in municipal stormwater programs on its website and thorough numerous publications. *See for example, Ex. PSA 057(EPA National Pollutant Discharge Elimination System (NPDES), Post-Construction Stormwater Management in New Development and Redevelopment)(posted on EPA's website); PSA Ex. 058, (EPA National Pollutant Discharge Elimination System (NPDES), Low Impact Development (LID) and Other Green Design Strategies)(posted on EPA's website); PSA 056 (EPA Fact Sheet for Stormwater Phase II Final*

Rule, Post-Construction Runoff Control Minimum Control Measure (Jan. 2000, rev'd 2005); Ex. PSA 066 (EPA Low Impact Development (LID), A Literature Review (Oct. 2000); Ex. PSA 059 (EPA 833-F-04-033, Resource List for Stormwater Management Programs (May 2004); Ex. PSA 060 (EPA National Management Measures to Control Nonpoint source Pollution for Urban Areas (Excerpts: Cover, Table of Content, Chapters 1-4, 10); Ex. PSA 061 (Memorandum from Benjamin Grumbles (Assistant Administrator, EPA) to EPA Regional Administrators Re: Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and Other Water Programs (Mar. 5, 2007); Testimony of Holz.

46.

Ecology's 2005 Stormwater Management Manual addresses the use of LID techniques in several ways, as part of the manual's Minimum Technical Requirements and Site Planning (Volume I), its Hydrologic Analysis and Flow Control Design/BMPs (Volume III), and its Runoff Treatment BMPs (Volume V). *Ex. ECY 4.*[17] One of the most significant changes during the 2005 update to the Manual included the addition of a "credit" system for projects that use LID techniques. *Ex. PSA 064.*

[17] The Manual is not a regulation but rather a guidance document that presents a presumptive approach to meeting requirements established through other means, such as permits. Washington is somewhat unique in its reliance on the Stormwater Management Manual for directing how stormwater management is to be conducted. *Testimony of Moore*. *Testimony of O'Brien*. The Manual represents Ecology's generalized determination of what constitutes AKART for stormwater management, without regard to how much horizontal development should be allowed (*i.e.*, whether a particular parcel, subdivision, or watershed should be developed or a particular project should be undertaken). The manual is also considered by the Department of Community, Trade, and Economic Development, the agency charged with state oversight of the implementation of the GMA, to constitute the best available science for use by local governments planning under the GMA. *Testimony of O'Brien*.

47.

Volume I covers several key elements of developing a stormwater site plan, including identifying the minimum requirements for stormwater management at all new development and redevelopment projects. Minimum Requirement #5, which directs on-site stormwater management for the purpose of using inexpensive practices on individual properties to reduce the amount of disruption of the natural hydrological characteristics of the site, requires the use of certain LID BMPs such as roof downspout control and dispersion and soil quality BMPs. This minimum requirement applies to single-family home sites and larger properties. *Testimony of O'Brien, Ex. ECY 4 (Phase 1), Vol I, at 2-26; Ex. Muni 0001, Appendix I at p.10 and 19.* The Phase I permit requires that permittees' local ordinances must meet Minimum Requirement #5, including requiring specified LID BMPs to reduce the hydrologic disruption of developed sites. *Testimony of O'Brien, Ex. Muni 0001, Condition S5.C.5 (at p. 9) and Appendix 1(at p.19).*

48.

Stormwater site planning requirements, also contained in Volume I, direct that site layouts minimize land disturbance and maximize on-site filtration by considering a number of LID strategies and techniques such as preserving areas with natural vegetation (especially forested areas) as much as possible, minimizing impervious areas, and maintaining and utilizing natural drainage patterns. *Testimony of O'Brien, Ex. ECY 4 (Phase I), Vol I, at 3-2.*

49.

Volume III of the Manual focuses primarily on BMPs to address the volume and timing of stormwater flows from developed sites, for the purpose of providing guidance on the

estimation and control of stormwater runoff quantity. Appendix III-C of this volume is Ecology's guidance explaining how Low Impact Development techniques can be represented in approved runoff models so that their benefits in reducing surface runoff can be estimated and credited in the flow duration model. It identifies seven categories of LID techniques, including permeable pavements, vegetated roofs, rainwater harvesting, reverse slope sidewalks, minimal excavation foundations, and rain gardens, and lists the basic design criteria Ecology considers necessary in order to justify use of the suggested runoff credit. *Testimony of O'Brien, Ex. ECY 4 (Phase I), Vol III, at Appendix III-C.*

50.

Finally, Volume V of the Manual identifies and discusses BMPs designed to treat runoff to remove sediment and other pollutants at developed sites, for the purpose of providing guidance on the selection, design and maintenance of permanent runoff treatment facilities. LID techniques are included in both the basic and advanced treatment options available to developers, and the method for determining the treatment credits for each technique is explained. Chapter 5 of this volume is devoted to the methods for analysis and design of on-site LID BMPs that serve to both control runoff flow rates as well as provide runoff treatment and, since 2005, has directed readers to use the PSAT Manual for various LID BMPs. *Testimony of O'Brien, Ex. ECY 4, Vol V.*

51.

Ecology wrote the first draft of the current Phase I Permit in 1999. At that time, LID was recognized as a stormwater management strategy, but there was not the same body of work

available on its use as there is today. Although much of the work and literature cited above post-dated the initial draft of the current Phase I Permit, Ecology recognized that a large body of work existed on LID as it finalized the Phase I permit. Despite the existence of many LID source or reference materials, Ecology believed that it could not at that time define minimum LID requirements, and was unable to define a regulatory performance standard to hold municipalities to, should LID requirements be imposed by the permit. The agency also recognized that local governments had adopted other land use and development standards that were obstacles to the implementation of LID on a broader scale. Some local governments also have limited experience with LID techniques and are reluctant to approve them. *Testimony of O'Brien*.

52.

Early drafts of the permit included requirements for basin or watershed planning as a LID technique. Use of a basin planning approach in the permit would, among other things, require municipalities to consider the effects of loss of impervious cover to water quality in larger, watershed, basin, and sub-basin areas (potentially measured in many square miles). The ideal area size for basin planning is two to ten acres. WRIA-scale (Water Resources Inventory Area) planning efforts are too large to address the impervious surface problem. *Testimony of Wessel*. Basin planning can also lead to the development of better site specific strategies, and some Ecology staff advocated for its inclusion into the Permit. *Testimony of O'Brien*.

53.

Ultimately, Ecology drafted a permit that requires municipalities to identify barriers to use of LID, and to take steps to also "allow" LID. Specific requirements for basin planning were

not included in the final permit, although the Endangered Species Act listing of various salmon species, and efforts of the Puget Sound Partnership are reasons to reexamine the need for basin planning as a permit requirement. *Testimony of Wessel, Moore; Ex. PSA 31*. Ecology rejected basin or watershed planning as a permit requirement, in part because the agency could not require a comprehensive planning effort, given that not all jurisdictions within a given watershed or basin were covered by the Phase I permit. Ecology also concluded that imposing both site level LID and basin planning requirements would move the agency too far into the land use regulatory arena, although Ecology witnesses conceded that imposition of more detailed LID requirements and a basin planning process could be harmonized with a parallel Growth Management Act land use process, thereby elevating water quality as a growth management planning priority. *Testimony of Moore, Wessel, O'Brien*.

54.

Ecology stated in its 2004 report to the Legislature that:

> Compact style development, with a smaller footprint, reduced impervious surfaces, natural areas within the urban core, and improved water detention can help local communities meet the Growth Management Act's goals of accommodating growth while protecting the environment.

Ex. ECY 6 (Phase I), p. 31. This same 2004 report to the Legislature highlighted the importance of stormwater basin planning in areas which are relatively undeveloped where new development is occurring. Ecology stated that in these areas:

> site specific controls alone cannot prevent impacts and preserve aquatic resources. Recent research should be used to identify development strategies that may protect the resources. Scientific modeling of the basin can help predict the extent of potential

> impacts and the effectiveness of alternative land development options to help avoid or minimize those impacts.

Id. at 28. Ecology also recommended in its report to the Legislature that state and local governments consider basin planning to address the known shortcomings of the stormwater permits. Ecology stated that:

> Stormwater basin planning is needed to quantify flow-related impacts and sources of pollution to urban water bodies. This information is needed to target resources spent on structural and non-structural controls (such as maintenance and public education) so that goals for urban water bodies can be met. In many basins, this planning can be combined with the planning for new development described earlier.

Id. at 30. Other types of water quality planning are taking place on a WRIA basis. The Board finds that information developed by permittees regarding their use of basin planning, and its possible interface with other planning efforts, would be very valuable to Ecology in its development of the next phase of the Permit.

55.

The Phase I Permit includes several conditions that address LID in various ways, nearly all of which are in the nature of encouraging or promoting rather than requiring LID by municipalities. In contrast to other permit terms, the final permit does not require municipalities to implement ordinances or other measures to use LID as a primary tool to manage stormwater within their jurisdictions. *See* S5.C.5.b.i (allowing local governments to tailor certain requirements applicable to new development through the use of basin plans or other similar water quality and quantity planning efforts)*;* S5.C.5.b.iii (requiring SWMPs to allow non-structural preventative actions and source reduction approaches such as LID techniques)*;*

S5.C.6.a (stating that permittees should consider other means to address impacts from existing development "such as reduction or prevention of hydrologic changes through the use of on-site (infiltration and dispersion) stormwater management BMPs and site design techniques, riparian habitat acquisition, or restoration of forest cover and riparian buffers . . ."); S5.C.10.b.(3) and (4) (requiring the inclusion of LID techniques in education and outreach programs); S8.F.1 and 7 (requiring monitoring of the effectiveness of one flow reduction strategy that is in use or planned for installation in their jurisdiction); and Appendix 1 § 4.5 (imposing, as a minimum requirement, on-site stormwater management where feasible, including use of roof downspout controls and dispersion and soil quality BMPs or their functional equivalent).[18] *Exs. Muni 0001, p. 9, 10, 12, 24, 25, 46, 47, and Appendix 1, p. 19.*

56.

Some commentors on the draft Phase I Permit criticized the lack of more mandatory LID requirements. The National Marine Fisheries Service and the U.S. Fish and Wildlife Service (jointly the Services) offered comments on the Draft Phase I Permit in May, 2006. While they supported many elements of the draft Permit, the Services recommended that the Permit employ methods to help ensure that several LID projects are completed within the permit term and strongly encouraged the use of basin planning to make better linkage with salmonid recovery plans organized at the watershed level. *Ex. PSA 030*. EPA offered its comments on the draft Phase I Permit in October, 2006. *Ex. PSA 067*. While EPA praised many aspects of the permit, it also recommended strengthening the permit by "promot[ing] the implementation of low impact

[18] This same requirement is included in The Manual. *Ex. ECY 0004 (Phase I), Vol. 1, p. 2-26*.

development and non-structural best management practices," and "add[ing] a basin planning program requirement." Similarly, a group of Washington Scientists sent an "open letter" to Ecology on October 26, 2006, in which they criticized the draft Phase I Permit for its continued focus on "end of pipe" management of stormwater, emphasizing the need to preserve existing "least-disturbed" watersheds, to limit forest loss, and to halt runoff from new impervious areas in the Puget Sound Basin. They recommended broad application of LID principles within the context of land use planning and development regulations efforts to prevent runoff to surface water. *Ex. PSA 010.*

57.

Ecology staff who developed the Phase I permit, as well as a number of stormwater experts who testified before the Board, agreed that no one stormwater management technique could solve the problem of polluted runoff from municipal stormwater systems. Even the extensive use of site-level LID is not sufficient, on its own, to fully protect aquatic resources. Rather, a combination of aggressive use of LID techniques, best conventional engineering techniques to manage high flows (such as the flow duration standard), and land use actions to preserve a high percentage of native land cover, are necessary to reduce pollutants in stormwater to the maximum extent, and to preserve water quality. Although the there is considerable dispute about the attainable performance of particular LID strategies and engineering techniques, there is no dispute that *in combination* these approaches offer the best available, known and tested methods to address stormwater runoff. *Testimony of O'Brien, Holtz, Booth*.

58.

There are existing design criteria for many LID techniques, just as there are for traditional BMPs employed to manage stormwater run-off used at the parcel or subdivision scale (for example, pond size or thickness of a liner). These aspects of LID can be employed at a site specific level. However, at this time there are no universal or broadly endorsed performance standards for LID, at either the parcel, subdivision, or watershed scale. Nor were experts before the Board willing to endorse or recommend such standards from among the many potential options identified, although it was undisputed that any permit condition requiring permittees to meet a new stormwater performance standard based on LID would implicate many other local government regulatory schemes, and require modification to local government GMA planning processes and requirements, zoning and development regulations, and building codes. *Testimony of Holz*.

59.

A zero runoff outcome from the use of LID techniques is one such performance standard, but actions to meet that standard would implicate a range of land use planning actions and watershed level assessments. It is possible to create other, more specific performance standards for LID, although the process would involve time and effort. Other jurisdictions are currently using such standards, or have proposed standards for use. For example, jurisdictions can require that LID BMPs be designed in accordance with guidelines in technical manuals, impose specific minimum technical requirements for buildings or roads, require protection of a specific amount of native vegetation at the site or basin level, limit the amount of effective impervious surface,

protect the natural hydrograph through various parameters, require maintenance of a certain percentage of predevelopment evapotranspiration capacity or minimize or eliminate surface runoff, or require that developers prioritize LID BMPs as the first choice before conventional BMPs. The Phase I Municipal Stormwater Permit for San Diego County, which was reissued in January, 2007, requires all new and redevelopment projects to implement LID BMPs where feasible. The Permittees are given the responsibility of defining the applicability and feasibility of LID BMPs, including the minimum standards to ensure maximum implementation. Another example of an NPDES permit from another jurisdiction that incorporates a LID performance criteria is the Ventura County MS4 Permit. This permit, which was in draft form at the time of the hearing, requires that developers prioritize LID BMPs as the first choice before conventional BMPS. *Testimony of Booth, Holz, Horner, Exs. PSA 048, p. 13-18; PSA 069, p. 49; PSA 070, 072, 080, Snohomish County Code 30.63C.*

60.

Requiring municipalities to impose parcel and subdivision-level LID best management practices represents a cost effective, practical advancement in stormwater management. Use of LID techniques at the parcel and subdivision level would not be feasible on every type of site, or under all rainfall conditions present in Western Washington. Use of LID techniques could in some instances allow pollutants to enter groundwater. LID BMPs require maintenance. All of these limitations are also applicable to the more traditional end of pipe BMPs. In fact, site attributes that make implementation of LID techniques difficult also typically make implementation of conventional techniques difficult. In the absence of watershed or basin level

efforts to utilize LID, parcel and subdivision-level use of LID will be less effective in overall stormwater management efforts, but still a substantial advancement. *Testimony of O'Brien, Booth, Holz, Horner, Exs. ECY 3 (Phase I), p. 34-36, PSA 066, p. 2, 3.*

61.

In many cases, implementation of LID techniques on the ground for new or redevelopment, or even retrofitting existing development, is less costly, or no more costly, than conventional engineered BMPS. Structural stormwater controls, such as detention ponds, curbs, gutters and pipes, require significant hardware and capital investment. LID techniques eliminate or reduce the need for these structural controls by reducing the volume of water to be managed. LID techniques may also require less space than these traditional methods. *Testimony of Holz, Booth, Horner, Exs. PSA 047, p. 6-10, PSA 066, p.1, ECY 3 (Phase I), p. 35-36.*

62.

A major cost consideration in utilizing LID techniques at a site level is not the engineering or construction associated with the LID techniques, but rather the costs associated with navigating a system of regulation and development that was not created with LID in mind. To fully incorporate LID principles into this system will require review, consideration, and in some instances modification, of existing zoning and building regulations that create obstacles to the use of LID. Some examples of common local government ordinances that could make it difficult to utilize certain LID techniques include requirements related to road width, curbs and gutters, vegetation clearing, and parking spaces. *Testimony of Holz, Horner*. The cost of implementing LID across a broader land use spectrum, through basin or watershed planning is

more speculative, and the Board was presented with no clear evidence on costs associated with broader scale implementation of LID in this manner. Although such planning is underway in certain areas, a longer public and political process could be expected to accompany such an effort.

63.

The cost of not expanding the application of LID strategies to manage municipal stormwater is very high. The biological health of Puget Sound is declining, and a significant cause of the decline is stormwater run-off. This decline carries with it a variety of environmental, economic, and social costs. *Ex. PSA 087, p. 1.* The Puget Sound Water Quality Plan, which is a plan mandated by the Legislature to be the state's long term strategy for protecting and restoring the Puget Sound, stated as early as 2000 that local governments needed to adopt ordinances that allow and encourage LID practices. *Ex. PSA 078, p. 101.* Many leading scientists concluded, in a paper submitted to the Puget Sound Partnership in July of 2007, that the problem of stormwater must be addressed in the land use context if the health of Puget Sound, the species that inhabit it, and its various important beneficial uses to the region, are to be protected and/or recovered. The group concluded that:

> We have well documented evidence that the impairment associated with stormwater runoff is primarily a **land use problem,** and that we cannot fully mitigate its effects if we approach it only site-by-site. We know that the problems must be addressed at a basin or landscape level-but we continue to manage land use and stormwater primarily on a site-by-site, end of pipe basis. At the same time, we also know that current site-by-site development techniques that result typically in wholesale loss of vegetation, compaction of native soils and connected impervious surfaces, can and should be improved upon significantly if we are to address stormwater problems.

Ex. PSA -012, p. 3 (emphasis in original).

64.

Recently, many local governments have begun incorporating LID techniques into their stormwater manuals, and/or adopting LID stormwater requirements. *Exs. PSA 072 (City of Olympia, Engineering Design and Development Standards, Ch. 9, Green Cove Basin); PSA 073 (Graham Community Plan, A Component of the Pierce County Comprehensive Plan, Excerpts: pp. Cover, Table of Contents, p. 70, 87, 109, 149, 208); PSA 074 (Gig Harbor Peninsula Community Plan, Excerpts: pp. cover, 29, 41, 63, 117, 210)*; *PSA 076 (King County, Washington, Surface Water Design Manual, Jan. 4, 2005, Excerpts: pp. cover, Table of Contents, 5-1 through 5-16); PSA 051 (Pierce County, Stormwater Management and Site Development Manual, Excerpts: Ch. 10, p. 10-1 to 10-82).*

65.

Examples of the approaches already being used by Phase I Permittees to encourage or require the use of LID techniques include reducing charges for surface water rates with the use of an approved LID stormwater and surface water runoff systems (*City of Tacoma, Ex. PSA 085, p. 4);* promoting LID during project scoping meetings with potential developers (*City of Tacoma, Ex. PSA 085, p. 4);* adopting LID Ordinances (*Snohomish County, PSA Ex. 077, p. 8);* incorporating LID Development Design concepts into existing regulations (*Snohomish County, Ex. PSA 077, p. 9*); and providing public outreach and education about LID (*City of Tacoma, Ex. PSA 085, p. 5, Snohomish County, Ex. PSA 077, p. 10-14, City of Seattle, Ex.PSA 079, p. 12, 13*). Other, more stringent examples include requiring project proponents to use LID techniques for all proposed Fully Contained Community developments in rural areas (*Snohomish County, Ex.*

PSA 077, p. 9); requiring LID for any UGA docket expansions proposals within the Little Bear Creek watershed (*Snohomish County, Ex. PSA 077, p. 10*); and requiring LID to be used on a large project in the Mill Creek pocket expansion (*Snohomish County, Ex. PSA 077, p. 9).*

66.

The Board finds that LID methods are at this time a known and available method to address stormwater runoff at the site, parcel, and subdivision level. Numerous reference documents, technical manuals, expert testimony, and Ecology's own Stormwater Management Manual, discussed above, support this finding. The Board also finds that LID methods are technologically and economically feasible and capable of application at the site, parcel, and subdivision level at this time. Because application of these methods at the basin and watershed level involves additional cost and practical considerations, we find Ecology must ready for the eventual use of this known and available method of stormwater treatment for future iterations of the permit, consistent with its obligation to impose increasingly stringent requirements on discharges covered by NPDES permits.

G. Existing development

67.

The Phase I Permit addresses stormwater runoff from existing development through the implementation of structural stormwater controls and source controls. Both of these are required components of Permittees' SWMPs, and the Permit includes minimum requirements for each

which are based on EPA's stormwater rules.[19] *Testimony of Wessel, Ex. Muni 0001, p. 12-15, Ex. Muni 0002, p. 34-36.*

68.

The structural stormwater control program, also referred to as the "retrofit" component, is targeted at discharges not adequately controlled by other aspects of the SWMP. S5.C.6. Through this program, permittees must consider construction of stormwater control projects, as well as other means to address impacts to state waters caused by MS4 discharges. The permit directs that the program "shall consider the construction of projects such as: regional flow control facilities; water quality treatment facilities; facilities to trap and collect contaminated particulates, retrofitting of existing stormwater facilities; and rights-of-way, or other property acquisition to provide additional water quality and flow control benefits." The Permit also provides that permittees "should consider" other means to address impacts, including LID techniques such as "reduction or prevention of hydrologic changes through the use of on-site (infiltration and dispersion) stormwater management BMPs and site design techniques. . ." S5.C.6.a. *Testimony of Wessel, Ex. Muni 0001, p. 12, 13.*

69.

The permit establishes minimum performance measures for the structural stormwater control program, including development of the program within 1 year of the effective date of the

[19] The Fact Sheet's reference to 40 C.F.R. 122.26(b)(2) appears to be a typographical error. Ecology's pre-hearing brief properly cites the applicable federal regulation for these program elements as 40 C.F.R. 122.26(d)(2). A portion of this federal rule, unrelated to municipal stormwater, was recently invalidated in Natural Resources Defense Council v. U.S. E.P.A., 526 F.3d 591 (9th Cir. 2008).

permit, and implementation of the program within 18 months from the effective date of the permit. S5.C.6.b.i. Permittees are required to provide a list of planned individual projects that are scheduled for implementation during the term of the permit. Municipalities are not required to prioritize the planned projects in any manner. Permittees are required to submit a description of their structural stormwater control program to Ecology along with the written documentation of their SWMP, but the permit does not set a minimum level of effort for this requirement or provide for Ecology review and/or approval of the structural stormwater control program. S5.C.6.b.ii. *Testimony of Wessel, Dalton, Ex. Muni 0001, p. 12, 13, Ex. Muni 0002, p. 35.*

70.

The requirements for the Source Control Program for existing development are set out in S5.C.7. Through this program, the permittee must "reduce" pollutants in runoff from areas that discharge to MS4s, through application of operational and structural source control BMPs, and if necessary treatment BMPs to pollution generating sources associated with existing land uses and activities. S5.C.7.a. The program required in this section also must include inspections, application and enforcement of local ordinances at applicable sites, and reduction of pollutants associated with application of pesticides, herbicides and fertilizer discharging to MS4s. S5.C.7.b.ii-iv. While reduction of pollutants is mandated, no objective standard is set for the amount of reduction, although Ecology must review and approve the source control program. S5.C.7.b.i. *Testimony of Wessel, Muni 0001, p. 13-15*. Under this section of the permit, permittees must also implement a progressive enforcement policy to assure compliance with

stormwater requirements within a reasonable time period. S5.C.7.b.iv. *Testimony of Wessel, Ex. Muni 0001, p. 13-15*.

H. Timing of Compliance

71.

PSA challenges the validity of several Phase I Permit provisions on the grounds that they do not require implementation of the permit within three years. PSA provides several examples of permit conditions that allow implementation after three years. Some of these examples include S5.C.2.b.ii (requiring outfalls to be mapped no later than four years from the effective date of the permit); S5.C.8.b.vi (requiring screening for illicit discharges in portion of each jurisdictions to be completed within four years.); and S.5.C.9.b.ii (3) (allowing permittees up to four years after the effective date of the permit to develop a schedule to inspect treatment and flow control facilities). PSA also provides examples of conditions that impose duties that are tied to the expiration of the permit. Some examples of these conditions include Condition S6.A.3 (full development of the co-permittee and secondary permittees' SWMPs no later than 180 days prior to the expiration of the permit); and S6.D.1. a.ii (Secondary permittees shall label all inlets 180 days prior to expiration of the permit). *Ex. Muni 0001, p. 7, 18, 20-21, 25, and 27.*

72.

Any Conclusion of Law deemed to be a Finding of Fact is hereby adopted as such.

CONCLUSIONS OF LAW

1.

The Board has jurisdiction over the parties and the issues in the case pursuant to RCW 43.21B.110(1)(c). The burden of proof is on the appealing party(s) as to each of the legal issues, and the Board considers the matter *de novo,* giving deference to Ecology's expertise in administering water quality laws and on technical judgments, especially where they involve complex scientific issues. *Port of Seattle v. Pollution Control Hearings Board*, 151 Wn.2d 568, 593-594, 90 P.3d 659 (2004). Pursuant to WAC 371-08-540(2), "In those cases where the board determines that the department issued a permit that is invalid in any respect, the board shall order the department to reissue the permit as directed by the board and consistent with all applicable statutes and guidelines of the state and federal governments."

A. Monitoring (Issues C.1, C3, and F.3.)

2.

Two counties, Pierce and Clark, challenge the monitoring requirements imposed by Special Condition S8.[20] They contend that their own monitoring programs, which focus on receiving water monitoring, are more advanced than the monitoring required by S8. While they support Ecology's S8 monitoring approach as a starting point for municipalities that do not already have well developed receiving water monitoring programs, Pierce and Clark Counties

[20] Issues C.1 and C.3.

argue that compliance with the S8 monitoring will hinder their own efforts to protect water quality.

3.

The Utilities also challenge the validity of the S8 monitoring program. They contend that it is deficient because it does not require receiving water or "compliance" monitoring. They argue that receiving water monitoring is necessary to establish whether the permittees have complied with water quality standards and whether they have treated their discharges with AKART or to the maximum extent practicable.[21]

4.

WAC 173-226-090(1) establishes monitoring requirements for general waste discharge permits. The Board has concluded in its past decisions that this regulation provides Ecology with the discretion to impose *reasonable* monitoring requirements. WAC 173-226-090(1)*; Puget Soundkeeper Alliance v. Ecology*, PCHB Nos. 05-150, 0151, 06-034, -040 (Jan. 26, 2007) (CL 22). Further, since a decision pertaining to monitoring requirements in a general permit falls within an area of Ecology's technical expertise, and involves complex scientific issues, the agency's decision is entitled to deference. *Port of Seattle* at 593-594. The disagreement between appellants and Ecology reflects different sides of a long-standing debate regarding the relative merits of instream versus outfall monitoring, and the most advantageous sequencing of the two. *Ex. P1 0048*. It is clear there is no one right approach, as the type and timing of monitoring that is best

[21] Issue F.3.

in any given situation depends on the particular purpose, context, and available resources, among other factors.

5.

Neither the Utilities nor the Counties have cited to any law requiring the Phase I Permit to require receiving water monitoring. The federal stormwater rules require only that municipalities propose a monitoring program for the term of the permit, but list few specific requirements. 40 C.F.R. 122.26(d)(2)(iii)(D).[22] The Board concludes that Ecology's decision not to require receiving water monitoring during this permit cycle is lawful and reasonable. Ecology's decision to require monitoring designed to understand the pollutants discharging from MS4s, and to evaluate the effectiveness of the BMP's in use, will provide the most useful data to establish what constitutes maximum extent practicable reduction in pollutants in discharges from MS4s for future permits. Further, as pointed out by Ecology, the counties are not prohibited from conducting receiving water monitoring in addition to the S8 monitoring required under the permit. [23]

6.

In light of the discretion Ecology has in this area, the deference its technical decisions are entitled to, and the fact that the burden of proof rests on the party challenging the permit, neither the Counties nor the Utilities have presented a sufficient case to convince the Board that it should

[22] A portion of this federal rule, unrelated to municipal stormwater, was recently invalidated in Natural Resources Defense Council v. U.S. E.P.A., 526 F.3d 591 (9th Cir. 2008).

[23] It is also possible that parts of the Pierce and Clark County programs could be used to satisfy the targeted effectiveness component of the S8 monitoring (S8.E). *Ex. Muni 0001, p. 45-46*. The Board encourages Ecology to work with Pierce and Clark Counties to find ways to make parts of their current monitoring programs satisfy some of the requirements under S8.

reverse Ecology's decision to select the S8 monitoring program and require all permittees to participate in it.

B. Ports (Issue E.5)

7.

The Ports contend that it is "unlawful, unreasonable, unjust, or invalid" to require them to prepare SWPPPs on all port owned land not covered by another discharge permit. The Ports argue that the primary permittees have to prepare SWPPPs only on areas on which industrial type activities occur (maintenance areas and material and heavy equipment storage) that are not covered by another discharge permit. The Ports assert that it is unreasonable to require SWPPPs without consideration to how property is used, it is unreasonably burdensome to the Ports because of the cost to prepare SWPPPs, and it is unnecessary because not all port-owned lands have polluting generating characteristics. The evidence presented, however, does not support these arguments.

8.

The evidence presented at the hearing establishes that lands owned by the Ports of Seattle and Tacoma are located close to vulnerable urban waters with documented water quality and sediment contamination problems. Almost all of the port-owned lands that discharge to MS4s have pollutant-generating characteristics. Therefore preparation of SWPPPs for these properties will have environmental benefits. The only exception is those few environmental mitigation sites owned by the Port of Tacoma. Most of these environmental mitigation sites probably do not discharge to the MS4s, and therefore would not require coverage under the Phase I Permit.

For the ones that do, however, there is no environmental benefit gained by requiring the preparation of a SWPPP, and it is appropriate to exempt these sites from preparation of SWPPPs.

9.

The Board concludes that it not an unreasonable burden to require the Ports to prepare a SWPPP for all port-owned lands which discharge to the MS4 and are not already covered by another discharge permit. Based on the permit's inventory of types of sites with potential pollutant generating sources (*Muni 0001, Appendix 8*), it was reasonable for Ecology to conclude that the Ports owned most or all of these type of pollution sources, and that the Ports needed to prepare plans to manage stormwater from such port-owned property. The Ports also have fewer requirements under the Phase I Permits than other primary permittees. They will have fewer SWPPPs to prepare than the primary permittees. For SWPPP preparation, they can use some generic conditions for sites with identical uses, such as commercial buildings or parking lots. This will reduce the amount of time it takes to prepare each SWPPP and the cost of preparation. The ports can also work cooperatively with their tenants who share some responsibility for the proper management of stormwater on port-owned properties, which will have the added environmental benefit of educating site operators about stormwater BMPs.

10.

The Board concludes that Special Condition S6.E.7, which requires the Ports to prepare SWPPPs on all port-owned lands is appropriate and valid. However, the permit should not mandate SWPPP preparation for environmental mitigation sites owned by the Port of Tacoma, as

the Port of Tacoma has shown that such sites are unlikely to generate untreated stormwater pollution.

C. LID (Issue F.1.a & .b)

11.

The LID issues raised in this appeal involve the question of whether the Phase I Permit fails to meet the required treatment standard of reducing pollutants to the "maximum extent practicable"(MEP) and applying "all known, available and reasonable methods of treatment" (AKART), because the permit does not require more extensive use of LID techniques.

12.

The Board has previously ruled in this appeal (on summary judgment in the Special Condition S4 proceeding) the CWA requires that NPDES permits issued for discharges from MS4s must reduce pollution to the maximum extent practicable (the "MEP" standard). The Board also concluded the WPCA contains a similar requirement, in that all wastewater discharge permits must incorporate permit conditions requiring all known, available and reasonable methods of treatment to control the discharge of toxicants and protect water quality (the "AKART" standard). Order on Dispositive Motions: S.4 issued on April 2, 2008.

13.

The MEP standard in the CWA provides:

> Permits for discharges from municipal stormsewers . . . (iii) shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

33 U.S.C. § 1342(p)(3)(B)(iii).

Neither Congress nor the EPA have defined the meaning of MEP in the municipal stormwater context, nor do the parties cite to federal court cases interpreting the MEP standard in the municipal stormwater context.[24] The Board, in a prior decision pertaining to the first round of the municipal stormwater permits, stated:

> The MEP standard is unique under water pollution laws and applicable only to municipal stormwater discharges. MEP reflects the difficulty of addressing stormwater on a system wide basis and the focus of regulating municipal stormwater discharges on prevention and control. This approach by its nature requires extensive planning and *prioritization* to achieve the underlying of goal of meeting water quality standards.

Save Lake Sammamish v. Ecology, PCHB Nos. 95-78 & 121, Order Granting Summary Judgment (Dec. 12, 1995) (emphasis added).

14.

The AKART standard originates in state law, but the Legislature has not explicitly defined the term. Ecology has incorporated the state AKART standard into several of its regulatory programs (*e.g.*, the state surface and ground water quality standards, state waste discharge and NPDES permit programs, sediment management standards, and domestic wastewater facilities regulations), and has defined the AKART standard through rulemaking. In the state's surface water quality standards, "AKART" is defined as "the most current methodology that can be reasonably required for preventing, controlling, or abating the

[24] The term "practicable" as used in a different section of the CWA, 33 USC § 1311(b)(1)(a), has been defined as meaning that technology is required unless the costs are "wholly disproportionate" to pollution reduction benefits. *Rybacheck v. U.S. EPA,* 904 F.2d 1276, 1289 (9th Cir. 1990).

pollutants associated with a discharge." WAC 173-201A-020. The Washington Supreme Court has further clarified that the "reasonableness" prong of AKART involves both technological and economic feasibility. *Puget Soundkeeper Alliance v. Ecology,* 102 Wn. App. 783, 792-793, 9 P.3d 892, 897 (2000).

15.

In evaluating MEP and AKART for the Phase I Permit, we start with the context that this is a "programmatic" permit that regulates the discharge from MS4 systems on a jurisdiction-wide basis, through the municipalities' implementation of their Stormwater Management Programs. In several instances the permit requires that through these Stormwater Management Programs, municipalities enact ordinances or orders, or adopt other enforceable documents, to control pollution in stormwater. *See, e.g.,* Condition S5.C.1. The nature and scope of the LID provisions in the Permit, and what can be required through the permit, must therefore be evaluated within the broader context of the SWMP requirements and the programmatic nature of this permit.

16.

The permit's reliance on a flow control standard as the primary method to control stormwater runoff from MS4s fails to reduce pollutants to the federal MEP standard, and without greater reliance on LID, does not represent AKART under state law. The permit's reliance on terms that simply require "removal of obstacles" and actions to "allow" use of LID is insufficient to meet these same federal and state pollution control standards. The testimony presented by PSA, the Utilities, and Ecology's technical experts leads to the indisputable conclusion that

application of LID techniques, at the parcel and subdivision level, is a currently known and existing methodology that is reasonable both technologically and economically to control discharges entering into MS4s covered by the Phase I Permit. The great weight of testimony before the Board, from various experts and Ecology witnesses, was that in order to reduce pollution in urban stormwater to the maximum extent practicable, and to apply AKART, it is necessary to aggressively employ LID practices *in combination with* conventional stormwater management methods. Thus, we conclude that under state law, the permit must require greater application of LID techniques, where feasible, in combination with the flow control standard, to meet the AKART standard. The permit must also require the application of LID, where feasible, and conventional engineered stormwater management techniques to remove pollutants from stormwater to the maximum extent practicable in order to comply with federal law. Our recognition that use of LID is to be employed where feasible recognizes that, like all stormwater management tools, it too is subject to limitations in its practical application by site or other constraints. *See* Findings of Fact 49-51. We do not change the applicable legal standard by use of this term. Accordingly, the permit must be remanded for modification in light of this conclusion.

17.

Although we conclude that the permit must require municipalities to employ broader use of LID at the parcel and subdivision level, we stop short of concluding that the permit must, at this time, require use of LID at a basin and watershed level. Based on the evidence before the Board, we cannot conclude that the current iteration of the permit must require implementation

of LID on a basin or watershed scale in order to meet federal and state water quality standards. Little evidence was presented as to the elements and cost of basin or watershed planning that would be necessary to implement LID at this level. Ecology testified that the current Phase I and Phase II permits result in a patchwork of regulation of municipal stormwater, and jurisdictions are at greatly varying degrees of readiness to manage stormwater on basin or watershed levels. The Phase II permittees themselves are at greatly varying degrees of readiness and capacity to undertake LID on a basin and watershed level, and would need to work with Phase I and other jurisdictions to do so. Given these several factors, the Board concludes that a permit condition requiring municipalities to implement LID at a basin or watershed level is not, at this time, reasonable or practicable. This is not to say that no steps can or should be taken at this time. Ecology has identified the particular importance of basin planning in areas which are relatively undeveloped where new development is occurring. The Board concludes that city and county permittees should identify such areas where potential basin planning would assist in reducing the harmful impacts of stormwater discharges upon aquatic resources. This will assist Ecology in readying for the next round of permits when such a requirement may be necessary to meet the state AKART standard and, under federal law, to reduce pollutants in municipal stormwater to MEP. As we discuss in further conclusions, we do not find the Growth Management Act to be an impediment to Ecology requiring greater use of LID than represented by the current permit, including at the basin and watershed planning level. Because the CWA and state water quality laws anticipate that there will be increasingly stringent requirements imposed on those that discharge pollutants to the state's waters, including municipalities, efforts to further basin and

watershed planning efforts in order to incorporate the known and available LID techniques should begin in anticipation of the next permit cycle.

18.

No party challenges Ecology's authority to require LID techniques if they are necessary to meet the AKART or MEP standards. The Board affirmed this point in its summary judgment order. Order on Dispositive Motions: (Phase I Municipal Stormwater Permit) (April 8, 2008). The Board further stated:

> As pointed out by PSA, it is impossible to untangle stormwater management from land use. Even the commonly accepted water quality technique of requiring a stormwater retention pond at a site takes up significant area in a development, potentially reducing the number of buildable sites and constituting a land use restriction. The challenge, as recognized by both Ecology and PSA, is to most effectively harmonize Ecology's authority over site design and land use standards under the water pollution laws with other state laws that are specifically aimed at addressing land use on a broader scale.

Id. While Ecology does not dispute that it has the authority to require the use of LID techniques, it was constrained in the full exercise of this authority because of concerns about intruding too far into local government land use planning efforts under the Growth Management Act. Ecology's position is somewhat puzzling, as it has, through various requirements of its Stormwater Management Manual, and the permit itself, already required a number of LID techniques, and has required local government to remove obstacles to use of the same.[25] The

[25] We also note that, in another context, Ecology has recently adopted rules for the implementation of the Shoreline Management Act which outline a comprehensive process for preparing or amending shoreline master programs that requires, among other things, local governments to incorporate the most current, accurate, and complete scientific and technical information available that is applicable to the issues of concern; prepare a characterization of shoreline ecological functions, including hydrologic functions; identify water quality and quantity issues relevant to master

Board concludes that contrary to the concerns raised by Ecology during permit development, that the GMA is not a barrier to greater use of LID but rather complements the efforts of Ecology to move forward with requiring the use of LID techniques under the Phase I Permit.

19.

The Legislature enacted the Growth Management Act (GMA), Ch. 36.70A RCW in 1990 and 1991, largely "in response to public concerns about rapid population growth and increasing development pressures in the state, especially in the Puget Sound region." *Quadrant Corp. v. State Growth Management Hearings Bd.*, 154 Wn.2d 224, 231-232, 110 P.3d 1132, 1136 (2005) (citations deleted). The GMA includes a broad statement of goals to guide local governments in their development and adoption of comprehensive plans including a goal to "Protect the environment and enhance the state's high quality of life, including air and water quality. . ." RCW 36.70A.020(10).

20.

The GMA mandates that local governments adopt comprehensive plans which include, among other elements, a land use element addressing, "drainage, flooding, and stormwater run-off in the area and nearby jurisdictions" and providing "guidance for corrective action to mitigate or cleanse those discharges that pollute waters of the state, including Puget Sound or waters entering Puget Sound." RCW 36.70A.070(1); *Swinomish Indian Tribal Community v. Skagit*

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program provisions; identify important ecological functions that have been degraded through loss of vegetation; and identify measures to ensure that new development meets vegetation conservation objectives. WAC 173-26-201.

Co., 138 Wn. App. 771, 774, 158 P.3d 1179 (2007) (concluding that the GMA mandates that local governments adopt comprehensive plans to protect surface and ground water resources.)

21.

The state WPCA predated the GMA, with the specific purpose of protecting the waters of the state. RCW 90.48.010. The Legislature tasked Ecology with the job of implementing the WPCA. RCW 90.48.030, .035. Clearly, there is an area of interface and overlap between the GMA and the WPCA.

22.

The Washington Courts have stated that statutes are to be read together harmoniously whenever possible. "The construction of two statutes shall be made with the assumption that the Legislature does not intend to create an inconsistency." *Peninsula Neighborhood Ass'n v. Dep't of Transportation*, 142 Wn.2d 328, 342, 12 P.3d 134 (2000). Further, as the Washington Supreme Court recently stated: "We do not favor repeal by implication, and where potentially conflicting acts can be harmonized, we construe each to maintain the integrity of the other". *Anderson v. State, Dept. of Corrections*, 159 Wash.2d 849, 859, 154 P.3d 220, 225 (2007)(citing *Misterek v. Washington Mineral Products, Inc.*, 85 Wn.2d 166, 168, 531 P.2d 805 (1975)). *See also Kariah Enterprises, LLC v. Ecology*, PCHB No. 05-021, Corrected Order Granting Partial Summary Judgment (Jan. 6, 2005).

23.

The Board has addressed the interface between the GMA and the WPCA in the *Kariah* decision, cited above. In that case, the appellant challenged Ecology's denial of a CWA Section

401 Water Quality Certification for a proposed residential development. The Appellant argued that the Legislature, through GMA, had delegated Ecology's authority over wetlands under the WPCA to local governments. The Board rejected this argument, concluding that neither chapter 90.48 RCW nor 36.70A RCW contained any express provisions delegating Ecology's authority over protecting water quality in wetlands to cities and counties. The Board went on to conclude that the WPCA and the GMA should be harmonized, and that:

> The legislative policy articulated in RCW 36.70A.010 indicates the GMA was directed at addressing uncoordinated and unplanned growth, not at shifting the responsibility to regulate wetlands from the state government to local governments.

Kariah, CL 33.

24.

Similarly, in a Shoreline Hearings Board decision addressing the interaction between the Shoreline Management Act (SMA) and the GMA, the Board concluded that Ecology's newly adopted shoreline rules did not improperly usurp the authority of local governments planning under the GMA, despite venturing into land use controls. *Association of Washington Businesses v. Ecology*, SHB No. 00-037, Order granting and denying appeal (2001)(Issue 9).[26]

[26] Although this decision was split on several issues, the holding on the GMA issue was unanimous. We note that even prior to the GMA, the Shoreline Management Act (SMA), Ch. 90.58 RCW, was enacted by initiative of the people in 1971 after recognizing the "ever increasing pressures of additional uses … being placed on the shorelines necessitate[e] increased coordination in the management and development of the shorelines of the state." RCW 90.58.020. The SMA includes a broad policy to protect the waters of the state and gives preference to uses that protect water quality and the natural environment. *Id*. The SMA establishes a balance of authority between local and state government, where cities and counties have the primary responsibility for initiating the planning required by the Act and administering the regulatory program, and Ecology is tasked with providing assistance to local governments in the development of their shoreline master programs and "insuring compliance with the policy and provisions of [the Act]." RCW 90.58.050.

25.

The Legislature has not expressed any intent, either through the GMA, SMA, or amendments to the WPCA, to redirect Ecology's role in water quality protection to the local governments. The Department of Community, Trade and Economic Development (CTED), the agency charged with implementing and interpreting the GMA, has considered the interaction between the GMA and pre-existing laws not specifically addressed in the GMA. In WAC 365-195-700, CTED's GMA regulations state:

> For local jurisdictions subject to its terms, the Growth Management Act mandates the development of comprehensive plans and development regulations that meet statutory goals and requirements. <u>These plans and regulations will take their place among existing laws relating to resource management, environmental protection, regulation of land use, utilities and public facilities. Many of these existing laws were neither repealed nor amended by the act.</u>
>
> <u>This circumstance places responsibilities both on local growth management planners and on administrators of preexisting programs to work toward producing a single harmonious body of law.</u>
>
> WAC 365-195-700 (emphasis added).[27]

CTED's regulations further explain that:

> Overall, the broad sweep of policy contained in the act implies a requirement that all programs at the state level accommodate the outcomes of the growth management process wherever possible. State agencies are rarely concerned solely with the rote application of fixed standards. The exercise of statutory powers, whether in permit functions, grant funding, property acquisition or otherwise, routinely involves such agencies in discretionary decision-making. The discretion they exercise should now take into account the new reality of legislatively mandated local growth management

[27] Ecology's SMA rules recognize a similar responsibility to harmonize overlapping bodies of law and regulation, which now provide: "It is the responsibility of the local government to assure consistency between the master program and other elements of the comprehensive plan and development regulations." WAC 173-26-191(e).

programs.

WAC 365-195-765(4).

26.

The Phase I permittees are all cities and counties required to plan under the GMA. RCW 36.70A.040. Their planning must address protection of surface and ground water. RCW 36.70A.070(1). CTED has identified the Ecology Stormwater Management Manual as best available science in regard to stormwater management under the GMA. Ecology, as a state agency, must also work toward implementation of the GMA. We conclude that there is no conflict between GMA and the WPCA, nor the roles of local governments and Ecology under these statutes. These roles support and complement each other and can be harmonized to allow water quality efforts to be considered and integrated into the growth management process outlined in the GMA.

27.

The Board concludes Ecology may, within the bounds of the GMA, require use of LID as a water quality management tool. The Board further concludes that the Phase I Permit must be modified to require use of LID where feasible, as it is necessary to meet the MEP and AKART standards of federal and state law, respectively. RCW 36.70A.070(1) already provides the mandate for local governments planning under the GMA to address drainage, flooding, and stormwater runoff in order to mitigate or cleanse discharges of water pollution. The Permit, including the Manual, merely sets forth the methods to accomplish this requirement.

D. Existing Development (Issue F.2)

28.

PSA and the Utilities contend that the permit provisions addressing existing development are inadequate to meet the MEP and AKART standards. Their primary complaint is that both the structural and source control provisions applicable to existing development require only that programs "reduce" impacts from discharges (S5.C.6) or that the permittees "reduce" pollutants in runoff (S5.C.7). They contend that these sections do not set any minimum expectation for the level of effort required and allow the permittees to make deminimus reductions in polluting discharges, and thus constitute impermissible self regulation. *PSA v. Ecology*, PCHB Nos. 02-162, -163, and -164, Order Granting Partial Summary Judgment (June 6, 2003)(CL XVI)(citing *Environmental Defense Center v. Environmental Protection Agency*, at U.S. App. 497, at 57-62 (9th Cir., Jan. 14, 2003)).

29.

The Board agrees the structural stormwater control program, as drafted, amounts to impermissible self-regulation. First, the permit fails to require a minimum level of effort for the permittees in the selection and prioritization of structural stormwater projects, and provides no review and approval role for Ecology. Second, the permit fails to comply with the applicable EPA rule and therefore amounts to impermissible self regulation on this basis as well. 40 C.F.R 122.26(d)(2)(iv) requires that "Proposed management programs shall describe priorities for implementing controls." Condition S5.C.6 merely requires the permittees to develop a program within 12 months and provide Ecology a "list of planned individual projects that are scheduled

for implementation" during the term of the permit. S5.C.6.b.i. While initial project selection is presumably subject to the MEP and AKART standard of the permit, Ecology plays no role in ensuring these standards are met, even through simple review of the selected projects. The permit does not contain any requirement that permittees describe their project priorities or require that Ecology review the permittees' structural stormwater control program. Ecology is not expected to approve the municipalities' prioritization of projects in relation to the pollution reduction requirements of the permit. While Ecology testified that the permit "implied" there needs to be a prioritization of planned structural stormwater control projects, and a schedule reviewed by Ecology *(Moore testimony)*, the permit does not expressly state this requirement and the fact sheet explicitly states that "review and approval by Ecology is not a permit requirement." *Ex. Muni 0002, p. 35*. Thus, the structural stormwater control program is left entirely to the discretion of the municipalities, not only with respect to which projects they initially select, but also in the timing and manner in which they implement the selected projects. Prioritization of projects is particularly important given that Conditions S5 and S6 are based upon actions taken by the permittees and not outcomes, and this structural stormwater control provision is to "address impacts that are not adequately controlled by the other required actions of the SWMP." Prioritization helps to ensure that the sites where the permittees choose to "act" are meaningful in providing environmental protection. It can also assist to engage the public as a partner in reducing pollutants in discharges and the overall volume of discharges. A community, for example, could request a permittee to focus a project in an area which discharges near shellfish beds. While the Board recognizes that local funding will influence the selection of planned

projects and that municipalities must therefore retain local control in the selection process, we conclude that the permit must require permittees to describe the prioritization of their selected projects in order to comply with federal rules, demonstrate compliance with the MEP and AKART standards, and facilitate oversight by Ecology to ensure the legal standards of the permit are applied on a programmatic level. *See Save Lake Sammamish v. Ecology*, PCHB Nos. 95-78 & -121, Order Granting Summary Judgment (Dec. 12, 1995).

30.

In contrast to the structural stormwater control program provisions, the source control program for existing development requires a more rigorous program to reduce pollutants in runoff from areas that discharge to MS4s owned or operated by the permittee, and does not suffer from the same flaws as the structural stormwater control program. The permit requires that Ecology must review and approve the source control program. S5.C.7.b.i. Therefore, the Board concludes that the source control program as drafted meets the MEP and AKART standard.

E. Water quality violations (Issues F.1.a., F.2.a,, and F.4)

PSA and PSE argue, through several different issues, that the permit fails to prevent discharges that violate water quality. *See* F.1.a (permit fails to require LID techniques which results in discharges that violate water quality); F.2.a (permit allows discharges from existing development that violate water quality); F.4 (Permit as a whole allows discharges that violate water quality standards; Prohibition on violations of water quality standards contained in Special Condition S4 conflicts with other provisions of the permit). The Board concludes that the

permit, with the amendments directed by the Board to meet AKART and MEP, and with the amendments directed by the Board to the S4.F compliance process,[28] is adequately conditioned to comply with state law.

F. Timelines for Compliance (Issue F.5)

31.

The CWA sets out a number of deadlines related to NPDES permits for industrial and large municipal dischargers, including a deadline for EPA to establish regulations setting forth permit application requirements, a deadline for filing permit applications, and a deadline for EPA's approval or denial of the permits. 33 U.S.C. § 1342 (p)(4)(A). The final sentence in 33 U.S.C. § 1342 (p)(4)(A) states: "Any such permit shall provide for compliance as expeditiously as practicable, but in no event later than 3 years after the date of issuance of such permit." PSA contends that the Phase I Permit violates this provision.

32.

The Board has addressed this specific sentence before, in a case involving a challenge to a renewal of the Industrial Stormwater General NPDES Permit. *PSA v. Ecology*, PCHB Nos. 02-162, -163, -164, Order Granting Partial Summary Judgment (June 6, 2003). In that case, involving industrial stormwater discharges, the Board concluded that the reference to "compliance" in the sentence referred to compliance with the permit requirement contained in 33 U.S.C. § 1342 (p)(3)(A)(the provision pertaining to industrial stormwater discharges). *PSA* at CL XXI. Applying that same analysis to this case, involving municipal stormwater discharges,

[28] These modifications are ordered in the Board's Findings, Conclusions and Order on S4, issued on August 7, 2008.

the reference to "compliance" is to 33 U.S.C. § 1342 (p)(3)(B)(the provision establishing the MEP standard for municipal stormwater discharges). Therefore, the question becomes whether the permit allows any actions to occur later than three years after the date of issuance of the permit that are necessary to reduce discharges of pollutants to the maximum extent practicable.

33.

Several of the conditions of the Phase I Permit allow actions required by the permit to occur more than three years after the date of issuance of the permit. PSA and the Utilities contend that this establishes that the permit violates 33 U.S.C. § 1342 (p)(4)(A). However, this fact alone does not establish a violation of 33 U.S.C. § 1342 (p)(4). PSA and the Utilities, as the parties with the burden of proof, must bring forth evidence establishing that earlier compliance with one of the permit provisions currently allowing implementation outside of the three year statutory window is necessary to meet the MEP standard. Ecology has developed a programmatic permit with multiple components to be implemented throughout the permit cycle which, collectively, represent MEP and AKART. To read the statute as suggested by PSA and the Utilities would inappropriately limit Ecology's ability to include within the permit additional conditions or requirements that may not be practicable within three years but which are reasonable within a longer time frame. The Board concludes that PSA and the Utilities have failed to meet their burden on this issue. The record does not contain sufficient evidence on any specific permit condition to convince the Board that the permit violates 33 U.S.C. § 1342 (p)(4)(A).

34.

Any Finding of Fact deemed to be a Conclusion of Law is hereby adopted as such.

Having so found and concluded, the Board enters the following

ORDER

Having concluded that portions of the Phase I Permit are invalid, the Board remands the Phase I Permit to Ecology pursuant to WAC 371-08-540, for modifications consistent with this opinion.

1. Ecology shall modify Special Condition S6.E.7 as follows:

> 7. Source Control in existing Developed Areas
>
> The SWMP shall include the development and implementation of one or more Stormwater Pollution Prevention Plans (SWPPPs). A SWPPP is a documented plan to identify and implement measures to prevent and control the contamination of discharges of stormwater to surface or ground water. SWPPP(s) shall be prepared and implemented for all Port-owned lands, **except environmental mitigation sites owned by the Port of Tacoma,** that are not covered by either a General Permit or an individual NPDES permit issued by Ecology that covers stormwater discharges.
>
> (modified language is in bold and underlined)

2. With respect to the use of LID, in addition to the specific modifications identified in No. 1 above, Ecology shall also modify the permit consistent with this opinion as follows :

   a. Modify Permit Condition S5.C.5.b to read as follows:

> iii. The program must ((~~allow~~)) **require** non-structural preventive actions and source reduction approaches ((~~such as~~)), **including** Low Impact Development Techniques (LID), to minimize the creation of impervious surfaces, and measures to minimize the disturbance of soils and vegetation **where feasible**.

b. Require permittees to identify barriers to implementation of LID and, in each annual report, identify actions taken to remove barriers identified.

c. Require permittees to adopt enforceable ordinances that require use of LID techniques where feasible in conjunction with conventional stormwater management methods.

d. Require permittees to address in their annual report to Ecology under the Phase I Permit, information on the extent to which basin planning is being conducted in their jurisdiction, either voluntarily, or pursuant to GMA or any other requirement.

e. Require permittees to identify, prior to the next permit cycle or renewal, areas for potential basin or watershed planning that can incorporate development strategies as a water quality management tool to protect aquatic resources.

3. Ecology shall modify Special Condition S5.C.6.b.ii, related to structural Stormwater control programs minimum performance measures, to require that permittees describe the prioritization of their selected projects as required by federal rules, in order to facilitate oversight by Ecology to ensure that the MEP and AKART standards are met on a programmatic level.

SO ORDERED this 7th day of August, 2008.

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Urban Stormwater Management in the United States

Committee on Reducing Stormwater Discharge Contributions to Water Pollution, National Research Council

ISBN: 0-309-12540-5, 610 pages, 6 x 9, (2008)

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http://www.nap.edu/catalog/12465.html

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URBAN STORMWATER MANAGEMENT IN THE UNITED STATES

Committee on Reducing Stormwater Discharge
Contributions to Water Pollution

Water Science and Technology Board

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
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Support for this project was provided by the U.S. Environmental Protection Agency under Award No. 68-C-03-081. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

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International Standard Book Number-13: 978-0-309-12539-0 (Book)
International Standard Book Number-10: 0-309-12539-1 (Book)
International Standard Book Number-13: 978-0-309-12540-6 (PDF)
International Standard Book Number-10: 0-309-12540-5 (PDF)
Library of Congress Control Number: 2008940395

Urban Stormwater Management in the United States is available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu. Cover photo courtesy of Roger Bannermann.

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Preface

Stormwater runoff from the built environment remains one of the great challenges of modern water pollution control, as this source of contamination is a principal contributor to water quality impairment of waterbodies nationwide. In addition to entrainment of chemical and microbial contaminants as stormwater runs over roads, rooftops, and compacted land, stormwater discharge poses a physical hazard to aquatic habitats and stream function, owing to the increase in water velocity and volume that inevitably result on a watershed scale as many individually managed sources are combined. Given the shift of the world's population to urban settings, and that this trend is expected to be accompanied by continued wholesale landscape alteration to accommodate population increases, the magnitude of the stormwater problem is only expected to grow.

In recognition of the need for improved control measures, in 1987 the U.S. Congress mandated the U.S. Environmental Protection Agency (EPA), under amendments to the Clean Water Act, to control certain stormwater discharges under the National Pollutant Discharge Elimination System. In response to this federal legislation, a permitting program was put in place by EPA as the Phase I (1990) and Phase II (1999) stormwater regulations, which together set forth requirements for municipal separate storm sewer systems and industrial activities including construction. The result of the regulatory program has been identification of hundreds of thousands of sources needing to be permitted, which has put a strain on EPA and state administrative systems for implementation and management. At the same time, achievement of water quality improvement as a result of the permit requirements has remained an elusive goal.

To address the seeming intractability of this problem, the EPA requested that the National Research Council (NRC) review its current permitting program for stormwater discharge under the Clean Water Act and provide suggestions for improvement. The broad goals of the study were to better understand the links between stormwater pollutant discharges and ambient water quality, to assess the state of the science of stormwater management, and to make associated policy recommendations. More specifically, the study was asked to:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent

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limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of best management practices (BMPs).

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

(5) Assess the design of the stormwater permitting program implemented under the Clean Water Act.

There are a number of related topics that one might expect to find in this report that are excluded, because EPA requested that the study be limited to problems addressed by the agency's stormwater regulatory program. Specifically, nonpoint source pollution from agricultural runoff, septic systems, combined sewer overflows, sanitary sewer overflows, and concentrated animal feeding operations are not addressed in this report. In addition, alteration of the urban base-flow hydrograph from a number of causes that are not directly related to storm events (e.g., interbasin transfers of water, leakage from water supply pipes, lawn irrigation, and groundwater withdrawals) is a topic outside the scope of the report and therefore not included in any depth.

In developing this report, the committee benefited greatly from the advice and input of EPA representatives, including Jenny Molloy, Linda Boornazian, and Mike Borst; representatives from the City of Austin; representatives from King County, Washington, and the City of Seattle; and representatives from the Irvine Ranch Water District. The committee heard presentations by many of these individuals in addition to Chris Crockett, City of Philadelphia Water Department; Pete LaFlamme and Mary Borg, Vermont Department of Environmental Conservation; Michael Barrett, University of Texas at Austin; Roger Glick, City of Austin; Michael Piehler, UNC Institute of Marine Sciences, Keith Stolzenbach, UCLA; Steve Burges, University of Washington; Wayne Huber, Oregon State University; Don Theiler, King County; Charlie Logue, Clean Water Services, Hillsboro, Oregon; Don Duke, Florida Gulf Coast University; Mike Stenstrom, UCLA; Gary Wolff, California Water Board; Paula Daniels, City of Los Angeles Public Works; Mark Gold, Heal the Bay; Geoff Brosseau, California Stormwater Quality Association; Steve Weisberg, Southern California Coastal Water Research Project; Chris Crompton, Southern California Stormwater Monitoring Coalition; David Beckman, NRDC; and Eric Strecker, Geosyntec. We also thank all those stakeholders who took time to

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share with us their perspectives and wisdom about the various issues affecting stormwater.

The committee was fortunate to have taken several field trips in conjunction with committee meetings. The following individuals are thanked for their participation in organizing and guiding these trips: Austin (Kathy Shay, Mike Kelly, Matt Hollon, Pat Hartigan, Mateo Scoggins, David Johns, and Nancy McClintock); Seattle (Darla Inglis, Chris May, Dan Powers, Scott Bawden, Nat Scholz, John Incardona, Kate McNeil, Bob Duffner, and Curt Crawford); and Los Angeles (Peter Postlmayr, Matthew Keces, Alan Bay, and Sat Tamaribuchi).

Completion of this report would not have been possible without the Herculean efforts of project study director Laura Ehlers. Her powers to organize, probe, synthesize, and keep the committee on track with completing its task were simply remarkable. Meeting logistics and travel arrangements were ably assisted by Ellen De Guzman and Jeanne Aquilino.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Michael Barrett, University of Texas; Bruce Ferguson, University of Georgia; James Heaney, University of Florida; Daniel Medina, CH2MHILL; Margaret Palmer, University of Maryland Chesapeake Biological Laboratory; Kenneth Potter, University of Wisconsin; Joan Rose, Michigan State University; Eric Strecker, Geosyntec; and Bruce Wilson, Minnesota Pollution Control Agency.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Michael Kavanaugh, Malcolm Pirnie, Inc., and Richard Conway, Union Carbide Corporation, retired. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and institution.

Claire Welty,
Committee Chair

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Summary

Urbanization is the changing of land use from forest or agricultural uses to suburban and urban areas. This conversion is proceeding in the United States at an unprecedented pace, and the majority of the country's population now lives in suburban and urban areas. The creation of impervious surfaces that accompanies urbanization profoundly affects how water moves both above and below ground during and following storm events, the quality of that stormwater, and the ultimate condition of nearby rivers, lakes, and estuaries.

The National Pollutant Discharge Elimination System (NPDES) program under the Clean Water Act (CWA) is the primary federal vehicle to regulate the quality of the nation's waterbodies. This program was initially developed to reduce pollutants from industrial process wastewater and municipal sewage discharges. These point sources were known to be responsible for poor, often drastically degraded conditions in receiving waterbodies. They were easily regulated because they emanated from identifiable locations, such as pipe outfalls. To address the role of stormwater in causing or contributing to water quality impairments, in 1987 Congress wrote Section 402(p) of the CWA, bringing stormwater control into the NPDES program, and in 1990 the U.S. Environmental Protection Agency (EPA) issued the Phase I Stormwater Rules. These rules require NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations over 100,000 and for runoff associated with industry, including construction sites five acres and larger. In 1999 EPA issued the Phase II Stormwater Rule to expand the requirements to small MS4s and construction sites between one and five acres in size.

With the addition of these regulated entities, the overall NPDES program has grown by almost an order of magnitude. EPA estimates that the total number of permittees under the stormwater program at any time exceeds half a million. For comparison, there are fewer than 100,000 non-stormwater (meaning wastewater) permittees covered by the NPDES program. To manage the large number of permittees, the stormwater program relies heavily on the use of general permits to control industrial, construction, and Phase II MS4 discharges. These are usually statewide, one-size-fits-all permits in which general provisions are stipulated.

To comply with the CWA regulations, industrial and construction permittees must create and implement a stormwater pollution prevention plan, and MS4 permittees must implement a stormwater management plan. These plans document the stormwater control measures (SCMs) (sometimes known as best management practices or BMPs) that will be used to prevent stormwater emanating from these sources from degrading nearby waterbodies. These SCMs range from structural methods such as detention ponds and bioswales to nonstructural methods such as designing new development to reduce the percentage of impervious surfaces.

A number of problems with the stormwater program as it is currently implemented have been recognized. First, there is limited information available on

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the effectiveness and longevity of many SCMs, thereby contributing to uncertainty in their performance. Second, the requirements for monitoring vary depending on the regulating entity and the type of activity. For example, a subset of industrial facilities must conduct "benchmark monitoring" and the results often exceed the values established by EPA or the states, but it is unclear whether these exceedances provide useful indicators of potential water quality problems. Finally, state and local stormwater programs are plagued by a lack of resources to review stormwater pollution prevention plans and conduct regular compliance inspections. For all these reasons, the stormwater program has suffered from poor accountability and uncertain effectiveness at improving the quality of the nation's waters.

In light of these challenges, EPA requested the advice of the National Research Council's Water Science and Technology Board on the federal stormwater program, considering all entities regulated under the program (i.e., municipal, industrial, and construction). The following statement of task guided the work of the committee:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of SCMs.

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

(5) Assess the design of the stormwater permitting program implemented under the CWA.

Chapter 2 of this report presents the regulatory history of stormwater control in the United States, focusing on relevant portions of the CWA and the federal and state regulations that have been created to implement the Act. Chapter 3 reviews the scientific aspects of stormwater, including sources of pollutants in stormwater, how stormwater moves across the land surface, and its impacts on receiving waters. Chapter 4 evaluates the current industrial and MS4 monitoring requirements, and it considers the multitude of models available for linking stormwater discharges to ambient water quality. Chapter 5 considers the vast

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suite of both structural and nonstructural measures designed to control stormwater and reduce its pollutant loading to waterbodies. In Chapter 6, the limitations and possibilities associated with a new regulatory approach are explored, as are those of a more traditional but enhanced scheme. This new approach, which rests on the broad foundation of correlative studies demonstrating the effects of urbanization on aquatic ecosystems, would reduce the impact of stormwater on receiving waters beyond any efforts currently in widespread practice.

THE CHALLENGE OF REGULATING STORMWATER

Although stormwater has been long recognized as contributing to water quality impairment, the creation of federal regulations to deal with stormwater quality has occurred only in the last 20 years. Because this longstanding environmental problem is being addressed so late in the development and management of urban areas, the laws that mandate better stormwater control are generally incomplete and are often in conflict with state and local rules that have primarily stressed the flood control aspects of stormwater management (i.e., moving water away from structures and cities as fast as possible). Many prior investigators have observed that stormwater discharges would ideally be regulated through direct controls on land use, strict limits on both the quantity and quality of stormwater runoff into surface waters, and rigorous monitoring of adjacent waterbodies to ensure that they are not degraded by stormwater discharges. Future land-use development would be controlled to minimize stormwater discharges, and impervious cover and volumetric restrictions would serve as proxies for stormwater loading from many of these developments. Products that contribute pollutants through stormwater—like de-icing materials, fertilizers, and vehicular exhaust—would be regulated at a national level to ensure that the most environmentally benign materials are used.

Presently, however, the regulation of stormwater is hampered by its association with a statute that focuses primarily on specific pollutants and ignores the volume of discharges. Also, most stormwater discharges are regulated on an individualized basis without accounting for the cumulative contributions from multiple sources in the same watershed. Perhaps most problematic is that the requirements governing stormwater dischargers leave a great deal of discretion to the dischargers themselves in developing stormwater pollution prevention plans and self-monitoring to ensure compliance. These problems are exacerbated by the fact that the dual responsibilities of land-use planning and stormwater management within local governments are frequently decoupled.

EPA's current approach to regulating stormwater is unlikely to produce an accurate or complete picture of the extent of the problem, nor is it likely to adequately control stormwater's contribution to waterbody impairment. The lack of rigorous end-of-pipe monitoring, coupled with EPA's failure to use flow or alternative measures for regulating stormwater, make it

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difficult for EPA to develop enforceable requirements for stormwater dischargers. Instead, the stormwater permits leave a great deal of discretion to the regulated community to set their own standards and to self-monitor. Current statistics on the states' implementation of the stormwater program, discharger compliance with stormwater requirements, and the ability of states and EPA to incorporate stormwater permits with Total Maximum Daily Loads are uniformly discouraging. Radical changes to the current regulatory program (see Chapter 6) appear necessary to provide meaningful regulation of stormwater dischargers in the future.

Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. These analogs for the traditional focus on the "discharge" of "pollutants" have great potential as a federal stormwater management tool because they provide specific and measurable targets, while at the same time they focus regulators on water degradation resulting from the increased volume as well as increased pollutant loadings in stormwater runoff. Without these more easily measured parameters for evaluating the contribution of various stormwater sources, regulators will continue to struggle with enormously expensive and potentially technically impossible attempts to determine the pollutant loading from individual dischargers or will rely too heavily on unaudited and largely ineffective self-reporting, self-policing, and paperwork enforcement.

EPA should engage in much more vigilant regulatory oversight in the national licensing of products that contribute significantly to stormwater pollution. De-icing chemicals, materials used in brake linings, motor fuels, asphalt sealants, fertilizers, and a variety of other products should be examined for their potential contamination of stormwater. Currently, EPA does not apparently utilize its existing licensing authority to regulate these products in a way that minimizes their contribution to stormwater contamination. States can also enact restrictions on or tax the application of pesticides or other particularly toxic products. Even local efforts could ultimately help motivate broader scale, federal restrictions on particular products.

The federal government should provide more financial support to state and local efforts to regulate stormwater. State and local governments do not have adequate financial support to implement the stormwater program in a rigorous way. At the very least, Congress should provide states with financial support for engaging in more meaningful regulation of stormwater discharges. EPA should also reassess its allocation of funds within the NPDES program. The agency has traditionally directed funds to focus on the reissuance of NPDES wastewater permits, while the present need is to advance the NPDES stormwater program because NPDES stormwater permittees outnumber wastewater permittees more than five fold, and the contribution of diffuse sources of pollution to degradation of the nation's waterbodies continues to increase.

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EFFECTS OF URBANIZATION ON WATERSHEDS

Urbanization causes change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture, or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a constructed drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed experience radically different flow regimes than prior to urbanization. Nearly all of the associated problems result from one underlying cause: loss of the water-retaining and evapotranspirating functions of the soil and vegetation in the urban landscape. In an undeveloped area, rainfall typically infiltrates into the ground surface or is evapotranspirated by vegetation. In the urban landscape, these processes of evapotranspiration and water retention in the soil are diminished, such that stormwater flows rapidly across the land surface and arrives at the stream channel in short, concentrated bursts of high discharge. This transformation of the hydrologic regime is a wholesale reorganization of the processes of runoff generation, and it occurs throughout the developed landscape. When combined with the introduction of pollutant sources that accompany urbanization (such as lawns, motor vehicles, domesticated animals, and industries), these changes in hydrology have led to water quality and habitat degradation in virtually all urban streams.

The current state of the science has documented the characteristics of stormwater runoff, including its quantity and quality from many different land covers, as well as the characteristics of dry weather runoff. In addition, many correlative studies show how parameters co-vary in important but complex and poorly understood ways (e.g., changes in macroinvertebrate or fish communities associated with watershed road density or the percentage of impervious cover). Nonetheless, efforts to create mechanistic links between population growth, land-use change, hydrologic alteration, geomorphic adjustments, chemical contamination in stormwater, disrupted energy flows and biotic interactions, and changes in ecological communities are still in development. Despite this assessment, there are a number of overarching truths that remain poorly integrated into stormwater management decision-making, although they have been robustly characterized for more than a decade and have a strong scientific basis that reaches even farther back through the history of published investigations.

There is a direct relationship between land cover and the biological condition of downstream receiving waters. The possibility for the highest levels of aquatic biological condition exists only with very light urban transformation of the landscape. Conversely, the lowest levels of biological condition are inevitable with extensive urban transformation of the landscape, commonly seen after conversion of about one-third to one-half of a contributing watershed into impervious area. Although not every degraded waterbody is a product of intense urban development, all highly urban watersheds produce severely degraded receiving waters.

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The protection of aquatic life in urban streams requires an approach that incorporates all stressors. Urban Stream Syndrome reflects a multitude of effects caused by altered hydrology in urban streams, altered habitat, and polluted runoff. Focusing on only one of these factors is not an effective management strategy. For example, even without noticeably elevated pollutant concentrations in receiving waters, alterations in their hydrologic regimes are associated with impaired biological condition. More comprehensive biological monitoring of waterbodies will be critical to better understanding the cumulative impacts of urbanization on stream condition.

The full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. Permanently increased stormwater volume is only one aspect of an urban-altered storm hydrograph. It contributes to high in-stream velocities, which in turn increase streambank erosion and accompanying sediment pollution of surface water. Other hydrologic changes, however, include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These all can affect both the physical and biological conditions of streams, lakes, and wetlands. Thus, effective hydrologic mitigation for urban development cannot just aim to reduce post-development peak flows to predevelopment peak flows.

Roads and parking lots can be the most significant type of land cover with respect to stormwater. They constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in these highly impervious areas, especially in regions of the country having mostly small rainfall events. As rainfall amounts become larger, pervious areas in most residential land uses become more significant sources of runoff, sediment, nutrients, and landscaping chemicals. In all cases, directly connected impervious surfaces (roads, parking lots, and roofs that are directly connected to the drainage system) produce the first runoff observed at a storm-drain inlet and outfall because their travel times are the quickest.

MONITORING AND MODELING

The stormwater monitoring requirements under the EPA Stormwater Program are variable and generally sparse, which has led to considerable skepticism about their usefulness. This report considers the amount and value of the data collected over the years by municipalities (which are substantial on a nationwide basis) and by industries, and it makes suggestions for improvement. The MS4 and particularly the industrial stormwater monitoring programs suffer from a paucity of data, from inconsistent sampling techniques, and from requirements

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that are difficult to relate to the compliance of individual dischargers. For these reasons, conclusions about stormwater management are usually made with incomplete information. Stormwater management would benefit most substantially from a well-balanced monitoring program that encompasses chemical, biological, and physical parameters from outfalls to receiving waters.

Many processes connect sources of pollution to an effect observed in a downstream receiving water—processes that can be represented in watershed models, which are the key to linking stormwater dischargers to impaired receiving waters. The report explores the current capability of models to make such links, including simple models and more involved mechanistic models. At the present time, stormwater modeling has not evolved enough to consistently say whether a particular discharger can be linked to a specific waterbody impairment. Some quantitative predictions can be made, particularly those that are based on well-supported causal relationships of a variable that responds to changes in a relatively simple driver (e.g., modeling how a runoff hydrograph or pollutant loading change in response to increased impervious land cover). However, in almost all cases, the uncertainty in the modeling and the data (including its general unavailability), the scale of the problems, and the presence of multiple stressors in a watershed make it difficult to assign to any given source a specific contribution to water quality impairment.

Because of a 10-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized. These results come from many thousands of storm events, systematically compiled and widely accessible; they form a robust dataset of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate stormwater pollutant concentrations from various land uses. Additional data are available from other stormwater permit holders that were not originally included in the database and from ongoing projects, and these should be acquired to augment the database and improve its value in stormwater management decision-making.

Industry should monitor the quality of stormwater discharges from certain critical industrial sectors in a more sophisticated manner, so that permitting authorities can better establish benchmarks and technology-based effluent guidelines. Many of the benchmark monitoring requirements and effluent guidelines for certain industrial subsectors are based on inaccurate and old information. Furthermore, there has been no nationwide compilation and analysis of industrial benchmark data, as has occurred for MS4 monitoring data, to better understand typical stormwater concentrations of pollutants from various industries.

Continuous, flow-weighted sampling methods should replace the traditional collection of stormwater data using grab samples. Data obtained from too few grab samples are highly variable, particularly for industrial monitoring

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programs, and subject to greater uncertainly because of experimenter error and poor data-collection practices. In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications. It should be replaced by more accurate and frequent continuous sampling methods that are flow weighted. Flow-weighted composite monitoring should continue for the duration of the rain event. Emerging sensor systems that provide high temporal resolution and real-time estimates for specific pollutants should be further investigated, with the aim of providing lower costs and more extensive monitoring systems to sample both streamflow and constituent loads.

Watershed models are useful tools for predicting downstream impacts from urbanization and designing mitigation to reduce those impacts, but they are incomplete in scope and do not offer definitive causal links between polluted discharges and downstream degradation. Every model simulates only a subset of the multiple interconnections between physical, chemical, and biological processes found in any watershed, and they all use a grossly simplified representation of the true spatial and temporal variability of a watershed. To speak of a "comprehensive watershed model" is thus an oxymoron, because the science of stormwater is not sufficiently far advanced to determine causality between all sources, resulting stressors, and their physical, chemical, and biological responses. Thus, it is not yet possible to create a protocol that mechanistically links stormwater dischargers to the quality of receiving waters. The utility of models with more modest goals, however, can still be high—as long as the questions being addressed by the model are in fact relevant and important to the functioning of the watershed to which that model is being applied, and sufficient data are available to calibrate the model for the processes included therein.

STORMWATER MANAGEMENT APPROACHES

A fundamental component of EPA's stormwater program is the creation of stormwater pollution prevention plans that document the SCMs that will be used to prevent the permittee's stormwater discharges from degrading local waterbodies. Thus, a consideration of these measures—their effectiveness in meeting different goals, their cost, and how they are coordinated with one another—is central to any evaluation of the stormwater program. The statement of task asks for an evaluation of the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality. Although the state of knowledge has yet to reveal the mechanistic links that would allow for a full assessment of that relationship, enough is known to design systems of SCMs, on a site-scale or local watershed scale, that can substantially reduce the effects of urbanization.

The characteristics, applicability, goals, effectiveness, and cost of nearly 20 different broad categories of SCMs to treat the quality and quantity of stormwa-

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ter runoff are discussed in Chapter 5, organized as they might be applied from the rooftop to the stream. SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. A multitude of case studies illustrates the use of SCMs in specific settings and demonstrates that a particular SCM can have a measurable positive effect on water quality or a biological metric. However, the implementation of SCMs at the watershed scale has been too inconsistent and too recent to be able to definitively link their performance to the prolonged sustainment—at the watershed level—of receiving water quality, in-stream habitat, or stream geomorphology.

Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds. SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.

Nonstructural SCMs such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.

SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the “first flush” of contaminants. SCMs designed to remove this class of storms from surface runoff (runoff-volume-reduction SCMs—rainwater harvesting, vegetated, and subsurface) can also help address larger watershed flooding issues.

Performance characteristics are starting to be established for most structural and some nonstructural SCMs, but additional research is needed on the relevant hydrologic and water quality processes within SCMs across

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different climates and soil conditions. Typical data such as long-term load reduction efficiencies and pollutant effluent concentrations can be found in the International Stormwater BMP Database. However, understanding the processes involved in each SCM is in its infancy, making modeling of these SCMs difficult. Seasonal differences, the time between storms, and other factors all affect pollutant loadings emanating from SCMs. Research is needed that moves away from the use of percent removal and toward better simulation of SCM performance. Research is particularly important for nonstructural SCMs, which in many cases are more effective, have longer life spans, and require less maintenance than structural SCMs. EPA should be a leader in SCM research, both directly by improving its internal modeling efforts and by funding state efforts to monitor and report back on the success of SCMs in the field.

The retrofitting of urban areas presents both unique opportunities and challenges. Promoting growth in these areas is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, it is more complex than Greenfields development because of the need to upgrade existing infrastructure, the limited availability and affordability of land, and the complications caused by rezoning. These sites may be contaminated, requiring cleanup before redevelopment can occur. Both innovative zoning and development incentives, along with the careful selection SCMs, are needed to achieve fair and effective storm-water management in these areas. For example, incentive or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Publicly owned, consolidated SCMs should be strongly considered as there may be insufficient land to have small, on-site systems. The performance and maintenance of the former can be overseen more effectively by a local government entity. The types of SCMs that are used in consolidated facilities—particularly detention basins, wet/dry ponds, and stormwater wetlands—perform multiple functions, such as prevention of streambank erosion, flood control, and large-scale habitat provision.

INNOVATIVE STORMWATER MANAGEMENT AND REGULATORY PERMITTING

There are numerous innovative regulatory strategies that could be used to improve the EPA's stormwater program. The course of action most likely to check and reverse degradation of the nation's aquatic resources would be to **base all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries.** Watershed-based permitting is the regulated allowance of discharges of water and wastes borne by those discharges to waters of the United States, with due consideration of: (1) the implications of those discharges for preservation or improvement of prevailing ecological conditions in the watershed's aquatic systems, (2) cooperation among political ju-

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risdictions sharing a watershed, and (3) coordinated regulation and management of all discharges having the potential to modify the hydrology and water quality of the watershed's receiving waters.

Responsibility and authority for implementation of watershed-based permits would be centralized with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees. Permitting authorities (designated states or, otherwise, EPA) would adopt a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses in the watershed's component waterbodies and additional goals in some cases aimed at recovering lost beneficial uses. Permittees, with support by the states or EPA, would then move to comprehensive impact source analysis as a foundation for targeting solutions. The most effective solutions are expected to lie in isolating, to the extent possible, receiving waterbodies from exposure to those impact sources. In particular, low-impact design methods, termed Aquatic Resources Conservation Design in this report, should be employed to the fullest extent feasible and backed by conventional SCMs when necessary.

The approach gives municipal co-permittees more responsibility, with commensurately greater authority and funding, to manage all of the sources discharging, directly or through municipally owned conveyances, to the waterbodies comprising the watershed. This report also outlines a new monitoring program structured to assess progress toward meeting objectives and the overlying goals, diagnosing reasons for any lack of progress, and determining compliance by dischargers. The proposal further includes market-based trading of credits among dischargers to achieve overall compliance in the most efficient manner and adaptive management to determine additional actions if monitoring demonstrates failure to achieve objectives.

As a first step to taking the proposed program nationwide, a pilot program is recommended that will allow EPA to work through some of the more predictable impediments to watershed-based permitting, such as the inevitable limits of an urban municipality's authority within a larger watershed.

Short of adopting watershed-based permitting, other smaller-scale changes to the EPA stormwater program are possible. These recommendations do not preclude watershed-based permitting at some future date, and indeed they lay the groundwork in the near term for an eventual shift to watershed-based permitting.

Integration of the three permitting types is necessary, such that construction and industrial sites come under the jurisdiction of their associated municipalities. Federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect

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water quality. The National Pretreatment Program, EPA's successful treatment program for municipal and industrial wastewater sources, could serve as a model for integration.

To improve the industrial, construction, and MS4 permitting programs in their current configuration, EPA should (1) issue guidance for MS4, industrial, and construction permittees on what constitutes a design storm for water quality purposes; (2) issue guidance for MS4 permittees on methods to identify high-risk industrial facilities for program prioritization such as inspections; (3) support the compilation and collection of quality industrial stormwater effluent data and SCM effluent quality data in a national database; and (4) develop numerical expressions of the MS4 standard of "maximum extent practicable." Each of these issues is discussed in greater detail in Chapter 6.

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Watershed-based permitting will require additional resources and regulatory program support. Such an approach shifts more attention to ambient outcomes as well as expanded permitting coverage. Additional resources for program implementation could come from shifting existing programmatic resources. For example, some state permitting resources may be shifted away from existing point source programs toward stormwater permitting. Strategic planning and prioritization could shift the distribution of federal and state grant and loan programs to encourage and support more watershed-based stormwater permitting programs. However, securing new levels of public funds will likely be required. All levels of government must recognize that additional resources may be required from citizens and businesses (in the form of taxes, fees, etc.) in order to operate a more comprehensive and effective stormwater permitting program.

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1
Introduction

URBANIZATION AND ITS IMPACTS

The influence of humans on the physical and biological systems of the Earth's surface is not a recent manifestation of modern societies; instead, it is ubiquitous throughout our history. As human populations have grown, so has their footprint, such that between 30 and 50 percent of the Earth's surface has now been transformed (Vitousek et al., 1997). Most of this land area is not covered with pavement; indeed, less than 10 percent of this transformed surface is truly "urban" (Grübler, 1994). However, urbanization causes extensive changes to the land surface beyond its immediate borders, particularly in ostensibly rural regions, through alterations by agriculture and forestry that support the urban population (Lambin et al., 2001). Within the immediate boundaries of cities and suburbs, the changes to natural conditions and processes wrought by urbanization are among the most radical of any human activity.

In the United States, population is growing at an annual rate of 0.9 percent (U.S. Census Bureau, *http://www.census.gov/compendia/statab/2007edition.html*); the majority of the population of the United States now lives in suburban and urban areas (Figure 1-1). Because the area appropriated for urban land uses is growing even faster, these patterns of growth all but guarantee that the influences of urban land uses will continue to expand over time. Cities and suburbia obviously provide the homes and livelihood for most of the nation's population. But, as this report makes clear, these benefits have been accompanied by significant environmental change. Urbanization of the landscape profoundly affects how water moves both above and below ground during and following storm events; the quality of that stormwater (defined in Box 1-1); and the ultimate condition of nearby rivers, lakes, and estuaries. Unlike agriculture, which can display significant interchange with forest cover over time scales of a century (e.g., Hart, 1968), there is no indication that once-urbanized land ever returns to a less intensive state. Urban land, however, does continue to change over time; by one estimate, 42 percent of land currently considered "urban" in the United States will be redeveloped by 2030 (Brookings Institute, 2004). In their words, "nearly half of what will be the built environment in 2030 doesn't even exist yet" (p. vi). This truth belies the common belief that efforts to improve management of stormwater are doomed to irrelevancy because so much of the landscape is already built. Opportunities for improvement have indeed been lost, but many more still await an improved management approach.

Measures of urbanization are varied, and the disparate methods of quantifying the presence and influence of human activity tend to confound analyses of environmental effects. Population density is a direct metric of human presence, but it is not the most relevant measure of the influence of those people on their surrounding landscape. Expressions of the built environment, most commonly

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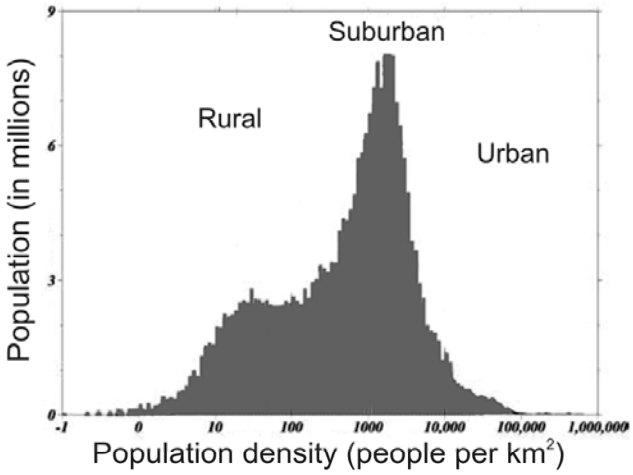

FIGURE 1-1 Histogram of population for the United States, based on 2000 census data. The median population density is about 1,000 people/km^2. SOURCE: Modified from Pozzi and Small (2005), who place the rural–suburban boundary at 100 people/km^2. Reprinted, with permission, from ASPRS (2005). Copyright 2005 by the American Society for Photogrammetry and Remote Sensing.

BOX 1-1
What Is "Stormwater"?

"Stormwater" is a term that is used widely in both scientific literature and regulatory documents. It is also used frequently throughout this report. Although all of these usages share much in common, there are important differences that benefit from an explicit discussion.

Most broadly, stormwater runoff is the water associated with a rain or snow storm that can be measured in a downstream river, stream, ditch, gutter, or pipe shortly after the precipitation has reached the ground. What constitutes "shortly" depends on the size of the watershed and the efficiency of the drainage system, and a number of techniques exist to precisely separate stormwater runoff from its more languid counterpart, "baseflow." For small and highly urban watersheds, the interval between rainfall and measured stormwater discharges may be only a few minutes. For watersheds of many tens or hundreds of square miles, the lag between these two components of storm response may be hours or even a day.

From a regulatory perspective, stormwater must pass through some sort of engineered conveyance, be it a gutter, a pipe, or a concrete canal. If it simply runs over the ground surface, or soaks into the soil and soon reemerges as seeps into a nearby stream, it may be water generated by the storm but it is not regulated stormwater.

This report emphasizes the first, more hydrologically oriented definition. However, attention is focused mainly on that component of stormwater that emanates from those parts of a landscape that have been affected in some fashion by human activities ("urban stormwater"). Mostly this includes water that flows over the ground surface and is subsequently collected by natural channels or artificial conveyance systems, but it can also include water that has infiltrated into the ground but nonetheless reaches a stream channel relatively rapidly and that contributes to the increased stream discharge that commonly accompanies almost any rainfall event in a human-disturbed watershed.

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road density or pavement coverage as a percentage of gross land area, are more likely to determine stormwater runoff-related consequences. An inverse metric, the percentage of mature vegetation or forest across a landscape, expresses the magnitude of related, but not identical, impacts to downstream systems. Alternatively, these measures of land cover can be replaced by measures of land use, wherein the types of human activity (e.g., residential, industrial, commercial) are used as proxies for the suite of hydrologic, chemical, and biological changes imposed on the surrounding landscape.

All of these metrics of urbanization are strongly correlated, although none can directly substitute for another. They also are measured differently, which renders one or another more suitable for a given application. Land use is a common measure in the realm of urban planning, wherein current and future conditions for a city or an entire region are characterized using equivalent categories across parcels, blocks, or broad regions. Road density can be reliably and rapidly measured, either manually or in a Geographic Information System environment, and it commonly displays a very good correlation with other measures of human activity. "Land cover," however, and particularly the percentage of impervious cover, is the metric most commonly used in studying the effects of urban development on stormwater, because it clearly expresses the hydrologic influence and watershed scale of urbanization. Box 1-2 describes the ways in which the percent of impervious cover in a watershed is measured.

There is no universally accepted terminology to describe land-cover or land-use conditions along the rural-to-urban gradient. Pozzi and Small (2005), for example, identified "rural," "suburban," and "urban" land uses on the basis of population density and vegetation cover, but they did not observe abrupt transitions that suggested natural boundaries (see Figure 1-1). In contrast, the Center for Watershed Protection (2005) defined the same terms but used impervious area percentage as the criterion, with such labels as "rural" (0 to 10 percent imperviousness), "suburban" (10 to 25 percent imperviousness), "urban" (25 to 60 percent imperviousness) and "ultra-urban" (greater than 60 percent imperviousness).

Beyond the problems posed by precise yet inconsistent definitions for commonly used words, none of the boundaries specified by these definitions are reflected in either hydrologic or ecosystem responses. Hydrologic response is strongly dependent on both land cover and drainage connectivity (e.g., Leopold, 1968); ecological responses in urbanizing watersheds do not show marked thresholds along an urban gradient (e.g., Figure 1-2) and they are dependent on not only the sheer magnitude of urban development but also the spatial configuration of that development across the watershed (Alberti et al., 2006). This report, therefore, uses such terms as "urban" and "suburban" under their common usage, without implying or advocating for a more precise (but ultimately limited and discipline-specific) definition.

Changing land cover and land use influence the physical, chemical, and biological conditions of downstream waterways. The specific mechanisms by which this influence occurs vary from place to place, and even a cursory review

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BOX 1-2
Measures of Impervious Cover

The percentage of impervious surface or cover in a landscape is the most frequently used measure of urbanization. Yet this parameter has its limitations, in part because it has not been consistently used or defined. Most significant is the distinction between ***total*** impervious area (TIA) and ***effective*** impervious area (EIA). TIA is the "intuitive" definition of imperviousness: that fraction of the watershed covered by constructed, non-infiltrating surfaces such as concrete, asphalt, and buildings. Hydrologically, however, this definition is incomplete for two reasons. First, it ignores nominally "pervious" surfaces that are sufficiently compacted or otherwise so low in permeability that the rate of runoff from them is similar or indistinguishable from pavement. For example, Burges and others (1998) found that the impervious unit-area runoff was only 20 percent greater than that from pervious areas—primarily thin sodded lawns over glacial till—in a western Washington residential subdivision. Clearly, this hydrologic contribution cannot be ignored entirely.

The second limitation of TIA is that it includes some paved surfaces that may contribute nothing to the stormwater-runoff response of the downstream channel. A gazebo in the middle of parkland, for example, probably will impose no hydrologic changes into the catchment except for a very localized elevation of soil moisture at the edge of its roof. Less obvious, but still relevant, would be the different downstream consequences of rooftops that drain alternatively into a piped storm-drain system with direct discharge into a natural stream or onto splash blocks that disperse the runoff onto the garden or lawn at each corner of the building. This metric therefore cannot recognize any stormwater mitigation that may result from alternative runoff-management strategies, for example, pervious pavements or rainwater harvesting.

The first of these TIA limitations, the production of significant runoff from nominally pervious surfaces, is typically ignored in the characterization of urban development. The reason for such an approach lies in the difficulty in identifying such areas and estimating their contribution, and because of the credible belief that the degree to which pervious areas shed water as overland flow should be related, albeit imperfectly, with the amount of *impervious* area: where construction and development are more intense and cover progressively greater fractions of the

of the literature demonstrates that many different factors can be important, such as changes to flow regime, physical and chemical constituents in the water column, or the physical form of the stream channel itself (Paul and Meyer, 2001). Not all of these changes are present in any given system—lakes, wetlands, and streams can be altered by human activity in many different ways, each unique to the activity and the setting in which it occurs. Nonetheless, direct influences of land-use change on freshwater systems commonly include the following (Naiman and Turner, 2000):

- Altering the composition and structure of the natural flora and fauna,
- Changing disturbance regimes,
- Fragmenting the land into smaller and more diverse parcels, and
- Changing the juxtaposition between parcel types.

Historically, human-induced alteration was not universally seen as a problem. In particular, dams and other stream-channel "improvements" were a

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watershed, it is more likely that the intervening green spaces have been stripped and compacted during construction and only imperfectly rehabilitated for their hydrologic functions during subsequent "landscaping."

The second of these TIA limitations, inclusion of non-contributing impervious areas, is formally addressed through the concept of EIA, defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream) system. Thus, any part of the TIA that drains onto pervious (i.e., "green") ground is excluded from the measurement of EIA. This parameter, at least conceptually, captures the hydrologic significance of imperviousness. EIA is the parameter normally used to characterize urban development in hydrologic models.

The direct measurement of EIA is complicated. Studies designed specifically to quantify this parameter must make direct, independent measurements of both TIA and EIA (Alley and Veenhuis, 1983; Laenen, 1983; Prysch and Ebbert, 1986). The results can then be generalized either as a correlation between the two parameters or as a "typical" value for a given land use. Sutherland (1995) developed an equation that describes the relationship between EIA and TIA. Its general form is:

$$EIA = A\ (TIA)^B$$

where *A* and *B* are a unique combination of numbers that satisfy the following criteria:

TIA = 1 then EIA = 0%
TIA = 100 then EIA = 100%

A commonly used version of this equation ($EIA = 0.15\ TIA^{1.41}$) was based on samples from highly urbanized land uses in Denver, Colorado (Alley and Veenhuis, 1983; Gregory et al., 2005). These results, however, are almost certainly region- and even neighborhood-specific, and, although highly relevant to watershed studies, they can be quite laborious to develop.

common activity of municipal and federal engineering works of the mid-20th century (Williams and Wolman, 1984). "Flood control" implied a betterment of conditions, at least for streamside residents (Chang, 1992). And fisheries "enhancements," commonly reflected by massive infrastructure for hatcheries or artificial spawning channels, were once seen as unequivocal benefits for fish populations (White, 1996; Levin et al., 2001).

By almost any currently applied metric, however, the net result of human alteration of the landscape to date has resulted in a degradation of the conditions in downstream watercourses. Many prior researchers, particularly when considering ecological conditions and metrics, have recognized a crude but monotonically declining relationship between human-induced landscape alteration and downstream conditions (e.g., Figure 1-2; Horner et al., 1997; Davies and Jackson, 2006). These include metrics of physical stream-channel conditions (e.g., Bledsoe and Watson, 2001), chemical constituents (e.g., Figure 1-3; House et al., 1993), and biological communities (e.g., Figure 1-4; Steedman, 1988; Wang et al., 1997).

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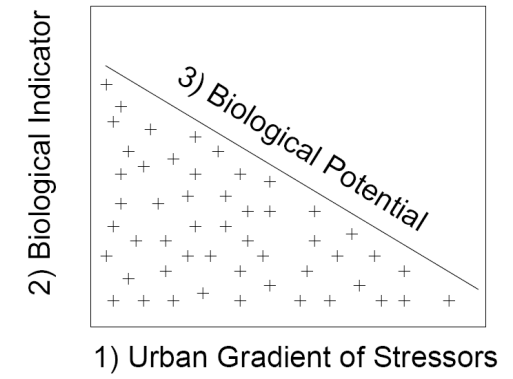

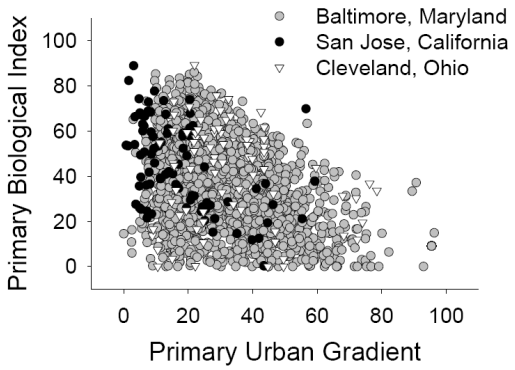

FIGURE 1-2 Conceptual model (top) and actual response (bottom) of a biological system's response to stress. The "Urban Gradient of Stressors" might be a single metric of urbanization, such as percent watershed impervious or road density; the "Biological Indicator" may be single-metric or multi-metric measures of the level of disturbance in an aquatic community. The right-declining line traces the limits of a "factor-ceiling distribution" (Thomson et al., 1986), wherein individual sites (i.e., data points) have a wide range of potential values for a given position along the urban gradient but are not observed above a maximum possible limit of the biological index. The bottom graph illustrates actual biological responses, using a biotic index developed to show responses to urban impacts plotted against a standardized urban gradient comprising urban land use, road density, and population. SOURCE: Top figure reprinted, with permission, from Davies and Jackson (2006). Copyright by the Ecological Society of America. Bottom figure reprinted, with permission, from Barbour et al. (2006). Copyright by the Water Environment Research Foundation.

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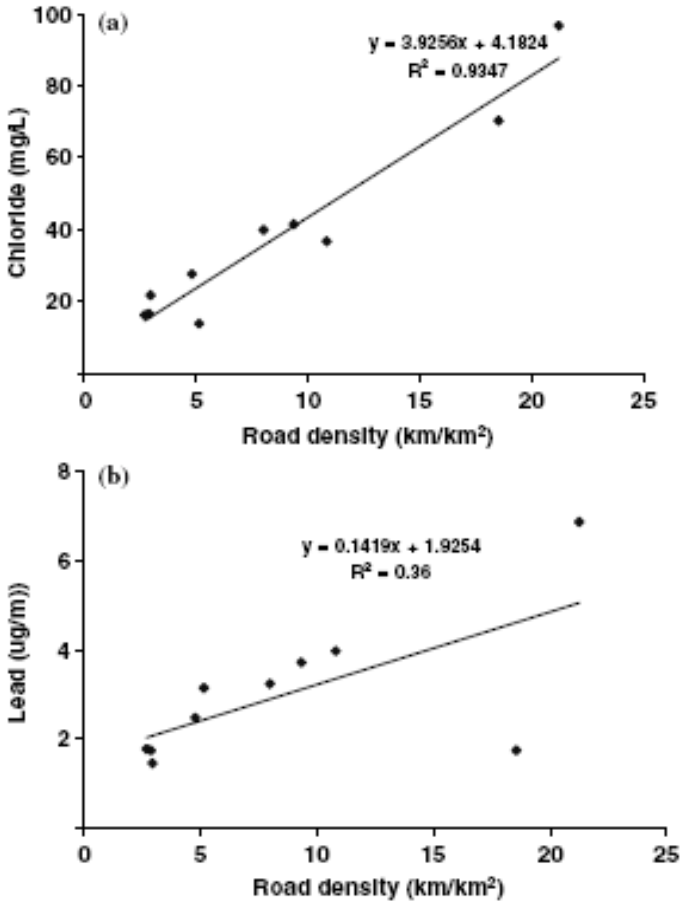

FIGURE 1-3 Example relationships between road density (a surrogate measure of urban development) and common water quality constituents. Direct causality is not necessarily implied by such relationships, but the monotonic increase in concentrations with increasing "urbanization," however measured, is near-universal. SOURCE: Reprinted, with permission, from Chang and Carlson (2005). Copyright 2005 by Springer.

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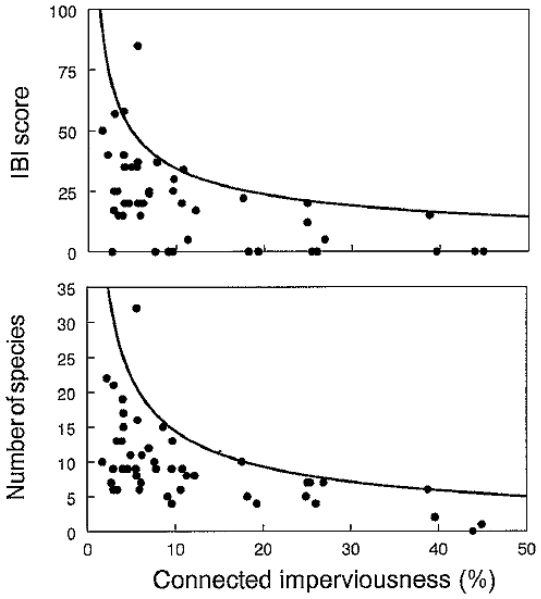

FIGURE 1-4 Plots of Effective Impervious Area (EIA, or "connected imperviousness") against metrics of biologic response in fish populations. SOURCE: Reprinted, with permission, from Wang et al. (2001). Copyright 2001 by Springer.

The association between watercourse degradation and landscape alteration in general, and urban development in particular, seems inexorable. The scientific and regulatory challenge of the last three decades has been to decouple this relationship, in some cases to reverse its trend and in others to manage where these impacts are to occur.

WHAT'S WRONG WITH THE NATION'S WATERS?

Since passage of the Water Quality Act of 1948 and the Clean Water Act (CWA) of 1972, 1977, and 1987, water quality in the United States has measurably improved in the major streams and rivers and in the Great Lakes. However, substantial challenges and problems remain. Major reporting efforts that have examined state and national indicators of condition, such as CWA 305(b) reports (EPA, 2002) and the Heinz State of the Nation's Ecosystem report (Heinz Center, 2002), or environmental monitoring that was designed to provide statistically valid estimates of condition (e.g., National Wadeable Stream Assessment; EPA, 2006), have confirmed widespread impairments related to diffuse sources of pollution and stressors.

The National Water Quality Inventory (derived from Section 305b of the CWA) compiles data in relation to use designations and water quality standards.

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As discussed in greater detail in Chapter 2, such standards include both (1) a description of the use that a waterbody is supposed to achieve (such as a source of drinking water or a cold water fishery) and (2) narrative or numeric criteria for physical, chemical, and biological parameters that allow the designated use to be achieved. As of 2002, 45 percent of assessed streams and rivers, 47 percent of assessed lakes, 32 percent of assessed estuarine areas, 17 percent of assessed shoreline miles, 87 percent of near-coastal ocean areas, 51 percent of assessed wetlands, 91 percent of assessed Great Lakes shoreline miles, and 99 percent of assessed Great Lakes open water areas were not meeting water quality standards set by the states (2002 EPA Report to Congress).[1]

The U.S. Environmental Protection Agency (EPA) has also embarked on a five-year statistically valid survey of the nation's waters (http://www.epa.gov/owow/monitoring/guide.pdf). To date, two waterbody types—coastal areas and wadeable streams—have been assessed. The most recent data indicate that 42 percent of wadeable streams are in poor biological condition and 25 percent are in fair condition (EPA, 2006). The overall condition of the nation's estuaries is generally fair, with Puerto Rico and Northeast Coast regions rated poor, the Gulf Coast and West Coast regions rated fair, and the Southeast Coast region rated good to fair (EPA, 2007). These condition ratings for the National Estuary Program are based on a water quality index, a sediment quality index, a benthic index, and a fish tissue contaminants index.

The impairment of waterbodies is manifested in a multitude of ways. Indeed, EPA's primary process for reporting waterbody condition (Section 303(d) of the CWA—see Chapter 2) identifies over 200 distinct types of impairments. As shown in Table 1-1, these have been categorized into 15 broad categories, encompassing about 94 percent of all impairments. 59,515 waterbodies fall into one of the top 15 categories, while the total reported number of waterbodies impaired from all causes is 63,599 (which is an underestimate of the actual total because not all waterbodies are assessed). Mercury, microbial pathogens, sediments, other metals, and nutrients are the major pollutants associated with impaired waterbodies nationwide. These constituents have direct impacts on aquatic ecosystems and public health, which form the basis of the water quality standards set for these compounds. Sediments can harm fish and macroinvertebrate communities by introducing sorbed contaminants, decreasing available light in streams, and smothering fish eggs. Microbial pathogens can cause disease to humans via both ingestion and dermal contact and are frequently cited as the cause of beach closures and other recreational water hazards in lakes and estuaries. Nutrient over-enrichment can promote a cascade of events in waterbodies from algal blooms to decreases in dissolved oxygen and associated fish kills. Metals like mercury, pesticides, and other organic compounds that enter

[1] EPA does not yet have the 2004 assessment findings compiled in a consistent format from all the states. EPA is also working on processing the states 2006 Integrated Reports as the 303(d) portions are approved and the states submit their final assessment findings. Susan Holdsworth, EPA, personal communication, September 2007.

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waterways can be taken up by fish species, accumulating in their tissues and presenting a health risk to organisms (including humans) that consume the fish.

However, Table 1-1 can be misleading if it implies that degraded *water quality* is the primary metric of impairment. In fact, many of the nation's streams, lakes, and estuaries also suffer from fundamental changes in their flow regime and energy inputs, alteration of aquatic habitats, and resulting disruption of biotic interactions that are not easily measured via pollutant concentrations. Such waters may not be listed on State 303(d) lists because of the absence of a corresponding water quality standard that would directly indicate such conditions (like a biocriterion). Figure 1-5A, B, and C show examples of such impacted waterbodies.

TABLE 1-1 Top 15 Categories of Impairment Requiring CWA Section 303(d) Action

Cause of Impairment	Number of Waterbodies	Percent of the Total
Mercury	8,555	14%
Pathogens	8,526	14%
Sediment	6,689	11%
Metals (other than mercury)	6,389	11%
Nutrients	5,654	10%
Oxygen depletion	4,568	8%
pH	3,389	6%
Cause unknown - biological integrity	2,866	5%
Temperature	2,854	5%
Habitat alteration	2,220	4%
PCBs	2,081	3%
Turbidity	2,050	3%
Cause unknown	1,356	2%
Pesticides	1,322	2%
Salinity/TDS/chlorides	996	2%

Note: "Waterbodies" refers to individual river segments, lakes, and reservoirs. A single waterbody can have multiple impairments. Because most waters are not assessed, however, there is no estimate of the number of unimpaired waters in the United States. SOURCE: EPA, National Section 303(d) List Fact Sheet (http://iaspub.epa.gov/waters/national_rept.control). The data are based on three-fourths of states reporting from 2004 lists, with the remaining from earlier lists and one state from a 2006 list.

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FIGURE 1-5A Headwater tributary in Philadelphia suffering from Urban Stream Syndrome. SOURCE: Courtesy of Chris Crockett, Philadelphia Water Department.

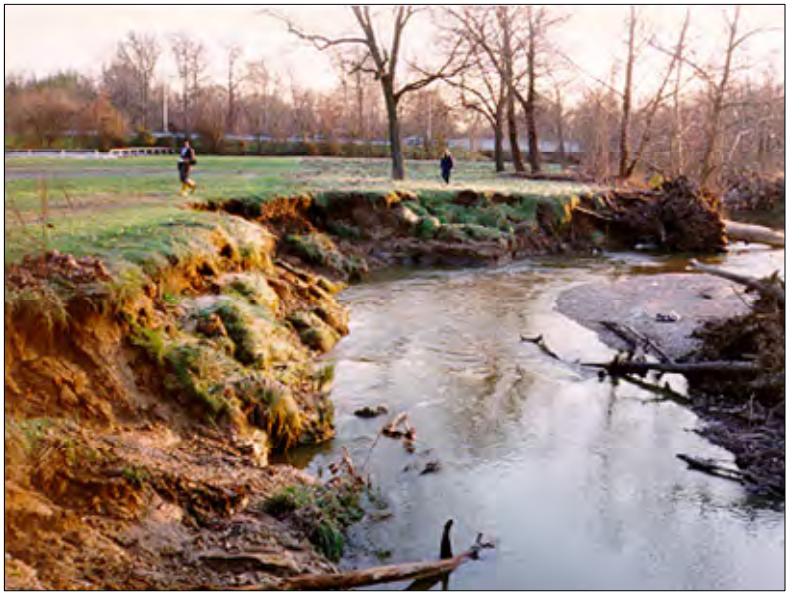

FIGURE 1-5B A destabilized stream in Vermont. SOURCE: Courtesy of Pete LaFlamme, Vermont Department of Environmental Conservation.

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FIGURE 1-5C An urban stream, the Lower Oso Creek in Orange County, California, following a storm event. Oso Creek was formerly an ephemeral stream, but heavy development in the contributing watershed has created perennial flow—stormwater flow during wet weather and minor wastewater discharges and authorized non-stormwater discharges such as landscape irrigation runoff during dry weather. Courtesy of Eric Stein, Southern California Coastal Research Water Project.

Over the years, the greatest successes in improving the nation's waters have been in abating the often severe impairments caused by municipal and industrial point source discharges. The pollutant load reductions required of these facilities have been driven by the National Pollutant Discharge Elimination System (NPDES) permit requirements of the CWA (see Chapter 2). Although the majority of these sources are now controlled, further declines in water quality remain likely if the land-use changes that typify more diffuse sources of pollution are not addressed (Palmer and Allan, 2006). These include land-disturbing agricultural, silvicultural, urban, industrial, and construction activities from which hard-to-monitor pollutants emerge during wet-weather events. Pollution from these landscapes has been almost universally acknowledged as the most pressing challenge to the restoration of waterbodies and aquatic ecosystems nationwide. All population and development forecasts indicate a continued worsening of the environmental conditions caused by diffuse sources of pollution under the nation's current growth and land-use trajectories.

Recognition of urban stormwater's role in the degradation of the nation's waters is but the latest stage in the history of this byproduct of the human envi-

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ronment. Runoff conveyance systems have been part of cities for centuries, but they reflected only the desire to remove water from roads and walkways as rapidly and efficiently as possible. In some arid environments, rainwater has always been collected for irrigation or drinking; elsewhere it has been treated as an unmetered, and largely benign, waste product of cities. Minimal (unengineered) ditches or pipes drained developed areas to the nearest natural watercourse. Where more convenient, stormwater shared conveyance with wastewater, eliminating the cost of a separate pipe system but commonly resulting in sewage overflows during rainstorms. Recognition of downstream flooding that commonly resulted from upstream development led to construction of stormwater storage ponds or vaults in many municipalities in the 1960s, but their performance has typically fallen far short of design objectives (Booth and Jackson, 1997; Maxted and Shaver, 1999; Nehrke and Roesner, 2004). Water-quality treatment has been a relatively recent addition to the management of stormwater, and although a significant fraction of pollutants can be removed through such efforts (e.g., Strecker et al., 2004; see http://www.bmpdatabase.org), the constituents remaining even in "treated" stormwater represent a substantial, but largely unappreciated, impact to downstream watercourses.

Of the waterbodies that have been assessed in the United States, impairments from urban runoff are responsible for about 38,114 miles of impaired rivers and streams, 948,420 acres of impaired lakes, 2,742 square miles of impaired bays and estuaries, and 79,582 acres of impaired wetlands (2002 305(b) report). These numbers must be considered an underestimate, since the urban runoff category does not include stormwater discharges from municipal separate storm sewer systems (MS4s) and permitted industries, including construction. Urban stormwater is listed as the "primary" source of impairment for 13 percent of all rivers, 18 percent of all lakes, and 32 percent of all estuaries (2000 305(b) report). Although these numbers may seem low, urban areas cover just 3 percent of the land mass of the United States (Loveland and Auch, 2004), and so their influence is disproportionately large. Indeed, developed and developing areas that are a primary focus of stormwater regulations contain some of the most degraded waters in the country. For example, in Ohio few sites with greater than 27 percent imperviousness can meet interim CWA goals in nearby waterbodies, and biological degradation is observed with much less urban development (Miltner et al., 2004). Numerous authors have found similar patterns (see Meyer et al., 2005).

Although no water quality inventory data have been made available from the EPA since 2002, the dimensions of the stormwater problem can be further gleaned from several past regional and national water quality inventories. Many of these assessments are somewhat dated and are subject to the normal data and assessment limitations of national assessment methods, but they indicate that stormwater runoff has a deleterious impact on nearly all of the nation's waters. For example:

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- Harvesting of shellfish is prohibited, restricted, or conditional in nearly 40 percent of all shellfish beds nationally due to high bacterial levels, and urban runoff and failing septic systems are cited as the prime causes. Reopening of shellfish beds due to improved wastewater treatment has been more than offset by bed closures due to rapid coastal development (NOAA, 1992; EPA, 1998).

- In 2006 there were over 15,000 beach closings or swimming advisories due to bacterial levels exceeding health and safety standards, with polluted runoff and stormwater cited as the cause of the impairment 40 percent of the time (NRDC, 2007).

- Pesticides were detected in 97 percent of urban stream water samples across the United States, and exceeded human health and aquatic life benchmarks 6.7 and 83 percent of the time, respectively (USGS, 2006). In 94 percent of fish tissues sampled in urban areas nationwide, organochlorine compounds were detected.

- Urban development was responsible for almost 39 percent of freshwater wetland loss (88,960 acres) nationally between 1998 and 2004 (Dahl, 2006), and the direct impact of stormwater runoff in degrading wetland quality is predicted to affect an even greater acreage (Wright et al., 2006).

- Eastern brook trout are present in intact populations in only 5 percent of more than 12,000 subwatersheds in their historical range in eastern North America, and urbanization is cited as a primary threat in 25 percent of the remaining subwatersheds with reduced populations (Trout Unlimited, 2006).

- Increased flooding is common throughout urban and suburban areas, sometimes as a consequence of improperly sited development (Figure 1-6A) but more commonly as a result of increasing discharges over time resulting from progressive urbanization farther upstream (Figure 1-6B). According to FEMA (undated), property damage from all types of flooding, from flash floods to large river floods, averages $2 billion a year.

- The chemical effects of stormwater runoff are pervasive and severe throughout the nation's urban waterways, and they can extend far downstream of the urban source. Stormwater discharges from urban areas to marine and estuarine waters cause greater water column toxicity than similar discharges from less urban areas (Bay et al., 2003).

- A variety of studies have shown that stormwater runoff is a vector of pathogens with potential human health implications in both freshwater (Calderon et al., 1991) and marine waters (Dwight et al., 2004; Colford et al., 2007).

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A



B



FIGURE 1-6 (A) New residential construction in the path of episodic stream discharge (Issaquah, Washington); (B) recent flooding of an 18th-century tavern in Collegeville, Pennsylvania following a storm event in an upstream developing watershed. SOURCES: Top, Derek Booth, Stillwater Sciences, Inc., and bottom, Robert Traver, Villanova University.

WHY IS IT SO HARD TO REDUCE THE IMPACTS OF STORMWATER?

"Urban stormwater" is the runoff from a landscape that has been affected in some fashion by human activities, during and immediately after rain. Most visibly, it is the water flow over the ground surface, which is collected by natural channels and artificial conveyance systems (pipes, gutters, and ditches) and ultimately routed to a stream, river, lake, wetland, or ocean. It also includes water that has percolated into the ground but nonetheless reaches a stream channel relatively rapidly (typically within a day or so of the rainfall), contributing to the high discharge in a stream that commonly accompanies rainfall. The subsurface

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flow paths that contribute to this stormflow response are typically quite shallow, in the upper layers of the soil, and are sometimes termed "interflow." They stand in contrast to deeper groundwater paths, where water moves at much lower velocities by longer paths and so reaches the stream slowly, over periods of days, weeks, or months. This deeper flow sustains streamflow during rainless periods and is usually called baseflow, as distinct from "stormwater." A formal distinction between these types of runoff is sometimes needed for certain computational procedures, but for most purposes a qualitative understanding is sufficient.

These runoff paths can be identified in virtually all modified landscapes, such as agriculture, forestry, and mining. However, this report focuses on those settings with the particular combination of activities that constitute "urbanization," by which we mean to include the commonly understood conversion (whether incremental or total) of a vegetated landscape to one with roads, houses, and other structures.

Although the role of urban stormwater in degrading the nation's waters has been recognized for decades (e.g., Klein, 1979), reducing that role has been notoriously difficult. This difficulty arises from three basic attributes of what is commonly termed "stormwater":

1. It is produced from literally everywhere in a *developed* landscape;
2. Its production and delivery are episodic, and these fluctuations are difficult to attenuate; and
3. It accumulates and transports much of the collective waste of the urban environment.

Wherever grasslands and forest are replaced by urban development in general, and impervious surfaces in particular, the movement of water across the landscape is radically altered (see Figure 1-7). Nearly all of the associated problems result from one underlying cause: loss of the water-retaining function of the soil and vegetation in the urban landscape. In an undeveloped, vegetated landscape, soil structure and hydrologic behavior are strongly influenced by biological activities that increase soil porosity (the ratio of void space to total soil volume) and the number and size of macropores, and thus the storage and conductivity of water as it moves through the soil. Leaf litter on the soil surface dissipates raindrop energy; the soil's organic content reduces detachment of small soil particles and maintains high surface infiltration rates. As a consequence, rainfall typically infiltrates into the ground surface or is evapotranspired by vegetation, except during particularly intense rainfall events (Dunne and Leopold, 1978).

In the urban landscape, these processes of evapotranspiration and water retention in the soil may be lost for the simple reason that the loose upper layers of the soil and vegetation are gone—stripped away to provide a better foundation for roads and buildings. Even if the soil still exists, it no longer functions if precipitation is denied access because of paving or rooftops. In either case, a stormwater

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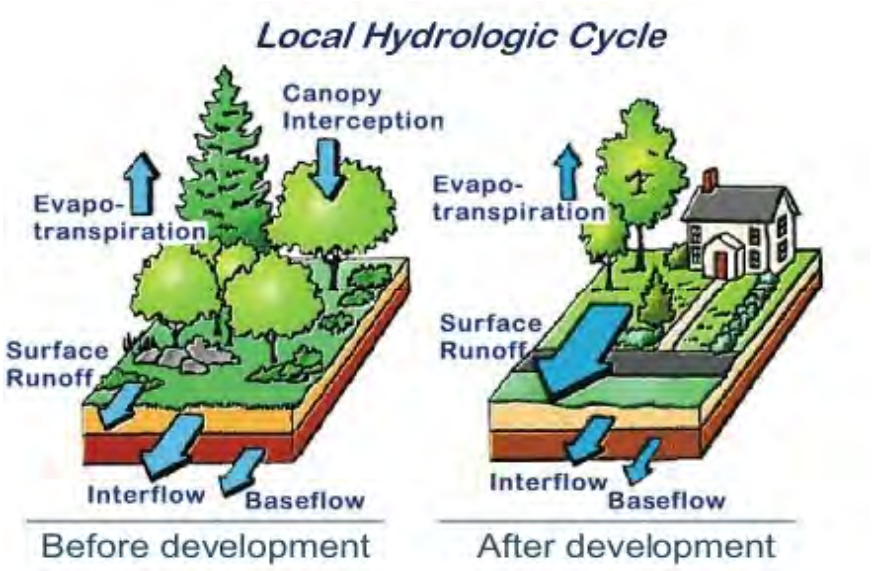

FIGURE 1-7 Schematic of the hydrologic pathways in humid-region watersheds, before and after urban development. The sizes of the arrows suggest relative magnitudes of the different elements of the hydrologic cycle, but conditions can vary greatly between individual catchments and only the increase in surface runoff in the post-development condition is ubiquitous. SOURCE: Adapted from Schueler (1987) and Maryland Department of the Environment; http://www.mde.state.md.us/Programs/WaterPrograms.

runoff reservoir of tremendous volume is removed from the stormwater runoff system; water that may have lingered in this reservoir for a few days or many weeks, or been returned directly to the atmosphere by evaporation or transpiration by plants, now flows rapidly across the land surface and arrives at the stream channel in short, concentrated bursts of high discharge.

This transformation of the hydrologic regime from one where subsurface flow once dominated to one where overland flow now dominates is not simply a readjustment of runoff flow paths, and it does not just result in a modest increase in flow volumes. It is a wholesale reorganization of the processes of runoff generation, and it occurs throughout the developed landscape. As such, it can affect every aspect of that runoff (Leopold, 1968)—not only its rate of production, its volume, and its chemistry, but also what it indirectly affects farther downstream (Walsh et al., 2005a). This includes erosion of mobile channel boundaries, mobilization of once-static channel elements (e.g., large logs), scavenging of contaminants from the surface of the urban landscape, and efficient transfer of heat from warmed surfaces to receiving waterbodies. These changes have commonly inspired human reactions—typically with narrow objectives but carrying additional, far-ranging consequences—such as the piping of once-exposed channels, bank armoring, and construction of large open-water detention ponds (e.g., Lieb and Carline, 2000).

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This change in runoff regime is also commonly accompanied by certain land-use activities that have the potential to generate particularly harmful or toxic discharges, notably those commercial activities that are the particular focus of the industrial NPDES permits. These include manufacturing facilities, transport of freight or passengers, salvage yards, and a more generally defined category of "sites where industrial materials, equipment, or activities are exposed to stormwater" (e.g., EPA, 1992).

Other human actions are associated with urban landscapes that do not affect stormwater directly, but which can further amplify the negative consequences of altered flow. These actions include clearing of riparian vegetation around streams and wetlands, introduction of atmospheric pollutants that are subsequently deposited, inadvertent release of exotic chemicals into the environment, and channel crossings by roads and utilities. Each of these additional actions further degrades downstream waterbodies and increases the challenge of finding effective methods to reverse these changes (Boulton, 1999). There is little doubt as to why the problem of urban stormwater has not yet been "solved"—because every functional element of an aquatic ecosystem is affected. Urban stormwater has resulted in such widespread impacts, both physical and biological, in aquatic systems across the world that this phenomenon has been termed the "Urban Stream Syndrome" (see Figure 1-5; Walsh et al., 2005b).

Of the many possible ways to consider these conditions, Karr (1991) has recommended a simple yet comprehensive grouping of the major stressors arising from urbanization that influence aquatic assemblages (Figure 1-8). These include chemical pollutants (water quality and toxicity); changes to flow magnitude, frequency, and seasonality of various discharges; the physical aspects of stream, lake, or wetland habitats; the energy dynamics of food webs, sunlight, and temperature; and biotic interactions between native and exotic species. Stormwater and stormwater-related impacts encompass all of these categories, some directly (e.g., water chemistry) and some indirectly (e.g., habitat, energy dynamics). Because of the wide-ranging effects of stormwater, programs to abate stormwater impacts on aquatic systems must deal with a broad range of impairments far beyond any single altered feature, whether traditional water-chemistry parameters or flow rates and volumes.

The broad spatial scale of where and how these impacts are generated suggests that solutions, if effective, should be executed at an equivalent scale. Although the "problem" of stormwater runoff is manifested most directly as an altered hydrograph or elevated concentrations of pollutants, it is ultimately an expression of land-use change at a landscape scale. Symptomatic solutions, applied only at the end of a stormwater collection pipe, are not likely to prove fully effective because they are not functioning at the scale of the original disturbance (Kloss and Calarusse, 2006).

The landscape-scale generation of stormwater has a number of consequences for any attempt to reduce its effects on receiving waters, as described below.

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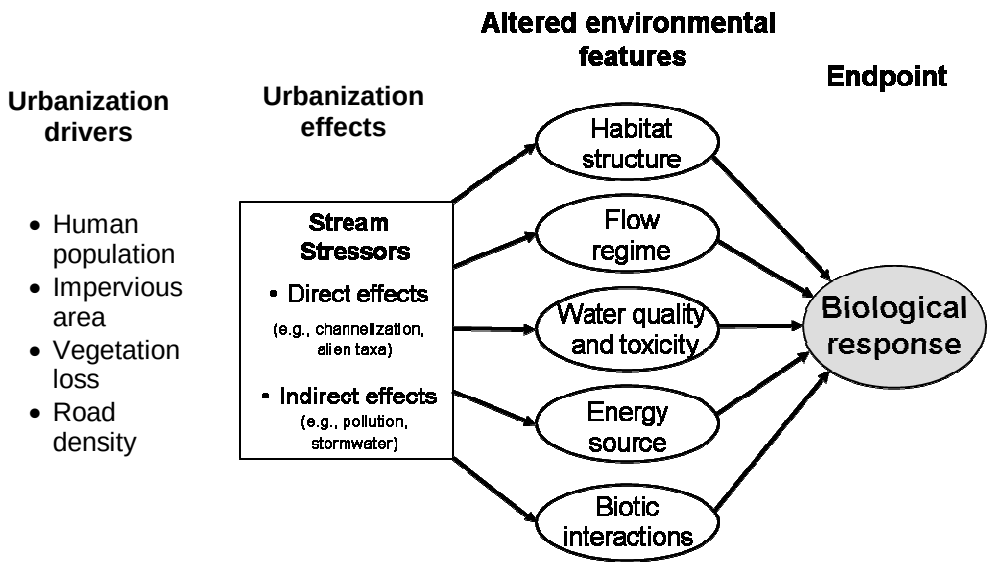

FIGURE 1-8 Five features that are affected by urban development and, in turn, affect biological conditions in urban streams. SOURCES: Modified from Karr (1991), Karr and Yoder (2004), and Booth (2005). Reprinted, with permission, from Karr (1991). Copyright 2001 by Ecological Society of America. Reprinted, with permission, from Karr and Yoder (2004). Copyright 2004 by American Society of Civil Engineers. Reprinted, with permission, from Booth (2005). Copyright 2005 by the North American Benthological Society.

Sources and Volumes

The "source" of stormwater runoff is dispersed, making collection and centralized treatment challenging. To the extent that collection is successful, however, the flip side of this condition—very large volumes—becomes manifest. Either an extensive infrastructure brings stormwater to centralized facilities, whose operation and maintenance may be relatively straightforward (e.g., Anderson et al., 2002) but of modest effectiveness, or stormwater remains dispersed for management, treatment, or both across the landscape (e.g., Konrad and Burges, 2001; Holman-Dodds et al., 2003; Puget Sound Action Team, 2005; Walsh et al., 2005a; Bloom, 2006; van Roon, 2007), better mimicking the natural processes of runoff generation but requiring a potentially unlimited number of "facilities" that may have their own particular needs for space, cost, and maintenance.

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Treatment Challenges

Regardless of the scale at which treatment is attempted, technological difficulties are significant because of the variety of "pollutants" that must be addressed. These include physical objects, from large debris to microscopic particles; chemical constituents, both dissolved and immiscible; and less easily categorized properties such as temperature. Wastewater treatment plants manage a similarly broad range of pollutants, but stormwater flows have highly unsteady inflows and, when present, typically much greater volumes to treat.

Industrial sources of stormwater pose a particularly challenging problem because potential generators of polluted or toxic runoff are widespread and are regulated under NPDES permitting by their *activities*, not by the specific category of industrial activity under which they fall. This complicates any systematic effort to identify those entities that should be regulated (Duke et al., 1999). Even for the limited number of regulated generators, pollution prevention measures are of uncertain effectiveness.

Soil erosion from construction sites is another pollution source that has proven difficult to effectively control. Although most bare sites are relatively small and only short-lived, at any given time there can be many sites under construction, each of which can deliver sediment loads to downstream waterbodies at rates that exceed background levels by many orders of magnitude (e.g., Wolman and Schick, 1967). Relatively effective approaches and technologies exist to dramatically reduce the magnitude of these sediment discharges (e.g., Raskin et al., 2005), but they depend on conscientious installation and regular maintenance. Enforcement of such requirements, normally a low-priority activity of local departments of building or public works, is commonly lacking.

Another difference between the stormwater and wastewater streams is that stormwater treatment must address not only "pollutants" but also physically and ecologically deleterious changes in flow rate and total runoff volume. Treating these changes constitutes a particularly difficult task for two reasons. First, there is simply more runoff, as a rule, and so replicating the predevelopment hydrograph is not an option—the increased volume of runoff guarantees that some discharges, some of the time, must be allowed to increase. Second, there is little agreement on what constitutes "adequate" or "effective" treatment for the various attributes of flow. Even the most basic metrics, such as the magnitude of peak flow, can require extensive infrastructure to achieve (e.g., Booth and Jackson, 1997); other flow metrics that correlate more directly with undesired effects on physical and biological systems can require even greater efforts to match. In many cases, the urban-induced transformation of the flow regime makes true "mitigation" virtually impossible.

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Widespread Cause and Effects

The spatial scale of stormwater generation and its impacts is wide-ranging. "Generators" are literally landscape-wide, and impacts can occur at every location in the path followed by urban runoff, from source to receiving waterbody (Hamilton et al., 2004). There are few ways to demonstrate causal connections between distributed landscape sources and cumulative downstream effects (Allan, 2004), and so site-specific mitigation typically provides little lasting improvement in the watershed as a whole (Maxted and Shaver, 1997).

Stormwater Measurements

The desired attributes of stormwater runoff are normally expressed through a combination of physical and chemical parameters. These parameters are commonly presumed to have direct correlation to attributes of human or ecological concern, such as the condition of human or fish communities, or the stability of a stream channel, even though these parameters do not directly measure those effects. The most commonly measured physical parameters are hydrologic and simply measure the rate of flow past a specified location. Both the absolute, instantaneous magnitude of that flow rate (i.e., the discharge) and the variations in that rate over multiple time scales (i.e., how rapidly the discharge varies over an hour, a day, a season, etc.) can be captured by analysis of a continuous time series of a flow. Obviously, however, a nearly unlimited number of possible metrics, capturing a multitude of temporal scales, could be defined (Poff et al., 1997, 2006; Cassin et al., 2004; Konrad et al., 2005; Roy et al., 2005; Chang, 2007). Commonly only a single parameter—the peak storm discharge for a given return period (Hollis, 1975)—has been emphasized in the past. Mitigation of urban-induced flow increases have followed this narrow approach, typically by endeavoring to reduce peak discharge by use of detention ponds but leaving the underlying increase in runoff volumes—and the associated augmentation of both frequency and duration of high discharges—untouched. This partly explains why evaluation of downstream conditions commonly document little improvement resulting from traditional flow-mitigation measures (e.g., Maxted and Shaver, 1997; Roesner et al., 2001; May and Horner, 2002).

Other physical parameters, less commonly measured or articulated, can also express the conditions of downstream watercourses. Measures of size or complexity, particularly for stream channels, are particularly responsive to the changes in flow regime and discharge. Booth (1990) suggested that discriminating between *channel expansion*, the proportional increase in channel cross-sectional area with increasing discharge, and *channel incision*, the catastrophic vertical downcutting that sometimes accompanies urban-induced flow increases, captures important end-members of the physical response to hydrologic change. The former (proportional expansion) is more thoroughly documented (Hammer, 1972; Hollis and Luckett, 1976; Morisawa and LaFlure, 1982; Neller, 1988;

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Whitlow and Gregory, 1989; Booth and Jackson, 1997; Moscrip and Montgomery, 1997; Booth and Henshaw, 2001); the latter (catastrophic incision) is more difficult to quantify but has been recognized in both urban and agricultural settings (e.g., Simon, 1989). Both types of changes result not only in a larger channel but also in substantial simplification and loss of features normally associated with high-quality habitat for fish and other in-stream biota. The sediment released by these "growing channels" also can be the largest component of the overall sediment load delivered to downstream waterbodies (Trimble, 1997; Nelson and Booth, 2002).

Chemical parameters (or, historically, "water-quality parameters"; see Dinius, 1987; Gergel et al., 2002) cover a host of naturally and anthropogenically occurring constituents in water. In flowing water these are normally expressed as instantaneous measurements of concentration. In waterbodies with long residence times, such as lakes, these may be expressed as either concentrations or as loads (total accumulated amounts, or total amounts integrated over an extended time interval). The CWA defined a list of priority pollutants, of which a subset is regularly measured in many urban streams (e.g., Field and Pitt, 1990). Parameters that are not measured may or may not be present, but without assessment they are rarely recognized for their potential (or actual) contribution to waterbody impairment.

Other attributes of stormwater do not fit as neatly into the categories of water quantity or water quality. Temperature is commonly measured and is normally treated as a water quality parameter, although it is obviously not a chemical property of the water (LeBlanc et al., 1997; Wang et al., 2003). Similarly, direct or indirect measures of suspended matter in the water column (e.g., concentration of total suspended solids, or secchi disk depths in a lake) are primarily physical parameters but are normally included in water quality metrics. Flow velocity is rarely measured in either context, even though it too correlates directly to stream-channel conditions. Even more direct expressions of a flow's ability to transport sediment or other debris, such as shear stress or unit stream power, are rarely reported and virtually never regulated.

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Urban runoff degrades aquatic systems in multiple ways, which confounds our attempts to define causality or to demonstrate clear linkages between mitigation and ecosystem improvement. It is generally recognized from the conceptual models that seek to describe this system that no single element holds the key to ecosystem condition. All elements must be functional, and yet every element can be affected by urban runoff in different ways. These impacts occur at virtually all spatial scales, from the site-specific to the landscape; this breadth and diversity challenges our efforts to find effective solutions.

This complexity and the continued growth of the built environment also present fundamental social choices and management challenges. Stormwater control measures entail substantial costs for their long-term maintenance, moni-

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toring to determine their performance, and enforcement of their use—all of which must be weighed against their (sometimes unproven) benefits. Furthermore, the overarching importance of impervious surfaces inextricably links stormwater management to land-use decisions and policy. For example, where a reversal of the effects of urbanization cannot be realized, more intensive land-use development in certain areas may be a paradoxically appropriate response to reduce the overall impacts of stormwater. That is, increasing population density and impervious cover in designated urban areas may reduce the creation of impervious surface and the associated ecological impacts in areas that will remain undeveloped as a result. In these highly urban areas (with very high percentages of impervious surface), aquatic conditions in local streams will be irreversibly changed and the Urban Stream Syndrome may be unavoidable to some extent. Where these impacts occur and what effort and cost will be used to avoid these impacts are both fundamental issues confronting the nation as it attempts to address stormwater.

IMPETUS FOR THE STUDY AND REPORT ROADMAP

In 1972 Congress amended the Federal Water Pollution Control Act (subsequently referred to as the Clean Water Act) to require control of discharges of pollutants to waters of the United States from point sources. Initial efforts to improve water quality using NPDES permits focused primarily on reducing pollutants from industrial process wastewater and municipal sewage discharges. These point source discharges were clearly and easily shown to be responsible for poor, often drastically degraded conditions in receiving waterbodies because they tended to emanate from identifiable and easily monitored locations, such as pipe outfalls.

As pollution control measures for industrial process wastewater and municipal sewage were implemented and refined during the 1970s and 1980s, more diffuse sources of water pollution have become the predominant causes of water quality impairment, including stormwater runoff. To address the role of stormwater in causing water quality impairments, Congress included Section 402(p) in the CWA; this section established a comprehensive, two-phase approach to stormwater control using the NPDES program. In 1990 EPA issued the Phase I Stormwater Rule (55 Fed. Reg. 47990; November 16, 1990) requiring NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations over 100,000 and for runoff associated with industrial activity, including runoff from construction sites five acres and larger. In 1999 EPA issued the Phase II Stormwater Rule (64 Fed. Reg. 68722; December 8, 1999), which expanded the requirements to small MS4s in urban areas and to construction sites between one and five acres in size.

Since EPA's stormwater program came into being, several problems inherent in its design and implementation have become apparent. As discussed in more detail in Chapter 2, problems stem to a large extent from the diffuse nature

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of stormwater discharges combined with a regulatory process that was created for point sources (the NPDES permitting approach). These problems are compounded by the shear number of entities requiring oversight. Although exact numbers are not available, EPA estimates that the number of regulated MS4s is about 7,000, including 1,000 Phase I municipalities and 6,000 from Phase II. The number of industrial permittees is thought to be around 100,000. Each year, the construction permit covers around 200,000 permittees each for both Phase I (five acres or greater) and Phase II (one to five acres) projects. Thus, the total number of permittees under the stormwater program at any time numbers greater than half a million. There are fewer than 100,000 non-stormwater (meaning wastewater) permittees covered by the NPDES program, such that stormwater permittees account for approximately 80 percent of NPDES-regulated entities. To manage this large number of permittees, the stormwater program relies heavily on the use of general permits to control industrial, construction, and Phase II MS4 discharges, which are usually statewide, one-size-fits-all permits in which general provisions are stipulated.

An example of the burden felt by a single state is provided by Michigan (David Drullinger, Michigan Department of Environmental Quality Water Bureau, personal communication, September 2007). The Phase I Stormwater regulations that became effective in 1990 regulate 3,400 industrial sites, 765 construction sites per year, and five large cities in Michigan. The Phase II regulations, effective since 1999, have extended the requirements to 7,000 construction sites per year and 550 new jurisdictions, which are comprised of about 350 "primary jurisdictions" (cities, villages, and townships) and 200 "nested jurisdictions" (county drains, road agencies, and public schools). Often, only a handful of state employees are allocated to administer the entire program (see the survey in Appendix C).

In order to comply with the CWA regulations, permittees must fulfill a number of requirements, including the creation and implementation of a stormwater pollution prevention plan, and in some cases, monitoring of stormwater discharges. Stormwater pollution prevention plans document the stormwater control measures (SCMs; sometimes known as best management practices or BMPs) that will be used to prevent or slow stormwater from quickly reaching nearby waterbodies and degrading their quality. These include structural methods such as detention ponds and nonstructural methods such as designing new development to reduce the percentage of impervious surfaces. Unfortunately, data on the degree of pollutant reduction that can be assigned to a particular SCM are only now becoming available (see Chapter 5).

Other sources of variability in EPA's stormwater program are that (1) there are three permit types (municipal, industrial, and construction), (2) some states and local governments have assumed primacy for the program from EPA while others have not, and state effluent limits or benchmarks for stormwater discharges may differ from the federal requirements, and (3) whether there are monitoring requirements varies depending on the regulating entity and the type of activity. For industrial stormwater there are 29 sectors of industrial activity

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covered by the general permit, each of which is characterized by a different suite of possible contaminants and SCMs.

Because of the industry-, site-, and community-specific nature of stormwater pollution prevention plans, and because of the lack of resources of most NPDES permitting authorities to review these plans and conduct regular compliance inspections, water quality-related accountability in the stormwater program is poor. Monitoring data are minimal for most permittees, despite the fact that they are often the only indicators of whether an adequate stormwater program is being implemented. At the present time, available monitoring data indicate that many industrial facilities routinely exceed "benchmark values" established by EPA or the states, although it is not clear whether these exceedances provide useful indicators of stormwater pollution prevention plan inadequacies or potential water quality problems. These uncertainties have led to mounting and contradictory pressure from permittees to eliminate monitoring requirements entirely as well as from those hoping for greater monitoring requirements to better understand the true nature of stormwater discharges and their impact.

To improve the accountability of it Stormwater Program, EPA requested advice on stormwater issues from the National Research Council's (NRC's) Water Science and Technology Board as the next round of general permits is being prepared. Although the drivers for this study have been in the industrial stormwater arena, this study considered all entities regulated under the NPDES program (municipal, industrial, and construction). The following statement of task guided the work of the committee:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of SCMs.

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

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(5) Assess the design of the stormwater permitting program implemented under the CWA.

The report is intended to inform decision makers within EPA, affected industries, public stormwater utilities, other government agencies and the private sector about potential options for managing stormwater.

EPA requested that the study be limited to those issues that fall under the agency's current regulatory scheme for stormwater, which excludes nonpoint sources of pollution such as agricultural runoff and septic systems. Thus, these sources are not extensively covered in this report. The reader is referred to NRC (2000, 2005) for more detailed information on the contribution of agricultural runoff and septic systems to waterbody impairment and on innovative technologies for treating these sources. Also at the request of EPA, concentrated animal feeding operations and combined sewer overflows were not a primary focus. However, the committee felt that in order to be most useful it should opine on certain critical effects of regulated stormwater beyond the delivery of traditional pollutants. Thus, changes in stream flow, streambank erosion, and habitat alterations caused by stormwater are considered, despite the relative inattention given to them in current regulations.

Chapter 2 presents the regulatory history of stormwater control in the United States, focusing on relevant portions of the CWA and the regulations that have been created to implement the Act. Federal, state, and local programs for or affecting stormwater management are described and critiqued. Chapter 3 deals with the first item in the statement of task. It reviews the scientific aspects of stormwater, including sources of pollutants in stormwater, how stormwater moves across the land surface, and its impacts on receiving waters. It reflects the best of currently available science, and addresses biological endpoints that go far beyond ambient water quality criteria. Methods for monitoring and modeling stormwater (the subject of the second item in the statement of task) are described in Chapter 4. The material evaluates the usefulness of current benchmark and MS4 monitoring requirements, and suggestions for improvement are made. The latter half of the chapter considers the multitude of models available for linking stormwater discharges to ambient water quality. This analysis makes it clear that stormwater pollution cannot yet be treated as a deterministic system (in which the contribution of individual dischargers to a waterbody impairment can be identified) without significantly greater investment in model development. Addressing primarily the third item in the statement of task, Chapter 5 considers the vast suite of both structural and nonstructural measures designed to control stormwater and reduce its pollutant loading to waterbodies. It also takes on relevant larger-scale concepts, such as the benefit of stormwater management within a watershed framework. In Chapter 6, the limitations and possibilities associated with a new regulatory approach are explored, as are those of an enhanced but more traditional scheme. Numerous suggestions for improving the stormwater permitting process for municipalities, industrial sites, and con-

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struction are made. Along with Chapter 2, this chapter addresses the final two items in the committee's statement of task.

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2
The Challenge of Regulating Stormwater

Although stormwater has long been regarded as a major culprit in urban flooding, only in the past 30 years have policymakers appreciated the significant role stormwater plays in the impairment of urban watersheds. This recent rise to fame has led to a cacophony of federal, state, and local regulations to deal with stormwater, including the federal Clean Water Act (CWA) implemented by the U.S. Environmental Protection Agency (EPA). Perhaps because this longstanding environmental problem is being addressed so late in the development and management of urban watersheds, the laws that mandate better stormwater control are generally incomplete and were often passed for other purposes, like industrial waste control.

This chapter discusses the regulatory programs that govern stormwater, particularly the federal program, explaining how these programs manage stormwater only impartially and often inadequately. While progress has been made in the regulation of urban stormwater—from the initial emphasis on simply moving it away from structures and cities as fast as possible to its role in degrading neighboring waterbodies—a significant number of gaps remain in the existing system. Chapter 6 returns to these gaps and considers the ways that at least some of them may be addressed.

FEDERAL REGULATORY FRAMEWORK FOR STORMWATER

The Clean Water Act

The CWA is a comprehensive piece of U.S. legislation that has a goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Its long-term goal is the elimination of polluted discharges to surface waters (originally by 1985), although much of its current effort focuses on the interim goal of attaining swimmable and fishable waters. Initially enacted as the Federal Water Pollution Control Act in 1948, it was revised by amendments in 1972 that gave it a stronger regulatory, water chemistry-focused basis to deal with acute industrial and municipal effluents that existed in the 1970s. Amendments in 1987 broadened its focus to deal with more diffuse sources of impairments, including stormwater. Improved monitoring over the past two decades has documented that although discharges have not been eliminated, there has been a widespread lessening of the effects of direct municipal and industrial wastewater discharges.

A timeline of federal regulatory events over the past 125 years relevant to stormwater, which includes regulatory precursors to the 1972 CWA, is shown in Table 2-1. The table reveals that while there was a flourish of regulatory activity related to stormwater during the mid-1980s to 1990s, there has been much less regulatory activity since that time.

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TABLE 2-1 Legal and Regulatory Milestones for the Stormwater Program

1886	**Rivers and Harbors Act.** A navigation-oriented statute that was used in the 1960s and 1970s to challenge unpermitted pollutant discharges from industry.
1948 *1952* *1955*	**Federal Water Pollution Control Act.** Provided matching funds for wastewater treatment facilities, grants for state water pollution control programs, and limited federal authority to act against interstate pollution.
1965	**Water Quality Act.** Required states to adopt water quality standards for interstate waters subject to federal approval. It also required states to adopt state implementation plans, although failure to do so would not result in a federally implemented plan. As a result, enforceable requirements against polluting industries, even in interstate waters, was limited.
1972	**Federal Water Pollution Control Act.** First rigorous national law prohibiting the discharge of pollutants into surface waters without a permit. • Goal is to restore and maintain health of U.S. waters • Protection of aquatic life and human contact recreation by 1983 • Eliminate discharge of pollutants by 1985 • Wastewater treatment plant financing
	Clean Water Act Section 303(d) • Contains a water quality-based strategy for waters that remain polluted after the implementation of technology-based standards. • Requires states to identify waters that remain polluted, to determine the total maximum daily loads that would reverse the impairments, and then to allocate loads to sources. If states do not perform these actions, EPA must.
	Clean Water Act Section 208 • Designated and funded the development of regional water quality management plans to assess regional water quality, propose stream standards, identify water quality problem areas, and identify wastewater treatment plan long-term needs. These plans also include policy statements which provide a common consistent basis for decision making.
1977 *1981*	**Clean Water Act Sections 301 and 402** • Control release of toxic pollutants to U.S. waters • Technology treatment standards for conventional pollutants and priority toxic pollutants. • Recognition of technology limitations for some processes.
1977	*NRDC vs. Costle.* Required EPA to include stormwater discharges in the National Pollution Discharge Elimination System (NPDES) program.
1987	**Clean Water Act Amended Sections 301 and 402** • Control toxic pollutants discharged to U.S. waters. • Manage urban stormwater pollution. • Numerical criteria for all toxic pollutants. • Integrated control strategies for impaired waters. • Stormwater permit programs for urban areas and industry. • Stronger enforcement penalties. • Anti-backsliding provisions.

Table continues next page

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TABLE 2-1 continued

1990	**EPA's Phase I Stormwater Permit Rules are Promulgated** • Application and permit requirements for large and medium municipalities • Application and permit requirements for light and heavy industrial facilities based on Standard Industrial Classification (SIC) Codes, and construction activity ≥ 5 acres
1999	**EPA's Phase II Stormwater Permit Rules are Promulgated** • Permit requirements for census-defined urbanized areas • Permit requirements for construction sites 1 to 5 acres
1997-2001	**Total Maximum Daily Load (TMDL) Program Litigation** • Courts order EPA to establish TMDLs in a number of states if the states fail to do so. The TMDLs assign Waste Load Allocations for stormwater discharges which must be incorporated as effluent limitations in stormwater permits.
2006-2008	**Section 323 of the Energy Policy Act of 2005** • EPA promulgates rule (2006) to exempt stormwater discharges from oil and gas exploration, production, processing, treatment operations, or transmission facilities from NPDES stormwater permit program. • In 2008, courts order EPA to reverse the rule which exempted certain activities in the oil and gas exploration industry from storm water regulations. In *Natural Resources Defense Council vs. EPA* (9th Cir. 2008), the court held that it was "arbitrary and capricious" to exempt from the Clean Water Act stormwater discharges containing sediment contamination that contribute to a violation of water quality standards.
2007	**Energy Independence and Security Act of 2007** • Requires all federal development and redevelopment projects with a footprint above 5,000 square feet to achieve predevelopment hydrology to the "maximum extent technically feasible."

The Basic NPDES Program: Regulating Pollutant Discharges

The centerpiece of the CWA is its mandate "that all *discharges* into the nation's waters are unlawful, unless specifically authorized by a permit" [42 U.S.C. §1342(a)]. Discharges do not include all types of pollutant flows, however. Instead, "discharges" are defined more narrowly as "point sources" of pollution, which in turn include only sources that flow through a discrete conveyance, like a pipe or ditch, into a lake or stream [33 U.S.C. §§ 1362(12) and (14)]. Much of the focus of the CWA program, then, is on limiting pollutants emanating from these discrete, point sources directly into waters of the United States. Authority to control nonpoint sources of pollution, like agricultural runoff (even when drained via pipes or ditches), is generally left to the states with more limited federal oversight and direction.

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All point sources of pollutants are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit and ensure that their pollutant discharges do not exceed specified effluent standards. Congress also commanded that rather than tie effluent standards to the needs of the receiving waterbody—an exercise that was far too scientifically uncertain and time-consuming—the effluent standards should first be based on the best available pollution technology or the equivalent. In response to a very ambitious mandate, EPA has promulgated very specific, quantitative discharge limits for the wastewater produced by over 30 industrial categories of sources based on what the best pollution control technology could accomplish, and it requires at least secondary treatment for the effluent produced by most sewage treatment plants. Under the terms of their permits, these large sources are also required to self-monitor their effluent at regular intervals and submit compliance reports to state or federal regulators.

EPA quickly realized after passage of the CWA in 1972 that if it were required to develop pollution limits for all point sources, it would need to regulate hundreds of thousands and perhaps even millions of small stormwater ditches and thousands of small municipal stormwater outfalls, all of which met the technical definition of "point source". It attempted to exempt all these sources, only to have the D.C. Circuit Court read the CWA to permit no exemptions [*NRDC vs. Costle*, 568 F.2d 1369 (D.C. Cir. 1977)]. In response, EPA developed a "general" permit system (an "umbrella" permit that covers multiple permittees) for smaller outfalls of municipal stormwater and similar sources, but it generally did not require these sources to meet effluent limitations or monitor their effluent.

It should be noted that, while the purpose of the CWA is to ensure protection of the physical, biological, and chemical integrity of the nation's waters, the enforceable reach of the Act extends only to the discharges of "pollutants" into waters of the United States [33 U.S.C. § 1311(a); cf. PUD No. 1 of Jefferson County v. Washington Department of Ecology, 511 U.S. 700 (1994) (providing states with broad authority under section 401 of the CWA to protect designated uses, not simply limit the discharge of pollutants)]. Even though "pollutant" is defined broadly in the Act to include virtually every imaginable substance added to surface waters, including heat, it has not traditionally been read to include water volume [33 U.S.C. § 1362(6)]. Thus, the focus of the CWA with respect to its application to stormwater has traditionally been on the water quality of stormwater and not on its quantity, timing, or other hydrologic properties. Nonetheless, because the statutory definition of "pollutant" includes "industrial, municipal, and agricultural waste discharged into water," using transient and substantial increases in flow in urban watersheds as a proxy for pollutant loading seems a reasonable interpretation of the statute. EPA Regions 1 and 3 have considered flow control as a particularly effective way to track sediment loading, and they have used flow in TMDLs as a surrogate for pollutant loading (EPA Region 3, 2003). State trial courts have thus far ruled that municipal separate storm sewer system (MS4) permits issued under delegated federal authority can

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impose restrictions on flow where changes in flow impair the beneficial uses of surface waters (Beckman, 2007). EPA should consider more formally clarifying that significant, transient increases in flow in urban watersheds serve as a legally valid proxy for the loading of pollutants. This clarification will allow regulators to address the problems of stormwater in more diverse ways that include attention to water volume as well as to the concentration of individual pollutants.

Stormwater Discharge Program

By 1987, Congress became concerned about the significant role that stormwater played in contributing to water pollution, and it commanded EPA to regulate a number of enumerated stormwater discharges more rigorously. Specifically, Section 402(p), introduced in the 1987 Amendments to the CWA, directs EPA to regulate some of the largest stormwater discharges—those that occur at industrial facilities and municipal storm sewers from larger cities and other significant sources (like large construction sites)—by requiring permits and promulgating discharge standards that require the equivalent of the best available technology [42 U.S.C. § 1342(p)(3)]. Effectively, then, Congress grafted larger stormwater discharges onto the existing NPDES program that was governing discharges from manufacturing and sewage treatment plants.

Upon passage of Section 402(p), EPA divided the promulgation of its stormwater program into two phases that encompass increasingly smaller discharges. The first phase, finalized in 1990, regulates stormwater discharges from ten types of industrial operations (this includes the entire manufacturing sector), construction occurring on five or more acres, and medium or large storm sewers in areas that serve 100,000 or more people [40 C.F.R. § 122.26(a)(3)(1990); 40 C.F.R. § 122.26 (b)(14) (1990)]. The second phase, finalized in 1995, includes smaller municipal storm sewer systems and smaller construction sites (down to one acre) [60 Fed. Reg. 40,230 (Aug. 7, 1995) (codified at 40 C.F.R. Parts 122, 124 (1995)]. If these covered sources fail to apply for a permit, they are in violation of the CWA.

Because stormwater is more variable and site specific with regard to its quality and quantity than wastewater, EPA found it necessary to diverge in two important ways from the existing NPDES program governing discharges from industries and sewage treatment plants. First, stormwater discharge limits are not federally specified in advance as they are with discharges from manufacturing plants. Even though Congress directed EPA to require stormwater sources to install the equivalent of the best available technology or "best management practices," EPA concluded that the choice of these best management practices (referred to in this report as stormwater control measures or SCMs) would need to be source specific. As a result, although EPA provides constraints on the choices available, it generally leaves stormwater sources with responsibility for

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developing a stormwater pollution prevention plan and the state with the authority to approve, amend, or reject these plans (EPA, 2006, p. 15).

Second, because of the great variability in the nature of stormwater flow, some sources are not required to monitor the pollutants in their stormwater discharges. Even when monitoring is required, there is generally a great deal of flexibility for regulated parties to self-monitor as compared with the monitoring requirements applied to industrial waste effluent (not stormwater from industries). More specifically, for a small subset of stormwater sources such as Phase I MS4s, some monitoring of effluent during a select number of storms at a select number of outfalls is required (EPA, 1996a, p. VIII-1). A slightly larger number of identified stormwater dischargers, primarily industrial, are only required to collect grab samples four times during the year and visually sample and report on them (so-called benchmark monitoring). The remaining stormwater sources are not required to monitor their effluent at all (EPA, 1996a). States and localities may still demand more stringent controls and rigorous stormwater monitoring, particularly in areas undergoing a Total Maximum Daily Load (TMDL) assessment, as discussed below. Yet, even for degraded waters subject to TMDLs, any added monitoring that might be required will be limited only to the pollutants that cause the degraded condition [40 C.F.R. §§ 420.32-420.36 (2004)].

Water Quality Management

Since technology-based regulatory requirements imposed on both stormwater and more traditional types of discharges are not tied to the conditions of the receiving water—that is, they require sources only to do their technological best to eliminate pollution—basic federal effluent limits are not always adequate to protect water quality. In response to this gap in protection, Congress has developed a number of programs to ensure that waters are not degraded below minimal federal and state goals [e.g., 33 U.S.C. §§ 1288, 1313(e), 1329, 1314(l)]. Among these, the TMDL program involves the most rigorous effort to control both point and nonpoint sources to ensure that water quality goals are met [33 U.S.C. § 1313(d)].

Under the TMDL program, states are required to list waterbodies not meeting water quality standards and to determine, for each degraded waterbody, the "total maximum daily load" of the problematic pollutant that can be allowed without violating the applicable water quality standard. The state then determines what types of additional pollutant loading reductions are needed, considering not only point sources but also nonpoint sources. It then promulgates controls on these sources to ensure further reductions to achieve applicable water quality goals.

The TMDL process has four separate components. The first two components are already required of the states through other sections of the CWA: (1) identify beneficial uses for all waters in the state and (2) set water quality stan-

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dards that correlate with these various uses. The TMDL program adds two components by requiring that states then (3) identify segments where water quality goals have not been met for one or more pollutants and (4) develop a plan that will ensure added reductions are made by point and/or nonpoint sources to meet water quality goals in the future. Each of these is discussed below.

Beneficial Uses. States are required to conduct the equivalent of "zoning" by identifying, for each water segment in the state, a beneficial use, which consists of ensuring that the waters are fit for either recreation, drinking water, aquatic life, or agricultural, industrial, and other purposes [33 U.S.C. § 1313(c)(2)(A)]. All states have derived "narrative definitions" to define the beneficial uses of waterbodies that are components of all water quality standard programs. Many of these narrative criteria are conceptual in nature and tend to define general aspects of the beneficial uses. For categories such as *aquatic life uses*, most states have a single metric for differentiating uses by type of stream (e.g., coldwater vs. warmwater fisheries). In general, the desired biological characteristics of the waterbody are not well defined in the description of the beneficial use. Some states, such as Ohio, have added important details to their beneficial uses by developing tiered aquatic life uses that recognize a strong gradient of anthropogenic background disturbance that controls whether a waterbody can attain a certain water quality and biological functioning (see Box 2-1; Yoder and Rankin, 1998). Any aquatic life use tier less stringent than the CWA interim goal of "swimmable–fishable" requires a Use Attainability Analysis to support a finding that restoration is not currently feasible and recovery is not likely in a reasonable period of time. This analysis and proposed designation must undergo public comment and review and are always considered temporary in nature. More importantly, typically one or more tiers above the operative interim goal of "swimmable–fishable" are provided. This method typically will protect the highest attainable uses in a state more effectively than having only single uses.

The concept of tiered beneficial uses and use attainability is especially important with regard to urban stormwater because of the potential irreversibility of anthropogenic development and the substantial costs that might be incurred in attempting to repair degraded urban watersheds to "swimmable–fishable" or higher status. Indeed, it is important to consider what public benefits and costs might occur for different designated uses. For example, large public benefits (in terms of aesthetics and safety) might be gained from initial improvements in an urban stream (e.g., restoring base flow) that achieve modest aquatic use and protect secondary human contact. However, achieving designated uses associated with primary human contact or exceptional aquatic habitat may be much more costly, such that the perceived incremental public gains may be much lower than the costs that must be expended to achieve that more ambitious designation.

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BOX 2-1
Ohio's Tiered Aquatic Life Uses

"Designated" or "beneficial" uses for waterbodies are an important aspect of the CWA because they are the explicit water quality goals or endpoints set for each water or class of waters. Ohio was one of the first states to implement tiered aquatic life uses (TALUs) in 1978 as part of its water quality standards (WQS). Most states have a single aquatic life use for a class of waters based on narrative biological criteria (e.g., warmwater or cold-water fisheries) although many states now collect data that would allow identification of multiple tiers of condition. EPA has recognized the management advantages inherent to tiered aquatic life uses and has developed a technical document on how to develop the scientific basis that would allow States to implement tiered uses (EPA, 2005a; Davies and Jackson, 2006).

Ohio's TALUs reflect the mosaic of natural features across Ohio and over 200 years of human changes to the natural landscape. Widespread information on Ohio's natural history (e.g., Trautman's 1957 *Fishes of Ohio*) provided strong evidence that the potential fauna of streams was not uniform, but varied geographically. Based on this knowledge, Ohio developed a more protective aquatic life use tier to protect streams of high biological diversity that harbored unique assemblages of rare or sensitive aquatic species (e.g., fish, mussels, invertebrates). In its WQS in 1978, Ohio established a narrative Exceptional Warmwater Habitat (EWH) aquatic life use to supplement its more widespread general or "Warmwater Habitat" aquatic life use (WWH) (Yoder and Rankin, 1995).

The CWA permits states to assign aquatic life uses that do not meet the baseline swimmable-fishable goals of the CWA under specific circumstances after conducting a Use Attainability Analysis (UAA), which documents that higher CWA aquatic life use goals (e.g., WWH and EWH in Ohio) are not feasibly attainable. These alternate aquatic life uses are always considered temporary in case land use changes or technology changes to make restoration feasible. The accrual of more than ten years of biological assessment data by the late 1980s and extensive habitat and stressor data provided a key link between the stressors that limited attainment of a higher aquatic life use in certain areas and reaches of Ohio streams. This assessment formed the basis for several "modified" (physical) warmwater uses for Ohio waters and a "limited" use (limited resource water, LRW) for mostly small ephemeral or highly artificial waters (Yoder and Rankin, 1995). Table 2-2 summarizes the biological and physical characteristics of Ohio TALUs and the management consequences of these uses. Channelization typically maintained by county or municipal drainage and flood control efforts, particularly where such changes have been extensive, are the predominant cause of Modified and Limited aquatic life uses. Extensive channel modification in urban watersheds has led to some modified warmwater habitat (MWH) and LRW uses in urban areas. There has been discussion of developing specific "urban" aquatic life uses; however the complexity of multiple stressors and the need to find a clear link between the sources limiting aquatic life and feasible remediation is just now being addressed in urban settings (Barbour et al., 2006).

The TALUs in Ohio (EWH→LRW) reflect a gradient of landscape and direct physical changes, largely related to changes to instream habitat and associated hydrological features. Aquatic life uses and the classification strata based on ecoregion and stream size (headwater, wadeable, and boatable streams) provide the template for the biocriteria expectations for Ohio streams (see Box 2-2). Identification of the appropriate tiers for streams and UAA are a routine part of watershed monitoring in Ohio and are based on biological, habitat, and other supporting data. Any recommendations for changes in aquatic life uses are subject to public comment when the Ohio WQS are changed.

Ohio's water quality standards contain specific listings by stream or stream reach with notations about the appropriate aquatic life use as well as other applicable uses (e.g., recreation). Much of the impact of tiered uses on regulated entities or watershed management

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TABLE 2-2 Key features associated with tiered aquatic life uses in the Ohio WQS. SOURCE: EPA (2005a), Appendix B.

Aquatic Life Use	Key Attributes	Why a Waterbody Would Be Designated	Practical Impacts (compared to a baseline of WWH)
Warmwater Habitat (WWH)	Balanced assemblages of fish/invertebrates comparable to least impacted *regional* reference condition	Either supports biota consistent with numeric biocriteria for that ecoregion **or** exhibits the habitat potential to support recovery of the aquatic fauna	Baseline regulatory requirements consistent with the CWA "fishable" and "protection & propagation" goals; criteria consistent with U.S. EPA guidance with State/regional modifications as appropriate
Exceptional Warmwater Habitat (EWH)	Unique and/or diverse assemblages; comparable to upper quartile of *statewide* reference condition	Attainment of the EWH biocriteria demonstrated by both organism groups	More stringent criteria for D.O., temperature, ammonia, and nutrient targets; more stringent restrictions on dissolved metals translators; restrictions on nationwide dredge & fill permits; may result in more stringent wastewater treatment requirements
Coldwater Habitat (CWH)	Sustained presence of Salmonid or non-salmonid coldwater aquatic organisms; bonafide trout fishery	Bioassessment reveals coldwater species as defined by Ohio EPA (1987); put-and-take trout fishery managed by Ohio DNR	Same as above except that common metals criteria are more stringent; may result in more stringent wastewater treatment requirements
Modified Warmwater Habitat (MWH)	Warmwater assemblage dominated by species tolerant of low D.O., excessive nutrients, siltation, and/or habitat modifications	Impairment of the WWH biocriteria; existence and/or maintenance of hydrological modifications that cannot be reversed or abated to attain the WWH biocriteria; a use attainability analysis is required	Less stringent criteria for D.O., ammonia, and nutrient targets; less restrictive applications of dissolved metals translators; Nationwide permits apply without restrictions or exception; may result in less restrictive wastewater treatment requirements
Limited Resource Waters (LRW)	Highly degraded assemblages dominated exclusively by tolerant species; *should not* reflect acutely toxic conditions	Extensive physical and hydrological modifications that cannot be reversed and which preclude attainment of higher uses; a use attainability analysis is required	Chemical criteria are based on the prevention of acutely lethal conditions; may result in less restrictive wastewater treatment requirements

efforts arises from the tiered chemical and stressor criteria associated with each TALU. Criteria for compounds such as ammonia and dissolved oxygen vary with aquatic life use (see Table 2-2). Furthermore, application of management actions in Ohio, ranging from assigning antidegradation tiers, awarding funding for wastewater infrastructure and other projects, to issuing CWA Section 401/404 permits, are influence by the TALU and the biological assemblages present.

Ohio has been expanding its use of tiered uses by proposing tiered uses for wetlands (*http://www.epa.state.oh.us/dsw/rules/draft_1-53_feb06.pdf*) and developing new aquatic life uses for very small (primary headwater, PHW) streams. Both of these water types have a strong intersection with urban construction and stormwater practices. In Ohio this is especially so because the proposed mitigation standards for steams and wetlands are linked to TALUs (Ohio EPA, 2007).

Davies and Jackson (2006) present a good summary of the Maine rationale for TALUs: "(1) identifying and preserving the highest quality resources, (2) more accurately depicting existing conditions, (3) setting realistic and attainable management goals, (4) preserving incremental improvements, and (5) triggering management action when conditions decline" (Davies et al., 1999). Appendices A and B of EPA (2005a) provide more detailed information about the TALUs in Maine and Ohio, respectively.

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Water Quality Criteria. Once a state has created a list of beneficial uses for its waters, water quality criteria are then determined that correspond with these uses. These criteria can target chemical, biological, or physical parameters, and they can be either numeric or narrative.

In response to the acute chemical water pollution that existed when the CWA was written, the primary focus of water quality criteria was the control of toxic and conventional pollutants from wastewater treatment plants. EPA developed water quality criteria for a wide range of conventional pollutants and began working on criteria for a list of priority pollutants. These were generally in the form of numeric criteria that are then used by states to set their standards for the range of waterbody types that exist in that state. While states do not have to adopt EPA water quality criteria, they must have a scientific basis for setting their own criteria. In practice, however, states have promulgated numerical water quality standards that can vary by as much as 1,000-fold for the same contaminant but are still considered justified by the available science [e.g., the water quality criteria for dioxin—*Natural Resources Defense Council, Inc. vs. EPA*, 16 F.3d 1395, 1398, 1403-05 (4th Cir. 1993)].

The gradual abatement of point source impairments and increased focus on ambient monitoring and nonpoint source pollutants has led to a gradual, albeit inconsistent, shift by states toward (1) biological and intensive watershed monitoring and (2) consideration of stressors that are not typical point source pollutants including nutrients, bedded sediments, and habitat loss. For these parameters, many states have developed narrative criteria (e.g., "nutrients levels that will not result in noxious algal populations"), but these can be subjective and hard to enforce.

The use of biological criteria (biocriteria) has gained in popularity because traditional water quality monitoring is now perceived as insufficient to answer questions about the wide range of impairments caused by activities other than wastewater point sources, including stormwater (GAO, 2000). As described in Box 2-2, Ohio has defined biocriteria in its water quality standards based on multimetric indices from reference sites that quantify the baseline expectations for each tier of aquatic life use.

Antidegradation. The antidegradation provision of the water quality standards deals with waters that already achieve or exceed baseline water quality criteria for a given designated use. Antidegradation provisions must be considered before any regulated activity can be authorized that may result in a lowering of water quality which includes biological criteria. These provisions protect the existing beneficial uses of a water and only allow a lowering of water quality (but never lower than the baseline criteria associated with the beneficial use) where necessary to support important social and economic development. It essentially asks the question: is the discharge or activity necessary? States with refined designated uses and biological criteria have used these programs to their advantage to craft scientifically sound, protective, yet flexible antidegradation rules (see Ohio and Maine). Antidegradation is not a replacement for tiered

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BOX 2-2
Ohio's Biocriteria

After it implemented tiered aquatic life uses in 1978, Ohio developed numeric biocriteria in 1990 (Ohio WQS; Ohio Administrative Code 3745-1) as part of its WQS. Since designated uses were formulated and described in ecological terms, Ohio felt that it was natural that the criteria should be assessed on an ecological basis (Yoder, 1978). Subsequent to the establishment of the EWH tier in its WQS, Ohio expanded its biological monitoring efforts to include both macroinvertebrates and fish (Yoder and Rankin, 1995) and established consistent and robust monitoring methodologies that have been maintained to the present. This core of consistently collected data has allowed the application of analytical tools, including multimetric indices such as the Index of Biotic Integrity (IBI), the Invertebrate Community Index (ICI), and other multivariate tools. The development of aquatic ecoregions (Omernik, 1987, 1995; Gallant et al., 1989), a practical definition of biological integrity (Karr and Dudley, 1981), multimetric assessment tools (Karr, 1981; Karr et al., 1986), and reference site concepts (Hughes et al., 1986) provided the basis for developing Ohio's ecoregion-based numeric criteria.

Successful application of biocriteria in Ohio was dependent on the ability to accurately classify aquatic ecosystem changes based on primarily natural abiotic features of the environment. Ohio's reference sites, on which the biocriteria are based, reflect spatial differences that were partially explained by aquatic ecoregions and stream size. Biological indices were calibrated and stratified on this basis to arrive at biological criteria that present minimally acceptable baseline ecological index scores (e.g., IBI, ICI). Ohio biocriteria stratified by ecoregion aquatic life use and stream size are depicted in Figure 2-1.

Huron Erie Lake Plain (HELP)

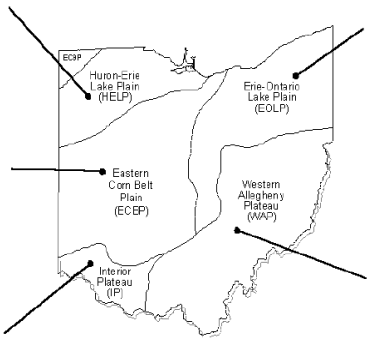
Use	Size	IBI	Mlwb	ICI
WWH	H	28	NA	34
	W	32	7.3	34
	B	34	8.6	34
MWH-C	H	20	NA	22
	W	22	5.6	22
	B	20	5.7	22
MWH-I	B	30	5.7	NA

Eastern Corn Belt Plains (ECBP)

Use	Size	IBI	Mlwb	ICI
WWH	H	40	NA	36
	W	40	8.3	36
	B	42	8.5	36
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Interior Plateau (IP)

Use	Size	IBI	Mlwb	ICI
WWH	H	40	NA	30
	W	40	8.1	30
	B	38	8.7	30
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA



Erie Ontario Lake Plain (EOLP)

Use	Size	IBI	Mlwb	ICI
WWH	H	40	NA	34
	W	38	7.9	34
	B	40	8.7	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Western Allegheny Plateau (WAP)

Use	Size	IBI	Mlwb	ICI
WWH	H	44	NA	34
	W	44	8.4	34
	B	40	8.6	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-A	H	24	NA	30
	W	24	5.5	30
	B	24	5.5	30
MWH-I	B	30	6.6	NA

Statewide Exceptional Criteria

Use	Size	IBI	Mlwb	ICI
EWH	H	50	NA	46
	W	50	9.4	46
	B	48	9.6	46

FIGURE 2-1 Numeric biological criteria adopted by Ohio EPA in 1990, using three biological indices [IBI, ICI, and the Modified Index of well-being (Mlwb), which is used to assessed fish assemblages] and showing stratification by stream size, ecoregion, and designated use (warmwater habitat, WWH; modified warmwater habitat-channelized, MWH-C; modified warmwater habitat-impounded, MWH-I; and exceptional warmwater habitat, EWH). SOURCE: EPA (2006, Appendix B). The basis for the Ohio biocriteria and sampling methods is found in Ohio EPA (1987, 1989a,b), DeShon (1995), and Yoder and Rankin (1995).

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uses, which provide a permanent floor against lowering water quality protection. Tiered beneficial uses and refined antidegradation rules can have substantial influence on stormwater programs because they influence the goals and levels of protection assigned to each waterbody.

Monitoring Programs to Identify Degraded Segments. Monitoring strategies by the states generally follow the regulatory efforts of EPA and seek to identify those waterbodies where water quality standards are not being met. Much of the initial ambient monitoring (i.e., monitoring of receiving waterbodies) was chemical based and focused on documenting changes in pollutant concentrations and exceedances of water quality criteria. Biological monitoring techniques have a long history of use as indicators of water quality impacts. However, it was not until such tools became more widespread—initially in states like Maine, North Carolina, and Ohio—that the extent of stormwater and other stressor effects on waterbodies became better understood. The biological response to common nonpoint stressors has driven the consideration of new water quality criteria (e.g., for nutrients, bedded sediments) that were not major considerations under an effluent-dominated paradigm of water management.

In parallel with the increase in biocriteria has been the development of biological monitoring to measure beneficial use attainment. Integrated biological surveys have revealed impairments of waterbodies that go beyond those caused by typical point sources (EPA, 1996b; Barbour et al., 1999a). The substantial increase in biological assemblage monitoring during the 1980s was enhanced by the development of more standard methods (Davis, 1995; Barbour et al., 1999a,b; Klemm et al., 2003) along with conceptual advances in the development of assessment tools (Karr, 1981; Karr and Chu, 1999). Development of improved classification tools (e.g., ecoregions, stream types), the reference site concept (Stoddard et al., 2006), and analytical approaches including multivariate (e.g., discriminant analysis) and multimetric indices such as IBI and ICI (see Box 2-3; Karr et al., 1986; DeShon, 1995) resulted in biological criteria being developed for several states. Biological monitoring approaches are becoming a widespread tool for assessing attainment of aquatic life use designation goals inherent to state water quality standards. Development of biocriteria represents a maturation of the use of biological data and provides institutional advantages for states in addressing pollutants without numeric criteria (e.g., nutrients) and non-chemical stressors such as habitat (Yoder and Rankin, 1998).

Setting Loads and Restricting Loading. Section 303d of the CWA requires that states compare existing water quality data with water quality standards set by the states, territories, and tribes. For those waters found to be in violation of their water quality standards, Section 303d requires that the state develop a TMDL. Currently, approximately 20,000 of monitored U.S. waters are in non-attainment of water quality standards, as evidenced by not meeting at least one specific narrative or numeric physical, chemical, or biological criterion, and thus require the development of a TMDL.

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BOX 2-3
Commonly Used Biological Assessment Indices

Much of the initial work using biological data to assess the effects of pollution on inland streams and rivers was a response to Chicago's routing of sewage effluents into the Illinois River in the late 1800s. Early research focused on the use of indicator species, singly or in aggregate, and how they changed along gradients of effluent concentrations (Davis, 1990, 1995). In the 1950s Ruth Patrick used biological data to assess rivers by observing longitudinal changes in taxonomic groups, and later in the 1950s and 1960s "diversity indices" (e.g., Shannon-Wiener index, Shannon and Weaver, 1949) were used to assess aquatic communities (Washington, 1984; Davis 1990, 1995). These indices were various mathematical constructs that measured attributes such as richness and evenness of species abundance in samples and are still widely used today in ecological studies. Similarity indices are another approach that is used to compare biological assemblages between sites. There are a wide multitude of such indices (e.g., Bray-Curtis, Jaccard) and all use various mathematical constructs to examine species in common and absent between samples.

Biotic indices are generally of more recent origin (1970s to the present). Hilsenhoff (1987, 1988) assigned organic pollution tolerances to macroinvertebrate taxa and then combined these ratings in a biotic index that is still widely used for macroinvertebrates. Karr (1981) developed the Index of Biotic Integrity (IBI), a "multimetric" index that is composed of a series of 12 metrics of a Midwest stream fish community. This approach has been widely adopted and adapted to many types of waterbodies (streams, lakes, rivers, estuaries, wetlands, the Great Lakes, etc.) and organism groups and is probably the most widely used biotic index approach in the United States. Examples include the periphyton IBI (PIBI; Hill et al., 2000) for algal communities, the Invertebrate Community Index (ICI; DeShon, 1995) and benthic IBI (B-IBI, Kerans and Karr, 1994) for macroinvertebrates, a benthic IBI for estuaries (B-IBI; Weisberg et al., 1997), and a vegetative IBI for wetlands (VIBI-E; Mack, 2007).

Various multivariate statistical approaches have also been used to assess aquatic assemblages, often concurrently with multimetric indices. Maine, for example, uses a discriminant analysis that assesses stream stations by comparison to reference sites (Davies and Tsomides, 1997). Predictive modeling approaches, incorporating both biotic and environmental variables, have been widely used in Great Britain and Europe (River Invertebrate Prediction and Classification System, RIVPACS; Wright et al., 1993), Australia (AUSRIVAS; Simpson and Norris, 2000), and more recently in the United States by Hawkins et al. (2000).

All of these approaches now have a wide scientific literature supporting their use and application. EPA (2002a) reports that most states have a biomonitoring program with at least one organism group to assess key waters in their states, although the level of implementation and sophistication varies by state. For example, only four states have numeric biocriteria in their state water quality standards, although 11 more are developing such biocriteria based on one or more of the above monitoring approaches (EPA, 2002a). The key to implementation of any of these approaches is to set appropriate goals for waters that can be accurately measured and then to use this type of information to identify limiting stressors (e.g., EPA Stressor Identification Process; EPA, 2000a).

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The TMDL process includes an enforceable pollution control plan for degraded waters based on a quantification of the loading of pollutants and an understanding of problem sources within the watershed [33 U.S.C. § 1313(d)(1)(C)]. Both point and nonpoint sources of the problematic pollutants, including runoff from agriculture, are typically considered and their contributions to the problem are assessed. A plan is then developed that may require these sources to reduce their loading to a level (the TMDL) that ensures that the water will ultimately meet its designated use. Most of the TMDL requirements have been developed through regulation. Additional effluent limits for point sources discharging into segments subject to TMDLs are incorporated into the NPDES permit.

Total Maximum Daily Load Program and Stormwater

The new emphasis on TMDLs and the revelation that impacts are primarily from diffuse sources has increased the attention given to stormwater. If a TMDL assigns waste load allocations to stormwater discharges, these must be incorporated as effluent limitations into stormwater permits. In addition, the TMDL program provides a new opportunity for states to regulate stormwater sources more vigorously. In degraded waterbodies, effluent reductions for point sources are not limited by what is economically feasible but instead include requirements that will ensure that the continued degradation of the receiving water is abated. If a permitted stormwater source is contributing pollutants to a degraded waterbody and the state believes that further reductions in pollution from that source are needed, then more stringent discharge limitations are required. For example, in *City of Arcadia vs. State Water Resources Control Board* [135 Cal. App. 4th 1392 (Ca. Ct. App. 2006)], the court held in part that California's zero trash requirements for municipal storm drains, resulting from state TMDLs, were not inconsistent with TMDL requirements or the CWA. Thus, the maximum-extent-practicable standard for MS4s, as well as other technology-based requirements for other stormwater permittees, are a floor, not a ceiling, for permit requirements when receiving waters are impaired (Beckman, 2007). Finally, since the TMDL program expects the states to regulate any source—point or nonpoint—that it considers problematic, any source of stormwater is fair game, regardless of whether it is listed in Section 402p, and regardless of whether it is a "point source." Nonpoint source runoff from agricultural and silvicultural operations is in fact a common target for TMDL-driven restrictions [see, e.g., *Pronsolino vs. Nastri*, 291 F.3d 1123, 1130 (9th Cir. 2002), upholding restrictions on nonpoint sources, such as logging, compelled by State's TMDLs)].

Despite the potential for positive interaction between stormwater regulation and the TMDL program, there appears to be little activity occurring at the stormwater–TMDL interface. This is partly because the TMDL program itself has been slow in developing. In 2000, the National Wildlife Federation applied 36 criteria to the 50 states' water quality programs and concluded that 75 per-

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cent of the states had failed to develop meaningful TMDL programs (National Wildlife Federation, 2000, pp. 1–2). The General Accounting Office (GAO, 1989) identified the lack of implementation of TMDLs as a major impediment to attaining the goals of the CWA, which led to a spate of lawsuits filed by environmental groups to reverse this pattern. The result was numerous settlements with ambitious deadlines for issuing TMDLs.

Commentators blame the delays in these TMDL programs on inadequate ambient monitoring data and on the technical and political challenges of causally linking individual sources to problems of impairment. In a 2001 report, for example, the National Research Council (NRC) noted that unjustified and poorly supported water quality standards, a lack of monitoring, uncertainty in the relevant models, and a failure to use biocriteria to assess beneficial uses directly all contributed to the delays in states' abilities to bring their waters into attainment through the TMDL program (NRC, 2001). Each of these facets is not only technically complicated but also expensive. The cost of undertaking a rigorous TMDL program in a single state has been estimated to be about $4 billion per state, assuming that each state has 100 watersheds in need of TMDLs (Houck, 1999, p. 10476).

As a result, the technical demands of the TMDL program make for a particularly bad fit with the technical impediments already present in monitoring and managing stormwater. As mentioned earlier, the pollutant loadings in stormwater effluent vary dramatically over time and stormwater is notoriously difficult to monitor for pollutants. It is thus difficult to understand how much of a pollutant a stormwater point source contributes to a degraded waterbody, much less determine how best to reduce that loading so that the waterbody will meet its TMDL. As long as the focus in these TMDLs remains on pollutants rather than flow (a point raised earlier that will be considered again), the technical challenges of incorporating stormwater sources in a water quality-based regulatory program are substantial. Without considerable resources for modeling and monitoring, the regulator has insufficient tools to link stormwater contributions to water quality impairments.

These substantial challenges in linking stormwater sources back to TMDLs are reflected by the limited number of reports and guidance documents on the subject. In one recent report, for example, EPA provides 17 case studies in which states and EPA regions incorporated stormwater control measures into TMDL plans, but it is not at all clear from this report that these efforts are widespread or indicative of greater statewide activity (EPA, 2007a). Indeed, it almost appears that these case studies represent the universe of efforts to link TMDLs and stormwater management together. The committee's statement of task also appears to underscore, albeit implicitly, EPA's difficulty in making scientific connections between the TMDL and stormwater programs. This challenge is returned to in Chapter 6, which suggests some ways that the two can be joined together more creatively.

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Other Statutory Authorities that Control Stormwater

Although the CWA is by far the most direct statutory authority regulating stormwater discharges, there are other federal regulatory authorities that could lead to added regulation of at least some stormwater sources of pollution.

Critical Resources

If there is evidence that stormwater flows or pollutants are adversely impacting either endangered species habitat or sensitive drinking water sources, federal law may impose more stringent regulatory restrictions on these activities. Under the Endangered Species Act, stormwater that jeopardizes the continued existence of endangered species may need to be reduced to the point that it no longer threatens the endangered or threatened populations in measurable ways, especially if the stormwater discharge results from the activity of a federal agency [16 U.S.C. §§ 1536(a), 1538(a)].

Under the Safe Drinking Water Act, a surface water supply of drinking water must conduct periodic "sanitary surveys" to ensure the quality of the supply (see 40 C.F.R. § 142.16). During the course of these surveys, significant stormwater contributions to pollution may be discovered that are out of compliance or not regulated under the Clean Water Act because they are outside of an MS4 area. Such a discovery could lead to more rigorous regulation of stormwater discharges. For a groundwater source that supplies 50 percent or more of the drinking water for an area and for which there is no reasonably available alternative source, the aquifer can be designated as a "Sole Source Aquifer" and receive greater protection under the Safe Drinking Water Act [42 U.S.C. § 300(h)-3(e)]. Stormwater sources that result from federally funded projects are also more closely monitored to ensure they do not cause significant contamination to these sole source aquifers.

Some particularly sensitive water supplies are covered by both programs. The Edwards Aquifer underlying parts of Austin and San Antonio, Texas, for example, is identified as a "Sole Source Aquifer." There are also several endangered species of fish and salamander in that same area. As a result, both the Safe Drinking Water Act and the Endangered Species Act demand more rigorous stormwater management programs to protect this delicate watershed.

Stormwater is also regulated indirectly by floodplain control requirements promulgated by the Federal Emergency Management Agency (FEMA). In order for a community to participate in the FEMA National Flood Insurance Program, it must fulfill a number of requirements, including ensuring that projects will not increase flood heights, including flood levels adjacent to the project site [see, e.g., 44 C.F.R. § 60.3(d)].

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Contaminated Sites

Continuous discharges of contaminated stormwater and other urban pollutants (particularly through combined sewer overflows) have led to highly contaminated submerged sediments in many urban bays and rivers throughout the United States. In several cases where the sediment contamination was perceived as presenting a risk to human health or has led to substantial natural resource damages, claims have been filed under the federal hazardous waste cleanup statute commonly known as Superfund (42 U.S.C. § 9601 et seq.). This liability under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) technically applies to any area—whether submerged or not—as long as there is a "release or a threat of release of a hazardous substance" and the hazardous substances have accumulated in such a way as to lead to the "incurrence of response [cleanup] costs" or to "natural resource damages" [42 U.S.C. §9607(a)]. Although only a few municipalities and sewer systems have been sued, Superfund liability is theoretically of concern for possibly a much larger number of cities or even industries whose stormwater contains hazardous substances and when at least some of the discharges were either in violation of a permit or unpermitted. The National Oceanic and Atmospheric Administration brought suit against the City of Seattle and the Municipality of Metropolitan Seattle alleging natural resource damages to Elliott Bay resulting from pollution in stormwater and combined sewer overflows; the case was settled in 1991 (*United States vs. City of Seattle*, No. C90-395WD, *http://www.gc.noaa.gov/natural-office1.html*). While some of the elements for liability remain unresolved by the courts, such as whether some or all of the discharges are exempted under the "federally permitted release" defense of CERCLA [42 U.S.C. § 9601(10)(H)], which exempts surface water discharges that are covered by a general or NPDES permit from liability, the prospect of potential liability is still present.

Diversion of Stormwater Underground or into Wetlands

In some areas, stormwater is eliminated by discharging it into wetlands. If done through pipes or other types of point sources, these activities require a permit under the CWA. Localities or other sources that attempt to dispense with their stormwater discharges in this fashion must thus first acquire an NPDES permit.

Even without a direct discharge into wetlands, stormwater can indirectly enter wetland systems and substantially impair their functioning. In a review of more than 50 studies, the Center for Watershed Protection found that increased urbanization and development increased the amount of stormwater to wetlands, which in turn "led to increased ponding, greater water level fluctuation and/or hydrologic drought in urban wetlands" (Wright et al., 2006). They found that, in

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some cases, the ability of the wetlands to naturally remove pollutants became overwhelmed by pollutant loadings from stormwater.

An even more common method of controlling stormwater is to discharge it underground. Technically, these subsurface discharges of stormwater, including dry wells, bored wells, and infiltration galleries, are considered by EPA to be infiltration or "Class V" wells, which require a permit under the CWA as long as they are in proximity to an underground source of drinking water (40 C.F.R. Parts 144, 146). While EPA's definition excludes surface impoundments and excavated trenches lined with stone (provided they do not include subsurface fluid distribution systems or amount to "improved sinkholes" that involve the man-made modification of a naturally occurring karst depression for the purpose of stormwater control), most other types of subsurface drainage systems are covered regardless of the volume discharged (40 C.F.R. § 144.81(4)).

Given EPA's recent description of SCMs considered to be Class V injection wells (EPA, 2008), most SCMs that rely on infiltration are exempted. For example, if an infiltration trench is wider than it is deep, it is exempted from the Class V well regulations. Residential septic systems are also exempted [see 40 C.F.R. §§ 144.1(g)(1)(ii) and (2)(iii)]. However, those that involve deeper dry wells or infiltration galleries appear to require Class V well permits under the Safe Drinking Water Act. Because the use of these SCMs is likely to involve expensive compliance requirements, dischargers may steer away from them.

Air Contaminants

Air pollutants from vehicular exhaust and industrial sources that precipitate on roads and parking lots can also be collected in stormwater and increase pollutant loading (see Chapter 3 discussion of atmospheric deposition). While the Clean Air Act regulates these sources of air contamination, it does not eliminate them. Stormwater that is contaminated with air pollutants may consist of both "legal" releases of air pollutants, as well as "illegal" releases emitted in violation of a permit, although the distinction between the two groups of pollutants is effectively impossible to make in practice.

Pesticides and Other Chemical Products Applied to Land and Road Surfaces

EPA regulates the licensing of pesticides as well as chemicals and chemical mixtures, although its actual authority to take action, such as restricting product use or requiring labeling, varies according to the statute and whether the product is new or existing. Although EPA technically is allowed to consider the extent to which a chemical is accumulating in stormwater in determining whether additional restrictions of the chemical are needed, EPA is not aware of any instances in its Toxic Substances Control Act (TSCA) chemical regulatory decision-

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making in which it actually used this authority to advance water quality protection (Jenny Molloy, EPA, personal communication, March 13, 2008).

In its pesticide registration program, EPA does routinely consider a pesticide's potential for adverse aquatic effects from stormwater runoff in determining whether the pesticide constitutes an unreasonable risk (Bill Jordan, EPA, personal communication, March 14, 2008). EPA has imposed use restrictions on a number of individual pesticides, such as prohibiting aerial applications, requiring buffer strips, or reducing application amounts. Presumably states and localities are tasked with primary enforcement responsibility for most of these use restrictions. EPA has also required a surface water monitoring program as a condition of the re-registration for atrazine and continues to evaluate available surface water and groundwater data to assess pesticide risks (Bill Jordan, EPA, personal communication, March 14, 2008).

EPA STORMWATER PROGRAM

Stormwater is defined in federal regulations as "storm water runoff, snow melt runoff, and surface runoff and drainage" [40 CFR §122.26(b)(13)]. EPA intended that the term describe runoff from precipitation-related events and not include any type of non-stormwater discharge (55 Fed. Reg. 47995). A brief discussion of the evolution of the EPA's stormwater program is followed by an explanation of the permitting mechanisms and the various ways in which the program has been implemented by the states. As shown in Figure 2-2, the entire NPDES program has grown by almost an order of magnitude over the past 35 years in terms of the number of regulated entities, which explains the reliance of the program on general rather than individual permits. Both phases of the stormwater program have brought a large number of new entities under regulation.

Historical Background

States like Florida, Washington, Maryland, Wisconsin, and Vermont and some local municipalities such as Austin, Texas, Portland, Oregon, and Bellevue, Washington, preceded the EPA in implementing programs to mitigate the adverse impacts of stormwater quality and quantity on surface waters. The State of Florida, after a period of experimentation in the late 1970s, adopted a rule that required a state permit for all new stormwater discharges and for modifications to existing discharges if flows or pollutants increased (Florida Administrative Code, Chapter 17-25, 1982). The City of Bellevue, WA, established a municipal utility in 1974 to manage stormwater for water quality, hydrologic balance, and flood management purposes using an interconnected system of natural areas and existing drainage features.

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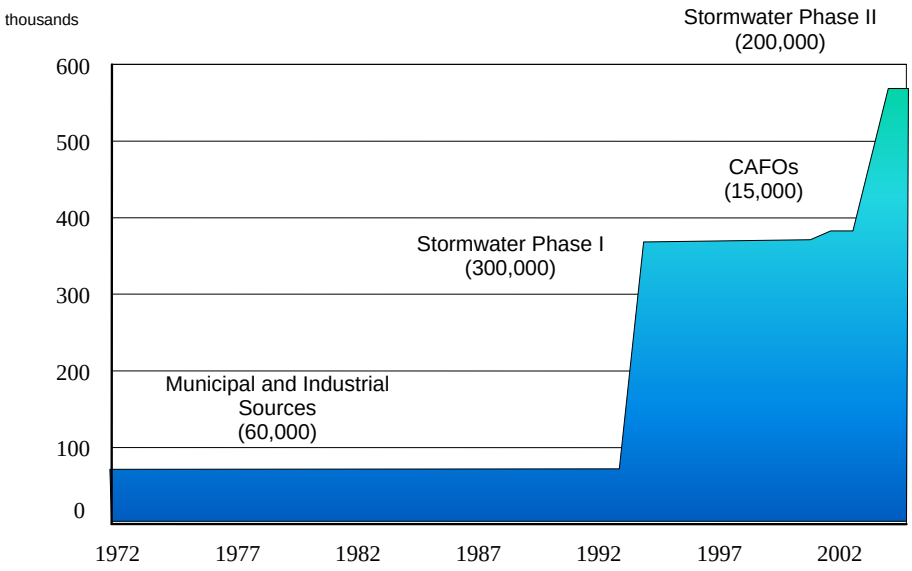

FIGURE 2-2 The number of permittees under the NPDES program of the Clean Water Act from 1972 to the present. Note that concentrated Animal Feeding Operations (CAFOs) are not considered in this report. SOURCE: Courtesy of Linda Boornazian, EPA.

EPA first considered regulating stormwater in 1973. At that time, it exempted from NPDES permit coverage conveyances carrying stormwater runoff not contaminated by industrial or commercial activity, unless the discharge was determined by the Administrator to be a significant contributor of pollutants to surface waters (38 Fed. Reg. 13530, May 22, 1973). EPA reasoned that while these stormwater conveyances were point sources, they were not suitable for end-of-pipe, technology-based controls because of the intermittent, variable, and less predictable nature of stormwater discharges. Stormwater pollution would be better managed at the local agency level through nonpoint source controls such as practices that prevent pollutants from entering the runoff. Further, EPA justified its decision by noting that the enormous numbers of individual permits that the Agency would have to issue would be administratively burdensome and divert resources from addressing industrial process wastewater and municipal sewage discharges, which presented more identifiable problems.

The Natural Resources Defense Council (NRDC) successfully challenged the EPA's selective exemption of stormwater point sources from the NPDES regulatory permitting scheme in federal court [*NRDC vs. Train*, 396 F.Supp. 1393 (D.D.C. 1975), *aff'd NRDC vs. Costle* 568 F.2d. 1369 (D.C. Cir. 1977)]. The court ruled that EPA did not have the authority to exempt point source discharges from the NPDES permit program, but recognized the Agency's discretion to use reasonable procedures to manage the administrative burden and to

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define what constitutes a stormwater point source. Consequently, EPA issued a rule establishing a comprehensive permit program for all stormwater discharges (except rural runoff) including municipal separate storm sewer systems (MS4s), which were to be issued "general" or area permits after a period of study (41 Fed. Reg. 11307, March 18, 1976). Individual permits were required for stormwater discharges from industrial or commercial activity, or where the stormwater discharge was designated by the permitting authority to be a significant contributor of pollutants. Comprehensive revisions to the NPDES regulations were published next, retaining the broad definition of stormwater discharges subject to the NPDES permit program and requiring permit application requirements similar to those for industrial wastewater discharges, including testing for an extended list of pollutants (44 Fed. Reg. 32854, June 7, 1979; 45 Fed. Reg. 33290, May 19, 1980).

The new NPDES regulations resulted in lawsuits filed in federal courts by a number of major trade associations, member companies, and environmental groups challenging several aspects of the NPDES program, including the stormwater provisions. The cases were consolidated in the D.C. Circuit Court of Appeals, and EPA reached a settlement with the industry petitioners on July 7, 1982, agreeing to propose changes to the stormwater regulations to balance environmental concerns with the practical limitations of issuing individual NPDES permits and limited resources. The Agency significantly narrowed the definition of stormwater point sources to conveyances contaminated by process wastes, raw materials, toxics, hazardous pollutants, or oil and grease, and it reduced application requirements by dividing stormwater discharges into two groups based on their potential for significant pollution problems (47 Fed. Reg. 52073, November 18, 1982). EPA issued a final rule retaining the broad coverage of stormwater point sources, and a two-tiered classification to administratively regulate these stormwater discharges (49 Fed. Reg. 37998, September 26, 1984).

The rule generated considerably controversy; trade associations and industry contended that application deadlines would be impossible to meet and that the sampling requirements were excessive, while the environmental community expressed a concern that additional changes or delays would exacerbate the Agency's failure to regulate sources of stormwater pollution. On the basis of the post-promulgation comments received, EPA determined that it was necessary to obtain additional data on stormwater discharges to assess their significance, and it conducted meetings with industry groups, who indicated an interest in providing representative data on the quality of stormwater discharges of their membership. The Agency determined that the submission of representative data was the most practical and efficient means of determining appropriate permit terms and conditions, as well as priorities for the multitude of stormwater point source discharges that needed to be permitted (50 Fed. Reg. 32548, August 12, 1985).

In the mean time, the U.S. House of Representatives and the Senate both passed bills to amend the CWA in mid-1985. The separate bills were reconciled in Conference Committee, and on February 4, 1987, Congress passed the Water

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Quality Act (WQA), which specifically addressed stormwater discharges. The WQA added Section 402(p) to the CWA, which requires stormwater permits to be issued prior to October 1992 for (i) municipal stormwater discharges from large and medium municipalities based on the 1990 census; (ii) discharges associated with industrial activity; and (iii) a stormwater discharge that the Administrator determines contributes to the violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. MS4s were required to reduce pollutants in stormwater discharges to the "maximum extent practicable" (MEP). Industrial and construction stormwater discharges must meet the best conventional technology (BCT) standard for conventional pollutants and the best available technology economically achievable (BAT) standard for toxic pollutants. EPA and the NPDES-delegated states were given the flexibility to issue municipal stormwater permits on a system-wide or jurisdiction-wide basis. In addition, the WQA amended Section 402(l)(2) of the CWA to not require a permit for stormwater discharges from mining and oil and gas operations if the stormwater discharge is not contaminated by contact, and it amended Section 502(14) of the CWA to exclude agricultural stormwater discharges from the definition of point source.

These regulations had been informed by the National Urban Runoff Program, conducted from 1978 to 1983 to characterize the water quality of stormwater runoff from light industrial, commercial, and residential areas (Athayde et al., 1983). The majority of samples collected were analyzed for eight conventional pollutants and three heavy metals, and a subset was analyzed for 120 priority pollutants. The study indicated that on an annual loading basis, some of the conventional pollutants were greater than the pollutant loadings resulting from municipal wastewater treatment plants. In addition, the study found that a significant number of samples exceeded EPA's water quality criteria for freshwater.

The Federal Highway Administration conducted studies over a ten-year period ending in 1990 to characterize the water quality of stormwater runoff from roadways (Driscoll et al., 1990). A total of 993 individual stormwater events at 31 highway sites in 11 states were monitored for eight conventional pollutants and three heavy metals. In addition, a subset of samples was analyzed for certain other conventional pollutant parameters. The studies found that urban highways had significantly higher pollutant concentrations and loads than non-urban highway sites. Also, sites in relatively dry semi-arid regions had higher concentrations of many pollutants than sites in humid regions.

Final Stormwater Regulations

EPA issued final regulations in 1990 establishing a process for stormwater permit application, the required components of municipal stormwater management plans, and a permitting strategy for stormwater discharges associated with industrial activities (55 Fed. Reg. 222, 47992, November 16, 1990). Stormwater

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discharges associated with industrial activity that discharge to MS4s were required to obtain separate individual or general NPDES permits. Nevertheless, EPA recognized that medium and large MS4s had a significant role to play in source identification and the development of pollution controls for industry, and thus municipalities were obligated to require the implementation of controls under local government authority for stormwater discharges associated with industrial activity in their stormwater management program. The final regulations also established minimum sampling requirements during permit application for medium and large MS4s (serving a population based on the 1990 census of 100,000 to 250,000, and 250,000 or more, respectively). MS4s were required to submit a two-part application over two years with the first part describing the existing program and resources and the second part providing representative stormwater quality discharge data and a description of a proposed stormwater management program, after which individual MS4 NPDES permits would be issued for medium and large MS4s.

In addition, the regulations identified ten industry groups and construction activity disturbing land area five acres or greater as being subject to stormwater NPDES permits. These industries were classified as either heavy industry or light industry where industrial activities are exposed to stormwater, based on the Office of Management and Budget Standard Industrial Classifications (SIC). The main industrial sectors subject to the stormwater program are shown in Table 2-3 and include 11 regulatory categories: (i) facilities with effluent limitations, (ii) manufacturing, (iii) mineral, metal, oil and gas, (iv) hazardous waste treatment, storage, or disposal facilities, (v) landfills, (vi) recycling facilities, (vii) steam electric plants, (viii) transportation facilities, (ix) treatment works, (x) construction activity, and (xi) light industrial activity.

The second phase of final stormwater regulations promulgated on December 8, 1999 (64 Fed. Reg. 68722) required small MS4s to obtain permit coverage for stormwater discharges no later than March 10, 2003. A small MS4 is defined as an MS4 not already covered by an MS4 permit as a medium or large MS4, or is located in "urbanized areas" as defined by the Bureau of the Census (unless waived by the NPDES permitting authority), or is designated by the NPDES permitting authority on a case-by-case basis if situated outside of urbanized areas. Further, the regulations lowered the construction activities regulatory threshold for permit coverage for stormwater discharges from five acres to one acre.

To give an idea of the administrative burden associated with the stormwater program and the different types of permits, Table 2-4 shows the number of regulated entities in the Los Angeles region that fall under either individual or general permit categories. Industrial and construction greatly outweigh municipal permittees, and stormwater permittees are vastly more numerous that traditional wastewater permittees.

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TABLE 2-3 Sectors of Industrial Activity Covered by the EPA Stormwater Program

Category (see page 69)	**Sector**	**SIC Major Group**	**Activity Represented**
(i)	A	24	Timber products
(ii)	B	26	Paper and allied products
(ii)	C	28 and 39	Chemical and allied products
(i), (ii)	D	29	Asphalt paving and roofing materials and lubricants
(i) (ii)	E	32	Glass, clay, cement, concrete, and gypsum products
(i) (iii)	F	33	Primary metals
(i), (iii)	G	10	Metal mining (ore mining and dressing)
(i), (iii)	H	12	Coal mines and coal mining-related facilities
(i), (iii)	I	13	Oil and gas refining
(i), (iii)	J	14	Mineral mining and dressing
(iv)	K	HZ	Hazardous waste, treatment, storage, and disposal
(v)	L	LF	Landfills, land application sites, and open dumps
(vi)	M	50	Automobile salvage yards
(vii)	N	50	Scrap recycling facilities
(vii)	O	SE	Steam electric generating facilities
(viii)	P	40, 41, 42, 43, 51	Land transportation and warehousing
(viii)	Q	44	Water transportation
(viii)	R	37	Ship and boat building or repairing yards
(viii)	S	45	Air transportation
(ix)	T	TW	Treatment works
(xi)	U	20, 21	Food and kindred products
(xi)	V	22, 23, 31	Textile mills, apparel, and other fabric product manufacturing, leather and leather products
(xi)	W	24, 25	Furniture and fixtures
(xi)	X	27	Printing and publishing
(xi)	Y	30, 39, 34	Rubber, miscellaneous plastic products, and miscellaneous manufacturing industries
(xi)	AB	35, 37	Transportation equipment, industrial or commercial machinery
(xi)	AC	35, 36, 38	Electronic, electrical, photographic, and optical goods
(x)			Construction activity
	AD		Non-classified facilities designated by Administrator under 40 CFR §122.26(g)(1)(l)

SOURCE: 65 Fed. Reg. 64804, October 30, 2000.

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TABLE 2-4 Number of NPDES Wastewater and Stormwater Entities Regulated by the CalEPA, Los Angeles Regional Water Board, as of May 2007

Waste Type	Individual Permittees	General Permittees
Wastewater and Non-stormwater Industry	103	574
Combined Wastewater and Stormwater	23	0
Stormwater (pre-1990)	45	0
Industrial Stormwater (post-1990)	0	2990
Construction Stormwater (post-1990)	0	2551
Municipal Stormwater (post-1990)	100	0
Total	271	6215

Municipal Permits

States with delegated NPDES permit authority (all except Alaska, Arizona, Idaho, Massachusetts, New Hampshire, and New Mexico) issued the first large and medium MS4 permits beginning in 1990, some of which are presently in their fourth permit term. These MS4 permits require large and medium municipalities to implement programmatic control measures (the six minimum measures) in the areas of (1) public education and outreach, (2) public participation and involvement, (3) illicit discharge detection and elimination, (4) construction site runoff control, (5) post-construction runoff control, and (6) pollution prevention and good housekeeping—all to reduce the discharge of pollutants in stormwater to the *maximum extent practicable*. Efforts to meet the six minimum measures are documented in a stormwater management plan. Non-stormwater discharges to the MS4 are prohibited unless separately permitted under the NPDES, except for certain authorized non-stormwater discharges, such as landscape irrigation runoff, which are deemed innocuous nuisance flows and not a source of pollutants. MS4 permits generally require analytic monitoring of pollutants in stormwater discharges for all Phase I medium and large MS4s from a subset of their outfalls that are 36 inches or greater in diameter or drain 50 acres or more. These data, at the discretion of the permitting authority, may be compared with water quality standards and considered (by default) to be effluent limitations, which refer to any restriction, including schedules of compliance, established by a state or the Administrator pursuant to CWA Section 304(b) on quantities, rates, and concentrations of chemical, physical, biological, and other constituents discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean (40 CFR §401.11). A future exceedance of an effluent limitation constitutes a permit violation. However, permitting authorities have so far not taken this approach to interpreting MS4 stormwater discharge data.

The Phase I stormwater regulations require medium and large MS4s to inspect "high-risk" industrial facilities and construction sites within their jurisdictions. Certain industrial facilities and construction sites of a minimum acreage are also subject to separate EPA/state permitting under the industrial and con-

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struction general permits (see below). While EPA envisioned a partnership with municipalities on these inspections in its Phase I Rule Making, it provided no federal funding to build these partnerships. Both industry and municipalities have argued that the dual inspection responsibilities are duplicative and redundant. Municipalities have further contended that the inspection of Phase I industrial facilities and construction sites are solely an EPA/state obligation, although state and federal courts have ruled otherwise. In the committee's experience, many MS4s do not oversee or regulate industries within their boundaries.

As part of the Phase II program, small MS4s are covered under general permits and are required to implement a stormwater management program to meet the six minimum measures mentioned above. Unlike with Phase I, Phase II MS4 stormwater discharge monitoring was made discretionary, and inspection of industrial facilities within the boundary of a Phase II MS4 is not required.

Industrial Permits

EPA issued the first nationwide multi-sector industrial stormwater general permit (MSGP) on September 29, 1995 (60 Fed. Reg. 50804), which was reissued on October 30, 2000 (65 Fed. Reg. 64746). A proposed new MSGP was released for public comment in 2005 (EPA, 2005b). The proposed MSGP requires that industrial facility operators prepare a stormwater pollution prevention plan (similar to an MS4's stormwater management plan) that documents the SCMs that will be implemented to reduce pollutants in stormwater discharges. They must achieve technology-based requirements using BAT or BCT or water quality-based effluent limits, which is the same requirement as for process wastewater permits.

All industrial sectors covered under the MSGP must conduct visual monitoring four times a year. The visual monitoring is performed by collecting a grab sample within the first hour of stormwater discharge and observing its characteristics qualitatively. A subset of MSGP industrial categories is required to perform analytical monitoring for benchmark pollutant parameters four times in Year 2 of permit coverage and again in Year 4 if benchmarks were exceeded in Year 2. The benchmark pollutant parameters, listed in Table 2-5, were selected based on the sampling data included with group permit applications submitted after the EPA issued its stormwater regulations in 1990. To comply with the benchmark monitoring requirements, a grab sample must be collected within the first hour of stormwater discharge after a rainfall event of 0.1 inch or greater and with an interceding dry period of at least 72 hours. A benchmark exceedance is not a permit violation, but rather is meant to trigger the facility operator to investigate SCMs and make necessary improvements.

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TABLE 2-5 Industry Sectors and Sub-Sectors Subject to Benchmark Monitoring

MSGP Sector	**Industry Sub-sector**	**Required Parameters for Benchmark Monitoring**
C	Industry organic chemicals Plastics, synthetic resins, etc. Soaps, detergents, cosmetics, perfumes Agricultural chemicals	Al, Fe, nitrate and nitrite N Zn Zn, nitrate and nitrite N Pb, Fe, Zn, P, nitrate and nitrite N
D	Asphalt paving and roofing materials	TSS
E	Clay products Concrete products	Al TSS and Fe
F	Steel works, blast furnaces, rolling and finishing mills Iron and steel foundries Non-ferrous rolling and drawing Non-ferrous foundries (casting)	Al, Zn Al, Cu, Fe, Zn, TSS Cu, Zn Cu, Zn
G	Copper ore mining and dressing	COD, TSS, nitrate and nitrite N
H	Coal mines and coal mining related facilities	TSS
J	Dimension stone, crushed stone, and non-metallic minerals (except fuels) Sand and gravel mining	TSS, Al, Fe Nitrate and nitrite N, TSS
K	Hazardous waste treatment, storage, or disposal	NH_3, Mg, COD, Ar, Cd, CN, Pb, Hg, Se, Ag
L	Landfills, land application sites, and open dumps	Fe, TSS
M	Automobile salvage yards	TSS, Al, Fe, Pb
N	Scrap recycling	Cu, Al, Fe, Pb, Zn, TSS, COD
O	Steam electric generating facilities	Fe
Q	Water transportation facilities	Al, Fe, Pb, Zn
S	Airports with deicing activities	BOD, COD, NH_3, pH
U	Grain mill products Fats and oils	TSS BOD, COD, nitrate and nitrite N, TSS
Y	Rubber products	Zn
AA	Fabricated metal products except coating Fabricated metal coating and engraving	Fe, Al, Zn, nitrate and nitrite N Zn, nitrate and nitrite N

NOTE: BOD, biological oxygen demand; COD, chemical oxygen demand; TSS, total suspended solids.
SOURCE: 65 Fed. Reg. 64817, October 30, 2000.

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EPA had already established technology-based effluent limitations for stormwater discharges for eight subcategories of industrial discharges prior to 1987, namely, for cement manufacturing, feedlots, fertilizer manufacturing, petroleum refining, phosphate manufacturing, steam electric, coal mining, and ore mining and dressing (see Table 2-6). Most of these facilities were covered under individual permits prior to 1987 and are generally required to stay covered under individual stormwater permits. Facilities in these sub-categories that had not been issued a stormwater discharge permit prior to 1992 are allowed to be covered under the MSGP, but they still have analytical monitoring requirements that must be compared to effluent limitation guidelines. An exceedance of the effluent limitation constitutes a permit violation.

TABLE 2-6 Select Stormwater Effluent Limitation Guidelines for Illustrative Purposes

Discharges	**Design Storm**	**Pollutant Parameters**	**Effluent Limitations (max per day)**
Phosphate Fertilizer Manufacturing Runoff (40 C.F.R. 418)	Not specified	Total P Fluoride	105 mg/L 75 mg/L
Petroleum Refining (40 C.F.R. 419)	Not specified	O&G TOC BOD5 COD Phenols Cr Hex Cr pH	15 mg/L 110 mg/L 48 kg/1000 m^3 flow 360 mg/1000 m^3 flow 0.35 mg/1000 m^3 flow 0.73 mg/1000 m^3 flow 0.062 mg/1000 m^3 flow 6–9
Asphalt Paving and Roofing Emulsion Products Runoff (40 C.F.R. 443)	Not specified	TSS O&G pH	0.023 kg/m^3 0.015 kg/m^3 6.0–9.0
Cement Manufacturing Material Storage Piles Runoff (40 C.F.R. 411)	10 yr, 24 hour	TSS pH	50 mg/L 6.0–9.0
Coal Mining (40 C.F.R. 434 Subpart B)	1 yr, 24 hour	Fe Mn TSS pH	7.0 mg/L 4 mg/L 70 mg/L 6.0–9.0
Steam Electric Power Generating (40 C.F.R. 423)	10 yr, 24 hour	TSS pH PCBs	50 mg/L 6.0–9.0 No discharge

NOTE: BOD5, biological oxygen demand; COD, chemical oxygen demand; O&G, oil and grease; PCBs, polychlorinated biphenyls; TOC, total organic carbon; TSS, total suspended solids. SOURCE: 40 C.F.R.

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At the issuance of the Final Storm Water Rule in 1990, EPA envisioned the use of a mix of general permits and individual permits to better manage the administrative burden associated with permitting thousands of industrial stormwater point sources. In its original permitting strategy for industrial stormwater discharges, EPA articulated a four-tier strategy with the nationwide general permits: Tier 1 was baseline permitting, Tier 2 would incorporate watershed permits, Tier 3 would be industry category-specific permitting, and Tier 4 would encompass facility-specific individual permits. In reality, individual permits, which would allow for the crafting of permit conditions to be better structured to the specific industrial facility based on its higher potential risk to water quality, and could include adequate monitoring for purposes of compliance and enforcement, have been sparsely used. Similarly, neither the watershed permitting strategy nor the industry category-specific permitting strategy has found favor in the absence of better federal guidance and funding.

Industrial stormwater general permits are issued by the State NPDES Permitting Authority in NPDES-delegated states, and may be in the form a single statewide permit covering thousands of industrial permittees or sector-specific stormwater general permits covering less than a hundred facilities. EPA Regions issue the MSGP in states without NPDES-delegated authority and for facilities on Native Indian and Tribal Lands. EPA's nationwide 2000 MSGP presently covers 4,102 facilities.

Construction Permits

EPA issued the first nationwide construction stormwater general permit (CGP) in February 1998 (63 Fed. Reg. 7858). The permits are valid for five-year terms. The most recent CGP was issued in 2005 (68 Fed. Reg. 39087), and the EPA in 2008 administratively continued the CGP until the end of 2009, when it is expected to have developed effluent guidelines for construction activity (73 Fed. Reg. 40338). The EPA is presently under court order to develop effluent limitation guidelines for stormwater discharges from the construction and land development industry. The construction general permit requires the implementation of stormwater pollution prevention plans to prevent erosion, control sediment in stormwater discharges, and manage construction waste materials. Operators of the construction activity are required to perform visual inspections regularly, but no sampling of stormwater discharge during rainfall events is required. As with the industrial and municipal permittees, an exceedance of an effluent limitation incorporated in a permit would be a violation of the CWA and is subject to penalties.

EPA's CGP covers construction activity in areas where EPA is the permitting authority, including Indian lands, Puerto Rico, the District of Columbia, Massachusetts, New Hampshire, New Mexico, Idaho, Arizona, and Alaska. All other states have been delegated the authority to issue NPDES permits, and

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these states issue CGPs based on the EPA model but with subtle variations. For example the California and Georgia CGPs include monitoring requirements for construction sites discharging to sediment-impaired waterbodies. Wisconsin requires weekly inspections and an inspection within 24 hours of a rain event of 0.5 inches or greater. Georgia imposes discharge limits of an increase of no more than 10 Nephelometric Turbidity Units (NTU) above background in trout streams and no more than 25 NTU above background in other types of streams.

Permit Creation, Administration, and Requirements

For individual permits, the entity seeking coverage submits an application and one permit is issued. The conditions of the permit are based on an analysis of information provided in a rather lengthy permit application by the facility operator about the facility and the discharge. Generally, it takes six to 18 months for the permittee to compile the application information and for the permitting authority to finalize the permit. Individual permits are common for medium and large MS4s (Phase I), small MS4s in a few states (Phase II), and a few industrial activities.

General permits, on the other hand, are issued by the permitting authority, and interested parties then submit an Notice of Intent (NOI) to be covered. This mechanism is used where large numbers of dischargers require permit coverage, such as construction activities, most industrial activities, and most small MS4s (Phase II). The permit must identify the area of coverage, the sources covered, and the process for obtaining coverage. Once the permit is issued, a permittee may submit a NOI and receive coverage either immediately or within a very short time frame (e.g., 30 days).

All permits contain "effluent limitations" or "effluent guidelines," adherence to which is required of the permittee. However, the terms (which are synonymous) are agonizingly broad and encompass (1) meeting numeric pollutant limits in the discharge, (2) using certain SCMs, and (3) meeting certain design or performance standards. Effluent limitations may be expressed as SCMs when numeric limits are infeasible or for stormwater discharges where monitoring data are insufficient to carry out the purposes and intent of the CWA [122.44(k)]. If EPA has promulgated numerical "effluent guidelines" for existing and new stormwater sources under CWA Sections 301, 304, or 306, then the permits must incorporate the "effluent guidelines" as permit limits.

Effluent limitations can be either technology-based or water quality-based requirements. Technology-based requirements establish pollutant limits for discharges on what the best pollution control technology installed for that industry would normally accomplish. Water-quality based requirements, by contrast, look to the receiving waters to determine the level of pollution reduction needed for individual sources. There are national technology-based standards available for many categories of point sources, including many industrial sectors and municipal wastewater treatment plants. In the absence of national standards, tech-

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nology-based requirements are developed on a case-by-case basis using best professional judgment. In general, BAT is the standard for toxic and non-conventional pollutants, while BCT is the standard for conventional pollutants. Water quality-based effluent limitations are required where technology-based limits are found to be insufficient to achieve applicable water quality standards, including restoring impaired waters, preventing impairments, and protecting high-quality waters. Limitations must control all pollutants or pollutant parameters that are or may be discharged at a level which will *cause, have reasonable potential to cause, or contribute to* an excursion above any applicable water quality standard. To distinguish between technology-based and water quality-based effluent limits, consider that a permittee is required to meet a numeric pollutant limit in their stormwater discharge. A technology-based limit would be based on studies of effluent concentrations coming from that technology, while a water quality-based limit would be based on some assessment of the impact of the discharge on a nearby receiving water (with the applicable water quality standard being the most conservative choice).

EPA is presently writing stormwater "effluent guidelines" for airport deicing operations and construction/development activity, with an estimated final action date of December 2009.

Permits Prior to 1990

A limited number of individual stormwater permits (perhaps in the low thousands) were first issued prior to 1990, the period before EPA promulgated regulations specific to stormwater discharges, and before EPA first received the authority to issue general NPDES permits. These individual NPDES permits for industrial stormwater discharges, like traditional individual wastewater NPDES permits, incorporate numerical effluent limits and they impose discharge monitoring requirements to demonstrate compliance. These facilities were selected for permitting before 1990, presumably because of the risk they presented to causing or contributing to the exceedance of water quality standards.

Do Permittees Have to Meet Water Quality Standards in their Effluent?

It is unclear as to whether municipal, industrial, and construction stormwater discharges must meet water quality standards. Furthermore, even if such discharges were required to meet water quality standards, the absence of monitoring found within the permits means that enforcement of the requirement would be difficult at best. Nonetheless, some sources suggest that, with the exception of Phase II MS4 discharges, EPA's intent is that stormwater discharges comply with water quality standards, especially where a TMDL is in place.

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First, the EPA Office of General Counsel issued a memorandum in 1991 stating that municipal stormwater permits must require that MS4s reduce stormwater pollutant discharges to the maximum extent practicable and must also comply with water quality standards. Recognizing the complexity of stormwater, EPA's 1996 Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits (61 Fed. Reg. 43761) stated that stormwater permits should use SCMs in first-term stormwater permits and expanded or better-tailored SCMs in subsequent term permits to provide for the attainment of water quality standards. However, where adequate information existed to develop more specific conditions or limitations to meet water quality standards, these conditions or limitations are to be incorporated into stormwater permits as necessary and appropriate.

As permitting authorities began to develop TMDL waste load allocations to address impaired receiving waters, and waste load allocations were assigned to stormwater discharges, EPA issued a TMDL Stormwater Policy. It stated that stormwater permits must include permit conditions consistent with the assumptions and requirements of available waste load allocations (EPA, 2002b). Since waste load allocations derive directly from water quality standards, this could be interpreted as saying that stormwater discharges must meet water quality standards. However, EPA expected that most water quality-based effluent limitations for NPDES-regulated stormwater discharges that implement TMDL waste load allocations would be expressed as SCMs, and that numeric limits would be used only in rare instances. This is understandable, given that storm events are dynamic and variable and it would be expensive to monitor all storm events and discharge points, particularly for MS4s, to demonstrate compliance with a waste load allocation expressed as a numeric effluent limitation. Effluent limitations expressed as SCMs appear to be the best interim approach to demonstrate compliance with TMDLs, provided that these SCMs are reasonably expected to satisfy the waste load allocation in the TMDL. As part of the TMDL, the NPDES permit must also specify the monitoring necessary to determine compliance with effluent limitations. Where effluent limits are specified as SCMs, the permit should specify the monitoring necessary to assess if the load reductions expected from SCM implementation are achieved (e.g., SCM performance data).

Implementation of the Stormwater Program by States and Municipalities

NPDES-delegated states and Indian Tribes generally utilize the CGP and the MSGP as model templates for adopting their respective general permits to regulate stormwater discharges associated with industrial activity, including construction, within their jurisdictions. Nevertheless, some variations exist. For example, the California CGP requires sampling of stormwater at construction sites that discharge to surface waters that are listed as being impaired for sediment. Connecticut's MSGP regulates stormwater discharges associated with

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commercial activity, in addition to industrial activity. With respect to the municipal permits, the variability with which the stormwater program is implemented reflects the flexibility inherent in the MEP standard. In the absence of a definite description of MEP or nationwide effluent guidelines issued by EPA, states and municipalities have not been very rigorous in determining what constitutes an adequate level of compliance. This self-defined compliance threshold has been translated into a wide range of efforts at program implementation.

A number of MS4 programs have been leaders in some areas of program implementation. For example, Prince George's County, Maryland, was a pioneer in implementing low impact development (LID) techniques. Notable efforts have been made by states and municipalities in the Pacific Northwest, such as Oregon and Washington. California and Florida also are in the forefront of implementing comprehensive and progressive stormwater programs.

Greater implementation is evident in states that had state stormwater regulations in place prior to the advent of the national stormwater program (GAO, 2007). Some states issued early MS4 permits (e.g., California, Florida, Washington, and Wisconsin) prior to the promulgation of the national stormwater program, while a number of MS4s (e.g., Austin, Texas,; Santa Monica, California; and Bellevue, Washington) were already implementing comprehensive stormwater management programs. In addition, some MS4s conducted individual stormwater management activities, such as street-sweeping, household hazardous waste collection, construction site plan review, and inspections, prior to the national stormwater program. These areas are more likely than areas without a stormwater program that predated the EPA program to be successfully meeting the requirements of the current program.

One of the obvious differences is the level of interest and effort exercised by coastal communities or communities in close proximity to a water resource that have immediate access to the beneficial uses of those resources but also have an immediate view of the impacts of polluted runoff. That interest may contrast with the less active posture of upstream or further inland communities that may not be as sensitive and willing to implement more stringent stormwater programs. A recent report has found that programs with more specific permit requirements generally result in more comprehensive and progressive stormwater management programs (TetraTech, 2006a). The report concluded that permittees should be required to develop measurable goals based on the desired outcomes of the stormwater program. Furthermore, additional stormwater permit requirements can be expected as more TMDLs are developed and wasteload allocations must be translated into permit conditions.

GAO Report on Current Status of Implementation

In 2007, the GAO issued a report to determine the impact of EPA's Stormwater Program on communities (GAO, 2007). Some of the relevant findings are

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that urban stormwater runoff continues to be a major contributor to the nation's degraded waters and that stormwater program implementation has been slow for both Phase I and Phase II communities, with almost 11 percent of all communities not yet permitted as of fall 2006. Litigation, among other reasons, delayed the issuance of some permits for years after the application deadlines. As a result, almost all Phase II and some Phase I communities are still in the early stages of program implementation although deadlines for permit applications were years ago—16 years for Phase I and six years for Phase II. EPA has acknowledged that it does not currently have a system in place to measure the success of the Phase I program on a national scale (EPA, 2000b). Therefore, it is reasonable to conclude that the level of implementation of the stormwater program ranges widely, from municipalities having completed a third-term permit (such as Los Angeles County MS4 permit) to municipalities not yet covered by a Phase II MS4 permit.

The GAO report also indicates that communities' inconsistent reporting of activities makes it difficult to evaluate program implementation nationwide. Based on the report's findings it seems that little auditing activity has been performed to gauge the status of implementation and effectiveness in achieving water quality improvements. Most often cited is the effort by EPA's Region 9 and the State of California auditors that recently discovered, among other things, that some MS4s (1) had not developed stormwater management plans, (2) were not properly performing an adequate number of inspections to enforce their stormwater ordinances, and (3) were lax in implementing SCMs at publicly owned construction sites. They also found that some MS4s were not adequately controlling stormwater runoff at municipally owned and operated facilities, such as maintenance yards. In response to these findings, EPA issued in January 2007 an MS4 Program Evaluation Guidance document (EPA, 2007b).

In the absence of a nationwide perspective of the implementation of the stormwater program, it is hard to make a determination about the program's success. There are communities and states that seem to have made great strides in implementing progressive stormwater programs, but it also seems that overall many programs are still in the early stages of implementation, while a number of communities are still waiting to obtain coverage under the MS4 permits. In addition, it appears that there is no national uniform system of tracking success or cost data. All these unknowns make it very difficult to formulate any definite statements about how successful the implementation of the program is on a national perspective.

Committee Survey

In order to get a better understanding of how the stormwater program is implemented by the states, during 2007 the committee conducted two surveys asking states about their monitoring requirements, compliance determination, and other facts for each program (municipal, industrial, and construction). For the

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larger survey, 18 states representing all ten EPA regions responded to the survey. Both surveys and all responses are found in Appendix C.

As expected, the responding states reported that Phase I MS4s are required to sample their stormwater discharges for pollutants, although the frequency of sampling and the number of pollutants being sampled tended to vary. No state reported requiring Phase II MS4s to sample stormwater discharges. Monitoring requirements for industrial stormwater varied by state from none in Minnesota, Nebraska, and Maine to benchmark monitoring required under the MSGP in Virginia, New York, and Wyoming. California, Connecticut, and Washington require all industrial facilities to monitor for select chemical pollutants. Connecticut, additionally, requires sampling for aquatic toxicity. Most of the responding states do not require construction sites to do much more than visual monitoring periodically and after rain events. Georgia and Washington require construction sites to monitor for parameters such as turbidity and pH. California and Oregon require sampling when the discharge is to a waterbody impaired by sediment.

As mentioned previously, Phase I MS4s (but not Phase II MS4s) are required to address industrial dischargers within their boundaries. There was considerable variability regarding the survey questions of whether MS4s can conduct inspections of industrial facilities and what industries are considered high risk. In all of the responding states except Virginia, the responders think that MS4s have the authority to inspect industries within their boundaries, although the extent to which this is done is not clear and, in the committee's experience, is quite rare. Many of the responding states have not identified "high-risk" facilities and targeted them for compliance scrutiny, although certain categories were felt to be problematic by the state employee responding to the survey, such as metal foundries, auto salvage yards, metal recyclers, cement plants, and saw mills. In California and Washington, however, some of the Phase I MS4 permits have identified high-risk facilities for the municipal permittee to inspect.

Georgia, Maine, Minnesota, Nevada, New York, Vermont, and Washington have State Guidance Manuals for MS4 implementation, while in California a coalition of municipalities and the California Department of Transportation have developed MS4 guidance manuals. The rest of the responding states rely on general guidance provided by the EPA. State guidance manuals for the implementation of the industrial stormwater program were less common than guidance manuals for construction activity, with only California and Washington having such guidance manuals. In contrast, except for Nebraska and Oklahoma, statewide guidance manuals for erosion and sediment control were available. This may have resulted from the fact that many states had laws in place that required erosion and sediment control practices during land development, timber harvesting, and agricultural farming that predated the EPA stormwater regulations.

In an attempt to determine the level of oversight that a state provides for industrial and construction operations, the survey asked whether and to whom

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stormwater pollution prevention plans (SWPPPs) are submitted. Most of the responding states require the stormwater pollution prevention plans that industrial facilities prepare to be retained at the facility and produced when requested by the state. Only Oregon, Vermont, Washington, and Hawaii required industrial SWPPPs to be submitted to the state when seeking coverage under the MSGP. The practice for the submittal of construction SWPPPs was similar, except that some states required that SWPPPs for large construction projects be submitted to the state.

Compliance with the MS4 permit in the responding States is mainly determined through the evaluation of annual reports and program audits, although no indication was given of the frequency of audits. Regulators in Maine have monthly meetings with municipalities. The responding states evaluate compliance with the MSGP by reviewing annual monitoring reports and conducting inspections of industrial facilities. Connecticut characterized its industrial inspections as "regular," Maine inspects industrial facilities twice per five-year permit cycle, while Vermont performs visual inspections four times a year. No other responding states specified the frequency of inspections. Inspections and reviews of the SWPPPs constitute the main ways for responding states to determine the compliance of sites and facilities covered under the CGP.

With respect to the extent of actual compliance, few states have such information, partly because it has not routinely been collected and analyzed. West Virginia has found that, of the 871 permitted industrial facilities in the state, 576 were delinquent in submitting the results of their benchmark monitoring. Several case studies of compliance rates for municipal, industrial, and construction sites in Southern California are presented in Box 2-4. The data suggest that compliance in all three groups is poor, particularly for industrial sites. This may be partly explained by the preponderance of small businesses covered by the MSGP, whose operators may have financial difficulty in committing funds to SCMs, or lack a recognition and knowledge of the stormwater program and its requirements.

Another aspect of compliance is the extent to which industrial facilities have identified themselves and applied for coverage under the state MSGP. Six states responded to the committee's survey about that topic; only two of the six (California and Vermont) have made efforts to determine the numbers of non-filers of an NOI to be covered by the MSGP. In both cases, the efforts, which involved mailings, telephone calls, and file review, found that the number of non-filing facilities that should be subject to the MSGP was substantial (see Box 2-5 for California's data). Duke and Augustenborg (2006) studied this level of compliance (whether industries are filing an NOI for permit coverage) and found incomplete compliance that is variable among states and urbanized areas. Texas and Oklahoma had higher levels of permit coverage than California or Florida.

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BOX 2-4
Compliance with Stormwater Permits in Southern California

Construction General Permits

In order to determine the compliance of construction sites with the general stormwater permit, data were collected and analyzed from three sources: (1) an audit performed in June 2004 of the development construction program of five cities that are permittees in the Los Angeles County MS4 permit (about 44 sites), (2) an audit performed in February 2002 of the development construction program (among others) of five Ventura County MS4 permittees (about 32 sites), and (3) a review and inspection of 24 large construction sites (50 acres or greater of disturbed land). These sites accounted for about 5 percent of all construction sites in the region at the time, and they represent both small and large construction sites. The most common violations on construction sites were paper violations, such as incomplete SWPPPs and a lack of record keeping. Forty (40) percent of the sites had some type of paper deficiency. A close second is the absence of erosion and/or sediment control, observed on 30 percent of the sites. SOURCE: TetraTech (2002, 2006b,c).

Industrial Multi-Sector General Permit

For industrial sites, information was obtained from the following sources: (1) a review of SCM inspections performed in February 2005 which consisted of 38 sites in the transportation sector; (2) a review of inspections and non-filer identification information in the plastics sector performed in 2007, which consisted of about 100 permitted sites among a large number of non-filer sites; and (3) a review of 13 area airport inspections and 55 port tenant inspections at the ports of Los Angeles and Long Beach. The sites are about 6 percent of the total number of permittees covered by California's MSGP and represent some of the major regulated industrial sectors. The most common violations observed at industrial sites were the lack of implementation of SCMs such as overhead cover, secondary containment and/or spill control. Sixty (60) percent of the sites had poor housekeeping problems. This was followed by incomplete stormwater pollution prevention plans (40 percent). (SOURCE: E. Solomon, California EPA, Los Angeles Regional Water Board, personal communication, 2008).

In another study, the California Water Boards with the assistance of an EPA contractor conducted inspections of 1,848 industrial stormwater permittees (21 percent of permitted facilities) between 2001 and 2005 (TetraTech, 2006d). Seventy-one (71) percent of the industrial facilities inspected were not in compliance with the MSGP and 18 percent were identified as a threat to water quality. Fifty-six (56) percent of facilities that collected one or more water quality samples reported an exceedance of a benchmark. Facility follow-up inspections indicated that field presence of the California Water Boards inspectors improved facility compliance with the MSGP.

Municipal Permits

An audit similar to the TetraTech study described above was conducted for 84 Phase I and Phase II MS4s in California during the same period (TetraTech, 2006e). The audits found that municipal maintenance facilities were often deficient in implementing SCMs, MS4 permittees did not obtain adequate legal authority to implement the program, they were not inspecting industrial facilities and construction sites or were inspecting them inadequately, and they were unable to evaluate program effectiveness in improving water quality. Overall, the audits found that programs with more specific permit requirements

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BOX 2-4 Continued

generally resulted in more comprehensive and progressive stormwater management programs. For example, the Los Angeles or San Diego MS4 permits enumerate in detail the permit tasks such as the frequency of inspection, the types of facilities, and the SCMs to be inspected that permittees must perform in implementing their stormwater program. The auditors concluded that the specificity of the provisions enabled the permitting authorities to enforce the MS4 permits and improve the quality of MS4 discharges.

Compliance with Industrial Permits within MS4s

The EPA and the California EPA Los Angeles Regional Water Board conducted a limited audit of the inspection program requirements of the Los Angeles County MS4 Permit and the City of Long Beach MS4 Permit in conjunction with industrial facilities covered under the MSGP within the Ports of Los Angeles and Long Beach (EPA, 2007c). The Port of Long Beach is covered under a single NOI for its 53 tenant facilities that discharge stormwater associated with industrial activity, while 137 industrial facilities within the Port of Los Angeles file independent NOIs. At the Port of Los Angeles, of the 23 facilities that were inspected, 30 percent were judged to pose a significant threat to water quality, 43 percent were determined to have some violations with regard to implementation of SCMs or paperwork requirements, and 26 percent appeared to be in compliance with the MSGP. At the Port of Long Beach, of the 21 tenant facilities that were inspected, 14 percent were judged to pose a significant threat to water quality, 52 percent were determined to have some deficiencies with regard to implementation of SCMs or paperwork requirements, and 33 percent appeared to be in full compliance with general permit requirements. The Port of Long Beach had a more comprehensive stormwater monitoring program which indicated that several pollutant parameters were above EPA benchmark values. Communication between the MS4 departments and the ports in both programs appeared deficient. The EPA issued 20 compliance orders for violations of the MSGP, but it did not pursue any action against the MS4s overseeing the industries because it was outside the scope of the EPA audit.

LOCAL CODES AND ORDINANCES THAT AFFECT STORMWATER MANAGEMENT

Zoning and building standards, codes, and ordinances have been the basis for city building in the United States for almost a century. They define how to build to protect the health, safety, and welfare of the public, and to establish a predictable, although often lengthy and cumbersome, process for ensuring that built improvements become a well-integrated part of the larger urban environment. Review processes can be as simple as a walk-through in a local building department for a minor house remodeling project. In other cases, extended rezoning processes for larger projects can require several years of planning; multiple public meetings; multiple reviews by city, state, and federal agencies; and specialized studies to determine impacts on the natural environment and water, sewer, and transportation systems.

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BOX 2-5
Searching for Non-Filers Under the Industrial MSGP in Southern California

The California Water Boards conducted an industrial non-filer identification study between 1995 and 1998 (CA SWB, 1999). The study had three components: (1) to develop a mechanism to identify facilities subject to the industrial stormwater general permit that had not filed an NOI, which involved a comparison of commercially available and agency databases with that maintained by the California Water Boards; (2) to communicate with operators of these facilities to inform them of their responsibility to comply, which was done using post-mail, telephone calls, and filed verification; and (3) to refer responses to the communication efforts to the Water Boards for any appropriate follow-up.

About 9 percent of the potential non-filers submitted an NOI after the initial mail contact. About 52 percent of facilities indicated that they were exempt. About 37 percent failed to respond and 16 percent of mailed packages were returned unopened. A follow-up on facilities that claimed they were exempt indicated that 16 percent of them indeed needed to comply. Similarly 33 percent of facilities that failed to respond were determined as needing to file NOIs. The study suggested that only half of facilities considered heavy industrial had filed NOIs through the first five years of the program (Duke and Shaver, 1999).

The California EPA Los Angeles Regional Water Board and the City of Los Angeles conducted a study in the City of Los Angeles between January 1998 and June 2000 to identify non-filers and evaluate compliance by door-to-door visits in industrially zoned areas of the city (Swamikannu et al., 2001). The field investigations covered industrial zones totaling about 4.2 square miles, or about 22 percent of the area in the City of Los Angeles zoned for industrial land use. A total of 1,103 of suspected non-filer facilities were subject to detailed on-site facility investigation. Ninety-three (93) were determined to have already have submitted NOIs, and 436 were determined not to be subject to the industrial stormwater general permit. The site visits identified 223 potential non-filers, or industrial facilities where site-visit evidence suggested the facilities probably needed to comply with relevant regulations but that had not filed NOIs or recognized their duty to comply at the time of the visit. Of the facilities identified as potential non-filers, 202 were identified during detailed on-site investigations, or 18 percent of facilities inspected with that methodology; and 21 were identified during the less-detailed non-filer assessment visits, or 6 percent of the 379 facilities inspected with that methodology. In total, 295 of the 1,103 facilities visited under the project (about 27 percent) were known or suspected to be required to file NOIs under the permit, including 93 facilities that had previously filed NOIs and 202 facilities identified as probably required to file NOIs based on visual evidence of industrial activities exposed to stormwater. Thus, prior to the project, only 31 percent of all facilities in the project area needing to comply had submitted an NOI.

There is an overlapping and conflicting maze of codes, regulations, ordinances, and standards that have a profound influence on the ability to implement stormwater control measures, although they can be loosely categorized into three areas. Land-use zoning is the first type of control. Zoning, which was developed in response to unsanitary and unhealthy living conditions in 19th-century cities, prescribes permitted land uses, building heights, setbacks, and the arrangement of different types of land uses on a given site. Zoning often requires improvements that enhance the aesthetic and functional qualities of communities. For example, ordinances prescribing landscaping, minimum parking requirements, paving types, and related requirements have been developed to

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improve the livability of cities. These ordinances have a significant impact on both how stormwater affects waterbodies and on attempts to mitigate its impacts.

The second category involves the design and construction of buildings. National and international building codes and standards, such as the International Building Code, and Uniform Plumbing, Electrical, and Fire Codes, for example, allow local governments to establish minimum requirements for building construction. Because these controls primarily affect building construction, they have less effect on stormwater discharges than zoning.

The third category includes engineering and infrastructure standards and practices that govern the design and maintenance of the public realm—streets, roads, utilities rights-of-way, and urban waterways. Roadway design standards and emergency access requirements have resulted in contemporary cities that are 30 percent or more pavement, just to accommodate the movement and storage of vehicles in the public right-of-way. The standards for the construction of deep utilities—water and sewer lines that are typically located underneath streets—are often the reason that streets are wider than necessary to safely carry traffic.

Over time, these codes, standards, and practices have become more complex, and they may no longer support the latest innovations in planning practices. The past 10 to 20 years have seen a number of innovations in zoning and related building standards. Mixed-use, mixed-density communities that incorporate traditional patterns of community development (often described as "New Urbanism"), low impact development (LID), and transit-oriented development are examples of building patterns that challenge traditional zoning and city design standards. With the exception of LID, proposed new patterns of development and regulations connected with their implementation rarely incorporate specific guidelines for innovations in stormwater management, other than to have general references to environmental responsibility, ecological restoration, and natural area protection.

The following sections describe in more detail the codes, ordinances, and standards that affect stormwater and our ability to control it, and alternative approaches to developing new standards and practices that support and encourage effective stormwater management.

Zoning

The primary, traditional purpose of zoning has been to segregate land uses thought to be incompatible. In practice, zoning is used as a permitting system to prevent new development from harming existing residents or businesses. Zoning is commonly controlled by local governments such as counties or cities, though the specifics of the zoning regime are determined primarily by state planning laws (see Box 2-6 for a discussion of land use acts in Oregon and Washington).

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BOX 2-6
Growth Management in the Pacific Northwest

In Oregon, the 1973 Legislative Assembly enacted the Oregon Land Use Act, which recognized that the uncoordinated use of lands threatens orderly development of the environment, the health, safety, order, convenience, prosperity and welfare of the people of Oregon. The state required all of Oregon's 214 cities and 36 counties to adopt comprehensive plans and land-use regulations. It specified planning concerns that had to be addressed, set statewide standards that local plans and ordinances had to meet, and established a review process to ensure that those standards were met. Aims of the program are to conserve farm land, forest land, coastal resources, and other important natural resources; encourage-efficient development; coordinate the planning activities of local governments and state and federal agencies; enhance the state's economy; and reduce the public costs that result from poorly planned development. Setting urban growth boundaries is a major mechanism for implementing the act.

The Washington State Legislature followed in 1990 with the Growth Management Act (GMA), adopted on grounds similar to Oregon's act. The GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans, and implementing them through capital investments and development regulations. Similar again to Oregon, rather than centralize planning and decision-making at the state level, the GMA established state goals, set deadlines for compliance, offered direction on how to prepare local comprehensive plans and regulations, and set forth requirements for early and continuous public participation. Urban growth areas (UGAs) are those areas, designated by counties pursuant to the GMA, "within which urban growth shall be encouraged and outside of which growth can occur only if it is not urban in nature." Within these UGAs, growth is encouraged and supported with adequate facilities. Areas outside of the UGAs are reserved for primarily rural and resource uses. Urban growth areas are to be based on population forecasts made by counties, which are required to have a 20-year supply of land for future residential development inside the boundary—a time frame also pertaining in the Oregon system. In both states urban growth boundaries are reconsidered and sometimes adjusted to meet this criterion.

It is important to note that the growth management efforts in the two states have no direct relationship to stormwater management. Rather, the laws control development density, which has implications for how stormwater should be managed (see discussion in Chapter 5). The local jurisdictions in Washington have reacted in different ways to link growth management and stormwater management. For example, the King County, Washington, stormwater code requires drainage review to evaluate and deal with stormwater impacts for development that adds 2,000 square feet or more of impervious surface or clears more than 7,000 square feet. For rural residential lots outside the UGA, the impervious threshold is reduced to 500 square feet.

Sources:
http://bluebook.state.or.us/state/executive/Land_Conservation/land_conservation_history.htm
http://www.oregonmetro.gov/index.cfm/go/by.web/id=277
http://www.gmhb.wa.gov/gma/ and *http://www.mrsc.org/Subjects/Planning/compfaqs.aspx*

Zoning involves regulation of the kinds of activities that will be acceptable on particular lots (such as open space, residential, agricultural, commercial or industrial), the densities at which those activities can be performed (from low-density housing such as single-family homes to high-density housing such as high-rise apartment buildings), the height of buildings, the amount of space

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structures may occupy, the location of a building on the lot (setbacks), the proportions of the types of space on a lot (for example, how much landscaped space and how much paved space), and how much parking must be provided. Thus, zoning can have a significant impact on the amount of impervious area in a development and on what constitutes allowable stormwater management.

As an example, local parking ordinances are often found within zoning that govern the size, number, and surface material of parking spaces, as well as the overall geometry of the parking lot as a whole. The parking demand requirements are tied to particular land uses and zoning categories, and can create needless impervious cover. Most local parking codes are overly generous and have few, if any, provisions to treat stormwater at the source (Wells, 1995). For example, in a co-housing project under construction in Fresno, California, current city codes require 27-foot-long parking spaces. The developer, in an effort to reduce construction costs, requested that the length of spaces be reduced to 24 feet. The city agreed to the smaller spaces if the developer would sign an indemnity clause guaranteeing that the local government would not be sued in case of an accident (Wenz, 2008).

Similarly, landscaping ordinances apply to certain commercial and institutional zoning categories and specify that a fixed percentage of site area be devoted to landscaping, screening, or similar setbacks. These codes may require as much as 5 to 10 percent of the site area to be landscaped, but seldom reference opportunities to capture and store runoff at the source, despite the fact that the area devoted to landscaping is often large enough to meet some or all of their stormwater treatment needs.

Zoning codes have evolved over the years as urban planning theory has changed, legal constraints have fluctuated, and political priorities have shifted. The various approaches to zoning can be divided into four broad categories: Euclidean, performance, planned unit development, and form-based.

Euclidean Zoning

Named for the type of zoning code adopted in the town of Euclid, Ohio, Euclidean zoning codes are by far the most prevalent in the United States, used extensively in small towns and large cities alike. Euclidean zoning is characterized by the segregation of land uses into specified geographic districts and dimensional standards stipulating limitations on the magnitude of development activity that is allowed to take place on lots within each type of district. Typical land-use districts in Euclidean zoning are residential (single- or multi-family), commercial, and industrial. Uses within each district are usually heavily prescribed to exclude other types of uses (for example, residential districts typically disallow commercial or industrial uses). Some “accessory” or “conditional” uses may be allowed in order to accommodate the needs of the primary uses. Dimensional standards apply to any structures built on lots within each zoning district and typically take the form of setbacks, height limits,

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minimum lot sizes, lot coverage limits, and other limitations on the building envelope.

Although traditional Euclidean zoning does not include any significant requirements for stormwater drainage, there is no reason that it could not. Modern Euclidean ordinances include a broad list of "development standards" that address topics like signage, lighting, steep slopes, and other topics, and that list could be expanded to included stormwater standards for private development.

Euclidean zoning is used almost universally across the country (with rare exceptions) because of its relative effectiveness, ease of implementation (one set of explicit, prescriptive rules), long-established legal precedent, and familiarity to planners and design professionals. However, Euclidean zoning has received heavy criticism for its unnecessary separation of land uses, its lack of flexibility, and its institutionalization of now-outdated planning theory. . In response, variances and other methods have been used to modify Euclidean zoning so that it is better adapted to localized conditions and existing patterns of development. The sections below briefly describe a range of innovations in local zoning regulations that have potential for incorporating stormwater controls into existing regulations.

Incentive Zoning. Incentive zoning systems are typically an add-on to Euclidean zoning systems. First implemented in Chicago and New York City in 1961, incentive zoning is intended to provide a reward-based system to encourage development that meets established urban development goals. Typically, a base level of prescriptive limitations on development will be established and an extensive list of incentive criteria with an associated reward scale will be established for developers to adopt at their discretion. Common examples include floor-area-ratio bonuses for affordable housing provided on-site and height-limit bonuses for the inclusion of public amenities on-site.

With incentive zoning, developers are awarded additional development capacity in exchange for a public benefit, such as a provision for low- or moderate-income housing, or an amenity, such as additional open space. Incentive zoning is often used in more highly urbanized areas. Consideration for water quality treatment and innovative SCMs fits well within the incentive zoning model. For example, redevelopment sites in urbanized areas are often required to incorporate stormwater control measures into developments to minimize impacts on aging, undersized stormwater systems in that area, and to meet new water quality requirements. An incentive could be to allow greater building height, and therefore higher density, than under existing zoning, freeing up land area for SCMs that could also serve as a passive park area. Another example would be to allow a higher density on the site and to require not an on-site system but a cash payment to the governing entity to provide for consolidated stormwater management and treatment. Off-site consolidated systems, discussed more extensively in Chapter 5, may require creation of a localized main-

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tenance district or an increase in stormwater maintenance fees to offset long-term maintenance costs.

Incentive zoning could be used to preserve natural areas or stream corridors as part of a watershed enhancement strategy. For example, transferrable development rights (TDR) could be used in the context of the urban or semi-urban interface with rural lands. Many of the formal TDR programs in Colorado (such as Fruita/Mesa County and Aspen/Pitkin) involve cities or counties seeking to preserve sensitive areas in the county, or outlying areas of the city, including the floodplain, in exchange for urban-level density on a more appropriate site (David D. Smith, Garfield & Hecht P.C., personal communication, 2008).

Incentive zoning allows for a high degree of flexibility, but it can be complex to administer. The more a proposed development takes advantage of incentive criteria, the more closely it has to be reviewed on a discretionary basis. The initial creation of the incentive structure can also be challenging and often requires extensive ongoing revision to maintain balance between incentive magnitude and value given to developers.

Performance Zoning

Performance zoning uses performance-based or goal-oriented criteria to establish review parameters for proposed development projects in any area of a municipality. At its heart, performance zoning deemphasizes the specific land uses, minimum setbacks, and maximum heights applicable to a development site and instead requires that the development meet certain performance standards (usually related to noise, glare, traffic generation, or visibility). Performance zoning sometimes utilizes a "points-based" system whereby a property developer can apply credits toward meeting established zoning goals through selecting from a menu of compliance options (some examples include mitigation of environmental impacts, providing public amenities, and building affordable housing units). Additional discretionary criteria may also be established as part of the review process.

The appeal of performance zoning lies in its high level of flexibility, rationality, transparency, and accountability. Because performance zoning is grounded in specific and in many cases quantifiable goals, it better accommodates market principles and private property rights with environmental protection. However, performance zoning can be extremely difficult to implement and can require a high level of discretionary activity on the part of the supervising authority. City staff must often be trained to use specialized equipment to measure the performance of the development, and sometimes those impacts cannot be measured until the building is completed and the activity operating, by which time it may be difficult and expensive to modify a building that turns out not to meet the required performance standards. Because stormwater performance is measurable (especially the amounts of water retained/detained and rates and amounts of water discharge), stormwater

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regulations could be integrated into a performance zoning system. As with other topics, however, it might be time-consuming or require special equipment to measure compliance (particularly before the building is built).

Planned Unit Development (Including Cluster Development and Conservation Design)

A planned unit development (PUD) is generally a large area of land under unified control that is planned and developed as a whole through a single development operation or series of development phases, in accord with a master plan. In California, these are known as Specific Plans. More specialized forms of PUDs include clustered subdivisions where density limitations apply to the development site as a whole but provide flexibility in the lot size, setback, and other standards that apply to individual house lots. These PUDs provide considerable flexibility in locating building sites and associated roads and utilities, allowing them to be concentrated in parts of the site, with the remaining land use for agriculture, recreation, preservation of sensitive areas, or other open-space purposes.

PUDs are typically, although not exclusively, found in new development areas and have significant open space and park areas that are often 25 percent or more of the total land area. This large amount of open space provides considerable opportunity for the use of consolidated, multifunctional stormwater controls.

Form-Based Zoning

Form-based zoning relies on rules applied to development sites according to both prescriptive and potentially discretionary criteria. These criteria are typically dependent on lot size, location, proximity, and other various site- and use-specific characteristics. Form-based codes offer considerably more flexibility in building uses than do Euclidean codes, but, as they are comparatively new, may be more challenging to create. When form-based codes do not contain appropriate illustrations and diagrams, they are criticized as being difficult to interpret.

One example of a recently adopted code with form-based features is the Land Development Code adopted by Louisville, Kentucky, in 2003. This zoning code creates “form districts” for Louisville Metro. Each form district intends to recognize that some areas of the city are more suburban in nature, while others are more urban. Building setbacks, heights, and design features vary according to the form district. As an example, in a “traditional neighborhood” form district, a maximum setback might be 15 feet from the property line, while in a suburban “neighborhood” there may be no maximum

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setback. Narrower setbacks allow increased density, requiring less land area for the same number of housing units and resulting in a smaller development footprint.

In rural and suburban areas, form-based codes can often reinforce the "open" character of development by preserving open site areas, which could be used for on-site stormwater management. In denser, urban areas, however, some form-based ordinances favor shorter, more pedestrian-scale buildings that cover more of the site than taller buildings of the same square footage, on the basis that keeping activity closer to the ground and enclosing street frontages results in a better pedestrian environment and urban form. One result of this preference is that there may be less of the site left potentially available for on-site stormwater detention or infiltration. Integrating stormwater management considerations into form-based codes may require a cash payment system where the developer contributes to financing of a district or regional stormwater treatment facility because on-site solutions are not available.

Building Codes

Building codes define minimum standards for the construction of virtually all types and scales of structures. With a few exceptions, building codes have limited direct impact on stormwater management. The main example is where structural and geotechnical design standards, which stem from the need to protect buildings and infrastructure from water damage, discourage or prohibit the potential infiltration of water adjacent to building foundations. Such standards can make it difficult to use landscape-based SCMs, such as porous pavement, bioinfiltration, and extended detention. There is a need to examine and redefine structural and geotechnical "standards of care" that ensure the structural integrity of buildings and other infrastructure like buried utilities, in order for landscaped areas adjacent to structures to be utilized more effectively for SCMs. For example, a developer building a mixed-use, medium-density infill development in Denver intended to incorporate innovative approaches to stormwater management by infiltrating stormwater in a number of areas around the site. The standard of care for the geotechnical design of building foundations typically requires that positive drainage be maintained a minimum of 5 feet from the building edge. The geotechnical engineer required, when informed that water might be infiltrated in the area of the building and without further study, that the minimum distance to an infiltration area must be at least to 20 feet from the building, greatly limiting the potential for using the building landscape areas as SCMs. The City of Los Angeles is in the process of updating its Building Code, but it is not clear if it will be sufficiently comprehensive to address the use of some LID practices, such as on-site infiltration. The 2002 Building Code now in effect is written to require the builder to convey water away from the building using concrete or some other "non-erosive device."

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Engineering and Infrastructure Standards and Practices

Engineering standards and practices for public rights-of-way complement building and zoning codes which control development on private property. Engineering standards and practices typically describe requirements for public utilities such as stormwater and wastewater, roadways, and related basic services. For example, there are standards for parking and roadway design that typically describe the specific type of roadway and parking surfacing requirements. Regulations and standards often require minimum gradients for surface drainage, site grading, and drainage pipe size, all of which play an important role in how stormwater is transported. There are also often landscape planting requirements, including the requirement to mound landscape areas to screen cars, which can preclude the opportunity to incorporate SCMs into landscape areas.

Unless right-of-way improvements are constructed as part of the subdivision process by private developers, improvements in the right-of-way are typically provided for by city government and public agencies. Because engineering standards are often based on decades of refinement and have evolved regionally and nationally, they are difficult to change. For example, street widths are determined more by the ability to maneuver emergency equipment and to accommodate water and sewer easements than the need for adequate lane widths for vehicles. Street lane-width requirements might be as narrow as 11 feet for each travel lane, resulting in a street width of 22 to 24 feet. This could accommodate emergency vehicle access, which typically can require a minimum of 20 feet of unobstructed street. However, because most streets also include potable water distribution lines and easement requirements for the lines, which are a minimum of 30 feet in width, this results in a minimum roadway width of 30 feet.

Local drainage codes govern the disposal of stormwater and essentially dictate the nature and capacity of the stormwater infrastructure from the roof to the floodplain. Like many codes, they were developed over time to address problems such as basement flooding, nuisance drainage problems, maintenance of floodplain boundaries, and protection of infrastructure such as bridges and sewers from storm damage. Local drainage codes, many of which predate the EPA's stormwater program, often involve peak discharge control requirements for a series of design storm events ranging from the 2-year storm up to the 100-year event. Traditional drainage codes can often conflict with effective approaches to reducing runoff volume or removing pollutants from stormwater. Examples of such codes include requirements for positive drainage, directly connected roof leaders, curbs and gutters, lined channels, storm-drain inlets, and large-diameter storm-drain pipes discharging to a downstream detention or flood control basins.

Often, standards have been tested through legal precedent, and case law has developed around certain standards of care, which can further deter innovation. Changes in design standards could result in unknown legal exposure and liabil-

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ity. Specific types of equipment, maintenance protocols and procedures, and extensive training further discourage changes in established standards and procedures.

Innovations in Codes and Regulations to Promote Better Stormwater Management

A number of innovations have been developed in the previously described zoning, building codes, and infrastructure and engineering standards that make them more amenable to stormwater management. These are described in detail below.

Separate Ordinances for New and Infill Development

Redevelopment of existing urban areas is almost universally more difficult and expensive than Greenfield development because of the deconstruction costs of the former, higher costs of designing around existing infrastructure, upgrading existing infrastructure, and higher costs and risks associated with assuming liability of pre-existing problems (contamination, etc). Redevelopment often occurs in areas of medium to high levels of impervious surface (e.g., downtown areas). Such severely space-limited areas with high land costs drive up stormwater management costs. Consequently, holding developers of such areas to the same stormwater standard as for Greenfield developments creates a financial disincentive for redevelopment. Without careful application, stormwater requirements may discourage needed redevelopment in existing urban areas. This would be unfortunate because redevelopment can take pressure off of the development of lands at the urban fringe, it can accommodate growth without introducing new impervious surfaces, and it can bring improvements in stormwater management to areas that had previously had none.

Stormwater planning can include the development of separate ordinances for infill and new developments. Wisconsin has administrative rules that establish specific requirements for stormwater management based on whether the site is new development, redevelopment, or infill. Requirements for new development include reducing total suspended solids (TSS) by 80 percent, maintaining the pre-development peak discharge for the 2-year, 24-hour storm, infiltrating 90 percent of the pre-development infiltration volume for residential areas, and infiltrating 60 percent of the pre-development infiltration volume for non-residential areas. Redevelopment varies from new development only in that the TSS requirement is less at 40 percent reduction. Requirements for existing developed areas in incorporated cities, villages, and towns do not include peak flow reduction or infiltration performance standards, but the municipalities must achieve a 40 percent reduction in their TSS load by 2013. Other requirements unique to developed areas include public education activities, proper application

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of nutrients on municipality property, and elimination of illicit discharges (*www.dnr.state.wi.us/org/water/wm/nps/stormwater/post-constr/*). Chapter 5 makes recommendations for the specific types of SCMs that should be used for new, low-density residential development as opposed to redevelopment of existing urban and industrial areas.

Integrated Stormwater Management and Growth Policies

In the city of San Jose, California, an approach was taken to link water quality and development policies that emphasized higher density in-fill development and performance-based approaches to achieving water quality goals. The city's approach encourages stormwater practices such as minimizing impervious surface and incorporating swales as the preferred means of conveyance and treatment. In urbanized areas, the policy then goes on to define criteria to determine the practicability of meeting numeric sizing requirements for stormwater control measures, and identifies Equivalent Alternative Compliance Measures for cases where on-site controls are impractical. Equivalent Measures can include regional stormwater treatment and other specific projects that "count" as SCMs, including certain affordable and senior housing projects, significant redevelopment within the urban core, and Brownfield projects. This is similar to in lieu fee programs that are sometimes implemented by municipalities to provide additional regulated parties with compliance options (see discussion in Chapter 6).

This approach is a breakthrough in terms of measuring environmental performance, which is now focused only on what happens within the boundaries of a site for a project. This myopic view tends to allow many environmentally unfriendly projects that encourage sprawl and expand the city's boundaries to qualify as "low impact," while more intense projects on a small footprint appear to have a much higher impact because they cover so much of the site. San Jose brought several other layers of review, including location in the watershed (close to other uses or not) as a means of estimating performance. A PowerPoint presentation describing their approach in greater detail is linked here (*http://www.cmcgc.com/media/handouts/260126/THR-PDF/040-Ketchum.PDF*, Lisa Nisenson, Nisenson Consulting, LLC, personal communication, May 8, 2007).

Unified Development Codes

A unified development code (UDC) consolidates development-related regulations into a single code that represents a more consistent, logical, integrated, and efficient means of controlling development. UDCs integrate zoning and subdivision regulations, simplifying development controls that are often con-

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flicting, confusing, and that require multiple layers of review and administration. UDC development standards may include circulation standards that address how vehicles and pedestrians move, including provision for adequate emergency access. Utility standards are described for water distribution and sewage collection, and necessary utility easements are prescribed. Because of the integrated nature of the code, efficiencies in requirements for right-of-way can reduce street widths or the reduction in setbacks, for example, resulting in more compact development.

Design Review Incentives to Speed Permitting

A number of incentives have been put in place to promote innovative stormwater control measures in cities such as Portland and Chicago, where environmental concerns have been identified as a key goal for development and redevelopment. Practices such as the waiver or reduction of development fees, preferential treatment and review and approval of innovative plans, reduction in stormwater fees, and related incentives encourage the use of innovative stormwater practices. In Chicago, the Green Permit Program initiated in April 2005 has proven attractive to many developers as it speeds up the permitting process. Under the Green Permit Program, a green building adviser reviews design plans under an aggressive schedule long before a permit application is submitted. There is one point of contact with intimate knowledge about the project to help speed up the permit process. Projects going through the Green Permit Program receive benefits based on their "level of green." Tier I commercial projects are designed to be Leadership in Energy and Environmental Design (LEED) certified (see Box 2-7). Tier II projects must obtain LEED silver rating. At this level, outside consultant review fees, which range from $5,000 to $50,000, are waived. Tier III projects must earn LEED gold. The goal for a Tier III project is to issue a permit in three weeks for a small project such as a 12-unit condo building. Thus, there is both time and money saved. Private developers are interested in the time savings because they can pay less interest on their construction loans by completing the building faster. By the end of 2005, 19 green permits were issued. The program's director estimated that about 50 would be issued in 2006, which exceeds the city's goal of 40.

In Portland, Oregon, the city's Green Building Program is considering instituting a new High-Performance Green Building Policy. Along with goals for reducing global warming pollution, it proposes (1) waiving development fees if goals are exceeded by specified percentages and (2) eligibility for cash rewards and qualification for state and federal financial incentives and tax credits if even higher goals are achieved. Developers can earn credits by incorporating enhanced stormwater management and water conservation features into their projects, including the use of green roofs (Wenz, 2008).

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BOX 2-7
Innovative Building Codes

An increased interest in energy conservation and more environmentally friendly building practices in general has led to various methods by which buildings can be evaluated for environmentally friendly construction, in addition to conventional code compliance. The most popular system in the United States is the Leadership in Energy and Environmental Design (LEED) system developed in 2000.

The LEED Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. The U.S. Green Building Council is a 501(c)(3) nonprofit organization that certifies sustainable businesses, homes, hospitals, schools, and neighborhoods.

The LEED system encourages progressive stormwater management practices as part of its rating system. The LEED system has identified specific criteria, with points assigned to each of the criteria, to assess the success of stormwater strategies. Generally, the criteria are based on LID principles and practices and relate directly to the *Better Site Design Handbook* of the Center for Watershed Protection (CWP, 1998). The system identifies eight categories by which building sites and site-planning practices are evaluated. Of the 69 points possible to achieve the highest LEED rating, 16 points are directly related to innovative site design and stormwater management practices. Six of the eight criteria describing sound site-planning practices relate directly to good stormwater practices, including the following:

- Erosion and sediment control;
- Site selection to protect farmland, wetlands, and watercourses;
- Site design to encourage denser infill development to protect Greenfield sites;
- Limitations on site disturbance;
- Specific requirements for the management of stormwater rate and quantity; and
- Specific requirements for the treatment of stormwater for TSS and phosphorous removal.

The LEED rating system has been criticized because it focuses on individual buildings in building sites. A new category, LEED neighborhood development, was developed in response to consider the interrelationship of buildings and building sites and connections to existing urban infrastructure. The category is currently in pilot testing. Evaluation criteria related directly to stormwater include:

- All requirements of the original site design criteria,
- A reduced requirement for parking based on access to transit and reduced auto use, and
- Site planning that emphasizes compact development.

There are parallel challenges in the realm of community development and city building that tend to discourage innovative stormwater management policies and practices. Building codes and zoning have evolved to reflect the complex relationship of legal, political, and social processes and frequently do not promote or allow the most innovative stormwater management. Engineering standards and practices that guide the development of roads and utilities present equal and possibly greater challenges, in that legal and technical precedents and

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large investments in public equipment and infrastructure present even more intractable reasons to resist change.

The difficulty of implementing stormwater control measures cannot be attributed to an individual code, standard, or regulation. It is important to unravel the complexities of codes, regulations, ordinances, and standards and practices that discourage innovative stormwater management and target the particular element (or multiple elements) that is a barrier to innovation. Elements that are barriers might not have been considered previously. For example, roadway design is controlled more by access for emergency equipment and utilities rights-of-way than by the need for wide travel lanes; it is the fire marshal and the water department that should be the focus of attention, rather than the transportation engineer.

LIMITATIONS OF THE FEDERAL STORMWATER PROGRAM

The regulation of stormwater discharges seems an inevitable next step to the CWA's objective of "restoring the nation's waters," and EPA's stormwater program is still evolving. Yet, in its current configuration EPA's approach seems inadequate to overcome the unique challenges of stormwater and therefore runs the risk of only being partly effective in meeting its goals. A number of regulatory, institutional, and societal obstacles continue to hamper stormwater management in the United States, as described below.

The Poor Fit Between the Clean Water Act's Regulatory Approach and the Realities of Stormwater Management

Controlling stormwater discharges with the CWA introduces a number of obstacles to effective stormwater regulation. Unlike traditional industrial effluent, stormwater introduces not only contaminants but also surges in volume that degrade receiving waterbodies; yet the statute appears focused primarily on the "discharge" of "pollutants." Moreover, unlike traditional effluent streams from manufacturing processes, the pollutant loadings in stormwater vary substantially over time, making effluent monitoring and the development of enforceable control requirements considerably more challenging. Traditional use of end-of-pipe control technologies and automated effluent monitors used for industrial effluent do not work for the episodic and variable loading of pollutants in stormwater unless they account for these eccentricities by adjustments such as flow-weighted measurements. Finally, at the root of the stormwater problem is increasingly intensive land use. Yet the CWA contains little authority for regulators to directly limit land development, even though the discharges that result from these developments increase stormwater loading at a predictably rapid pace. The CWA thus expects regulators to reduce stormwater loadings, but gives them incomplete tools for effectuating this goal.

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A more straightforward way to regulate stormwater contributions to waterbody impairment would be to use flow or a surrogate, like impervious cover, as a measure of stormwater loading (such as in the Barberry Creek TMDL [Maine DEP, 2003, pp. 16–20] or the Eagle Brook TMDL [Connecticut DEP, 2007, pp. 8–10]). Flow from individual stormwater sources is easier to monitor, model, and even approximate as compared to calculating the loadings of individual contaminants in stormwater effluent. Efforts to reduce stormwater flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality. Flow provides an inexpensive, convenient, and realistic means of tracking stormwater contributions to surface waters. Congress itself recently underscored the usefulness of flow as a measure for aquatic impairments by requiring that all future developments involving a federal facility with a footprint larger than 5,000 square feet ensure that the development achieves predevelopment hydrology to the maximum extent technically feasible "with regard to the temperature, rate, volume, and duration of flow" (Energy Independence and Security Act of 2007, § 438). Several EPA regions have also used flow in modeling stormwater inputs for TMDL purposes (EPA, 2007a, Potash Brook TMDL, pp. 12–13).

Permitting and Enforcement

For industrial wastewater discharged directly from industrial operations (rather than indirectly through stormwater), the CWA requirements are relatively straightforward. In these traditional cases, EPA essentially identifies an average manufacturer within a category of industry, like iron and steel manufacturers engaged in coke-making, and then quantifies the pollutant concentrations that would result in the effluent if the industry installed the best available pollution control technology. EPA promulgates these effluent standards as national, mandatory limits (e.g., see Table 2-7).

TABLE 2-7 Effluent Limits for Best Available Technology Requirements for By-product Coke-making in Iron and Steel Manufacturing

Regulated Parameter	Maximum Daily[1]	Maximum Monthly Average[1]
Ammonia-N	0.00293	0.00202
Benzo(a)pyrene	0.0000110	0.00000612
Cyanide	0.00297	0.00208
Naphthalene	0.0000111	0.00000616
Phenols (4AAP)	0.0000381	0.000238

[1]pounds per thousand pound of product.
SOURCE: 40 C.F.R. § 420.13(a).

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By contrast, the uncertainties and variability surrounding both the nature of the stormwater discharges and the capabilities of various pollution controls for any given industrial site, construction site, or municipal storm sewer make it much more difficult to set precise numeric limits in advance for stormwater sources. The quantity and quality of stormwater are quite variable over time and vary substantially from one property to another. Natural causes of variation in the pollutant loads in stormwater runoff include the topography of a site, the soil conditions, and of course, the nature of storm flows in intensity, frequency, and volume. In addition, the manner in which the facility stores and uses materials, the amount of impervious cover, and sometimes even what materials the facility uses can vary and affect pollutant loads in runoff from one site to another. Together, these sources of variability, particularly the natural features, make it much more difficult to identify or predict a meaningful "average" pollutant load of stormwater runoff from a facility. As a result, EPA generally leaves it to the regulated facilities, with limited oversight from regulators, to identify the appropriate SCMs for a site. Unfortunately, this deferential approach makes the permit requirements vulnerable to significant ambiguities and difficult to enforce, as discussed below for each permit type.

Municipal Stormwater Permits. MS4 permits are difficult to enforce because the permit requirements have not yet been translated into standardized procedures to establish end-of-pipe numerical effluent limits for MS4 stormwater discharges. CWA Section 402(p) requires that pollutants in stormwater discharges from the MS4 be reduced to the maximum extent practicable and comply with water quality standards (when so required by the permitting authority). However, neither EPA nor NPDES-delegated states have yet expressed these criteria for compliance in numerical form.

The EPA has not yet defined MEP in an objective manner that could lead to convergence of MS4 programs to reduce stormwater pollution. Thus, at present MS4 permittees have no more guidance on the level of effort expected other than what is stated in the CWA:

> [S]hall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practice, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants. [CWA Section 402(p)(3)(B)(iii)]

A legal opinion issued by the California Water Board's Office of Chief Counsel in 1993 stated that MEP would be met if MS4 permittees implemented technically feasible SCMs, considering costs, public acceptance, effectiveness, and regulatory compliance (Memorandum from Elizabeth Miller Jennings, Office of Chief Counsel, to Archie Matthews, Division of Water Quality, California Water Board, February 11, 1993). In its promulgation of the Phase II Rule in 1999, the EPA described MEP as a flexible site-specific standard, stating that:

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> The pollutant reductions that represent MEP may be different for each [MS4 Permittee] given the unique local hydrological and geological concerns that may exist and the differing possible pollutant control strategies. (64 Fed. Reg. 68722, 68754)

As matters stand today, MS4 programs are free to choose from the EPA's menu of SCMs, with MEP being left to the discretionary judgment of the implementing municipality. Similarly, there are no clear criteria to be met for industrial facilities that discharge to MS4s in order for the MS4s to comply with MEP. The lack of federal guidance for MS4s is understandable. A stormwater expert panel convened by the California EPA State Water Board in 2006 (CA SWB, 2006) concluded that it was not yet feasible to establish strictly enforceable end-of-pipe numeric effluent limits for MS4 discharges. The principal reasons cited were (1) the lack of a design storm (because in any year there are few storms sufficiently large in volume and/or intensity to exceed the design volume capacity or flow rates of most treatment SCMs) and (2) the high variability of stormwater quality influenced by factors such as antecedent dry periods, extent of connected impervious area, geographic location, and land use.

Industrial and Construction Stormwater Permits. The industrial and construction stormwater programs suffer from the same kind of deficiencies as the municipal stormwater program. These stormwater discharges are not bound by the MEP criterion, but they are required to comply with either technology-based or, less often, water quality-based effluent limitations. In selecting SCMs to comply with these limitations, the industrial discharger or construction operator similarly selects from a menu of options devised by the EPA or, in some cases, the states or localities for their particular facility (EPA, 2006, p. 15). For example, the regulated party will generally identify structural SCMs, such as fences and impoundments that minimize runoff, and describe how they will be installed. The SWPPP must also include nonstructural SCMs, like good housekeeping practices, that require the discharger to minimize the opportunity for pollutants to be exposed to stormwater. The SWPPP and the accompanying SCMs constitute the compliance requirements for the stormwater discharger and are essentially analogous to the numeric effluent limits listed for industrial effluents in the Code of Federal Regulations.

This set of requirements leaves considerable discretion to regulated parties in several important ways. First, the regulations require the discharger to evaluate the site for problematic pollutants; but where the regulated party does not have specific knowledge or data, they need only offer "estimates" and "predictions" of the types of pollutants that might be present at the site (EPA, 1996a, pp. IV-3, V-3). With the exception of visible features, the deferential site investigation requirements allow regulated parties to describe site conditions in ways that may effectively escape accountability unless there is a vigorous regulatory presence.

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Second, dischargers enjoy considerable discretion in drafting the SWPPP (EPA, 1996a, p. IV-3). Despite EPA's instructions to consider a laundry list of considerations that will help the facility settle on the most effective plan (EPA, 2006, p. 20), rational operators may take advantage of the wiggle room and develop ambiguous requirements that leave them with considerable discretion in determining whether they are in compliance (EPA, 2006, pp. 15, 20, 132). Indeed, the federal regulations do little to prevent regulated parties from devising requirements that maximize their discretion. Instead, EPA describes many of the permit requirements in general terms. For example, in its industrial stormwater permit program the EPA commands the regulated party to "implement any additional SCMs that are economically reasonable and appropriate in light of current industry practice, and are necessary to eliminate or reduce pollutants in . . . stormwater discharges" (EPA, 2006, p. 23).

EPA's program provides few rewards or incentives for dischargers to go beyond the federal minimum and embrace rigorous or innovative SCMs. In fact, if the regulated party invests resources to measure pollutant loads on their property, they are creating a paper trail that puts them at risk of greater regulation. Under the EPA's regulations, a regulated party "must provide a summary of existing stormwater discharge sampling data previously taken at [its] facility," but if there are no data or sampling efforts, then the facility is off the hook (EPA, 2006, p. 20). Quantitative measures can thus be incriminating, particularly in a regulatory setting where the regulator is willing to settle for estimates.

Dilemma of Self-Monitoring

Unlike the wastewater program where there are relatively rigid self-monitoring requirements for the end-of-pipe effluent, self-monitoring is much more difficult to prescribe for stormwater discharges, which are variable over time and space. [For example, *compare* 33 U.S.C. § 1342(a)(2)-(b)(2) (2000) (outlining requirements for compliance under NPDES) *with* EPA, 2006, p. 26 (outlining requirements for self-compliance under EPA regulations.)] EPA's middle ground, in response to these challenges, requires self-monitoring of select chemicals in stormwater for only a subset of regulated parties—Phase I MS4 permittees and a limited number of industrial facilities (see Table 2-8, EPA, 2006, pp. 93-94). Yet even for these more rigid monitoring requirements, the discharger enjoys some discretion in sampling. The EPA's sampling guidelines do prescribe regular intervals for sampling but ultimately must defer to the discharger insofar as requiring only that the samples should be taken within 30 minutes after the storm begins, and only if it is the first storm in three days (EPA, 2006, p. 33).

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TABLE 2-8 Effluent Monitoring Requirements for Various Dischargers of Stormwater

Source Category	**Type of Effluent Monitoring Required by EPA**
Phase I MS4	Municipality must develop a monitoring plan that provides for representative data collection. This requires the municipality, at the very least, to select at least 5 to 10 of its most representative outfalls for regular sampling and sample for selected conventional pollutants and heavy metals in its effluent.
Phase II MS4	None
Small subset of highest risk industries, like hazardous waste landfills	Must conduct compliance monitoring as specified in effluent guidelines and ensure compliance with these effluent limits. Must also conduct visual monitoring and benchmark monitoring.
Larger subset of higher risk industrial dischargers	Benchmark monitoring: Must conduct analytic monitoring to determine whether effluent exceeds numeric benchmark values; compliance with the numeric values is not required, however. Must also conduct visual monitoring.
Remaining set of industry except construction	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.
Construction (larger than 5 acres)	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.
Construction (between 1 and 5 acres)	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.

Note: State regulators can and sometimes do require more—see Appendix C.

Moreover, while the monitoring itself is mandatory, the legal consequences of an exceedance of a numerical limit vary and may be quite limited. For a small number of identified industries, exceedances of effluent limits established by EPA are considered permit violations (65 Fed. Reg. 64766). For the other high-risk industries subject to benchmark monitoring requirements (see Table 2-5), the analytical limits do not lead to violations per se, but only serve to "flag" the discharger that it should consider amending its SWPPP to address the problematic pollutant (EPA, 2006, pp. 10, 30, 34). Although municipalities are required to do more extensive sampling of stormwater runoff and enjoy less sampling discretion, even municipalities are allowed to select what they believe are their most representative outfalls for purposes of monitoring pollutant loads (EPA, 1996a. p. VIII-1).

A large subset of dischargers—the remaining industrial dischargers and construction sites—are subject to much more limited monitoring requirements. They are not required to sample contaminant levels, but instead are required only to conduct a visual inspection of a grab sample of their stormwater runoff on a quarterly basis and describe the visual appearance of the sample in a document that is kept on file at the site (EPA, 2006, p. 28). Certainly a visual sample is better than nothing, but the requirement allows the discharger not only some discretion in determining how and when to take the sample (explained below), but also discretion in how to describe the sample.

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A final set of regulated parties, the Phase II MS4s, are not required to perform any quantitative monitoring of runoff to test the effectiveness of SCMs (EPA, 1996a, p. 3).

Making matters worse, in some states there appear to be limited regulatory resources to verify compliance with many of these permit requirements. Thus, even though monitoring plans are subject to review and approval by permitting agencies, there may be insufficient resources to support this level of oversight. As shown in Appendix C, the total number of staff associated with state stormwater programs is usually just a handful, except in cases of larger states (California and Georgia) or those where there is a longer history of stormwater management (Washington and Minnesota). In its survey of state stormwater programs, the committee asked states how they tracked sources' compliance with the stormwater permits. For the 18 states responding to the questionnaire, review of (1) monitoring data, (2) annual reports, and (3) SWPPP as well as onsite inspections were the primary mechanisms. However, several states indicated that they conduct an inspection only after receiving complaints. West Virginia tracked whether industrial facilities submitted their required samples and followed up with a letter if they failed to comply, but in 2006 it found that over 65 percent of the dischargers were delinquent in their sampling. Although the states were not asked in the survey to estimate the overall compliance rate, Ohio admitted that at least for construction, "the general sense is that no site is 100 percent in compliance with the Construction General Permit" (see Appendix C).

Even where considerable regulatory resources are dedicated to ensuring that dischargers are in compliance, it is not clear how well regulators can independently assess compliance with the permit requirements. For example, some of the permits will require "good housekeeping" practices that should take place daily at the facility. Whether or how well these practices are followed cannot be assessed during a single inspection. While a particularly non-compliant facility might be apparent from a brief visual inspection, a facility that is mildly sloppy**,** or at least has periods during which it is not careful**,** can escape detection on one of these pre-announced audits. Facilities also know best the pollutants they generate and how or whether those pollutants might make contact with stormwater. Inspectors might be able to notice some of these problems, but because they do not have the same level of information about the operations of the facility, they can be expected to miss some problems.

Identifying Potentially Regulatable Parties

Evidence suggests that a sizable percentage of industrial and construction stormwater dischargers are also failing to self-identify themselves to regulators, and hence these unreported dischargers remain both unpermitted and unregulated (GAO, 2005; Duke and Augustenborg, 2006). In contrast to industrial pipes that carry wastes from factories out to receiving waters, the physical pres-

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ence of stormwater dischargers may be less visible or obvious. Thus, particularly for some industries and construction, if a stormwater discharger does not apply for a permit, the probability of detecting it is quite low.

In Maine, less than 20 percent of the stormwater dischargers that fall within the regulatory jurisdiction of the federal stormwater program actually applied for permits before 2005—more than a decade after the federal regulations were promulgated (Richardson, 2005). Yet there is no record of enforcement action taken by Maine against the unpermitted dischargers during that interim period. Indeed, in the one enforcement action brought by citizens in Maine for an unpermitted discharge, the discharger claimed ignorance of the stormwater program. In Washington, the State Department of Ecology speculates that between 10 and 25 percent of all businesses that should be covered by the federal stormwater permit program are actually permitted (McClure, 2004). In a four-state study, Duke and Augustenborg (2006) found a higher percentage of stormwater dischargers—between 50 and 80 percent—had applied for permits by 2004, but they concluded that this was still "highly incomplete" compliance for an established permit program.

In 2007, the committee sent a short survey to each state stormwater program inquiring as to whether and how they tracked non-filing stormwater dischargers, but only six states replied to the questions and only two of the six states had any methods for tracking non-filers or conducting outreach to encourage all covered parties to apply for permits (see Appendix C). While the low response rate cannot be read to mean that the states do not take the stormwater program seriously, the responses that were received lend some support to the possibility that there is substantial noncompliance at the filing stage.

In response to this problem of unpermitted discharges, the EPA appears to be targeting enforcement against stormwater dischargers that do not have permits. In several cases, the EPA pursued regulated industries that failed to apply for stormwater permits (EPA Region 9, 2005; Kaufman et al., 2005). The EPA has also brought enforcement actions against at least three construction companies for failing to apply for a stormwater permit for their construction runoff (EPA Region 1, 2004). Such enforcement actions help to make the stormwater program more visible and give the appearance of a higher probability of enforcement associated with non-compliance. Nevertheless, the non-intuitive features of needing a permit to discharge stormwater, coupled with a rational perception of a low probability of being caught, likely encourage some dischargers to fail to enter the regulatory system.

Absence of Regulatory Prioritization

Many states have been overwhelmed with the sheer numbers of permittees, particularly industry and construction sites, and lack a prioritization strategy to identify high-risk sources in particular need of rigorous and enforceable permit

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conditions. For example, in California major facilities like the Los Angeles International Airport and the Los Angeles and Long Beach ports are covered under California's MSGP along with a half-acre metal plating facility in El Segundo—all subject to the same level of compliance scrutiny even after nearly two decades of implementation! Similarly, a multiphase, 20-year, thousand-acre residential development such as Newhall Land Development in North Los Angeles County is covered by the same California CGP as a one-acre residential home construction project in West Los Angeles, and subject to the same level of compliance scrutiny. The lack of an EPA strategy to identify and address high-risk industrial facilities and construction sites (i.e., those that pose the greatest risk of discharging polluted stormwater) remains an enormous deficiency. Phase I MS4s, for example, are left to their own devices to determine how to identify the most significant contributors to their stormwater systems (Duke, 2007).

Limited Public Participation

Public participation is more limited in the stormwater program in comparison to the wastewater permit program, providing less citizen-based oversight over stormwater discharges. Typically, during the issuance of an individual NPDES permit (for either wastewater or stormwater) the public has a chance to comment and review the draft permit requirements that are specifically prescribed for a certain site and discharge. While the same is true about the public participation during the adoption of a general stormwater permit, those general permits contain only the framework of the requirements and the menu of conditions, but do not prescribe specific requirements. Instead, it is up to the permittee to tailor the compliance to the specific conditions of the site in the form of a SWPPP. However, at this phase neither the public nor the regulators have access to the site-specific plan developed by the permittee to comply with the obligations of the permit. In the case of general permits, then, the discharger has enormous flexibility in designing its compliance activities.

Citizens also encounter difficulties in enforcing stormwater permit requirements. Citizens have managed to sue facilities for unpermitted stormwater discharges: this is a straightforward process because citizens need only verify that the facility should be covered and lacks a permit (Richardson, 2005). Overseeing facility compliance with stormwater permit requirements is a different story, however, and citizens are stymied at this stage of ensuring facility compliance. Citizens can access a facility's SWPPP, but only if they request the plan from the facility in writing (EPA, 2006, p. 25). Moreover, the facility is given the authority to make a determination—apparently without regulator oversight—of whether the plan contains confidential business information and thus cannot be disclosed to citizens (EPA, 2006, p. 26). But, even if the facility sends the plan to the citizens, it will be nearly impossible for them to independently assess whether the facility is in compliance unless the citizens station telescopes,

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conduct air surveillance of the site, or are allowed to access the facility's records of its own self-inspections. Moreover, to the extent that the stormwater outfalls are on the facility's property**,** citizens might not be able to conduct their own sampling without trespassing.

Not surprisingly, significant progress has nevertheless been made in reducing stormwater pollution when stormwater becomes a visible public issue. This increased visibility is often accomplished with the help of local environmental advocacy groups who call attention to the endangered species, tourism, or drinking water supplies that are jeopardized by stormwater contamination. Box 2-8 describes two cases of active public participation in the management of stormwater.

BOX 2-8
Citizen Involvement/Education in Stormwater Regulations

The federal Clean Water Act, under Section 505, authorizes citizen groups to bring an action in U.S. or state courts if the EPA or a state fails to enforce water quality regulations. Unsurprisingly, the few areas nationally where stormwater quality has become a visible public issue and significant progress has been made in reducing stormwater pollution have prominent local environmental advocacy groups actively involved.

Heal the Bay, Santa Monica, California. In Southern California, Santa Monica-based Heal the Bay has utilized research, education, community action, public advocacy, and political activism to improve the quality of stormwater discharges from MS4s in Southern California. Heal the Bay operates an aquarium to educate the public, conducts stream teams to survey local streams, posts a beach report card on the web to inform swimmers on beach quality, appears before the California Water Boards to comment on NPDES stormwater permits, and works with lawmakers to sponsor legislative bills that protect water quality.

In 1998, the organization helped co-author legislation to notify the public when shoreline water samples show that water may be unsafe for swimming. California regulations (AB411) require local health agencies (county or city) to monitor water quality at beaches that are adjacent to a flowing storm drain and have 50,000 visitors annually (from April 1 to October 31). At a minimum, these beaches are tested on a weekly basis for three specific bacteria indicators: total coliform, fecal coliform, and *enterococcus*. Local health officials are required to post or close the beach, with warning signs, if state standards for bacterial indicators are exceeded. The monitoring data collected are available to the public.

In order to better inform and engage the public, Heal the Bay has followed up with a web-based Weekly Beach Report Card (*http://healthebay.org/brc/statemap.asp*) and the release of an Annual California Beach Report Card assigning an "A" to "F" letter grade to more than 500 beaches throughout the state based on their levels of bacterial pollution. Heal the Bay's Annual Beach Report Card is a comprehensive evaluation of California coastal water quality based on daily and weekly samples gathered at beaches from Humboldt County to the Mexican border. A poor grade means beachgoers face a higher risk of contracting illnesses such as stomach flu, ear infections, upper respiratory infections, and skin rashes than swimmers at cleaner beaches.

Heal the Bay was instrumental in passing Proposition O in the City of Los Angeles which sets aside half a billion dollars to improve the quality of stormwater discharges. In the 2007 term of the California Legislature, the organization has sponsored five legislative bills to address marine debris, including plastic litter transported in stormwater runoff, that

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Box 2-8 Continued

foul global surface waters (*Currents*, Vol. 21, No. 2, p.8, 2007). Heal the Bay also coordinates its actions and partners with other regional and national environmental organizations, such as the WaterKeepers and the NRDC, in advancing water quality protection nationally.

Save Our Springs, Austin, Texas. Citizen groups have played a very influential role in the development of a rigorous stormwater control program in the City of Austin, Texas. Catalyzed in 1990 by a proposal for extensive development that threatened the fragile Barton Springs area, a citizens group named Save Our Springs Legal Defense Fund (later renamed Save our Springs Alliance) formed to oppose the development. It orchestrated an infamous all-night council meeting, with 800 citizens registering in opposition to the proposed development and ultimately led to the City Council's rejection of the 4,000-acre proposal and the formulation of a "no degradation" policy for the Barton Creek watershed. The nonprofit later sponsored the Save Our Springs Ordinance, a citizen initiative supported by 30,000 signatures, which passed by a 2 to 1 margin in 1992 to further strengthen protection of the area. The Save Our Springs Ordinance limits impervious cover in the Barton Springs watershed to a maximum of between 15 and 25 percent, depending on the location of the development in relation to the recharge and contributing zones. The ordinance also mandates that stormwater runoff be as clean after development as before. The ordinance was subject to a number of legal challenges, all of which were successfully defended by the nonprofit in a string of court battles.

Since its initial formation in 1990, the Save Our Springs Alliance has continued to serve a vital role in educating the community about watershed protection and organizing citizens to oppose development that threatens Barton Springs. The organization has also been instrumental in working with a variety of government and nonprofit organizations to set aside large areas of parkland and open spaces within the watershed. Other citizen groups, like the Save Barton Creek Association, also play a very active, complementary role to the Save Our Springs Alliance in protecting the watershed. These other nonprofits are sometimes allied and sometimes diverge to take more moderate stances to development proposals. The resulting constellation of citizen groups, citizen outreach, and community participation is very high in the Austin area and has unquestionably led to a much more informed citizenry and a more rigorous watershed protection program than would exist without such grassroots leadership.

Accounting for Future Land Use

One of the challenges of managing stormwater from urban watersheds thus involves anticipating and channeling future urban growth. Currently, the CWA does little to anticipate and control for future sources of stormwater pollution in urban watersheds. Permits are issued individually on a technology-based basis, allowing for uncontrolled cumulative increases in pollutant and volume loads over time as individual sources grow in number. The TMDL process in theory requires states to account for future growth by requiring a "margin of safety" in loading projections. However, it is not clear how frequently future growth is included in individual TMDLs or how vigorous the growth calculations are (for example, see EPA [2007a, pp. 12, 37], mentioning considerations of future land use as a consideration in stormwater related TMDLs for only a few—Potash Brook and the lower Cuyahoga River—of the 17 TMDLs described in the report). In any event, as already noted a TMDL is generally triggered only after

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waters have been impaired, which does nothing to anticipate and channel land development before waters become degraded.

The fact that stormwater regulation and land-use regulation are largely decoupled in the federal regulatory system is understandable given the CWA's industrial and municipal wastewater focus and concerns about federalism, but this limited approach is not a credible approach to stormwater management in the future. Federal incentives must be developed to encourage states and municipalities to channel growth in a way that acknowledges, estimates, and minimizes stormwater problems.

Picking up the Slack at the Municipal and State Level

Because it involves land use, any stormwater discharge program strikes at a target that is traditionally within the province of state and even more likely local government regulation. Indeed, it is possible that part of the reason for the EPA's loosely structured permit program is its concern about intruding on the province of state and local governments, particularly given their superior expertise in regulating land-use practices through zoning, codes, and ordinances.

In theory, it is perfectly plausible that some state and local governments will step into the void and overcome some of the problems that afflict the federal stormwater discharge program. If local or state governments required mandatory monitoring or more rigorous and less ambiguous SCMs, they would make considerable progress in developing a more successful stormwater control program. In fact, some states and localities have instituted programs that take these steps. For example, Oregon has established its own benchmarks based on industrial stormwater monitoring data, and it uses the benchmark exceedances to deny industries coverage under Oregon's MSGP. In such cases, the facility operator must file for an individual stormwater discharge NPDES permit. Some municipalities are also engaging in these problems, such as the City of Austin and its ban on coal tar sealants.

Despite these bursts of activity, most state and local governments have not taken the initiative to fill the gaps in the EPA's federal program (see Tucker [2005] for some exceptions). Because they involve some expense, stormwater discharge requirements can increase resident taxes, anger businesses, and strain already busy regulatory staff. Moreover, if the benefits of stormwater controls are not going to materialize in waters close to or of value to the community instituting the controls, then the costs of the program from the locality's standpoint are likely to outweigh its benefits. Federal financial support for state and local stormwater programs is very limited (see section below). Until serious resources are allocated to match the seriousness and complexity of the problem and the magnitude of the caseload, it seems unlikely that states and local communities will step in to fill the gaps in EPA's program. These impediments help explain why there appear to be so many stormwater sources out of compliance

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with the stormwater discharge permit program as discussed above, at least in the few states that have gone on record.

Funding Constraints

Without a doubt, the biggest challenge for states, regions, and municipalities is having adequate fiscal resources dedicated to implement the stormwater program. Box 2-9 highlights the costs of the program for the State of Wisconsin, which has been traditionally strong in stormwater management. Phase I regulations require that a brief description of the annual proposed budget for the following year be included in each annual report, but this requirement has been dispensed with entirely for Phase II.

Ever since the promulgation of the stormwater amendments to the CWA and the issuance of the stormwater regulations, the discharger community pointed out that this statutory requirement had the flavor of an unfunded mandate. Unlike the initial CWA that provided significant funding for research, design, and construction of wastewater treatment plants, the stormwater amendments did not provide any funding to support the implementation of the requirements by the municipal operators. The lack of a meaningful level of investment in addressing the more complex and technologically challenging problem of cleaning up stormwater has left states and municipalities in the difficult position of scrambling for financial support in an era of multiple infrastructure funding challenges.

While a number of communities have passed stormwater fees linked to water quality as described below, a significant number of communities still do not have that financial resource. Municipalities that have not formed utility districts or imposed user fees have had to rely on general funds, where stormwater permit compliance must compete with public safety, fire protection, and public libraries. This circumstance explains why elected local government officials have been reluctant to embrace the stormwater program. Stormwater quality management is often not regarded as a municipal service, unlike flood control or wastewater conveyance and treatment. A concerted effort will need to be made by all stakeholders to make the practical and legal case that stormwater quality management is truly another municipal service like trash collection, wastewater treatment, flood control, etc. Even in states that do collect fees to finance stormwater permit programs, the programs appear underfunded relative to other types of water pollution initiatives. Table 2-10 shows the water quality budget of the California EPA, Los Angeles Regional Water Board. The amount of money per regulated entity (see Table 2-4) dedicated to the stormwater program pales in comparison to the wastewater portion of the NPDES program, and it has

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BOX 2-9
Preliminary Cost Estimates for Complying with Stormwater Discharge Permits in Wisconsin

The Wisconsin Department of Natural Resources (WDNR) was delegated authority under the CWA to administer the stormwater permit program under Chapter NR 216. There are 75 municipalities regulated under individual MS4 permits and 141 MS4s regulated under a general permit for a total of 216 municipalities with stormwater discharge permits.

As part of the "pollution prevention" minimum measure the municipalities are required to achieve compliance with the developed urban area performance standards in Chapter NR 151.13. By March 10, 2008, municipalities subject to a municipal stormwater permit under NR 216 must reduce their annual TSS loads by 20 percent. These same permitted municipalities are required to achieve an annual TSS load reduction of 40 percent by March 10, 2013. The reduction in TSS is compared to no controls, and any existing SCMs will be given credit toward achieving the 20 or 40 percent. As part of their compliance with NR151.13 developed area performance standards, the municipalities are preparing stormwater plans describing how they will achieve the 20 and 40 percent TSS reduction. They are required to use an urban runoff model, such as WinSLAMM or P8, to do the pollutant load analysis.

As the permitted municipalities comply with the six minimum control measures and submit the stormwater plans for their developed area urban areas, the WDNR is learning how much it is going to cost to achieve the requirements in the stormwater discharge permits. Some cities have already been submitting annual reports that include the cost of the six minimum measures. Nine of the permitted municipalities in the southeast part of Wisconsin have been submitting their annual reports for at least four years. The average population of these nine communities is 17,700 with a range of about 6,000 to 65,000. The average cost of the six minimum measures in 2007 for the nine municipalities is $162,900 with a range of $11,600 to $479,000. These costs have not changed significantly from year to year. The average per capita cost is $9 with a range of $1 to $16 per person. Street cleaning and catch basin cleaning (Figures 2-3 and 2-4) cost are included in the cost for the pollution prevention measure, and most of the cities were probably incurring costs for these two activities before the issuing of the permit. On average the street cleaning and catch basin cleaning represent about 40 percent of the annual cost for the six minimum measures. These two activities will help the cities achieve the 20 and 40 percent TSS performance standards for developed urban areas.

Information is available on the preliminary cost of achieving the 40 percent TSS performance standard for selected cities in Wisconsin. The costs were prepared for 15 municipalities by Earth Tech Inc. in Madison, Wisconsin. Areas of the municipality developed after October 2004 are not included in the TSS load analysis. At this point in the preparation of the stormwater plans the costs are just capital cost estimates done at the planning level (Table 2-9). Because the municipalities receive credit for their existing practices, these capital costs represent the additional practices needed to achieve the annual 40 percent TSS reduction. The costs per capita appear to decline for cities with a population over 50,000. All of the costs in Table 2-9 will increase when other costs, such as maintenance and land cost, are included.

For most of the 15 municipalities, the capital costs are for retrofitting dry ponds with permanent pools, installing new wet detention ponds, and improved street cleaning capabilities. Because of their lower cost, the regional type practices have received more attention in the stormwater plans than the source area practices, such as proprietary devices and biofilters. Municipalities with a higher percentage of newer areas will usually have lower cost because the newer developments tend to have stormwater control measures designed to achieve a high level of TSS control, such as wet detention ponds. Older parts of a municipality are usually limited to practices with a lower TSS reduction, such as street cleaning and catch basin cleaning. Of course, retrofitting older areas with higher efficiency practices is expensive,

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BOX 2-9 Continued

and the cost can go higher than expected when unexpected site limitations occur, such as the presence of underground utilities.

Over the next five years all of the 15 municipalities must budget the costs in Table 2-9. It is not clear yet how much of a burden these costs represent to the taxpayers in each municipality. All the permits will be reviewed for compliance with the performance standards in 2013.

TABLE 2-9 Planning-Level Capital Cost Estimate to Meet 40 Percent TSS Reduction

Population	Number of Cities	Average Cost ($)	Minimum Cost ($)	Maximum Cost ($)	Avg. Cost per Capita per Year over 5 Years ($)
5,000 to 10,000	5	1,380,000	425,000	2,800,000	34
10,000 to 50,000	6	4,600,00	2,700,00	9,200,000	35
50,000 to 100,000	4	9,200,000	7,000,000	12,500,000	26

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FIGURE 2-3 Catch basin cleaning. SOURCE: Robert Pitt, University of Alabama.



FIGURE 2-4 Street cleaning. SOURCE: Courtesy of the U.S. Geological Survey.

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TABLE 2-10 Comparison of Fiscal Year (FY) 02–03 Budget with FY 06–07 Budget for Water Quality Programs at the California EPA, Los Angeles Regional Water Board

Program	Funding Source	2002–2003	2006–2007
NPDES[1]	Federal	$2.8 million	$2.6 million
Stormwater	State	$2.3 million	$2.1 million
TMDLs	Federal	$1.47 million	$1.38 million
Spills, Leaks, Investigation Cleanup	State	$1.32 million	$2.87 million
Underground Storage Tanks	State	$2.78 million	$2.74 million
Non-Chapter 15 (Septics)	State	$0.93 million	$0.93 million
Water Quality Planning	Federal	$0.2 million	$0.21 million
Well Investigation	State	$1.36 million	$0.36 million
Water Quality Certification	Federal	$0.2 million	$0.23 million
Total		$17.1 million	$15.82 million

[1]The NPDES row is entirely wastewater funding, as there is no federal money for implementing the stormwater program. Note that the stormwater program in the table is entirely state funded.

declined over time. Furthermore, of the more than $5 billion dollars in low-interest loans provided in 2006 for investments in water quality improvements, 96 percent of that total funding went to wastewater treatment (EPA, 2007d).

There are a number of potential methods that agencies can use to collect stormwater quality management fees, as described more extensively in Chapter 5. A number of states now levy permit fees, with some permits costing in excess of $10,000, to help defray the costs of implementation and enforcement of their stormwater programs. The State of Colorado, for example, has developed an elaborate fee structure for separate types of general permits for industry and construction, as well as MS4s (see *http://www.cdphe.state.co.us/wq/permitsunit/stormwater/StormwaterFees.pdf*). The ability of a state agency to collect fees generally must first be authorized by the state legislatures (see, e.g., Revised Code of Washington 90.48.465, providing the state agency with the authority to "collect expenses for issuing and administering each class of permits"). The lack of state legislative authorization may limit some state agencies from creating such programs on their own. In fact, in those states where fees cannot be levied against permittees, the stormwater programs appear to be both underfinanced and understaffed. Some municipalities have even experienced political backlash because of the absence of a strong state or federal program requiring them to engage in rigorous stormwater management (see Box 2-10).

Stormwater Management Expertise

Historically, engineering curriculum dealt with stormwater management by focusing on the flood control aspects, with little attention given to the water quality aspects. Thus, there has been a significant gap in knowledge and a lack

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BOX 2-10
A City's Ability to Pay for Stormwater, Water, and Sewage Utility Fees

With the implementation of the stormwater permit program of the CWA, stormwater utilities are becoming more common as a way to jointly address regional stormwater quality and drainage issues. One such program is the Jefferson County, Alabama, Storm Water Management Authority (SWMA), formed in 1997 under state legislation that enables local governments to pool their resources in a regional stormwater authority to meet regulations required by the CWA. Jefferson County, the City of Birmingham, and 22 other regional municipalities in Jefferson, part of Shelby and part of St. Clair counties, Alabama, were required to comply with CWA regulations. The act gave the stormwater program the ability to develop a funding mechanism for the program and to form a Public Corporation.

Over the years, SWMA has been responsible for many activities. One of their first goals was to develop a comprehensive GIS database to map outfalls, land uses, stormwater practices, and many other features that were required as part of the permit program. Another major activity conducted by SWMA was the collection of water samples from about 150 sites in the authority's jurisdiction, both during wet and dry weather. SWMA also inspects approximately 4,000 outfalls during dry weather to check for inappropriate connections to the storm drainage system. SWMA coordinates public volunteer efforts with local environmental groups, including the Alabama Water Watch, the Alabama River Alliance, the Black Warrior Riverkeeper, and the Cahaba River Society. SWMA also inspects businesses and industries (including construction sites) within their jurisdictions that are not permitted by the Alabama Department of Environmental Management (ADEM). SWMA does not enforce rules or issue fines, although it can report violators to the state. In its most famous case, it reported McWane Inc. for pollution that led to investigations by the state and the federal government, and ultimately a trial and criminal convictions.

The Birmingham News (Bouma, 2007) reported that from 1997 to 2005, SWMA's responsibilities under the CWA increased substantially, although their fees did not rise. In late 2005, SWMA proposed that member cities increase their stormwater charges from $5 a year to $12 a year per household for residences and from $15 to $36 per year for businesses. At that point, the Business Alliance for Responsible Development (BARD), a group of large businesses, utilities, mining interests, developers and landowners, began to argue that the group was financially irresponsible, and its attorneys convinced member cities that they could save money by withdrawing from SWMA. Even though SWMA withdrew its fee increase request, many local municipalities have pulled out of SWMA, significantly reducing the agency's budget and ability to conduct comprehensive monitoring and reporting. BARD claims the pollution control programs of the ADEM are sufficient. In their countersuit, several environmental groups maintain that ADEM has failed to adequately protect the state's waters because the agency is underfunded, understaffed, and ineffective at enforcement. Much of the Cahaba and Black Warrior River systems within Jefferson County have such poor water quality that they frequently violate water quality standards (*http://www.southernenvironment.org*). SWMA has been significantly impaired in its ability to monitor and report water quality violations with the withdrawal of many of its original member municipalities and the associated reduced budget.

At the same time, the sewer bill for a family of four in the region is expected to be about $63 per month in 2008. Domestic water rates have also increased, up to about $32 per month (*The Birmingham News*, Barnett Wright, December 30, 2007). Domestic water rates have increased in recent years in attempts to upgrade infrastructure in response to widespread and long-lasting droughts and to cover rising fuel costs. It is ironic that stormwater management agency fees are very small compared to these other urban water agency fees per household by orders of magnitude. The $12 per year stormwater fee was used to justify the dismantling of an agency that was doing its job and identifying CWA violators. In order to bring some reasonableness to the stormwater management situation and expected fees, it may be possible for the EPA to re-examine its guidelines of 2 percent of the household income for sewer fees to reflect other components of the urban water system, and to ensure adequate enforcement of existing regulations, especially by underfunded state environmental agencies.

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of qualified personnel. In areas where SCMs are just beginning to be introduced, many municipalities, industrial operators, and construction site operators are not prepared to address water quality issues; the problem is especially difficult for smaller municipalities and operators. The profession and academia are moving to correct this shortfall. Professional associations such as the Water Environment Federation (WEF) and the American Society for Civil Engineers (ASCE) are co-authoring an update of the WEF/ASCE Manual of Practice "Design of Urban Runoff Controls" that integrates quality and quantity, after years of issuing separate manuals of design and operation for the water quality and water quantity elements of stormwater management.

The split between water quantity and quality is evident in municipal efforts that have focused primarily on flood control issues and design of appropriate appurtenances tailored for this purpose. As discussed earlier, most municipal codes specify practices to collect and move water away as fast as possible from urbanized areas. Very little focus has been put on practices to mitigate the quality of the stormwater runoff. This is especially true in urbanized areas with separate municipal storm sewer systems. Even the designation "sewer" is borrowed from the sanitary sewer conveyance system terminology. In arid or semiarid areas, these flood control systems have been maximally engineered such that river beds have become concrete channels. A typical example is the Los Angeles River, which most of the year resembles an empty freeway. This analysis does not intend to minimize the engineering feat of designing a robust and reliable flood control system. For example, during the unusually wet 2005 season in Southern California, the Los Angeles area did not have any major flooding incidents. However, based on recent studies (Stein and Ackerman, 2007) up to 80 percent of the annual metals loading from six watersheds in the Los Angeles area was transported by stormwater events.

Because of the historical lack of focus on stormwater quality, municipal departments in general are not designed to address the issue of pollution in urban runoff. Just recently and due to the stormwater regulations, cities have been adding personnel and creating new sections to deal with the issue. However, because of the complexities of the task, many duties are spread among various municipal departments, and more often than not coordination is still lacking. Perhaps most problematic is the fact that the local governmental entities in charge of stormwater management are often different from those that oversee land-use planning and regulation. This disconnect between land-use planning and stormwater management is especially true for large cities. It is not unusual for program responsibilities to be compartmentalized, with industrial aspects of the program handled by one group, construction by another, and planning and public education by other distinct units. Smaller cities may have one person handling all aspects of the program assisted by a consulting firm. While coordination may be ensured, the task can be overwhelming for a single staff person.

Beyond water quality issues, training to better understand the importance of volume control and the role of LID has not yet reached many practitioners.

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Many established practices and industry standards in the fields of civil, geotechnical, and structural engineering were developed prior to the introduction of the current group of SCMs and can unnecessarily limit their use. Indeed, certain SCMs such as porous landscape detention, extended detention, and vegetated swales require special knowledge about soils and appropriate plant communities to ensure their longevity and ease of maintenance.

Supplementing the Clean Water Act with Other Federal Authorities that Can Control Stormwater Pollutants at the Source

EPA does have other supplemental authorities that are capable of making significant progress in reducing or even eliminating some of the problematic stormwater pollutants at the national level. Under both the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the TSCA, for example, EPA could restrict some of the most problematic pollutants at their source by requiring labels that alert consumers to the deleterious water quality impacts caused by widely marketed chemical products, restricting their use, or even banning them. This source-based regulation bypasses the need of individual dischargers or governments to be concerned with reducing the individual contaminants in stormwater.

The City of Austin's encounter with coal tar-based asphalt sealants provides an illustration of the types of products contributing toxins to stormwater discharges that could be far better controlled at the production or marketing stage. Through detective work, the City of Austin learned that coal tar-based asphalt sealants leach high levels of polycyclic aromatic hydrocarbons (PAHs) into surface waters (Mahler et al., 2005; Van Metre et al., 2006). The city discovered this because the PAHs were found in sediments in Barton Springs, which were in turn leading to the decline of the endangered Barton Creek salamander (Richardson, 2006). By tracing upstream, the city was able to find the culprit—a parking lot at the top of the hill that was recently sealed with coal tar sealant and produced very high PAH readings. Further tests revealed that coal tar sealants typically leach very high levels of PAHs, but other types of asphalt sealants that are not created from coal tar are much less toxic to the environment and are no more expensive than the coal tar-based sealants (City of Austin, 2004). As a result of its findings, the City of Austin banned the use of coal tar-based asphalt sealants. Several retailers, including Lowes and Home Depot followed the city's lead and refused to carry coal tar sealants. Dane County in the State of Wisconsin has now also banned coal tar sealants[1].

[1] See, e.g., Coal Tar-based pavement sealants studied, Science Daily, February 12, 2007, available at *http://www.sciencedaily.com/upi/index.php?feed=Science&article=UPI-1-20070212-10255500-bc-us-sealants.xml*; Matthew DeFour, Dane County bans Sealants with Coal Tar, Wisconsin State Journal, April 6, 2007, available at *http://www.madison.com/wsj/home/local/index.php?ntid=128156&ntpid=5.*

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For reasons that appear to inure to the perceived impotency of TSCA and the enormous burdens of restricting chemicals under that statute, EPA declined to take regulatory action under TSCA against coal tar sealants (Letter from Brent Fewell, Acting Assisting Administrator, U.S. EPA, to Senator Jeffords, October 16, 2006, p. 3). Yet, it had authority to consider whether this particular chemical mixture presents an "unreasonable risk" to health and the environment, particularly in comparison to a substitute product that is available at the same or even lower price [15 U.S.C. § 2605(a); *Corrosion Proof Fittings vs. EPA*, 947 F.2d 1201 (5th Cir. 1991)]. Indeed, if EPA had undertaken such an assessment, it might have even discovered that the coal tar sealants are not as inferior as Austin and others have concluded; alternatively it could reveal that these sealants do present an "unreasonable risk" since there are substantial risks from the sealant without corresponding benefits, given the availability of a less risky substitute.

A similar situation holds for other ubiquitous stormwater pollutants, such as the zinc in tires, roof shingles, and downspouts; the copper in brake pads; heavy metals in fertilizers; creosote- and chromated copper arsenate (CCA)-treated wood; and de-icers, including road salt. Each of these sources may be contributing toxins to stormwater in environmentally damaging amounts, and each of these products might have less deleterious and equally cost-effective substitutes available, yet EPA and other federal agencies seem not to be undertaking any analysis of these possibilities. The EPA's phase-out of lead in gasoline in the 1970s, which led to measurable declines in the concentrations of lead in stormwater by the mid-1980s (see Figure 2-5), may provide a model of the type of gradual regulatory ban EPA could use to reduce contaminants in products that are non-essential.

Some states are taking more aggressive forms of product regulation. For example, in the mid-1990s, numerous scientific studies conducted in California by stormwater programs, wastewater treatment plants, the University of California, California Water Boards, the U.S. Geological Survey, and EPA showed widespread toxicity in local creeks, stormwater runoff, and wastewater treatment plant effluent from pesticide residues, particularly diazinon and chlopyrifos (which are commonly used organophosphate pesticides available in hundreds of consumer products) (Kuivila and Foe, 1995; MacCoy et al., 1995). As a result, the California Water Boards and EPA listed many waters in urban areas of California as being impaired in accordance with CWA Section 303(d). Many cities and counties were required to implement expensive programs to control the pollution under the MS4 NPDES permits to restore the designated beneficial uses of pesticide-impaired waters. Figure 2-6 shows the results of one such action—a ban on diazinon.

In sum, even though there are a number of sources of pollutants—from roof tiles to asphalt sealants to de-icers to brake linings—that could be regulated more restrictively at the product and market stage, EPA currently provides little meaningful regulatory oversight of these sources with regard to their contri-

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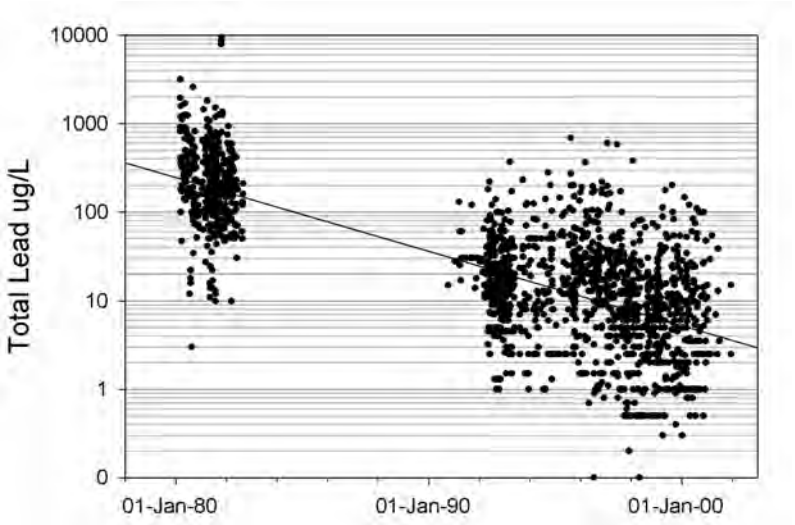

FIGURE 2-5 Trend of lead concentrations in stormwater in EPA rain zone 2 from 1980 to 2001. Although the range of lead concentrations for any narrow range of years is quite large, there is a significant and obvious trend in concentration for these 20 years. SOURCE: National Stormwater Quality Database (version 3).

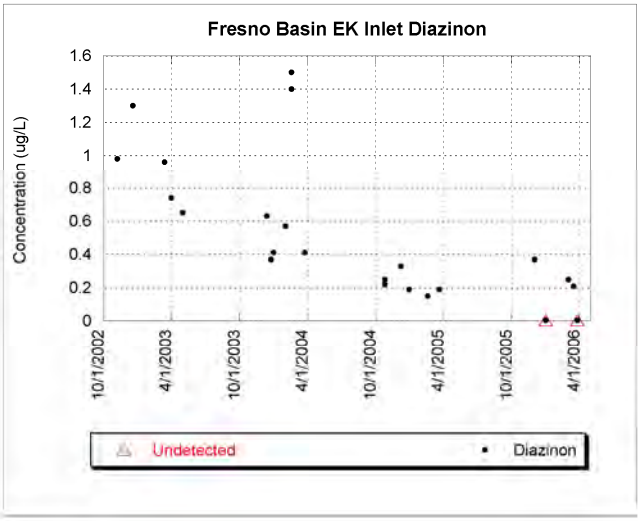

FIGURE 2-6 Trend of the organophosphate pesticide diazinon in MS4 discharges that flow into a stormwater basin in Fresno County, California, following a ban on the pesticide. The figure shows the significant drop in the diazinon concentration in just four years to levels where it is no longer toxic to freshwater aquatic life. EPA prohibited the retail sale of diazinon for crack and crevice and virtually all indoor uses after December 31, 2002, and non-agriculture outdoor use was phased out by December 31, 2004. Restricted use for agricultural purposes is still allowed. SOURCE: Reprinted, with permission, from Brosseau (2007). Copyright 2006 by Fresno Metropolitan Flood Control District.

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bution to stormwater pollution. The EPA's authority to prioritize and target products that increase pollutants in runoff, both for added testing and regulation, seems clear from the broad language of TSCA [15 U.S.C. § 2605(a)]. The underutilization of this national authority to regulate environmentally deleterious stormwater pollutants thus seems to be a remediable shortcoming of EPA's current stormwater regulatory program.

CONCLUSIONS AND RECOMMENDATIONS

In an ideal world, stormwater discharges would be regulated through direct controls on land use, strict limits on both the quantity and quality of stormwater runoff into surface waters, and rigorous monitoring of adjacent waterbodies to ensure that they are not degraded by stormwater discharges. Future land-use development would be controlled to prevent increases in stormwater discharges from predevelopment conditions, and impervious cover and volumetric restrictions would serve as a reliable proxy for stormwater loading from many of these developments. Large construction and industrial areas with significant amounts of impervious cover would face strict regulatory standards and monitoring requirements for their stormwater discharges. Products and other sources that contribute significant pollutants through stormwater—like de-icing materials, urban fertilizers and pesticides, and vehicular exhaust—would be regulated at a national level to ensure that the most environmentally benign materials are used when they are likely to end up in surface waters.

In the United States, the regulation of stormwater looks quite different from this idealized vision. Since the primary federal statute—the CWA—is concerned with limiting pollutants into surface waters, the volume of discharges are secondary and are generally not regulated at all. Moreover, given the CWA's focus on regulating pollutants, there are few if any incentives to anticipate or limit intensive future land uses that generate large quantities of stormwater. Most stormwater discharges are regulated instead on an individualized basis with the demand that existing point sources of stormwater pollutants implement SCMs, without accounting for the cumulative contributions of multiple sources in the same watershed. Moreover, since individual stormwater discharges vary with terrain, rainfall, and use of the land, the restrictions governing regulated parties are generally site-specific, leaving a great deal of discretion to the dischargers themselves in developing SWPPPs and self-monitoring to ensure compliance. While states and local governments are free to pick up the large slack left by the federal program, there are effectively no resources and very limited infrastructure with which to address the technical and costly challenges faced by the control of stormwater. These problems are exacerbated by the fact that land use and stormwater management responsibilities within local governments are frequently decoupled. The following conclusions and recommendations are made.

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EPA's current approach to regulating stormwater is unlikely to produce an accurate or complete picture of the extent of the problem, nor is it likely to adequately control stormwater's contribution to waterbody impairment. The lack of rigorous end-of-pipe monitoring, coupled with EPA's failure to use flow or alternative measures for regulating stormwater, make it difficult for EPA to develop enforceable requirements for stormwater dischargers. Instead, under EPA's program, the stormwater permits leave a great deal of discretion to the regulated community to set their own standards and self-monitor.

Implementation of the federal program has also been incomplete. Current statistics on the states' implementation of the stormwater program, discharger compliance with stormwater requirements, and the ability of states and EPA to incorporate stormwater permits with TMDLs are uniformly discouraging. Radical changes to the current regulatory program (see Chapter 6) appear necessary to provide meaningful regulation of stormwater dischargers in the future.

Future land development and its potential increases in stormwater must be considered and addressed in a stormwater regulatory program. The NPDES permit program governing stormwater discharges does not provide for explicit consideration of future land use. Although the TMDL program expects states to account for future growth in calculating loadings, even these more limited requirements for degraded waters may not always be implemented in a rigorous way. In the future, EPA stormwater programs should include more direct and explicit consideration of future land developments. For example, stormwater permit programs could be predicated on rigorous projections of future growth and changes in impervious cover within an MS4. Regulators could also be encouraged to use incentives to lessen the impact of land development (e.g., by reducing needless impervious cover within future developments).

Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. These analogs for the traditional focus on the "discharge" of "pollutants" have great potential as a federal stormwater management tool because they provide specific and measurable targets, while at the same time they focus regulators on water degradation resulting from the increased volume as well as increased pollutant loadings in stormwater runoff. Without these more easily measured parameters for evaluating the contribution of various stormwater sources, regulators will continue to struggle with enormously expensive and potentially technically impossible attempts to determine the pollutant loading from individual dischargers or will rely too heavily on unaudited and largely ineffective self-reporting, self-policing, and paperwork enforcement.

Local building and zoning codes, and engineering standards and practices that guide the development of roads and utilities, frequently do not promote or allow the most innovative stormwater management. Fortu-

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nately, a variety of regulatory innovations—from more flexible and thoughtful zoning to using design review incentives to guide building codes to having separate ordinances for new versus infill development can be used to encourage more effective stormwater management. These are particularly important to promoting redevelopment in existing urban areas, which reduces the creation of new impervious areas and takes pressure off of the development of lands at the urban fringe (i.e., reduces sprawl).

EPA should provide more robust regulatory guidelines for state and local government efforts to regulate stormwater discharges. There are a number of ambiguities in the current federal stormwater program that complicate the ability of state and local governments to rigorously implement the program. EPA should issue clarifying guidance on several key areas. Among the areas most in need of additional federal direction are the identification of industrial dischargers that constitute the highest risk with regard to stormwater pollution and the types of permit requirements that should apply to these high-risk sources. EPA should also issue more detailed guidance on how state and local governments might prioritize monitoring and enforcement of the numerous and diverse stormwater sources within their purview. Finally, EPA should issue guidance on how stormwater permits could be drafted to produce more easily enforced requirements that enable oversight and enforcement not only by government officials, but also by citizens. Further detail is found in Chapter 6.

EPA should engage in much more vigilant regulatory oversight in the national licensing of products that contribute significantly to stormwater pollution. De-icing chemicals, materials used in brake linings, motor fuels, asphalt sealants, fertilizers, and a variety of other products should be examined for their potential contamination of stormwater. Currently, EPA does not apparently utilize its existing licensing authority to regulate these products in a way that minimizes their contribution to stormwater contamination. States can also enact restrictions on or tax the application of pesticides or even ban particular pesticides or other particularly toxic products. Austin, for example, has banned the use of coal-tar sealants within city boundaries. States and localities have also experimented with alternatives to road salt that are less environmentally toxic. These local efforts are important and could ultimately help motivate broader scale, federal restrictions on particular products.

The federal government should provide more financial support to state and local efforts to regulate stormwater. State and local governments do not have adequate financial support to implement the stormwater program in a rigorous way. At the very least, Congress should provide states with financial support for engaging in more meaningful regulation of stormwater discharges. EPA should also reassess its allocation of funds within the NPDES program. The agency has traditionally directed funds to focus on the reissuance of NPDES

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wastewater permits, while the present need is to advance the NPDES stormwater program because NPDES stormwater permittees outnumber wastewater permittees more than five fold, and the contribution of diffuse sources of pollution to degradation of the nation's waterbodies continues to increase.

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3
Hydrologic, Geomorphic, and Biological Effects of Urbanization on Watersheds

A watershed is defined as the contributing drainage area connected to an outlet or waterbody of interest, for example a stream or river reach, lake, reservoir, or estuary. Watershed structure and composition include both naturally formed and constructed drainage networks, and both undisturbed areas and human dominated landscape elements. Therefore, the watershed is a natural geographic unit to address the cumulative impacts of urban stormwater. Urbanization has affected change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a built drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed can experience radically different flow regimes than they did prior to urbanization. This altered hydrology, when combined with the introduction of pollutant sources that accompany urbanization (such as people, domesticated animals, industries, etc.), has led to water quality degradation of many urban streams.

This chapter first discusses the typical land-use and land-cover composition of urbanized watersheds. This is followed by a description of changes to the hydrologic and geomorphic framework of the watershed that result from urbanization, including altered runoff, streamflow mass transport, and stream-channel stability. The chapter then discusses the characteristics of stormwater runoff, including its quantity and quality from different land covers, as well as the characteristics of dry weather runoff. Finally, the effects of urbanization on aquatic ecosystems and human health are explored.

LAND-USE CHANGES

Land use has been described as the human modification of the natural environment into the built environment, such as fields, pastures, and settlements. Important characteristics of different land uses are the modified surface characteristics of the land and the activities that take place within that land use. From a stormwater viewpoint, land uses are usually differentiated by building density and comprised of residential, commercial, industrial, institutional, recreational, and open-space land uses, among others. Each of these land uses usually has distinct activities taking place within it that affect runoff quality. In addition, each land use is comprised of various amounts of surface land cover, such as roofs, roads, parking areas, and landscaped areas. The amount and type of each cover also affect the quality and quantity of runoff from urban areas. Changes in land use and in the land covers within the land uses associated with develop-

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ment and redevelopment are therefore important considerations when studying local receiving water problems, the sources of these problems within the watershed, and the stormwater control opportunities.

Land-Use Definitions

Although there can be many classifications of residential land use, a crude and common categorization is to differentiate by density. High-density residential land use refers to urban single-family housing at a density of greater than 6 units per acre, including the house, driveway, yards, sidewalks, and streets. Medium density is between 2 and 6 units per acre, while low density refers to areas where the density is 0.7 to 2 units per acre. Another significant residential land use is multiple-family housing for three or more families and from one to three stories in height. These units may be adjoined up-and-down, side-by-side, or front-and-rear.

There are a variety of commercial land uses common in the United States. The strip commercial area includes those buildings for which the primary function is the sale of goods or services. This category includes some institutional lands found in commercial strips, such as post offices, court houses, and fire and police stations. This category does not include warehouses or buildings used for the manufacture of goods. Shopping centers are another common commercial area and have the unique distinction that the related parking lot that surrounds the buildings is at least 2.5 times the area of the building roof area. Office parks are a land use on which non-retail business takes place. The buildings are usually multi-storied and surrounded by larger areas of lawn and other landscaping. Finally, downtown central business districts are highly impervious areas of commercial and institutional land use.

Industrial areas can be differentiated by the intensity of the industry. For example, “manufacturing industrial” is a land use that encompasses those buildings and premises that are devoted to the manufacture of products, with many of the operations conducted outside, such as power plants, steel mills, and cement plants. Institutional areas include a variety of buildings, for example schools, churches, and hospitals and other medical facilities that provide patient overnight care.

Roads constitute a very important land use in terms of pollutant contributions. The “freeway” land use includes limited-access highways and the interchange areas, including any vegetated rights-of-ways. Finally, there are a variety of open-space categories, such as cemeteries, parks, and undeveloped land. Parks include outdoor recreational areas such as municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas. Undeveloped lands are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, transformer stations, radio and TV transmission areas, water towers, and railroad rights-of-way.

The preceding land-use descriptions are the traditional categories that make

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up the vast majority of the land in U.S. cities. However, there are emerging categories of land use, such as those espoused under the term New Urbanism, which combine several area types (such as commercial and high-density residential areas). Although land use can be broadly and generally categorized, local variations can be extremely important such that locally available land-use data and definitions should always be used. For example, local planning agencies typically do not separate the medium-density residential areas into subcategories. However, this may be necessary to represent different development trends that have occurred with time, and to represent newly emerging types of land uses for an area. Box 3-1 discusses the subtle influence that tree canopy could have on the residential land-use classification.

Trends in Urbanization

Researchers at Columbia University (de Sherbinin, 2002) state that 83 percent of the Earth's land surface has been affected by human settlements and activities, with the urbanized areas comprising about 4 percent of the total land use of the world. Urban areas are expanding world-wide, especially in developing countries. The United Nations Population Division estimates suggest that the

BOX 3-1
The Role of Tree Cover in Residential Land Use

Figure 3-1 shows two medium-density residential neighborhoods, one older and one newer. Tree canopy is obviously different in each case, and it may have an effect on seasonal organic debris in an area and possibly on nutrient loads (although nutrient discharges appear to be more related to homeowner fertilizer applications). Increased tree canopy cover also has a theoretical benefit in reducing runoff quantities due to increased interception losses. In both cases, however, monitoring data to quantify these benefits are sparse. Xiao (1998) examined the effect urban tree cover had on the rainfall volume striking the ground in Sacramento, California. The results indicated that the type of tree or type of canopy cover affected the amount of rainfall reduction measured during a rain event, such that large broad-leafed evergreens and conifers reduced the rainfall that reached the ground by 36 percent, while medium-sized conifers and deciduous trees reduced the rainfall by 18 percent. Cochran (2008) compared the volume and intensity of rain that reached the ground in an open area (no canopy cover) versus two areas with intact canopy covers in Shelby County, Alabama, over a year. The sites were sufficiently close to each other to assume that the rainfall characteristics were the same in terms of the intensity and the variation of intensity and volume during the storm. Rainfall "throughfall" was reduced by about 13.5 percent during the spring and summer months when heavily wooded cover existed. The rainfall characteristics at the leafless tree sites (winter deciduous trees) were not significantly different from the parking lot control sites. In many locations around the county, very high winds are associated with severe storms, significantly decreasing the interception losses. Of course, mature trees are known to provide other benefits in urban areas, including shading to counteract stormwater temperature increases and massive root systems that help restore beneficial soil structure conditions. Additional research is needed to quantify the benefits of urban trees through a comprehensive monitoring program.

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BOX 3-1 Continued



FIGURE 3-1 Two medium-density residential areas (no alleys); the area below is older. SOURCE: Robert Pitt, University of Alabama.

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world's population will become mostly urbanized by 2010, whereas only 37 percent of the world's population was urbanized in 1970. De Sherbinin (2002) concludes that although the extent of urban areas is not large when compared with other land uses (such as agriculture or forestry) their environmental impact is significant. Population densities in the cities are large, and their political, cultural, and economic influence is great. Most industrial activity is also located near cities. The influence of urban areas extends beyond their boundaries due to the need for large amounts of land for food and energy production, to generate raw materials for industry, for building water supplies, for obtaining other resources such as construction materials, and for recreational areas. One study estimated that the cities of Baltic Europe require from 500 to more than 1,000 times the urbanized land area (in the form of forests, agricultural, marine, and wetland areas) to supply their resources and to provide for waste disposal (de Sherbinin, 2002).

Currently, considerable effort is being spent investigating land-use changes world-wide and in the United States in support of global climate change research. The U.S. Geological Survey (USGS, 1999) has prepared many research reports describing these changes; Figure 3-2 shows the results for one study in the Chicago and Milwaukee areas, and Figure 3-3 shows the results for a study in the Chesapeake Bay area. These maps graphically show the dramatic rate of change in land use in these areas. The very large growth in urban areas during the 20 years between 1975 and 1995 is especially astonishing. By 1995, Milwaukee and Chicago's urbanized areas more than doubled in size from prior years. Even more rapid growth has occurred in the Washington, D.C.–Baltimore area.

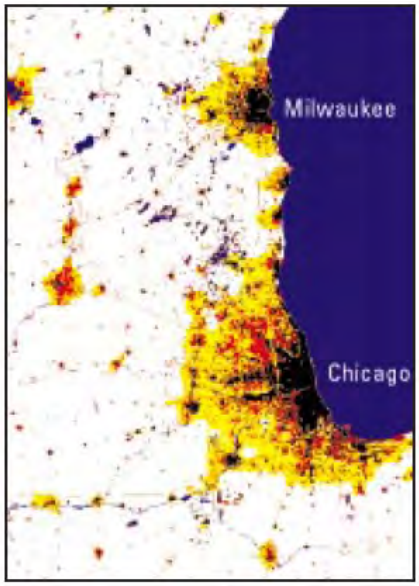

FIGURE 3-2 The extent of urban land in Chicago and Milwaukee in 1955 (black), 1975 (medium gray), and 1995 (light gray). SOURCE: USGS (1999).

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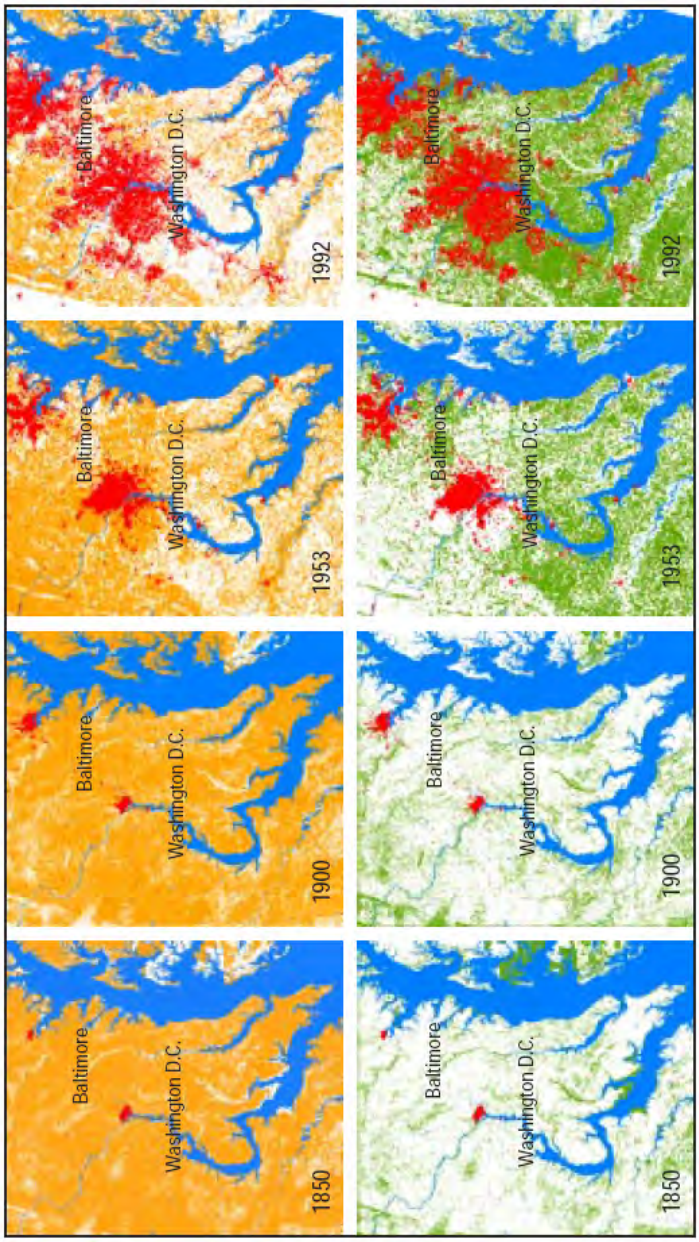

FIGURE 3-3 This series of maps compares changes in urban, agricultural, and forested lands in the Patuxent River watershed over the past 140 years. The top series shows the extent of urban areas (black) along with agriculture (gray), which was at its peak in the mid- to late 1800s. The bottom series show that urban (black) and forested land (gray) have increased since 1900. SOURCE: USGS (1999).

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Many different metrics can be used to measure the rate of urbanization in the United States, including the number of housing starts and permits and the level of new U.S. development. The latter is tracked by the U.S. Department of Agriculture's (USDA) National Resources Inventory (USDA, 2000). The inventory, conducted every five years, covers all non-federal lands in the United States, which is 75 percent of the U.S. total land area. The inventory uses land-use information from about 800,000 statistically selected locations. From 1992 to 1997, about 2.2 million acres per year were converted from non-developed to developed status. According to the USDA (2000), the per capita developed land use (acres per person, a classical measure of urban sprawl) has increased in the United States between the years of 1982 and 1997 from about 0.43 to about 0.49 acres per person. The smallest amount of developed land used per person was for New York and Hawaii (0.15 acres), while the largest land consumption rate was for North Dakota, at about 10 times greater. Surprisingly, Los Angeles is the densest urban area in the country at 0.11 acres per person. The amount of urban sprawl is also directly proportionate to the population growth. According to Beck et al. (2003):

> In the 16 cities that grew in population by 10 percent or less between 1970 and 1990 (but whose population did not decline), developed area expanded 38 percent—more than in cities that declined in population but considerably less than in the cities where population increased more dramatically. Cities that grew in population by between 10 and 30 percent sprawled 54 percent on average. Cities that grew between 31 and 50 percent sprawled 72 percent on average. Cities that grew in population by more than 50 percent sprawled on average 112 percent. These findings confirm the common sense, but often unacknowledged proposition, that there is a strong positive relationship between sprawl and population growth.

In most areas, the per capita use of developed land has increased, along with the population growth. However, even some cities that had no population growth or had negative growth, such as Detroit, still had large amounts of sprawl (increased amounts of developed land used per person), but usually much less than cities that had large population growth. Los Angeles actually had an 8 percent decreased rate of land consumption per resident during this period, but the city still experienced tremendous growth in land area due to its very large population growth. The additional 3.1 million residents in the Los Angeles area during this time resulted in the development of almost an additional 400 square miles.

Land-Cover Characteristics in Urban Areas

As an area urbanizes, the land cover changes from pre-existing rural sur-

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faces, such as agricultural fields or forests, to a combination of different surface types. In municipal areas, land cover can be separated into various common categories—pictured and described in Box 3-2—that include roofs, roads, parking areas, storage areas, other paved areas, and landscaped or undeveloped areas.

Most attention is given to impervious cover, which can be easily quantified for different types of land development. Given the many types of land cover described in Box 3-2, impervious cover is composed of two principal components: building rooftops and the transportation system (roads, driveways, and parking lots). Compacted soils and unpaved parking areas and driveways also have "impervious" characteristics in that they severely hinder the infiltration of water, although they are not composed of pavement or roofing material. In terms of total impervious area, the transportation component often exceeds the rooftop component (Schueler, 1994). For example, in Olympia, Washington, where 11 residential multifamily and commercial areas were analyzed in detail, the areas associated with transportation-related uses comprised 63 to 70 percent of the total impervious cover (Wells, 1995). A significant portion of these impervious areas—mainly parking lots, driveways, and road shoulders—experience only minimal traffic activity. Most retail parking lots are sized to accommodate peak parking usage, which occurs only occasionally during the peak holiday shopping season, leaving most of the area unused for a majority of the time. On the other hand, many business and school parking areas are used to their full capacity nearly every work day and during the school year. Other differences at parking areas relate to the turnover of parking during the day. Parked vehicles in business and school lots are mostly stationary throughout the work and school hours. The lighter traffic in these areas results in less vehicle-associated pollutant deposition and less surface wear in comparison to the greater parking turnover and larger traffic volumes in retail areas (Brattebo and Booth, 2003).

As described in Box 1-1, impervious cover is broken down into two main categories: directly connected impervious areas (or effective impervious area) and non-directly connected (disconnected) impervious areas (Sutherland, 2000; Gregory et al., 2005) (although it is recognized that these two states are end-members of a range of conditions). Directly connected impervious area includes impervious surfaces which drain directly to the sealed drainage system without flowing appreciable distances over pervious surfaces (usually a flow length of less than 5 to 20 feet over pervious surfaces, depending on soil and slope characteristics and the amount of runoff). Those areas are the most important component of stormwater runoff quantity and quality problems. Approximately 80 percent of directly connected impervious areas are associated with vehicle use such as streets, driveways, and parking (Heaney, 2000).

Values of imperviousness can vary significantly according to the method used to estimate the impervious cover. In a detailed analysis of urban imperviousness in Boulder, Colorado, Lee and Heaney (2003) found that hydrologic modeling of the study area resulted in large variations (265 percent difference)

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BOX 3-2
Land Cover in Urban Areas

For any given land use, there is a range of land covers that are typical. Common land covers are described below, along with some indication of their contribution to stormwater runoff and their pollutant-generating ability.

Roofs. These are usually either flat or pitched, as both have significantly different runoff responses. Flat roofs can have about 5 to 10 mm of detention storage while pitched roofs have very little detention storage. Roofing materials are also usually quite different for these types of roofs, further affecting runoff quality. In addition, roof flashing and roof gutters may be major sources of heavy metals if made of galvanized metal or copper. Directly connected roofs have their roof drains efficiently connected to the drainage system, such as direct connections to the storm drainage itself or draining to driveways that lead to the drainage system. These directly connected roofs have much more of their runoff waters reaching the receiving waters than do partially connected roofs, which drain to pervious areas.



A directly connected roof drain



A disconnected roof drain (drains to pervious area)

Parking Areas. These can be asphalt or concrete paved (impervious surface) or unpaved (traditionally considered a pervious surface) and are either directly connected or drain to adjacent pervious areas. Areas that have rapid turnover of parked cars throughout the day likely have greater levels of contamination due to the frequent starting of the vehicles, an expected major source of pavement pollutants. Unpaved parking areas actually should be considered impervious surfaces, as the compacted surface does not allow any infiltration of runoff. Besides automobile activity in the parking areas, other associated activities contribute to contamination. For example, parked cars in disrepair awaiting service can contribute to parking area runoff contamination. In addition, maintenance of the pavement surface, such as coal-tar seal coating, can be significant sources of polycyclic aromatic hydrocarbons (PAHs) to the runoff.

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BOX 3-2 Continued



Paved parking area with frequent automobile movement



Contamination of paved parking areas due to commercial activities

Storage Areas. These can also be paved, unpaved, directly connected, or drained to pervious areas. As with parking areas, unpaved storage areas should not be considered pervious surfaces because the compacted material effectively hinders infiltration. Detention storage runoff losses from unpaved storage areas can be significant. In storage areas (especially in commercial and industrial land uses), activities in the area can have significant effects on runoff quality.



Contaminated paved storage area at vehicle junk yard



Heavy equipment storage area on concrete surface

Streets. Streets in municipal areas are usually paved and directly connected to the storm drainage system. In municipal areas, streets constitute a significant percentage of all impervious surfaces and runoff flows. Features that affect the quality of runoff from streets include the varying amounts of traffic on different roads and the amount and type of roadside vegetation. Large seasonal phosphorus loads can occur from residential roads in heavily wooded areas, for example.

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Wide arterial street with little roadside vegetation (left) and narrow residential street with substantial vegetation (top, right)

Other Paved Areas. Other paved areas in municipal regions include driveways, playgrounds, and sidewalks. Depending on their slopes and local grading, these areas may drain directly to the drainage system or to adjacent pervious areas. In most cases, the runoff from these areas contributes little to the overall runoff for an area, and the runoff quality is of relatively better quality than from the other "hard" surfaces.

Landscaped and Turf Areas. Although these are some of the only true pervious surfaces in municipal areas, disturbed urban soils can be severely compacted, with much more reduced infiltration rates than are assumed for undisturbed regional soils. Besides the usually greater than expected quantities of runoff of pervious surfaces in urban areas, they can also contribute high concentrations of various pollutants. In areas with high rain intensities, erosion of sediment can be high from pervious areas, resulting in much higher concentrations of total suspended solids (TSS) than from paved areas. Also, landscaping chemicals, including fertilizers and pesticides, can be transported from landscaped urban areas. Undeveloped woods in urban areas can have close to natural runoff conditions, but many parks and other open-space areas usually have degraded runoff compared to natural conditions. Turf grass has unique characteristics compared to other landscaped areas in that the soil structure is usually more severely degraded compared to natural conditions. The normally shallower root systems are not as effective in restoring compacted soils and they can remain compacted due to some activities (pathways, parked cars, playing fields, etc.) that do not occur on areas planted with shrubs and trees.

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BOX 3-2 Continued



Soil erosion from turf areas with fine-grained soils during periods of high rain intensities

Undeveloped Areas. Undeveloped areas in otherwise urban locations differ from natural areas. In many situations, they can be previously disturbed (cleared and graded) areas that have not been sold or developed. They may be overgrown with various local vegetation types that thrive in disturbed locations. In other situations, undeveloped areas may be small segments of natural areas that have not been disturbed or revegetated. In this case, their stormwater characteristics may approach natural conditions but still be degraded due to adjacent activities and atmospheric deposition.

SOURCE: Pitt and Voorhees (1995, 2002). Photographs courtesy of Robert Pitt, University of Alabama.

in the calculations of peak discharge when impervious surface areas were determined using different methods. They concluded that the main focus should be on effective impervious area (EIA) when examining the effects of urbanization on stormwater quantity and quality.

Runoff from disconnected impervious areas can be spread over pervious surfaces as sheet flow and given the opportunity to infiltrate before reaching the drainage system. Therefore, there can be a substantial reduction in the runoff volume and a delay in the remaining runoff entering the storm drainage collection system, depending on the soil infiltration rate, the depth of the flow, and the

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available flow length. Examples of disconnected impervious surfaces are rooftops that discharge into lawns, streets with swales, and parking lots with runoff directed to adjacent open space or swales. From a hydrologic point of view, road-related imperviousness usually exerts a larger impact than rooftop-related imperviousness, because roadways are usually directly connected whereas roofs can be disconnected (Schueler, 1994).

Methods for Determining Land Use and Land Cover

Historically, land-use and land-cover information was acquired by a combination of field measurements and aerial photographic analyses—methods that required intensive interpretation and cross validation to guarantee that the analyst's interpretations were reliable (Goetz et al., 2003). Figure 3-4 is an example of a high-resolution panchromatic aerial photograph that was taken from an airplane in Toronto and used for measurements of urban surfaces (Pitt and McLean, 1986). Most recently, satellite images have become available at high spatial resolution for many areas (<1 to 5 m resolution) and have the advantage of digital multi-spectral information more complete than even that provided by digital orthophotographs. Minnesota has one of the longest records (over 20 years) of continuously recorded statistics on land cover and impervious surfaces derived from satellite images—information which has been incorporated into the



FIGURE 3-4 Example of a high-resolution panchromatic aerial photograph of an industrial area used for measurements of urban surfaces. SOURCE: Pitt and McLean (1986).

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Minnesota Statewide Conservation and Preservation Plan. Some of the remaining problems to be overcome with satellite imagery include difficulties in obtaining consistent sequential acquisition dates, intensive computer processing time requirements, and large computer storage space requirements to store massive amounts of image information.

The recommended approach for conducting a survey of land uses and development characteristics (land cover and activities) for an area is to use both aerial photography and site surveys. Aerial photography has improved greatly in recent years, but it is still not suitable for obtaining all the information needed for developing a comprehensive stormwater management plan. Initially, aerial photos should be used to identify the locations and extents of the various land uses in the study area. Neighborhoods representing homogenous land uses should then be identified for site surveys. Usually, about 10 to 15 neighborhoods for each land use are sufficient for a community being studied (Burton and Pitt, 2002). After the field surveys are conducted, the aerials are again used to measure the actual areas associated with land surface cover. This information can be used with field survey data to separate the surfaces into the appropriate categories for analyses and modeling.

Box 3-3 presents a detailed study of land cover for several land uses in the southern United States using satellite imagery and ground surveys (Bochis, 2007; Bochis et al., 2008). The results presented here have been found to be broadly similar to other areas studied in the United States, although few studies have been as detailed, and there are likely to be regional differences.

The general conclusion of many land-use and land-cover studies is that in urban areas, the amount of impervious surfaces has increased since the early years of the 20th century because of the tendency toward increased automobile use and bigger houses, which is associated with an increase in the facilities necessary to accommodate them (wider streets, more parking lots, and garages). As shown in later sections of this report, the construction of impervious surfaces leads to multiple impacts on stream systems. Therefore, future development plans and water resource protection programs should consider reducing impervious cover in the potential expansion of communities. Wells (1995), Booth (2000), Stone (2004), and Gregory et al. (2005) show that reducing the size and dimensions of residential parcels, promoting cluster developments (clustered medium-density residential areas in conjunction with open space, instead of large tracts of low-density areas), building taller buildings, reducing the residential street width (local access streets), narrowing the width and/or building one-side sidewalks, reducing the size of paved parking areas to reflect the average parking needs instead of peak needs, and using permeable pavement for intermittent/overflow parking can reduce the traditional impervious cover in communities by 10 to 50 percent. Many of these benefits can also be met by paying better attention to how the pavement and roof areas are connected to the drainage system. Impervious surfaces that are “disconnected” by allowing their drainage water to flow to adjacent landscaped areas can result in reduced runoff quantities.

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BOX 3-3
Land Use and Land Cover for the Little Shades Creek Watershed

Data collected by Bochis-Micu and Pitt (2005) and Bochis (2007) for the Little Shades Creek watershed near Birmingham, Alabama, were acquired using IKONOS satellite imagery (provided by the Jefferson County Storm Water Management Authority) as an alternative to classical aerial photography to map the characteristics of the land uses in the monitored watershed areas, supplemented with verified ground truth surveys. IKONOS is the first commercially owned satellite that provides 1-m-resolution panchromatic image data and 4-m multi-spectral imagery (Goetz et al., 2003).

This project was conducted to evaluate the effects of variable site conditions associated with each land-use category. About 12 homogeneous neighborhoods were investigated in each of the 16 major land uses in this 2,500-hectare watershed. Detailed land-cover measurements were made using a variety of techniques, as listed above, including field surveys for small details that were not visible with remote sensing tools (such as roof drain connectiveness, pavement texture, and landscaping maintenance practices). Each of these individual neighborhoods was individually modeled to investigate the resultant variability in runoff volume and pollutant discharges. These were statistically evaluated to determine if the land-use categories properly stratified these data by explaining significant fractions of the variability. Bochis-Micu and Pitt (2005) and Bochis (2007) concluded that land-use categories were an appropriate surrogate that can be used to describe the observed combinations of land surfaces. However, proper stormwater modeling should examine the specific land surfaces in each land-use category in order to better understand the likely sources of the pollutants and the effectiveness of candidate stormwater control measures (SCMs).

This watershed has an overall impervious cover of about 35 percent, of which about 25 percent is directly connected to the drainage system. Table 3-1 shows the average land covers for each of the surveyed land uses, along with the major source areas in each of the directly connected and disconnected impervious and pervious surface categories. The impervious covers include streets, driveways, parking, playgrounds, roofs, walkways, and storage areas. The directly connected areas are indicated as “connected” or “draining to impervious” and do not include the pervious area or the impervious areas that drain to pervious areas. As expected, the land uses with the least impervious cover are open space (vacant land, cemeteries, golf courses) and low-density residential, and the land uses with the largest impervious covers are commercial areas, followed by industrial areas. For a typical high-density residential land use in this region (having 15 or more units per hectare), the major land cover was found to be landscaped areas, subdivided into front- and backyard categories, while 25 percent of this land-use area is covered by impervious surfaces broken down into three major subcategories: roofs, streets, and driveways. The subareas making up each land use show expected trends, with roofs and streets being the predominant directly connected impervious covers in residential areas, and parking and storage areas also being important in commercial and industrial areas.

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BOX 3-3 Continued

TABLE 3-1 Little Shades Creek Watershed Land Cover Information (percent and the predominant land cover)

Land Use	Directly Connected Impervious Cover (%)	Disconnected Impervious Cover (%)	Pervious Cover (%)
High-Density Residential	14 (streets and roof)	10 (roofs)	76 (front and rear landscaping)
Medium-Density Residential (<1960 to 1980)	11 (streets and roofs)	8 (roofs)	81 (front and rear landscaping)
Medium-Density Residential (>1980)	14 (streets and roofs)	5 (roofs)	80 (front and rear landscaping)
Low-Density Residential	6 (streets)	4 (roofs)	89 (front and rear landscaping)
Apartments	21 (streets and parking)	22 (roofs)	58 (front and rear landscaping)
Multiple Families	28 (roofs, parking , and streets)	7 (roofs)	65 (front and rear landscaping)
Offices	59 (parking, streets, and roofs)	3 (parking)	39 (front and rear landscaping)
Shopping Centers	64 (parking, roofs, and streets)	4 (roofs)	31 (front landscaping)
Schools	16 (roofs and parking)	20 (playground)	64 (front and rear landscaping, large turf)
Churches	53 (parking and streets)	7 (parking)	40 (front landscaping)
Industrial	39 (storage, parking, and streets)	18 (storage and roofs)	44 (front and rear landscaping)
Parks	32 (streets and parking)	33 (playground)	34 (large turf and undeveloped)
Cemeteries	7 (streets)	15 (parking)	78 (large turf)
Golf Courses	2 (streets)	4 (roofs)	95 (large turf)
Vacant	5 (streets)	1 (driveways)	94 (undeveloped and large turf)

SOURCE: Bochis-Micu and Pitt (2005) and Bochis (2007). Reprinted, with permission, from Bochis (2007). Copyright 2007 by Celina Bochis.

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HYDROLOGIC AND GEOMORPHIC CHANGES

The watershed provides an organizing framework for the management of stormwater because it determines the natural patterns of water flow as well as the constituent sediment, nutrient, and pollutant loads. In undeveloped watersheds, hillslope hydrologic flow-path systems co-evolve with microclimate, soils, and vegetation to form topographic patterns within which ecosystems are spatially arranged and adjusted to the long-term patterns of water, energy, and nutrient availability. The landforms that comprise the watershed include the network patterns of streams, rivers, and their associated riparian zones and floodplains, as well as component freshwater lakes, reservoirs, wetlands, and estuaries.

This section starts with a discussion of precipitation measurement and characteristics before turning to the typical changes in hydrology and geomorphology of the watershed brought on by urbanization. In both the terrestrial and aquatic phases, retention and residence time of sediment and solutes decreases with increasing flow volume and velocity. This results in relatively high retention and low export of water and nutrients in undeveloped watersheds compared to decreasing retention and greater pollutant export in disturbed or developed systems.

The Storm in Stormwater

The magnitude and frequency of stormwater discharges are not just determined by rainfall. Instead, they are the combined product of storm and interstorm characteristics, land use, the natural and built drainage system, and any stormwater control measures (SCMs) that have been implemented. The total volume and peak discharge of runoff, as well as the mobilization and transport of pollutants, are dependent on all aspects of the storm magnitude, catchment antecedent moisture conditions, and the interstorm period. Therefore, information on the frequency distribution of storm events and properties is an important aspect of understanding the distribution of pollutant concentrations and loads in stormwater discharges. In northern climates, runoff production from precipitation can be significantly delayed by the accumulation, ripening, and melt of snowpacks, such that much of the annual load of certain pollutants may be mobilized in peak flow from snowmelt events. Therefore, measurement of precipitation and potential accumulation in both liquid and solid form is critical for stormwater assessment.

Precipitation Measurements

Any given storm is characterized by the storm's total rainfall (depth), its duration, and the average and peak intensity. A *storm hyetograph* depicts meas-

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ured precipitation depth (or intensity) at a precipitation gauge as a function of time; an example is shown in Figure 3-5. This figure illustrates the typical high degree of variability of precipitation over the total duration of a storm. In this example, the total storm depth is 50.9 mm, the duration is 19 hours, and the peak intensity is 0.56 mm/minute (peak depth of 2.79 mm divided by the measurement increment of 5 minutes). The average intensity is 0.045 mm/minute, quite a bit lower than the peak intensity, since the storm duration is punctuated by periods of low and no measurable precipitation.

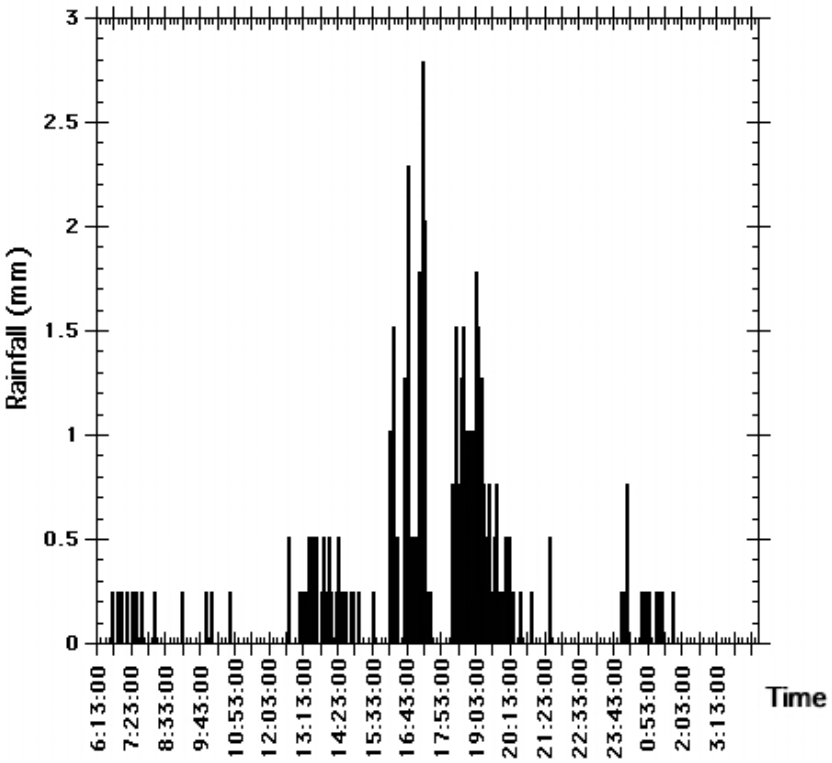

FIGURE 3-5 Example of a storm hyetograph at location RG2, September 20–21, 2001, Valley Creek watershed, Chester County, Pennsylvania. The time increment of measurement is 5 minutes, while the entire duration of this storm is about 16 hours.

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In addition to measurements of individual storm events, precipitation data are routinely collected for longer time periods and compiled and analyzed annually when trying to understand local rainfall patterns and their impact on baseflow, water quality, and infrastructure design. Figure 3-6 shows the rainfall during 2007 at both humid (Baltimore) and arid (Phoenix) locations. Especially apparent in the Baltimore data is the fact that the majority of storm events are less than 20 mm in depth.

Several networks of precipitation gauges are available in the United States; gauge data are available online from the National Climatic Data Center (NCDC) (*http://ncdc.nws.noaa.gov*). High-resolution precipitation data (i.e., with measurement intervals of an hour or less) are typically not recorded except at primary weather service meteorological stations, while daily precipitation records are more extensively collected and available through the Cooperative Weather Observer Program (*http://www.nws.noaa.gov/om/coop/*). This distinction is important to stormwater managers because most stormwater applications require short-duration measurements or model results (minutes to hours). Fortunately, a combination of precipitation gauges and precipitation radar estimates are available to estimate precipitation depth and duration, as well as additional methods to estimate snowfall and snowpack water equivalent depth and conditions. (A thorough description of precipitation measurement by radar is given by Krajewski and Smith [2001]). While most of the conterminous United States is covered by NEXRAD radar for estimation of high-temporal-resolution precipitation at current resolutions of ~4 km, the radar backscatter information requires calibration and correction with precipitation gauge data, and satellite estimates

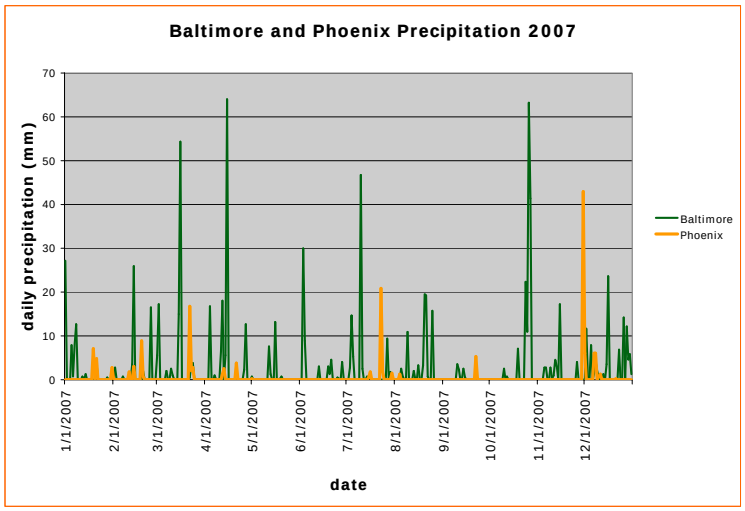

FIGURE 3-6 Daily precipitation totals for the Baltimore-Washington and Phoenix airports for 2007. SOURCE: Data from the National Weather Service.

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of precipitation are generally not sufficiently reliable for stormwater applications. It goes without saying that the measurement, quality assurance, and maintenance of long-term precipitation records are both vital and nontrivial to stormwater management.

Precipitation Statistics

The basic characterization of precipitation is by depth-duration-frequency curves, which describe the return period, recurrence interval, and exceedance probability (terms all denoting frequency) of different precipitation intensities (depths) over different durations. The methodology for determining the curves is described in Box 3-4. Precipitation durations of interest in stormwater management range from a few minutes (important for determining peak discharge from small urban drainage areas) to a year (where the interest is in the total annual volume of runoff production). As an example, one might be interested in the return period of the 1-inch, 1-hour event, or the 1-inch, 24-hour event; the latter would have a much shorter return period, because accumulating an inch of rain over a day is much more common than accumulating the same amount over just an hour.

BOX 3-4
Determining Depth-Duration-Frequency Curves

Depth-duration-frequency curves are developed from precipitation records using either annual maximum data series or annual exceedance data series. Annual maximum data series are calculated by extracting the annual maximum precipitation depths of a chosen duration from a record. In cases where there are only a few years of data available (less than 20 to 25 years), then an annual exceedance series (a type of "partial duration series") for each storm duration can be calculated, where N largest values from N years are chosen. An annual maximum series excludes other extreme values of record that may occur in the same year. For example, the second highest value on record at an observing station may occur in the same year as the highest value on record but will not be included in the annual maximum series. The design precipitation depths determined from the annual exceedance series can be adjusted to match those derived from an annual maximum series using empirical factors (Chow et al., 1988; NOAA Atlas data series, see *http://www.weather.gov/oh/hdsc/currentpf.htm*, e.g., Bonnin et al., 2006). Hydrologic frequency analysis is then applied the data series to determine desired return periods by fitting a probability distribution to the data to determine the return periods[1] of interest. The process is repeated for other chosen storm durations.

[1]Analysis of annual maximum series produces estimates of the average period between years when a particular value is exceeded ("average recurrence interval"). Analysis of partial duration (annual exceedance) series gives the average period between cases of a particular magnitude ("annual exceedance probability"). The two results are numerically similar at rarer average recurrence intervals but differ at shorter average recurrence intervals (below about 20 years). NOAA (e.g., Bonnin et al., 2006) notes that the use of the terminology "average recurrence interval" and "annual exceedance probability" typically reflects the analysis of the two different series, but that sometimes the term "average recurrence interval" is used as a general term for ease of reference.

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The National Weather Service has developed an online utility to estimate the return period for a range of depth–duration events for any place in the conterminous United States (*http://hdsc.nws.noaa.gov/hdsc/pfds/*). Figures 3-7 and 3-8 show examples of precipitation depth-duration-frequency curves for a humid location (Baltimore, Maryland) and an arid site (Phoenix, Arizona). As an illustration of the climatic influence on the depth-duration-frequency curves, the 2-year, 1-hour storm is associated with a depth of 1.2 inches of precipitation in Baltimore, whereas this same recurrence interval and duration are associated with a depth of only 0.6 inch of precipitation in Phoenix. Durations from 5 minutes to one day are shown because this is the range typically used in the design of stormwater management facilities. The shorter durations provide expected magnitude and frequency for brief but significant precipitation intensity peaks that can mobilize and transport large amounts of pollutants and erode soil, and they are used in high-resolution stormwater models. More commonly, however, stormwater regulations are written for 24-hour durations at 2-, 10-, 25-, 50-, or 100-year recurrence intervals.

Because storm magnitudes and frequencies vary by climatic region, it is reasonable to expect them to change during recurring climate events (e.g., El Niño) or over the long term by climate change. Alteration in convective precipitation by major urban centers has been documented for some time (Huff and Changnon, 1973). Some evidence exists that precipitation regimes are shifting systematically toward an increase in more intense rainfall events, which is consistent with modeled projections of global climate change increases in hydrologic extremes. Kunkel et al. (1999) analyzed precipitation data from 1,295 weather stations from 1931 to 1996 across the contiguous United States and found that storms with extreme levels of precipitation have increased in frequency. The analysis considered short-duration events (1, 3, and 7 days) of 1-year and 5-year return intervals. A linear trend analysis using Kendall's slope estimator statistic indicated that the overall trend in 7-day, 1-yr events for the conterminous United States is upward at a rate of about 3 percent per decade for 1931 to 1996; the upward trend in 7-day, 5-year events is about 4 percent per decade. These two time series are shown in Figure 3-9. An increased frequency of intense precipitation events will shift depth-frequency-duration curves for a given location, with a given return period being associated with a more intense event. Alternatively, the return period for a given intensity (or depth) of an event will be reduced if the event is occurring more frequently. In light of climate change, depth-duration-frequency curves will need to be updated regularly in order to ensure that stormwater management facilities are not underdesigned for an increasing intensity of precipitation. Additional implications of climate change for stormwater management are discussed in Box 3-5.

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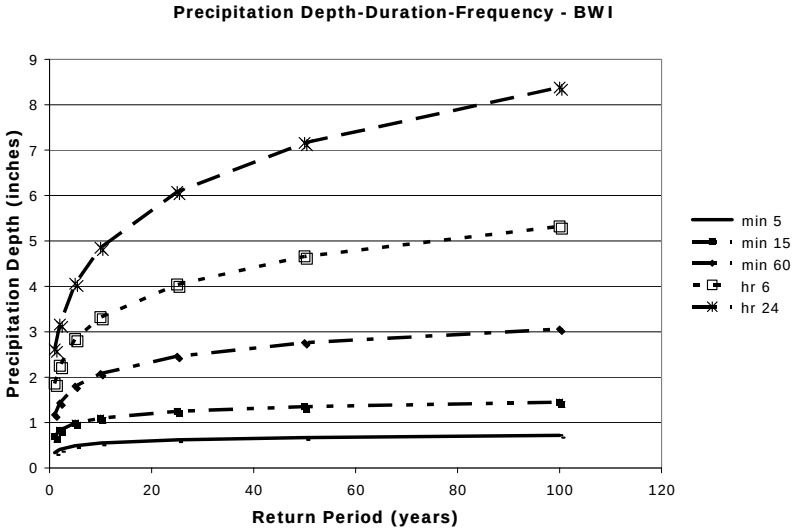

FIGURE 3-7 Depth-duration-frequency curves for Baltimore, Maryland. SOURCE: Data from the National Weather Service.

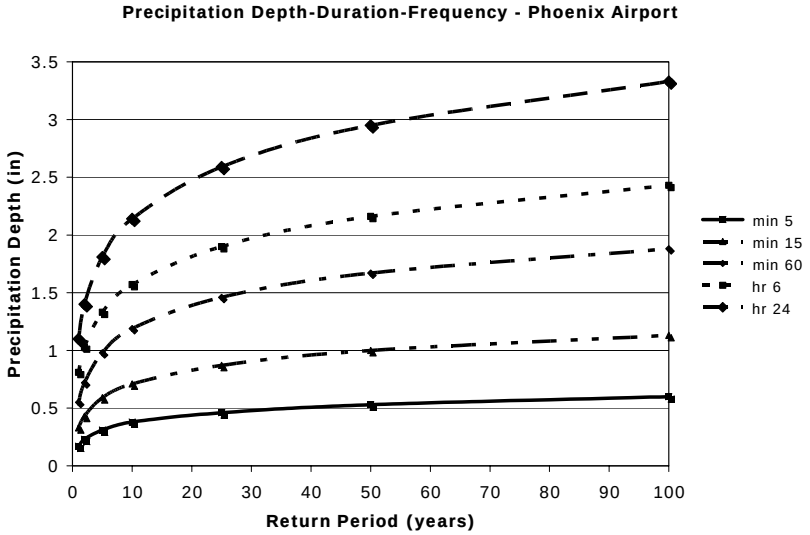

FIGURE 3-8 Depth-duration-frequency curves for Phoenix, Arizona. SOURCE: Data from the National Weather Service.

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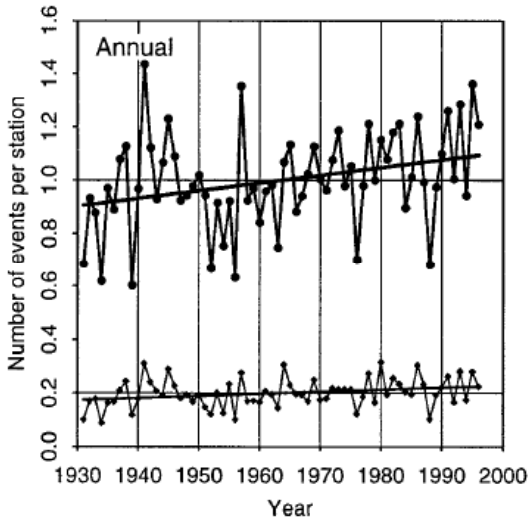

FIGURE 3-9 Nationally averaged annual U.S. time series of the number of precipitation events of 7-day duration exceeding 1-year (dots) and 5-year (diamonds) recurrence intervals. SOURCE: Reprinted, with permission, from Kunkel et al. (1999). Copyright 1999 by American Meteorological Society.

BOX 3-5
Climate Change and Stormwater Management

An ongoing report series issued by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research summarizes the evidence for climate change to date and expected impacts of climate change, including impacts on the water resources sector (*http://www.climatescience.gov/*). According to the Intergovernmental Panel on Climate Change (IPCC 2007), annual precipitation will likely increase in the northeastern United States and will likely decrease in the southwestern United States over the next 100 years. In the western United States, precipitation increases are projected during the winter, whereas decreases are projected for the summer. As temperatures warm, precipitation will increasingly fall as rain rather than snow, and snow season length and snow depth are very likely to decrease in most of the country. More extreme precipitation events are also projected, which, when coupled with an anticipated increase in rain-on-snow events, would contribute to more severe flooding due to increases in extreme stormwater runoff.

The predictions for increases in the intensity and frequency of extreme events have significant implications for future stormwater management. First, many of the design standards currently in use will need to be revised, since they are based on historical data. For example, depth-duration-frequency curves used for design storm data will need to be updated, because the magnitude of the design storms will change. Even with revised design standards, in light of future uncertainty, new SCMs will need to be designed conservatively to allow for additional storage that will be required for regions with predicted trends in increased precipitation. In addition, existing SCM designs based on old standards may prove to be undersized in the future. Implementation of a monitoring program to check existing SCM inflows against original design inflows may be prudent to aid in judging whether retrofit of existing facilities or additional stormwater infrastructure is needed.

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Design Storms

Given that only daily precipitation records are widely available, but short-duration data are required for stormwater analysis and prediction, *design storms* have been developed for the different regions of the United States by different state and federal resource agencies. A *design storm* is a specified temporal pattern of rainfall at a location, created using an overall storm duration and frequency relevant to the design problem at hand. Examples of design storms include the 24-hour, 100-year event for flood control and the 24-hour, 2-year event for channel protection. The magnitude of the design storm can be derived from data at a single gauge, or from synthesized regional data published by state or federal agencies. The simplest form of a design storm is a triangular hyetograph where the base is the duration and the height is adjusted so that the area under the curve equals the total precipitation. In instances where the hyetograph is to be used to estimate sequences of shorter duration intensities (i.e., minutes to a few hours) within larger duration events, depth-duration-frequency curve data can be used to synthesize a design storm hyetograph (see Chow et al., 1988). An example design storm for the 100-year storm event for St. Louis based on NOAA Atlas 14 depth-duration-frequency data is shown in Figure 3-10.

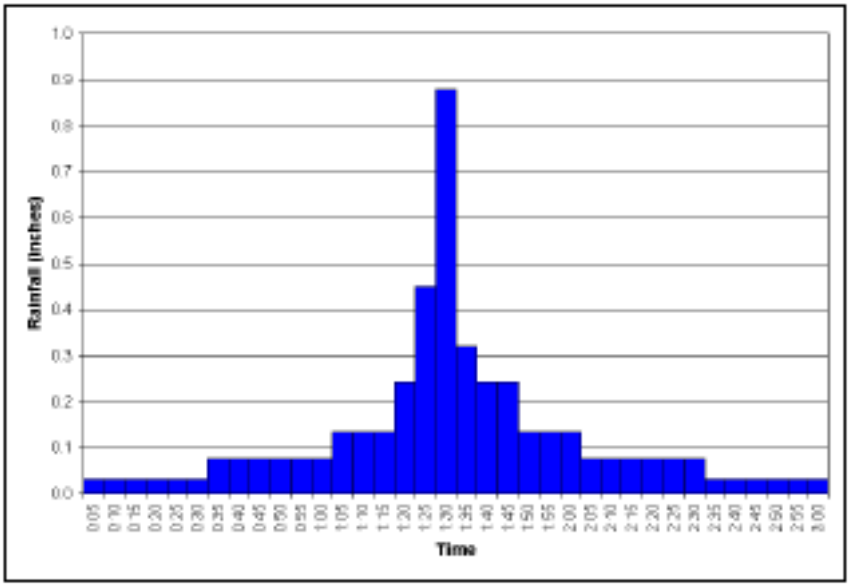

FIGURE 3-10 Hundred-year design storm for St. Louis based on NOAA Atlas 14 data. SOURCE: Hoblit et al. (2004) based on data from Bonnin et al. (2003).

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Conversion of Precipitation to Runoff

Dynamics of Watershed Flowpaths

Precipitation falling on the land surface is subject to evaporative loss to the atmosphere by vegetation canopy and leaf litter interception, evaporation directly from standing water on the surface and upper soil layers or impervious surfaces, and later transpiration through root uptake by vascular plants. Snowpack is also subject to sublimation (conversion of snow or ice directly to vapor), which results in the loss of a portion of the snow prior to melt. The rate of evaporative loss depends on local weather conditions (temperature, humidity, wind speed, solar radiation) and the rate and duration of precipitation. Precipitation (or snowmelt) in excess of interception and potential evaporative loss rates is then partitioned into infiltration and direct runoff.[1]

There is a gradation of flowpaths transporting water, sediment, and solutes through a watershed, ranging from rapid surface flowpaths through generally slower subsurface flowpaths. Residence times generally increase from surface to subsurface flowpaths, with rapid surface flow providing the major contribution to flood flow while subsurface flowpaths contribute to longer-term patterns of surface wetness. Watershed characteristics that influence the relative dominance of surface versus subsurface flowpaths include infiltration capacity as affected by land cover, soil properties, and macropores; subsurface structure or soil horizons with varying conductivity; antecedent soil moisture and groundwater levels; and the precipitation duration and intensity for a particular storm.

The distribution and activity of flowpaths result in changing patterns of soil moisture and groundwater depth, which result in patterns of soil properties, vegetation, and microbial communities. These ecosystem patterns, in turn, can have strong influences on the hydraulics of flow and biogeochemical transformations within the flowpaths, with important implications for sources, sinks, and transport of solutes and sediment in the watershed. Riparian areas, wetlands, and the benthos of streams and waterbodies are nodes of interaction between surface and groundwater flowpaths, yielding reactive environments in which "hot spots" of biogeochemical transformation develop (McClain et al., 2003). Thus, any alteration of surface and subsurface hydrologic flowpaths, for

[1] The term *runoff* is often used in two senses. For a given precipitation event, direct *storm runoff* refers to the rainfall (minus losses) that is shed by the landscape to a receiving waterbody. In an area of 100 percent imperviousness, the runoff nearly equals the rainfall (especially for larger storms). Over greater time and space scales, *surface water runoff* refers to streamflow passing through the outlet of a catchment, including base flow from groundwater that has entered the stream channel. The raw units of runoff in either case are volume per time, but the volumetric flowrate (discharge) is often divided by contributing area to express runoff in units of depth per time. In this way, unit runoff rates from various-sized watersheds can be compared to account for differences other than the contributing area.

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example due to urbanization, not only alters the properties of soil and vegetation canopy but also reforms the ecosystem distribution of biogeochemical transformations.

Runoff Measurements

Surface water runoff for a given area is measured by dividing the discharge at a given point in the stream channel by the contributing watershed area. The basic variables describing channel hydraulics include width, mean depth, slope, roughness, and velocity. Channel discharge is the product of width, depth, and velocity and is typically estimated by either directly measuring each of these three components, or by development of a rating curve of measured discharge as a function of water depth, or stage relative to a datum, of the channel that is more easily estimated by a staff gauge or pressure transducer. The establishment of a gauging station to measure discharge typically requires a stable cross section so that stage can be uniquely related to discharge. Maintenance of reliable, long-term gauge sites is expensive and requires periodic remeasurement to update rating curves, as well as to remove temporary obstructions that may raise stage relative to unobstructed conditions.

Most stream gauging in the United States is carried out by the USGS, and can be found on-line at *http://waterdata.usgs.gov/nwis*. Recent reviews of standard methods of stream gauging and the status of the USGS stream gauging network are given by the USGS (1998) and the National Research Council (NRC, 2004). A major concern is the overall decline in the number of active gauges, particularly long-term gauges, as well as the representativeness of the stream gauge network relative to the needs of stormwater permitting. For example, restored streams typically lack any gauged streamflow or water quality information prior to or following restoration. This makes it very difficult to assess both the potential for successful restoration and whether project goals are met.

Support of existing and development of new gauges is often in collaboration through a co-funding mechanism with other agencies. Municipal co-funding for stations in support of National Pollutant Discharge Elimination System (NPDES) permitting is common and has tended to shift the concentration of active gauges toward more urban areas. Note that the USGS river monitoring system was originally designed for resource inventory, and therefore did not originally sample many headwater streams, particularly intermittent and ephemeral channels that are typically most proximal to stormwater discharges. While this is beginning to change with municipal co-funding, headwater streams are still underrepresented in the National Water Information System relative to their ecological significance.

Reliable records for stream discharge are vital because the frequency distribution and temporal trends of flows must be known to evaluate long-term loading to waterbodies. Magnitude and frequency analysis of sediment and other

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stream constituent loads consists of a transport equation as a function of discharge, integrated over the discharge frequency distribution (e.g., Wolman and Miller, 1960). Different constituent loads have different forms of dependency on discharge, but are often nonlinear such that long-term or expected loads cannot be simply evaluated from mean flow conditions. Similar to precipitation, discharge levels often follow an Extreme Value distribution, dependent on climate, land use, and hydrogeology, but which is typically dampened compared to precipitation due to the memory effects of subsurface storage and flows (e.g., Winter, 2007).

Impacts of Urbanization on Runoff

Shift from Infiltration and Evapotranspiration to Surface Runoff

Replacement of vegetation with impervious or hardened surfaces affects the hydrologic budget—the quantity of water moving through each component of the hydrologic cycle—in a number of predictable ways. As the percent of the landscape that is paved over or compacted is increased, the land area available for infiltration of precipitation is reduced, and the amount of stormwater available for direct surface runoff becomes greater, leading to increased frequency and severity of flooding. Reduced infiltration of precipitation leads to reduced recharge of the groundwater reservoir; absent new sources of recharge, this can lead to reduction in base flow of streams (e.g., Simmons and Reynolds, 1982; Rose and Peters, 2001). Vegetation removal also results in a lower amount of evapotranspiration compared to undeveloped land. This can have particularly profound hydrologic effects in those regions of the country where a significant percent of precipitation is evapotranspirated, such as the arid Southwest (Ng and Miller, 1980). Figure 3-11 illustrates the changes to these components of the hydrologic budget as the percent of impervious area is increased.

It should be noted that the conversion in hydrology from infiltrated water to surface runoff following urbanization is not entirely straightforward in all cases. Leaking pressurized water supply pipes and sanitary sewers, subsurface discharge of septic system effluent (Burns et al., 2005), infiltration of stormwater from unlined detention ponds, and lawn irrigation can offset reduced infiltration of precipitation, such that stream baseflow levels may actually be increased, especially during low base flow months, when such effects would be most pronounced (Konrad and Booth, 2005; Meyer, 2005). Cracks in sealed surfaces can also provide concentrated points of infiltration (Sharp et al., 2006).

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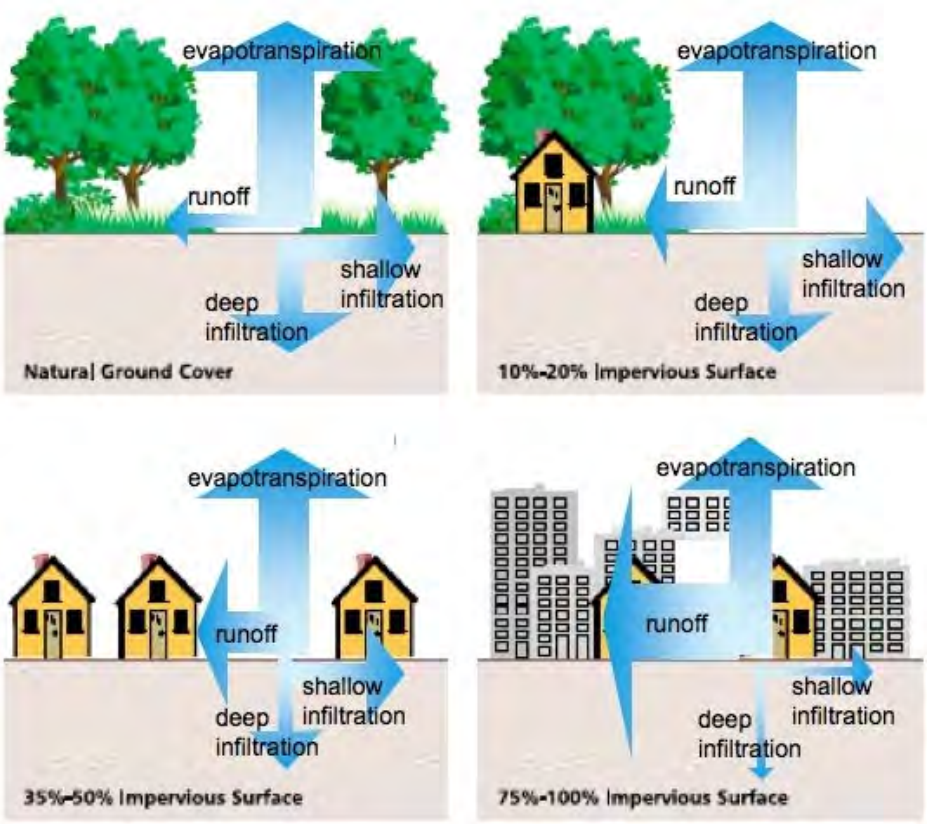

FIGURE 3-11 As land cover changes from vegetated and undeveloped (upper left) to developed with increased connected impervious surfaces (lower right), the partitioning of precipitation into other components of the hydrologic cycle is shifted. Evapotranspiration and shallow and deep infiltration are reduced, and surface runoff is increased. SOURCE: Adapted from the Federal Interagency Stream Restoration Working Group (FISRWG, 2000).

Relationship Between Imperviousness, Drainage Density, and Runoff

Excess runoff due to urbanization is a direct reflection of the land uses onto which the precipitation falls, as well as the presence of drainage systems that receive stormwater from many separate source areas before it enters receiving waters. Thus, a functional way of partitioning urban areas is by the nature of the impervious cover and by its connection to the drainage system, underlying the differentiation of total impervious area and effective impervious area discussed in Box 1-2.

As examples of how runoff changes with urbanization, Figure 3-12 shows

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daily stream flow values for a low-density suburban catchment and a high-density urban catchment in the Baltimore, Maryland area. The low-density site (Figure 3-12A) shows a strong seasonal signal and a marked decline in flow during an extreme drought in 2002. In contrast, the more densely urbanized catchment (Figure 3-12B) shows a much greater variability in flow that is dominated by impervious surface runoff, and a dampened response to the drought because natural groundwater flow is a much smaller component of the total discharge.

The percentage of time a discharge level is equaled or exceeded is displayed by flow duration curves, which show the cumulative frequency distributions of flows for a given duration. Examples for three catchments in the Baltimore area are given in Figure 3-13, showing the tendency for urban areas to produce high flows with much longer aggregate durations.

As another example of how runoff changes with imperviousness, a locally calibrated version of WinSLAMM was used to investigate the relationships between watershed and runoff characteristics for 125 individual neighborhoods in

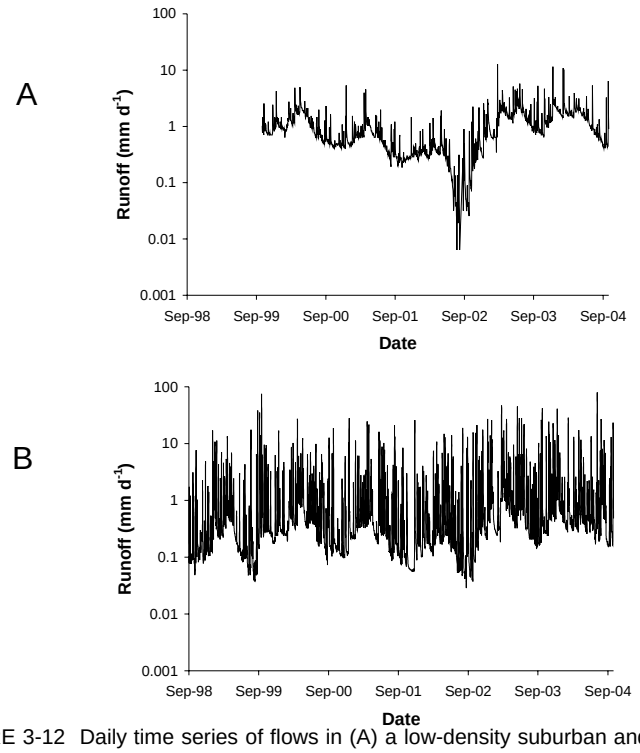

FIGURE 3-12 Daily time series of flows in (A) a low-density suburban and forested catchment (Baisman Run, *http://waterdata.usgs.gov/md/nwis/uv/?site_no=01583580*) and (B) a catchment dominated by medium- to high-density residential and commercial land uses (Dead Run, *http://waterdata.usgs.gov/md/nwis/uv/?site_no=01589330*). Both lie within the Piedmont physiographic province.

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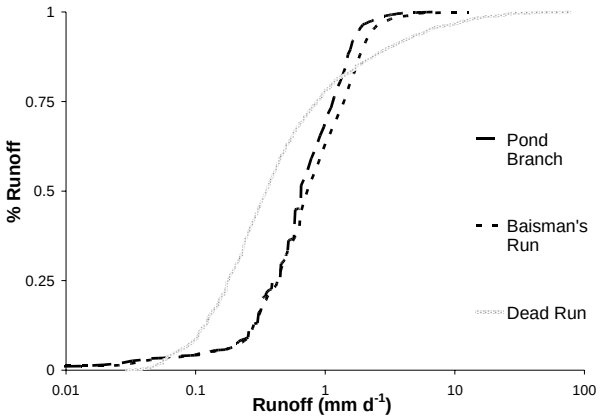

FIGURE 3-13 Flow duration curves for three watersheds with distinct land use in the Baltimore, Maryland area. Pond branch is a forested reference site, Baisman's Run is exurban, and Dead Run is urban. Urban areas have flashier runoff with greater frequency of low and high extreme flows.

Jefferson County, Alabama (Bochis-Micu and Pitt, 2005). Figure 3-14 shows the relationships between the directly connected impervious area values and the calculated volumetric runoff coefficient (R_v, which is the volumetric fraction of the rainfall that occurs as runoff), based on 43 years of local rain data. As expected, there is a strong relationship between these parameters for both sandy and clayey soil conditions. It is interesting to note that the R_v values are relatively constant until values of directly connected impervious cover of 10 to 15 percent are reached (at R_v values of about 0.07 for sandy soil areas and 0.16 for clayey soil areas)—the point where receiving water degradation typically has been observed to start (as discussed later in the chapter). The 25 to 30 percent directly connected impervious levels (where significant degradation is usually observed) is associated with R_v values of about 0.14 for sandy soil areas and 0.25 for clayey soil areas; this is where the curves start to greatly increase in slope.

Relationship Between Runoff and Rainfall Conditions

The runoff that results from various land uses also varies depending on rainfall conditions. For small rain depths, almost all the runoff originates solely from directly connected impervious areas, as disconnected areas have most of their flows infiltrated (Pitt, 1987). For larger storms, both directly connected

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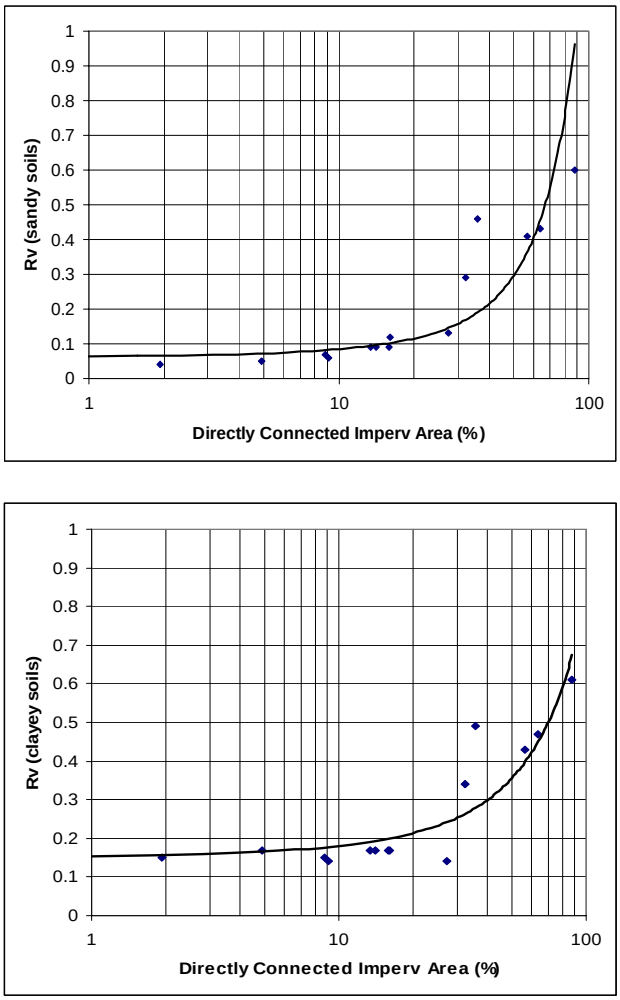

FIGURE 3-14 Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (R_v) for sandy soil (top) and clayey soil (bottom). SOURCE: Reprinted, with permission, from Bochis-Micu and Pitt (2005). Copyright 2005 by Water Environment Federation, Alexandria, Virginia.

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and disconnected impervious areas contribute runoff to the stormwater management system. For example, Figure 3-15 (created using WinSLAMM; Pitt and Voorhees, 1995) shows the relative runoff contributions for a large commercial/mall area in Hoover, Alabama, for different rains (Bochis, 2007). In this example, about 80 percent of the runoff originates from the parking areas for the smallest runoff-producing rains. This contribution decreases to about 55 percent at rain depths of about 0.5 inch (13 mm). This decrease in the importance of parking areas as a source of runoff volume is associated with an increase in runoff contributions from streets and directly connected roofs. In many areas, pervious areas are not hydrologically active until the rain depths are relatively large and are not significant runoff contributors until the rainfall exceeds about 25 mm for many land uses and soil conditions. However, compacted urban soils can greatly increase the flow contributions from pervious areas during smaller rains. Burges and others (1998), for example, found that more than 60 percent of the storm runoff in a suburban development in western Washington State originated from nominally "green" parts of the landscape, primarily lawns.

A further example illustrating the relationship between rainfall and runoff is given for Milwaukee, summarized in Box 3-6. The two curves of Figure 3-16 show a relationship between rainfall and runoff that is typical of urban areas. Very small storms (< 0.05 inch) produce no measurable runoff, owing to removal by interception storage and evaporation. Storms that deposit up to one inch of rainfall constitute about 90 percent of the storm events in this region, but these events produced only about 50 percent of the runoff. Very large events (greater than 3 inches of precipitation) are rare and destructive, accounting for only a few percent of the annual rainfall events.

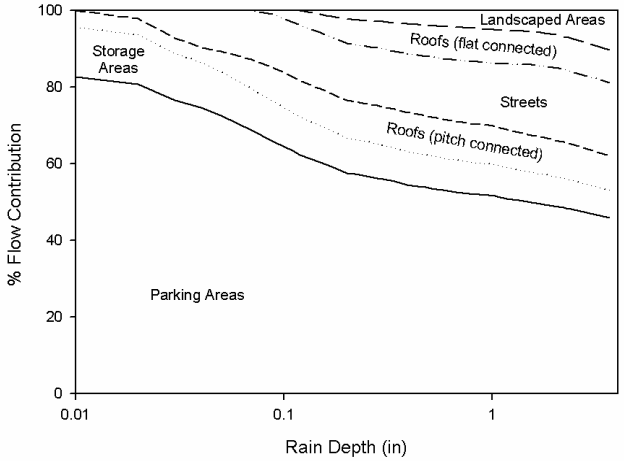

FIGURE 3-15 Surfaces contributing to runoff for a commercial/mall area. SOURCE: Reprinted, with permission, from Bochis (2007). Copyright 2007 by Celina Bochis.

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BOX 3-6
Example Rainfall and Runoff Distributions

Figure 3-16 is an example of rainfall and runoff observed at Milwaukee, Wisconsin (Bannerman et al., 1983), as monitored during the Nationwide Urban Runoff Program (NURP) (EPA, 1983). This observed distribution is interesting because of the unusually large rains that occurred twice during the monitoring program. These two major rains would be in the category of design storms for conventional drainage systems. These plots indicate that these very large events, in the year they occurred, caused a measureable fraction of the annual pollutant loads and runoff volume discharges, but smaller events were responsible for the vast majority of the discharges. In typical years, when these rare design events do not occur, their pro-rated contributions would be even smaller.

More than half of the runoff from this typical medium-density residential area was associated with rain events that were smaller than 0.75 inch. Two large storms (about 3 and 5 inches in depth), which are included in the figure, distort this figure because, on average, the Milwaukee area only expects one 3.5-inch storm about every five years, and 5-inch storms even less frequently. If these large rains did not occur, such as for most years, then the significance of the smaller rains would be even greater. The figure also shows the accumulated mass discharges of different pollutants (suspended solids, chemical oxygen demand [COD], phosphates, and lead) monitored during the Milwaukee NURP project. When these figures are compared, it is seen that the runoff and pollutant mass discharge distributions are very similar and that variations in the runoff volume are much more important than variations in pollutant concentrations (the mass divided by the runoff volume) for determining pollutant mass discharges.

These rainfall and runoff distributions for Milwaukee can thus be divided into four regions:

- **Less than 0.5 inch.** These rains account for most of the events, but little of the runoff volume, and they are therefore easiest to control. They produce much less pollutant mass discharge and probably have less receiving water effects than other rains. However, the runoff pollutant concentrations likely exceed regulatory standards for several categories of critical pollutants (bacteria and some total recoverable heavy metals). They also cause large numbers of overflow events in uncontrolled combined sewers. These rains are very common, occurring once or twice a week (accounting for about 60 percent of the total rainfall events and about 45 percent of the total runoff-generating events), but they only account for about 20 percent of the

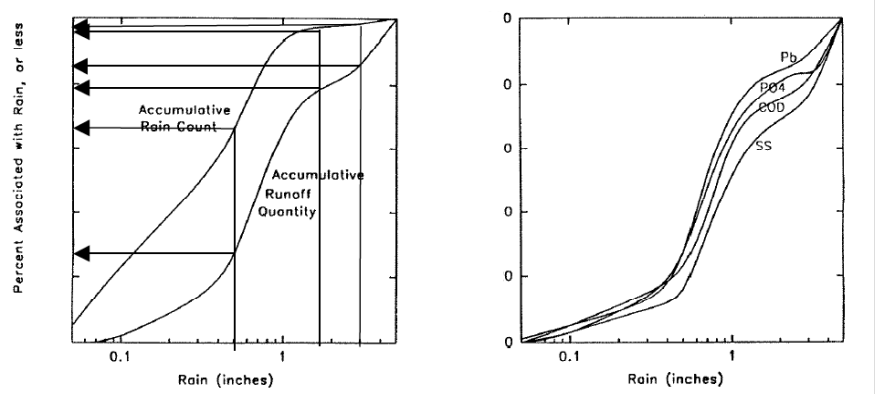

FIGURE 3-16 Milwaukee rainfall and runoff probability distributions, and pollutant mass discharge probability distributions (1981 to 1983). Rain count refers to the number of rain events. SOURCE: Data from Bannerman et al. (1983).

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BOX 3-6 Continued

annual runoff and pollutant discharges. Rains less than about 0.05 inch did not produce noticeable runoff.

- **0.5 to 1.5 inches**. These rains account for the majority of the runoff volume (about 50 percent of the annual volume for this Milwaukee example) and produce moderate to high flows. They account for about 35 percent of the annual rain events, and about 20 percent of the annual runoff events, by number. These rains occur on average about every two weeks from spring to fall and subject the receiving waters to frequent high pollutant loads and moderate to high flows.

- **1.5 to 3 inches**. These rains produce the most damaging flows from a habitat destruction standpoint and occur every several months (at least once or twice a year). These recurring high flows, which were historically associated with much less frequent rains, establish the energy gradient of the stream and cause unstable streambanks. Only about 2 percent of the rains are in this category, but they are responsible for about 10 percent of the annual runoff and pollutant discharges.

- Greater than **3 inches.** The rains in this category are included in design storms used for traditional drainage systems in Milwaukee, depending on the times of concentration and rain intensities. These rains occur only rarely (once every several years to once every several decades, or less frequently) and produce extremely large flows that greatly exceed the capacities of the storm drainage systems, causing extensive flooding. The monitoring period during the Milwaukee NURP was unusual in that two of these events occurred. Less than 2 percent of the rains were in this category (typically <<1 percent would be in this category), and they produced about 15 percent of the annual runoff quantity and pollutant discharges. However, when they do occur, substantial property and receiving water damage results (mostly associated with habitat destruction, sediment scouring, and the flushing of organisms great distances downstream and out of the system). The receiving water can conceivably recover naturally to pre-storm conditions within a few years. These storms, while very destructive, are sufficiently rare that the resulting environmental problems do not justify the massive controls that would be necessary to decrease their environmental effects.

Alteration of the Drainage Network

As shown in Figure 3-17, urbanization disrupts natural systems in ways that further complicate the hydrologic budget, beyond the imperviousness effects on runoff discussed earlier. As an area is urbanized, lower-order stream channels are typically re-routed or encased in pipes and paved over, resulting in a highly altered drainage pattern. The buried stream system is augmented by an extensive system of storm drains and pipes, providing enhanced drainage density (total lengths of pipes and channels divided by drainage area) compared to the natural system. Figure 3-18 shows how the drainage density of Baltimore today compares to the natural watershed before the modern stormwater system was fully developed. The artificial drainage system occupies a greater percentage of the landscape compared to natural conditions, permanently altering the terrestrial component of the hydrologic cycle.

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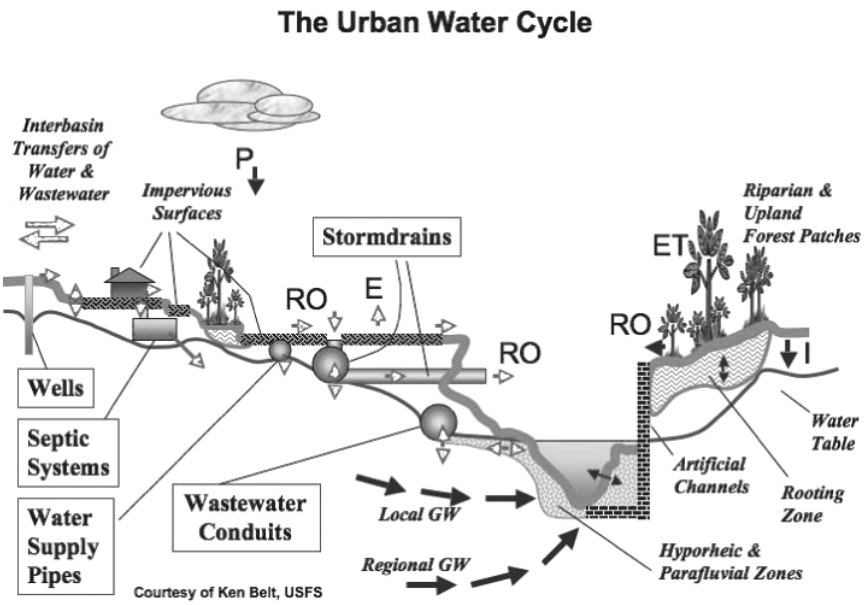

FIGURE 3-17 Alteration of the natural hydrologic cycle by the presence of piped systems. Black arrows represent the natural system; outlined arrows indicate short-circuiting due to piped systems. Note that several elements of the water cycle shown in this diagram are not considered in this report, such as septic systems, interbasin transfers of water and wastewater, and the influence of groundwater withdrawals. SOURCE: Courtesy of Kenneth Belt, USDA Forest Service, Baltimore, Maryland.

Flowpaths are altered in other ways by urban infrastructure. Buried stormwater and sewer pipes can act as infiltration galleries for groundwater, causing shortened groundwater flowpaths between groundwater reservoirs and stream systems. Natural surface water pathways are often interrupted or reversed, as shown by the blue lines in Figure 3-19 for a drainage system in Baltimore. Understanding how the system operates as a whole can often require knowledge of the history of construction conditions and field verification of the actual flow paths.

Large-scale infrastructure such as dams, ponds, and bridges can also have a major impact on stormwater flows. Figure 3-20 illustrates the interruption of the drainage network by bridges and culverts, even in places where there have been attempts to keep excessive development out of the riparian corridor. Simulations and post-flood mapping in areas around Baltimore have shown that bridge abutments such as those shown in Figure 3-20 can slow down channel floodwaters during storms. This is because water backs up behind bridges constructed

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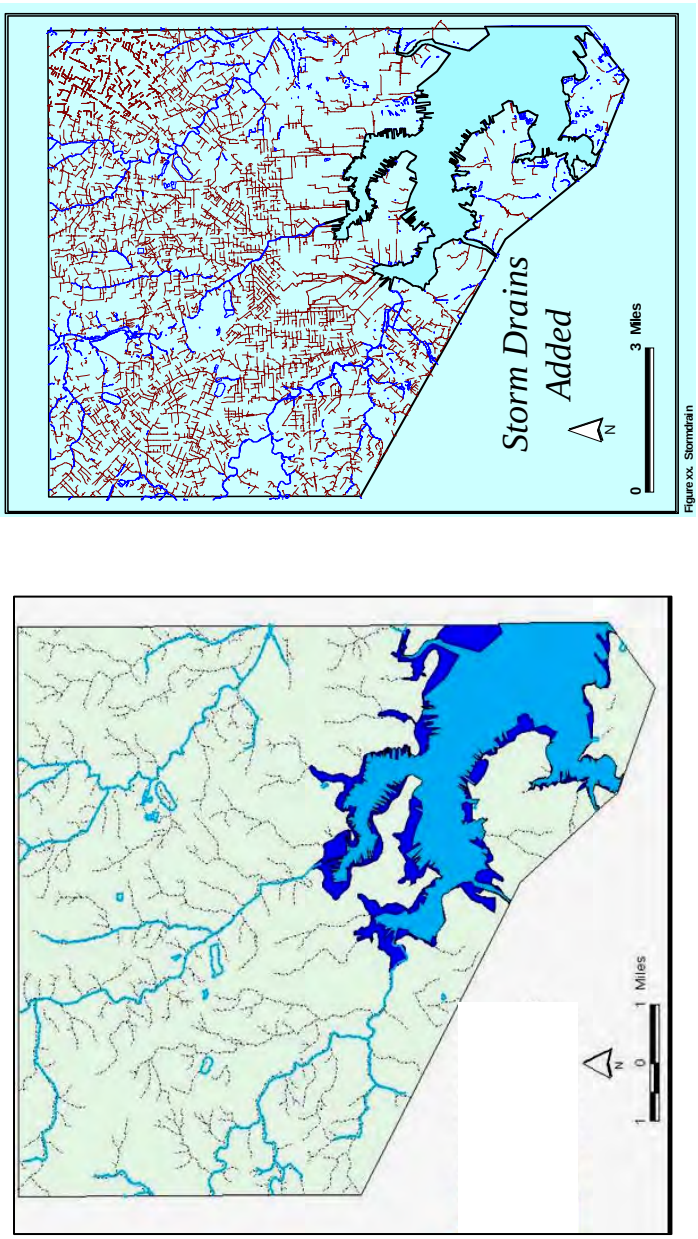

FIGURE 3-18 Baltimore City before and after development of its stormwater system. The left-hand panel shows first- and second-order streams lost to development. The right-hand panel shows the increase in drainage density resulting from construction of the modern storm-drain network. SOURCE: Courtesy of William Stack, Baltimore Department of Public Works.

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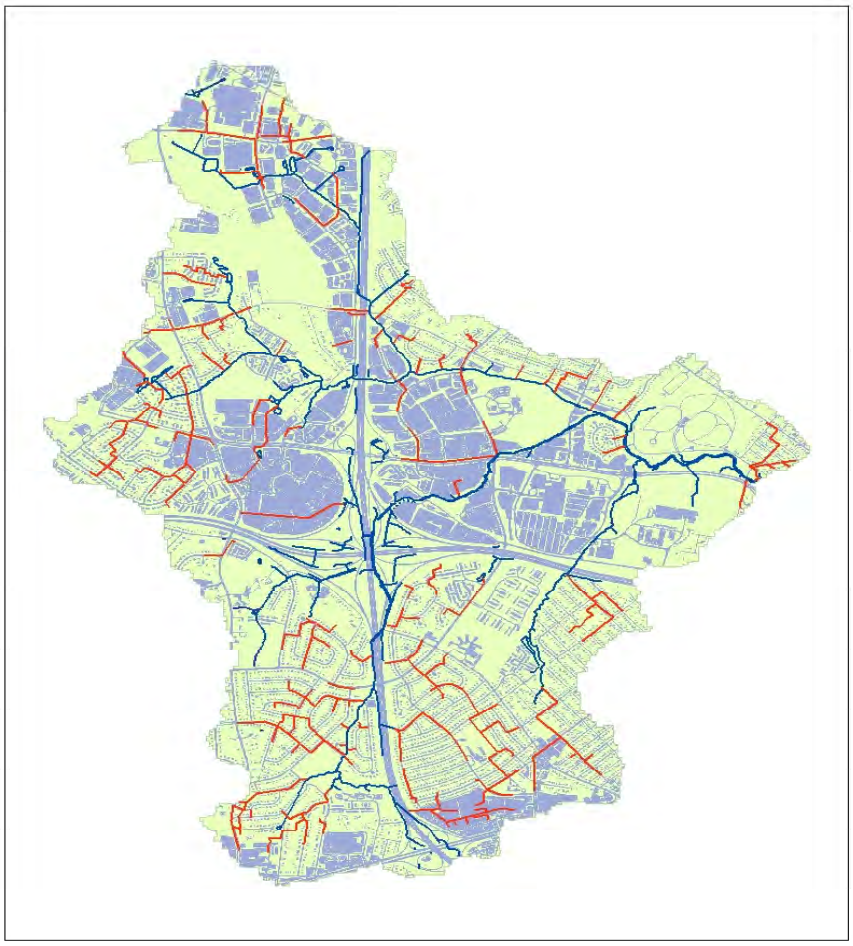

FIGURE 3-19 Dead Run drainage system, Baltimore, Maryland. Black lines indicate surface (daylighted) drainage; dark grey indicates the subsurface storm-drain system. The surface drainage system is highly disconnected. From the coverage it is difficult to impossible to discern the flow direction of some of the surface drainage components. SOURCE: Reprinted, with permission, from Meierdierks et al. (2004). Copyright 2004 by the American Geophysical Union.

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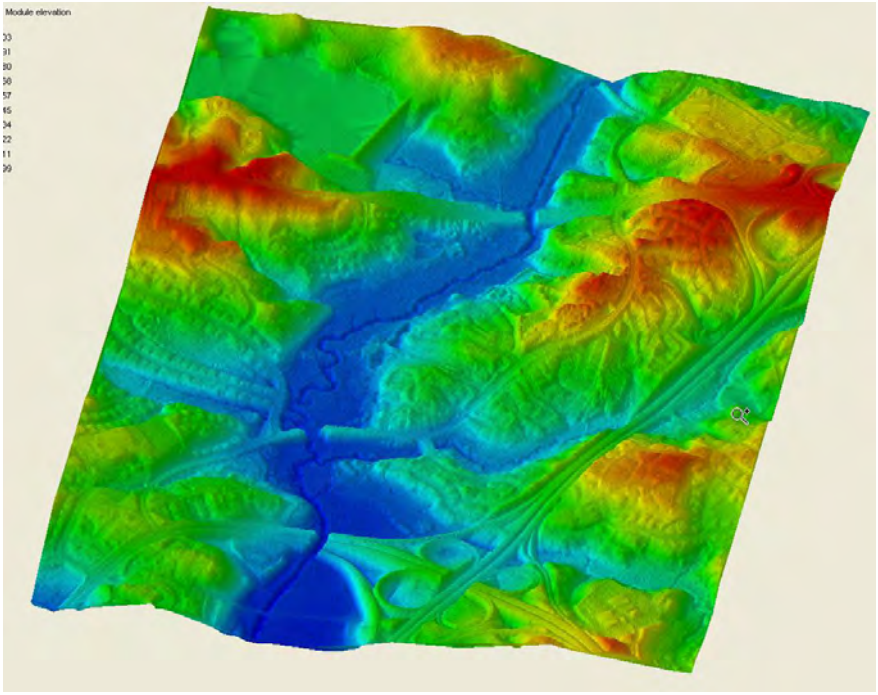

FIGURE 3-20 Shaded-relief lidar image of a portion of the Middle Patuxent River valley in Howard County, Maryland, showing the pervasive interruption of the drainage network by bridges and culverts, even in places where there is an attempt to keep excessive development out of the riparian corridor. SOURCE: Reprinted, with permission, from Miller, University of Maryland, Baltimore County. Copyright 2006 by Andrew J. Miller.

across the floodplain and spreads out over land surfaces and then flows back into channels as floodwaters subside. Although reducing the severity of downstream flooding, this phenomenon also interrupts the transport of sediment, leading to local zones of both enhanced deposition and downstream scour.

Alteration of Travel Times

The combination of impervious surface and altered drainage density provides significantly more rapid hydraulic pathways for stormwater to enter the nearest receiving waterbody compared to a natural landscape. This is illustrated quantitatively by Figure 3-21, which shows that the lag time—the difference in time between the center of mass of precipitation and the center of mass of the storm response hydrograph—is reduced for an urbanized landscape compared to a natural one.

The increase in surface runoff volumes and reduction in lag times between

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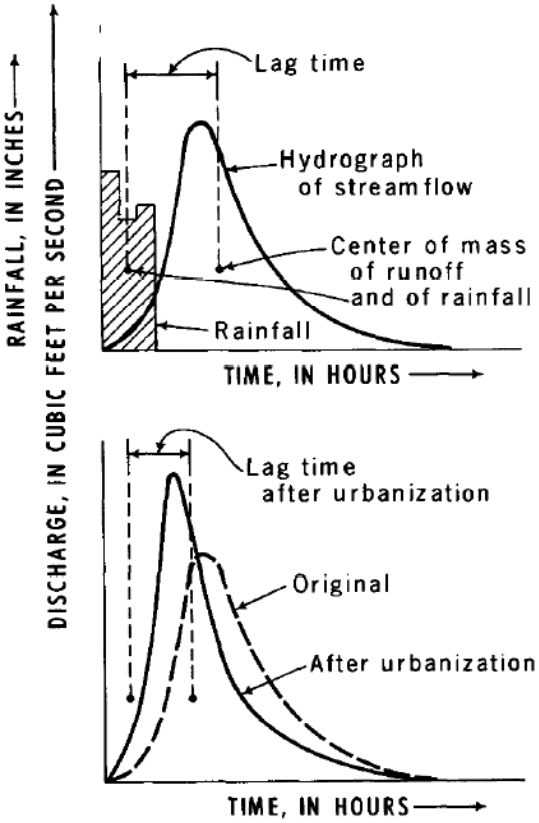

FIGURE 3-21 Illustration of the effect of urbanization on storm hydrograph lag time, the difference in time between the center of mass of rainfall and runoff response before and after urbanization. SOURCE: Leopold (1968).

precipitation and a waterbody's response give rise to greater velocities and volumetric discharges in receiving waters. Storm hydrographs in a developed setting peak earlier and higher than they do in undeveloped landscapes. This altered flow regime is of concern to property owners because upstream development can increase the probability of a flood-prone property being inundated. Properties in the floodplain and near stream channels are particularly susceptible to flooding from upstream development. Such increased flood risk is accompanied by associated potential property damages and costs of replacement or repair.

Various descriptors can be used to quantify the effects of urbanization on streamflow including flood frequency, flow duration, mean annual flood, discharge at bankfull stage, and frequency of bankfull stage. The "classic" view of

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urban-induced changes to runoff was presented by Leopold (1968), who provided several quantitative descriptors of the effects of urbanization on the mean annual flood. For example, Figure 3-22 shows the ratio of discharge before and after urbanization for the mean annual flood for a 1-square-mile area as a function of percentage of impervious area and percentage area served by a storm-drain system. This shows that for unsewered areas, increases from 0 to 100 percent impervious area will increase the peak discharge by a factor of 2.5. However, for 100 percent sewered areas, the ratio of peak discharges ranges from 1.7 to 8 for 0 to 100 percent impervious area. Clearly both impervious surfaces and the presence of a storm-drain system combine to increase discharge rates in receiving waters. Combining this information with regional flood frequency data, a discharge–frequency relationship can be developed that shows the expected discharge and recurrence interval for varying degrees of storm-drain coverage and impervious area coverage. An example is shown in Figure 3-23, using data from the Brandywine Creek watershed in Pennsylvania (Leopold, 1968). Bankfull flow for undeveloped conditions in general has a recurrence interval of about 1.5 years (which, in the particular case of the Brandywine, was 67 cubic feet per second); with 40 percent of the watershed area paved, this discharge would occur about three times as often.

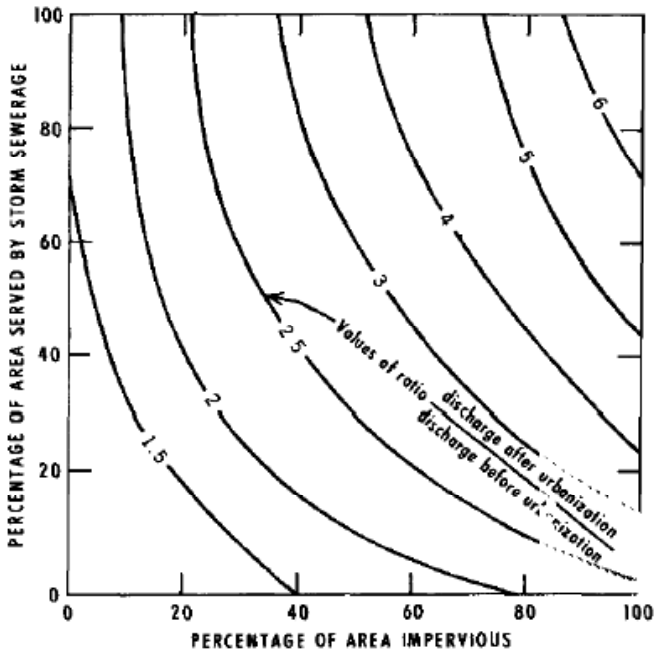

FIGURE 3-22 Ratio of peak discharge after urbanization to peak discharge before urbanization for the mean annual flood for a 1-square-mile drainage area, as a function of percent impervious surface and percent area drained by storm sewers. SOURCE: Leopold (1968).

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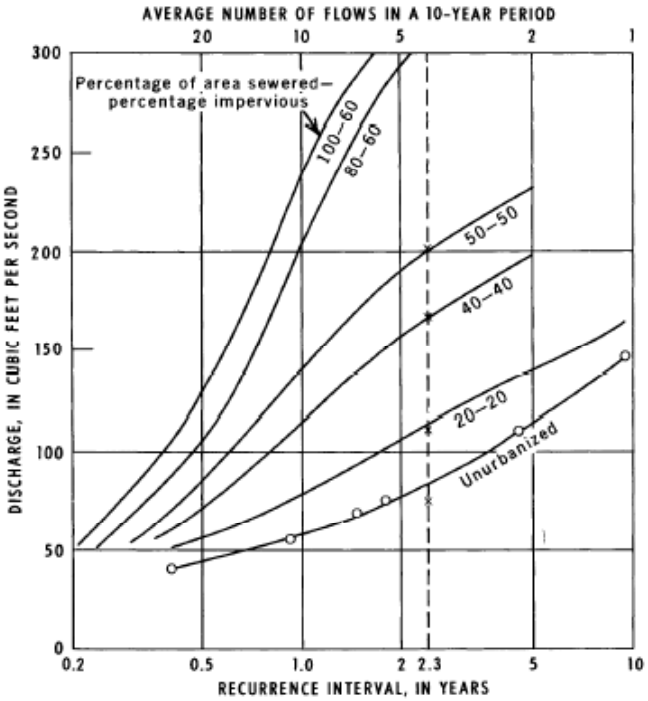

FIGURE 3-23 Flood frequency curves as a function of percent impervious area and percent of area serviced by storm sewers. The unurbanized data are from Brandywine Creek, Pennsylvania. SOURCE: Leopold (1968).

Over the past four decades since this first quantitative characterization of urban hydrology, a much greater variety of hydrologic changes resulting from urbanization has been recognized. Increases in peak discharge are certainly among those changes, and they will always gather attention because of their direct impact on human infrastructure and potential for more frequent and more severe flooding. The extended duration of flood flows, however, also affects natural channels because of the potential increase in erosion. Ecological effects of urban-altered flow regimes are even more diverse, because changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and even the season of the year in which high flows can occur all have significant ecological effects and can be dramatically altered by watershed urbanization (e.g., Rose and Peters, 2001; Konrad et al., 2005; Roy et al., 2005; Poff et al., 2006).

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The overarching conclusion of many studies is that the impact of urbanization on the hydrologic cycle is dramatic. Increased impervious area and drainage connectedness decreases stormwater travel times, increases flow rates and volumes, and increases the erosive potential of streams. The flooding caused by increased flows can be life-threatening and damaging to property. As described below, changes to the hydrologic flow regime also can have deleterious effects on the geomorphic form of stream channels and the stability of aquatic ecosystems. Although these impacts are commonly ignored in efforts to improve "water quality," they are inextricably linked to measured changes in water chemistry and must be part of any attempt to recover beneficial uses that have been lost to upstream urbanization.

Geomorphology

Watershed geomorphology is determined by the arrangement, interactions, and characteristics of component landforms, which include the stream-channel network, the interlocking network of ridges and drainage divides, and the set of hillslopes between the channel (or floodplain) and ridge. The stream and ridge systems define complementary networks, with the ridge (or drainage divide) network separating the drainage areas contributing to each reach in the stream network. At the hillslope scale, the ridges provide upper boundaries of all surface flowpaths which converge into the complementary stream reaches. A rich literature describes the topology and geometry of stream and ridge networks (e.g., Horton, 1945; Strahler, 1957, 1964; Shreve, 1966, 1967, 1969; Smart, 1968; Abrahams, 1984; Rodriguez-Iturbe et al., 1992).

Besides stream channels, a variety of other water features and landforms make up a watershed. Fresh waterbodies (ponds, lakes, and reservoirs) are typically embedded within the stream network, while wetlands may be either embedded within the stream network or separated and upslope from the channels. Estuaries represent the interface of the stream network with the open ocean. Additional fluvial and colluvial landforms include alluvial fans, landslide features, and a set of smaller features within or near the channels and floodplains including bar deposits, levees, and terraces. Each of these landforms are developed and maintained by the fluvial and gravitational transport and deposition of sediment, and are therefore potentially sensitive to disruption or alteration of flowpaths, hydrologic flow regimes, and sediment supply.

Stream Network Form and Ordering Methods

Most watersheds are fully convergent, with tributary streams combining to form progressively larger channels downstream. The manner is which streams from different source areas join to produce mainstreams strongly influences the propagation of stormwater discharge and pollutant concentrations, and the con-

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sequent level of ecological impairment in the aquatic ecosystem.

Methods for indexing the topologic position of individual reaches within the drainage network have been introduced by Horton (1945), Strahler (1957), Shreve (1966, 1967) and others. All stream topologic systems are dependent on the identification of first-order streams—the most upstream element of the network—and their lengths and drainage areas. Unfortunately, no universal standards exist to define where the stream head is located, or whether perennial, intermittent, and ephemeral channels should be considered in this determination. While this may seem like a trivial process, the identification and delineation of these sources effectively determines what lengths and sections of channels are defined to be *waterbodies* and, thus, the classification of all downstream waterbodies.

Nadeau and Rains (2007) have recently reviewed stream-channel delineation in the United States using standardized maps and hydrographic datasets to better relate climate to the extent of perennial, intermittent, and ephemeral channel types. Because this may influence the set of stream channels that are regulated by the Clean Water Act (CWA), it is the subject of current legal arguments in courts up to and including the Supreme Court (e.g., *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 [2001], *John A. Rapanos et al. vs. United States* [U.S., No. 04-1034, 2005]). In addition to the stream-channel network, additional features (discussed below) that are embedded in or isolated from the delineated stream network (lakes, ponds, and wetlands) are subject to regulation under the CWA based on their proximity or interaction with the defined stream and river network. Therefore, definition of the extent and degree of connectivity of the nation's stream network, with an emphasis on the headwater region, is a critical determinant of the set of waterbodies that are regulated for stormwater permitting (Nadeau and Rains, 2007).

Stream Reach Geomorphology

Within the channel network, stream reaches typically follow a regular pattern of changes in downstream channel form. Hydraulic geometry equations, first introduced by Leopold and Maddock (1953), describe the gross geomorphic adjustment of the channel (in terms of average channel depth and width) to the flow regime and sometimes the sediment supply. Within this general pattern of larger flows producing larger channels, variations in channel form are evident, particularly the continuum among straight, meandering, or braided patterns. These forms are dependent on the spatial and temporal patterns of discharge, sediment supply, transport capacity, and roughness elements.

Most natural channels have high width-to-depth ratios and complexity of channel form compared with engineered channels. Meanders are ubiquitous self-forming features in channels, created as accelerated flow around the outside of the meander entrains and transports more sediment, producing greater flow depths and eroding the bank, while decelerated flow on the inside of the mean-

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der results in deposition and the formation of lower water depth and bank gradients. These channels typically show small-scale alternation between larger cross sections with lower velocities and defining pools, and smaller cross sections with higher velocity flow in riffles. Braided streams form repeated subdivision and reconvergence of the channel in multiple threads, with reduced specific discharge compared to a single channel. Natural obstructions including woody debris, boulders, and other large (relative to channel dimensions) features all contribute to hydraulic and habitat heterogeneity. The complexity of these channel patterns contributes to hydraulic roughness, further dissipating stream energy by increasing the effective wetted perimeter of the channel through a valley and deflecting flow between banks.

Embedded Standing Waterbodies

Standing waterbodies include natural, constructed, or modified ponds and lakes and are characterized by low or near-zero lateral velocity. They can be thought of as extensions of pools within the drainage network, although there is no clear threshold at which a pool can be defined as a pond or lake. When they are embedded within the channel network, they are characterized with much greater cross-sectional area (width x depth), lower surface water slopes (approaching flat), and lower velocities than a stream reach of similar length. Therefore, standing waterbodies function as depositional zones, have higher residence times, and provide significant storage of water, sediment, nutrients, and other pollutants within the stream network.

Riparian Zone

The riparian area is a transitional zone between the active channel and the uplands, and between surface water and groundwater. The area typically has shallower groundwater levels and higher soil moisture than the surrounding uplands, and it may support wetlands or other vegetation communities that require higher soil moisture. Riparian zones provide important ecosystem functions and services, such as reducing peak flood flows, transforming bioavailable nutrients into organic matter, and providing critical habitat.

In humid landscapes, a functioning riparian area commonly is an area where shallow groundwater forms discharge seeps, either directly to the surface and then to the stream channel or through subsurface flowpaths to the stream channel. The potential for high moisture and organic material content provides an environment conducive to anaerobic microbial activity, which can provide effective sinks for inorganic nitrogen by denitrification, reducing nitrate loading to the stream channel. However, the width of the effective riparian zone depends on local topographic gradients, hydrogeology, and the channel geomorphology (Lowrance et al., 1997). In steeply incised channels and valleys, or areas with

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deeper flowpaths, the riparian zone may be narrow and relatively well drained.

Under more arid conditions with lower groundwater levels, riparian areas may be the only areas within the watershed with sufficient moisture levels to support significant vegetation canopy cover, even though saturation conditions may occur only infrequently. Subsurface flowpaths may be oriented most commonly from the channel to the bed and banks, forming the major source of recharge to this zone from periodic flooding. In monsoonal climates in the U.S. southwest, runoff generated in mountainous areas or from storm activity may recharge riparian aquifers well downstream from the storm or snowmelt activity. Channelization that reduces this channel-to-riparian recharge may significantly impair riparian and floodplain ecosystems that provide critical habitat and other ecosystem services (NRC, 2002).

Floodplains

The presence and distribution of alluvial depositional zones, including floodplains, is dependent on the distribution and balance of upstream sediment sources and sediment transport capacity, the temporal and spatial variability of discharge, and any geological structural controls on valley gradient. Lateral migration of streams contributes to the development of floodplains as the outer bank of the migrating channel erodes sediment and deposition occurs on the opposite bank. This leads to channels that are closely coupled to their floodplains, with frequent overbank flow and deposition, backwater deposits, wetlands, abandoned channels, and other floodplain features. During major events, overbank flooding and deposition adds sediment, nutrients, and contaminants to the floodplain surface, and may significantly rework preexisting deposits and drainage patterns. Constructional landforms typical of urbanized watersheds, such as levees, tend to disconnect streams from their floodplains.

Changes in Geomorphology from Urbanization

Changes to channel morphology are among the most common and readily visible effects of urban development on natural stream systems (Booth and Henshaw, 2001). The actions of deforestation, channelization, and paving of the uplands can produce tremendous changes in the delivery of water and sediment into the channel network. In channel reaches that are alluvial, the responses are commonly rapid and often dramatic. Channels widen and deepen, and in some cases may incise many meters below the original level of their beds. Alternatively, channels may fill with sediment derived from farther upstream to produce a braided form where a single-thread channel previously existed.

The clearest single determinant of urban channel change is the alteration of the hydrologic response of an urban watershed, notably the increase in streamflow discharges. Increases in runoff mobilize sediment both on the land surface

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and within the stream channel. Because transport capacity increases nonlinearly with flow velocity (Vogel et al., 2003), much greater transport will occur in higher flow events. However, the low frequency of these events may result in decreasing cumulative sediment transport during the highest flows, as described by standard magnitude and frequency analysis (Wolman and Miller, 1960), such that the maximum time-integrated sediment transport occurs at moderate flows (e.g., bankfull stage in streams in the eastern United States).

If the increase in sediment transport caused by the shift in the runoff regime is not matched by the sediment supply, channel bed entrenchment and bank erosion and collapse lead to a deeper, wider channel form. Increases in channel dimensions caused by increased discharges have been observed in numerous studies, including Hammer (1972), Hollis and Luckett (1976), Morisawa and LaFlure (1982), Neller (1988), Whitlow and Gregory (1989), Moscrip and Montgomery (1997), and Booth and Jackson (1997). MacRae (1997), reporting on other studies, found that channel cross-sectional areas began to enlarge after about 20 to 25 percent of the watershed was developed, commonly corresponding to about 5 percent impervious cover. When the watersheds were completely developed, the channel enlargements were about 5 to 7 times the original cross-sectional areas. Channel widening can occur for several decades before a new equilibrium is established between the new cross-section and the new discharges.

Construction results in a large—but normally temporary—increase in sediment load to aquatic systems (e.g., Wolman and Schick, 1967). Indeed, erosion and sediment transport rates can reach up to more than 200 Mg/ha/yr on construction sites, which is well in excess of typical rates from agricultural land (e.g., Wolman and Schick, 1967; Dunne and Leopold, 1978); rates from undisturbed and well-vegetated catchments are negligible (e.g., <<1 Mg/ha/yr). The increased sediment loads from construction exert an opposing tendency to channel erosion and probably explain much of the channel narrowing or shallowing that is sometimes reported (e.g., Leopold, 1973; Nanson and Young, 1981; Ebisemiju, 1989; Odemerho, 1992).

Additional sediment is commonly introduced into the channel network by the erosion of the streambank and bed itself. Indeed, this source can become the largest single fraction of the sediment load in an urbanizing watershed (Trimble, 1997). For example, Nelson and Booth (2002) reported on sediment sources in the Issaquah Creek watershed, an urbanizing, mixed-use watershed in the Pacific Northwest. Human activity in the watershed, particularly urban development, has caused an increase of nearly 50 percent in the annual sediment yield, now estimated to be 44 tons/km^2/yr^1. The main sources of sediment in the watershed are landslides (50 percent), channel-bank erosion (20 percent), and stormwater discharges (15 percent).

The higher flow volumes and peak discharge caused by urbanization also tend to preferentially remove fine-grained sediment, leaving a lag of coarser bed material (armoring) or removing alluvial material entirely and eroding into the geologic substrate (Figure 3-24). The geomorphic outcome of these changes is a

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FIGURE 3-24 Example of an urban stream that has eroded entirely through its alluvium to expose the underlying consolidated geologic stratum below (Thornton Creek, Seattle, Washington). SOURCE: Derek Booth, Stillwater Sciences, Inc.

mix of erosional enlargement of some stream reaches, significant sedimentation in others, and potential head-ward downcutting of tributaries as discharge levels from small catchments increase. The collective effects of these processes have been described by Walsh et al. (2005) as "Urban Stream Syndrome," which includes not only the visible alteration of the physical form of the channel but also the consequent deterioration of stream biogeochemical function and aquatic trophic structures.

Other changes also accompany these geomorphic changes. Episodic inundation of the floodplain during floods may be reduced in magnitude and frequency, depending on the increases in peak flow relative to the deepening and resultant increase in flow capacity of the channel. Where deeply entrenched, this channel morphology will lower the groundwater level adjacent to the channel. The effectiveness of riparian areas in filtering or removing solutes is thus reduced because subsurface water may reach the channel only by flowpaths now well below the organic-rich upper soil horizons. Removal of fine-grained stream-bottom sediment, or erosion down to bedrock, may substantially lower the exchange of stream water with the surrounding groundwater of the hyporheic zone.

In addition to these indirect effects on the physical form of the stream channel, urbanization also commonly modifies streams directly to improve drainage, applying channel straightening and lining to reduce friction, increase flow capacity, and stabilize channel position (Figure 3-25). The enlarged and often

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FIGURE 3-25 Example of a channelized urban stream for maximized flood conveyance and geomorphic stability (Los Angeles River, California). SOURCE: Robert Pitt, University of Alabama.

lined and straightened stream-channel cross section reduces the complexity of the bed and the contact between the stream and floodplain, and increases transport efficiency of sediment and solutes to receiving waterbodies. Enhanced sedimentation of receiving waterbodies, in turn, reduces water clarity, decreases depth, and buries the benthic environment.

POLLUTANT LOADING IN STORMWATER

Hydrologic flowpaths influence the production of particulate and dissolved substances on the land surface during storms, as well as their delivery to the stream-channel network. Natural watersheds typically develop a sequence of ecosystem types along hydrologic flowpaths that utilize available limiting resources, thereby reducing their export farther downslope or downstream, such that in-stream concentrations of these nutrients are low. As a watershed shifts from having mostly natural pervious surfaces to having heavily disturbed soils, new impervious surfaces, and activities characteristic of urbanization, the runoff quality shifts from relatively lower to higher concentrations of pollutants. Anthropogenic activities that can increase runoff pollutant concentrations in urban watersheds include application of chemicals for fertilization and pest control; leaching and corrosion of pollutants from exposed materials; exhaust emissions,

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leaks from, and wear of vehicles; atmospheric deposition of pollutants; and inappropriate discharges of wastes.

Most lands in the United States that have been developed were originally grasslands, prairies, or forest. About 40 percent of today's developed land went through an agricultural phase (cropland or pastureland) before becoming urbanized, while more than half of today's developed land area has been a direct conversion of natural covers (USDA, 2000). Agricultural land can produce stormwater runoff with high pollutant concentrations via soil erosion, the introduction of chemicals (fertilizers, pesticides, and herbicides), animal operations that are major sources of bacteria in runoff, and forestry operations. Indeed, urban stormwater may actually have slightly lower pollutant concentrations than other nonpoint sources of pollution, especially for sediment and nutrients. The key difference is that urban watersheds produce a much larger annual volume of runoff waters, such that the mass of pollutants discharged is often greater following urbanization. Some of the complex land-use–pollutant loading relationships are evident in Box 3-7, which shows the measured annual mass loads of nitrogen and phosphorus in four small watersheds of different land use monitored as part of the Baltimore Long-Term Ecological Research program. Depending on the nutrient and the year, the agricultural and urban watersheds had a higher nutrient export rate than the forested subwatershed.

Table 3-3 summarizes the comparative importance of urban land-use types in generating pollutants of concerns that can impact receiving waters (Burton and Pitt, 2002). This summary is highly qualitative and may vary depending on the site-specific conditions, regional climate, activities being conducted in each land use, and development characteristics. It should be noted that the rankings in Table 3-3 are relative to one another and classified on a per-unit-area basis. Furthermore, this table shows the parameters for each land-use category, such that the effects for a community at large would be dependent on the areas of each land use shown. Thus, although residential land use is shown to be a relatively smaller source of many pollutants, it is the largest fraction of land use in most communities, typically making it the largest stormwater source on a mass pollutant discharge basis. Similarly, freeway, industrial, and commercial areas can be very significant sources of many stormwater problems, and their discharge significance is usually much greater than their land area indicates. Construction sites are usually the overwhelming source of sediment in urban areas, even though they make up very small areas of most communities. A later table (Table 3-4) presents observed stormwater discharge concentrations for selected constituents for different land uses.

The following section describes stormwater characteristics associated with urbanized conditions. At any given time, parts of an urban area will be under construction, which is the source of large sediment losses, flow path disruptions, increased runoff quantities, and some chemical contamination. Depending on the time frame of development, increased stormwater pollutant discharges associated with construction activities may last for several years until land covers are stabilized. After construction has been completed, the characteristics of urban

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BOX 3-7
Comparison of Nitrogen and Phosphorus Export from Watersheds with Different Land Uses

Land use is a significant influence on nutrient export as controlled by impervious area, sanitary infrastructure, fertilizer application, and other determinants of input, retention, and stormwater transport. Tables 3-2A and 3-2B compare dissolved nitrate, total nitrogen, phosphate, and total phosphorus loads exported from forest catchments with catchments in different developed land uses studied by the Baltimore Ecosystem Study (Groffman et al., 2004). Loads were computed with the Fluxmaster system (Schwarz et al., 2006) from weekly samples taken at outlet gauges. In these sites in Baltimore County, the forested catchment, Pond Branch, has nitrogen loads one to two orders of magnitude lower than the developed catchments. Baisman Run, with one-third of the catchment in low-density, septic-served suburban land use, has nitrogen export exceeding Dead Run, an older, dense urban catchment. In this case, nutrient load does not follow the direct variation of impervious area because of the switch to septic systems and greater fertilizer use in lower density areas. However, Figure 3-26 shows that as impervious area increases, a much greater proportion of the total nitrogen load is discharged in less frequent, higher runoff events (Shields et al., 2008), reducing the potential to decrease loads by on-site SCMs. Total phosphorus loads were similarly as low (0.05–0.6 kg P/ha/yr) as nitrogen in the Pond Branch catchment (forest) over the 2000–2004 time period, and one to two orders of magnitude lower compared to agricultural and residential catchments.

It should be noted that specific areal loading rates, even in undeveloped catchments, can vary significantly depending on rates of atmospheric deposition, disturbance, and climate conditions. The hydrologic connectivity of nonpoint pollutant source areas to receiving waterbodies is also a critical control on loading in developed catchments (Nadeau and Rains, 2007) and is dependent on both properties of the pollutant as well as the catchment hydrology. For example, total nitrogen was high in both the agricultural and low-density suburban sites. Total phosphorus, on the other hand, was high in the Baltimore Ecosystem Study agricultural catchment, but close to the concentration of the forest site in the low-density suburban site serviced by septic systems. This is because septic systems tend to retain phosphorus, while septic wastewater nitrogen is typically nitrified in the unsaturated zone below a spreading field and efficiently transported in the groundwater to nearby streams.

TABLE 3-2A Dissolved Nitrate and Total Nitrogen Export Rates from Forest and Developed Land-Use Catchments in the Baltimore Ecosystem Study

Catchment	Land Use	Nitrate (kg N/ha/yr)			Total N (kg N/ha/yr)		
		2000	2001	2002	2000	2001	2002
Pond Branch	Forest	0.11	0.08	0.04	0.47	0.37	0.17
McDonogh	Agriculture	17.6	12.9	4.3	20.5	14.5	4.5
Baisman Run	Mixed Forest and Suburban	7.2	3.8	1.5	8.2	4.2	1.7
Dead Run	Urban	3.0	2.9	2.9	5.6	5.3	4.2

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TABLE 3-2B Dissolved Phosphate and Total Phosphorus Export Rates from Forest and Developed Land-Use Catchments in the Baltimore Ecosystem Study

Catchment	Land Use	Phosphate (kg P/ha/yr)			Total P (kg P/ha/yr)		
		2000	2001	2002	2000	2001	2002
Pond Branch	Forest	0.009	0.007	0.003	0.02	0.014	0.006
McDonogh	Agriculture	0.12	0.080	0.022	0.22	0.14	0.043
Baisman Run	Mixed Forest and Suburban	0.009	0.005	0.002	0.02	0.011	0.004
Dead Run	Urban	0.039	0.037	0.03	0.10	0.10	0.08

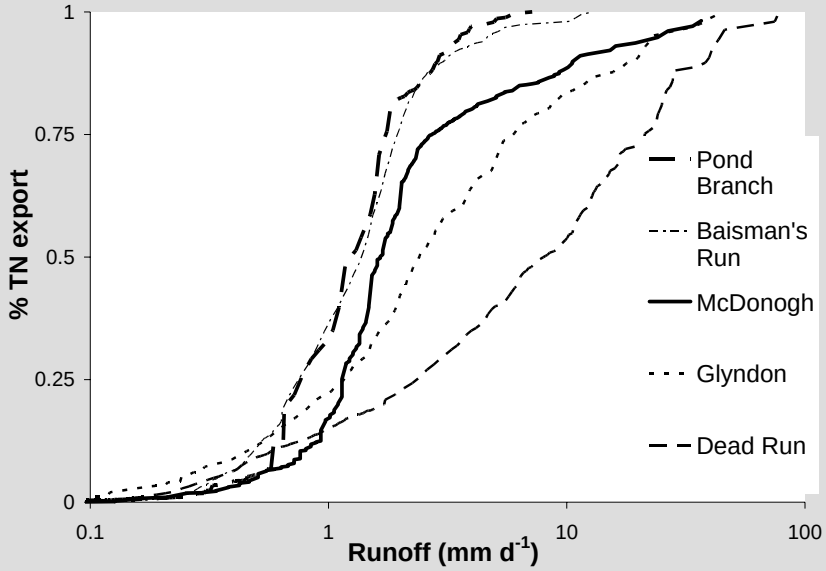

FIGURE 3-26 Cumulative transport of total nitrogen at increasing flow levels from catchments in Baltimore City and County including dominantly forest (Pond Branch), low-density development on septic systems and forest (Baisman Run), agricultural (McDonogh), medium-density suburban development on separate sewers (Glyndon), and higher-density residential, commercial, and highway land cover (Dead Run). SOURCE: Reprinted, with permission, from Shields et al. (2008). Copyright 2008 by the American Geophysical Union.

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TABLE 3-3 Relative Sources of Parameters of Concern for Different Land Uses in Urban Areas

Problem Parameter	Residential	Commercial	Industrial	Freeway	Construction
High flow rates (energy)	Low	High	Moderate	High	Moderate
Large runoff volumes	Low	High	Moderate	High	Moderate
Debris (floatables and gross solids)	High	High	Low	Moderate	High
Sediment	Low	Moderate	Low	Low	Very high
Inappropriate discharges (mostly sewage and cleaning wastes)	Moderate	High	Moderate	Low	Low
Microorganisms	High	Moderate	Moderate	Low	Low
Toxicants (heavy metals/organics)	Low	Moderate	High	High	Moderate
Nutrients (eutrophication)	Moderate	Moderate	Low	Low	Moderate
Organic debris (SOD and DO)	High	Low	Low	Low	Moderate
Heat (elevated water temperature)	Moderate	High	Moderate	High	Low

NOTE: SOD, sediment oxygen demand; DO, dissolved oxygen.
SOURCE: Summarized from Burton and Pitt (2002), Pitt et al. (2008), and CWP and Pitt (2008).

runoff are controlled largely by the increase in volume and the washoff of pollutants from impervious surfaces. Stormwater in this phase is associated with increases in discharges of most pollutants, but with less sediment washoff than from construction and likely less sediment and nutrient discharges compared to any pre-urbanization agricultural operations (although increased channel erosion may increase the mass of sediment delivered in this phase; Pitt et al., 2007). A third significant urban land use is industrial activity. As described later, industrial site stormwater discharges are highly variable, but often greater than other land uses.

Construction Site Erosion Characteristics

Problems associated with construction site runoff have been known for many years. More than 25 years ago, Willett (1980) estimated that approximately 5 billion tons of sediment reached U.S. surface waters annually, of which 30 percent was generated by natural processes and 70 percent by human activities. Half of this 70 percent was attributed to eroding croplands. Although construction occurred on only about 0.007 percent of U.S. land in the 1970s, it ac-

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counted for approximately 10 percent of the sediment load to all U.S. surface waters and equaled the combined sediment contributions of forestry, mining, industrial, and commercial land uses (Willett, 1980).

Construction accounts for a much greater proportion of the sediment load in urban areas than it does in the nation as a whole. This is because construction sites have extremely high erosion rates and because urban construction sites are efficiently drained by stormwater drainage systems installed early during the construction activities. Construction site erosion losses vary greatly throughout the nation, depending on local rain, soil, topographic, and management conditions. As an example, the Birmingham, Alabama, area may have some of the highest erosion rates in the United States because of its combination of very high-energy rains, moderately to severely erosive soils, and steep slopes (Pitt et al., 2007). The typically high erosion rates mean that even a small construction project may have a significant detrimental effect on local waterbodies.

Extensive evaluations of urban construction site runoff problems have been conducted in Wisconsin for many years. Data from the highly urbanized Menomonee River watershed in southeastern Wisconsin indicate that construction sites have much greater potentials for generating sediment and phosphorus than do other land uses (Chesters et al., 1979). For example, construction sites can generate approximately 8 times more sediment and 18 times more phosphorus than industrial sites (the land use that contributes the second highest amount of these pollutants) and 25 times more sediment and phosphorus than row crops. In fact, construction sites contributed more sediment and phosphorus to the Menomonee River than any other land use, although in 1979, construction comprised only 3.3 percent of the watershed's total land area. During this early study, construction sites were found to contribute about 50 percent of the suspended sediment and total phosphorus loading at the river mouth (Novotny and Chesters, 1981).

Similar conclusions were reported by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in a 1978 modeling study of the relative pollutant contributions of 17 categories of point and nonpoint pollution sources to 14 watersheds in the southeast Wisconsin regional planning area (SEWRPC, 1978). This study revealed construction as the first or second largest contributor of sediment and phosphorus in 12 of the 14 watersheds. Although construction occupied only 2 percent of the region's total land area in 1978, it contributed approximately 36 percent of the sediment and 28 percent of the total phosphorus load to inland waters, making construction the region's second largest source of these two pollutants. The largest source of sediment was estimated to be cropland; livestock operations were estimated to be the largest source of phosphorus. By comparison, cropland comprised 72 percent of the region's land area and contributed about 45 percent of the sediment and only 11 percent of the phosphorus to regional watersheds. When looking at the Milwaukee River watershed as a whole, construction is a major sediment contributor, even though the amount of land under active construction is very low. Construction areas were estimated to contribute about 53 percent of the total sediment discharged by the

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Milwaukee River in 1985 (total sediment load of 12,500 lb/yr), while croplands contributed 25 percent, streambank erosion contributed 13 percent, and urban runoff contributed 8 percent.

Line and White (2007) recently investigated runoff characteristics from two similar drainage areas in the Piedmont region of North Carolina. One of the drainage areas was being developed as part of a large residential subdivision during the course of the study, while the other remained forested or in agricultural fields. Runoff volume was 68 percent greater for the developing compared with the undeveloped area, and baseflow as a percentage of overall discharge was approximately zero compared with 25 percent for the undeveloped area. Overall annual export of sediment was 95 percent greater for the developing area, while export of nitrogen and phosphorus forms was 66 to 88 percent greater for the developing area.

The biological stream impact of construction site runoff can be severe. For example, Hunt and Grow (2001) describe a field study conducted to determine the impact to a stream from a poorly controlled construction site, with impact being measured via fish electroshocking and using the Qualitative Habitat Evaluation Index. The 33-acre construction site consisted of severely eroded silt and clay loam subsoil and was located within the Turkey Creek drainage, Scioto County, Ohio. The number of fish species declined (from 26 to 19) and the number of fish found decreased (from 525 to 230) when comparing upstream unimpacted reaches to areas below the heavily eroding site. The Index of Biotic Integrity and the Modified Index of Well-Being, common fisheries indexes for stream quality, were reduced from 46 to 32 and 8.3 to 6.3, respectively. Upstream of the area of impact, Turkey Creek had the highest water quality designation available, but fell to the lowest water quality designation in the area of the construction activity. Water quality sampling conducted at upstream and downstream sites verified that the decline in fish diversity was not due to chemical affects alone.

Municipal Stormwater Characteristics

The suite of stormwater pollutants generated by municipal areas is expected to be much more diverse than construction sites because of the greater variety of land uses and pollutant source areas found within a typical city. Many studies have investigated stormwater quality, with the U.S. Environmental Protection Agency's (EPA's) NURP (EPA, 1983) being the best known and earliest effort to collect and summarize these data. Unfortunately, NURP was limited in that it did not represent all areas of the United States or all important land uses. More recently, the National Stormwater Quality Database (NSQD) (CWP and Pitt, 2008; Pitt et al., 2008 for version 3) has been compiling data from the EPA's NPDES stormwater permit program for larger Phase I municipal separate storm sewer system (MS4) communities. As a condition of their Phase I permits, municipalities were required to establish a monitoring program to characterize their local stormwater quality for their most important land uses discharging to the

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MS4. Although only a few samples from a few locations were required to be monitored each year in each community, the many years of sampling and large number of communities has produced a database containing runoff quality information for nearly 8,000 individual storm events over a wide range of urban land uses. The NSQD makes it possible to statistically compare runoff from different land uses for different areas of the country.

A number of land uses are represented in MS4 permits and also the database, including industrial stormwater discharges to an MS4. However, there is no separate compilation of quantitative mass emissions from specific industrial stormwater sources that may have been collected under industrial permit monitoring efforts. The observations in the NSQD were all obtained at outfall locations and do not include snowmelt or construction erosion sources. The most recent version of the NSQD contains stormwater data from about one-fourth of the total number of communities that participated in the Phase I NPDES stormwater permit monitoring activities. The database is located at *http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml*.

Table 3-4 is a summary of *some* of the stormwater data included in NSQD version 3, while Figure 3-27 shows selected plots of these data. The table describes the total number of observations, the percentage of observations above the detection limits, the median, and coefficients of variation for a few of the major constituents for residential, commercial, industrial, institutional, freeway, and open-space land-use categories, although relatively few data are available for institutional and open-space areas. It should be noted that even if there are significant differences in the median concentrations by the land uses, the range of the concentrations within single land uses can still be quite large. Furthermore, plots like Figure 3-27 do not capture the large variability in data points observed at an individual site.

There are many factors that can be considered when examining the quality of stormwater, including land use, geographical region, and season. The following is a narrative summary of the entire database and may not reflect information in Table 3-4 and Figure 3-29, which show only subsets of the data. First, statistical analyses of variance on the NSQD found significant differences among land-use categories for all of the conventional constituents, except for dissolved oxygen. (Turbidity, total solids, total coliforms, and total *E. coli* did not have enough samples in each group to evaluate land-use differences.) Freeway sites were found to be significant sources of several pollutants. For example, the highest TSS, COD, and oil and grease concentrations (but not necessarily the highest *median* concentrations) were reported for freeways. The median ammonia concentration in freeway stormwater is almost three times the median concentration observed in residential and open-space land uses, while freeways have the lowest orthophosphate and nitrite–nitrate concentrations—half of the concentration levels that were observed in industrial land uses.

In almost all cases the median metal concentrations at the industrial areas were about three times the median concentrations observed in open-space and residential areas. The highest lead and zinc concentrations (but not necessarily

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TABLE 3-4 Summary of Selected Stormwater Quality Data Included in NSQD, Version 3.0

	TSS (mg/L)	COD (mg/L)	Fecal Coliform (mpn/100 mL)	Nitrogen, Total Kjeldahl (mg/L)	Phosphorus, Total (mg/L)	Cu, Total (µg/L)	Pb, Total (µg/L)	Zn, Total (µg/L)
All Areas Combined (8,139)								
Coefficient of variation (COV)	2.2	1.1	5.0	1.2	2.8	2.1	2.0	3.3
Median	62.0	53.0	4300	1.3	0.2	15.0	14.0	80.0
Number of samples	6780	5070	2154	6156	7425	5165	4694	6184
% samples above detection	99	99	91	97	97	88	78	98
All Residential Areas Combined (2,586)								
COV	2.0	1.0	5.7	1.2	1.6	1.9	2.1	3.3
Median	59.0	50.0	4200	1.2	0.3	12.0	6.0	70.0
Number of samples	2167	1473	505	2026	2286	1640	1279	1912
% samples above detection	99	99	89	98	98	88	77	97
All Commercial Areas Combined (916)								
COV	1.7	1.0	3.0	0.8	1.2	1.4	1.7	1.4
Median	55.0	63.0	3000	1.3	0.2	17.9	15.0	110.0
Number of samples	843	640	270	726	920	753	605	839
% samples above detection	97	98	89	98	95	85	79	99
All Industrial Areas Combined (719)								
COV	1.7	1.3	6.1	1.1	1.4	2.1	2.0	1.7
Median	73.0	59.0	2850	1.4	0.2	19.0	20.0	156.2
Number of samples	594	474	317	560	605	536	550	596
% samples above detection	98	98	94	97	95	86	76	99

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All Freeway Areas Combined (680)								
COV	2.6	1.0	2.7	1.2	5.2	2.2	1.1	1.4
Median	53.0	64.0	2000	1.7	0.3	17.8	49.0	100.0
Number of samples	360	439	67	430	585	340	355	587
% samples above detection	100	100	100	99	99	99	99	99
All Institutional Areas Combined (24)								
COV	1.1	1.0	0.4	0.6	0.9	0.6	1.0	0.9
Median	18.0	37.5	3400	1.1	0.2	21.5	8.6	198.0
Number of samples	23	22	3	22	23	21	21	22
% samples above detection	96	91	100	91	96	57	86	100
All Open -Space Areas Combined (79)								
COV	1.8	0.6	1.2	1.2	1.5	0.4	0.9	0.8
Median	10.5	21.3	2300	0.4	0.0	9.0	48.0	57.0
Number of samples	72	12	7	50	77	15	10	16
% samples above detection	97	83	100	96	97	47	20	50

NOTE: The complete database is located at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml. SOURCE: National Stormwater Quality Database.

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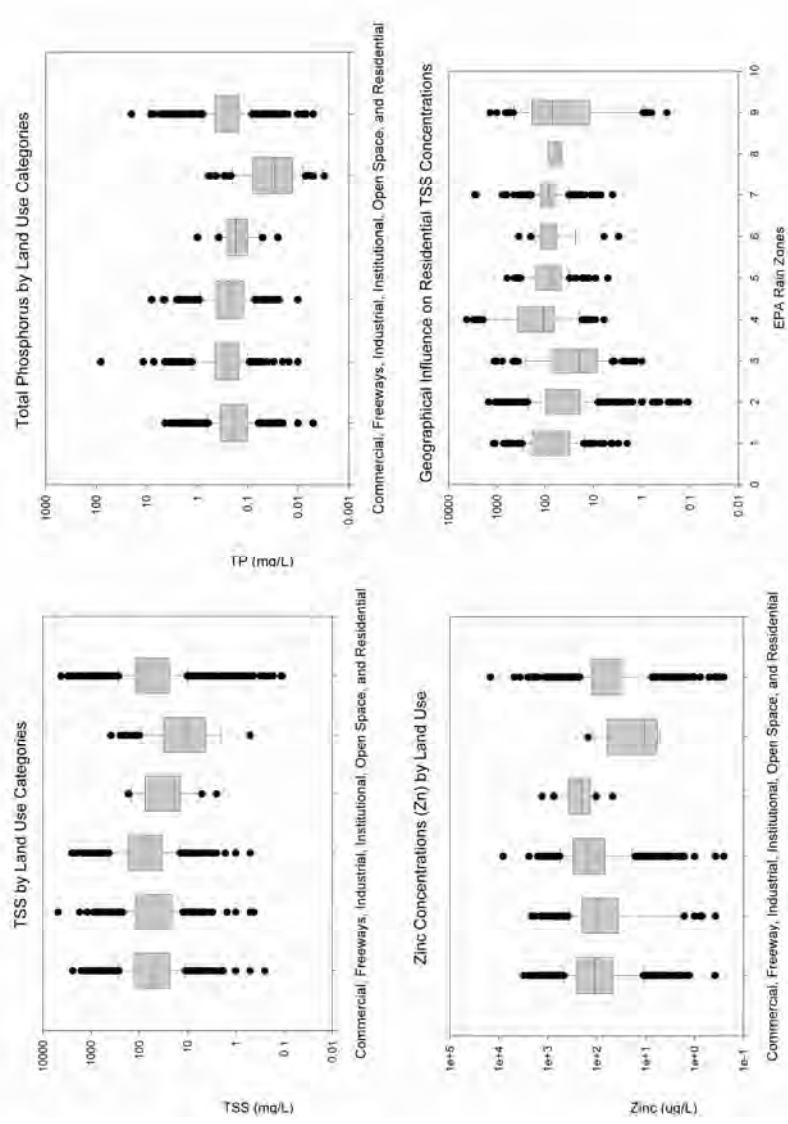

FIGURE 3-27 Grouped box and whisker plots of data from the NSQD. The median values are indicated with the horizontal line in the center of the box, while the ends of the box represent the 25th and 75th percentile values. The whickers extend to the 5th and 95th percentile values, and values outside of these extremes are indicated with separate dots. These groups were statistically analyzed and were found to have at least one group that is significantly different from the other groups. The ranges of the values in each group are large, but a very large number of data points is available for each group. The grouping of the data into these categories helps explain much of the total variability observed, and the large number of samples in each category allows suitable statistical tests to be made. Many detailed analyses are presented at the NSQD website (Maestre and Pitt, 2005).

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the highest *median* concentrations) were found in industrial land uses. Lower concentrations of TDS, five-day biological oxygen demand (BOD_5), and fecal coliforms were observed in industrial land-use areas. By contrast, the highest concentrations of dissolved and total phosphorus were associated with residential land uses. Fecal coliform concentrations are also relatively high for residential and mixed residential land uses. Open-space land-use areas show consistently low concentrations for the constituents examined. There was no significant difference noted for total nitrogen among any of the land uses monitored.

In terms of regional differences, significantly higher concentrations of TSS, BOD_5, COD, total phosphorus, total copper, and total zinc were observed in arid and semi-arid regions compared to more humid regions. In contrast, fecal coliforms and total dissolved solids were found to be higher in the upper Midwest. More detailed discussions of land use and regional differences in stormwater quality can be found in Maestre et al. (2004) and Maestre and Pitt (2005, 2006). In addition to the information presented above, numerous researchers have conducted source area monitoring to characterize sheet flows originating from urban surfaces (such as roofs, parking lots, streets, landscaped areas, storage areas, and loading docks). The reader is referred to Pitt et al. (2005a,b,c) for much of this information.

Industrial Stormwater Characteristics

The NSQD, described earlier, has shown that industrial-area stormwater has higher concentrations of most pollutants compared to other land uses, although the variability is high. MS4 monitoring activities are usually conducted at outfalls of drainage systems containing many individual industrial activities, so discharge characteristics for specific industrial types are rarely available. This discussion provides some additional information concerning industrial stormwater beyond that included in the previous discussion of municipal stormwater. In general, there is a profound lack of data on industrial stormwater compared to municipal stormwater, and a correspondingly greater uncertainty about industrial stormwater characteristics.

The first comprehensive monitoring of an industrial area that included stormwater, dry weather base flows, and snowmelt runoff was conducted in selected Humber River catchments in Ontario (Pitt and McLean, 1986). Table 3-5 shows the annual mass discharges from the monitored industrial area in North York, along with ratios of these annual discharges compared to discharges from a mixed commercial and residential area in Etobicoke. The mass discharges of heavy metals, total phosphorus, and COD from industrial stormwater are three to six times that of the mixed residential and commercial areas.

Hotspots of contamination on industrial sites are a specific concern. Stormwater runoff from "hotspots" may contain loadings of hydrocarbons, trace metals, nutrients, pathogens and/or other toxicants that are greater than the loadings of "normal" runoff. Examples of these hotspots include airport de-icing

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TABLE 3-5 Annual Storm Drainage Mass Discharges from Toronto-Area Industrial Land Use

Measured Parameter	Units	Annual Mass Discharges from Industrial Drainage Area	Stormwater Annual Discharge Ratio (Industrial Compared to Residential and Commercial Mixed Area)
Runoff volume	m^3/hr/yr	6,580	1.6
total solids	kg/ha/yr	6,190	2.8
total phosphorus	kg/ha/yr	4,320	4.5
TKN	g/ha/yr	16,500	1.2
COD	kg/ha/yr	662	3.3
Cu	g/ha/yr	416	4.0
Pb	g/ha/yr	595	4.2
Zn	g/ha/yr	1,700	5.8

SOURCE: Pitt and McLean (1986).

facilities, auto recyclers/junkyards, commercial garden nurseries, parking lots, vehicle fueling and maintenance stations, bus or truck (fleet) storage areas, industrial rooftops, marinas, outdoor transfer facilities, public works storage areas, and vehicle and equipment washing/steam cleaning facilities (Bannerman et al., 1993; Pitt et al., 1995; Claytor and Schueler, 1996).

The elevated concentrations and mass discharges found in stormwater at industrial sites are associated with both the activities that occur and the materials used in industrial areas, as discussed in the sections that follow.

Effects of Roofing Materials on Stormwater Quality

The extensive rooftops of industrial areas can be a significant pollutant source area. A summary of the literature on roof-top runoff quality, including both roof surfaces and underlying materials used as subbases (such as treated wood), is presented in Table 3-6. Good (1993) found that dissolved metals' concentrations and toxicity remained high in roof runoff samples, especially from rusty galvanized metal roofs during both first flush and several hours after a rain has started, indicating that metal leaching continued throughout the events and for many years. During pilot-scale tests of roof panels exposed to rains over a two-year period, Clark et al. (2008) found that copper roof runoff concentrations for newly treated wood panels exceeded 5 mg/L (a very high value compared to median NSQD stormwater concentrations of about 10 to 40 µg/L for different land uses) for the first nine months of exposure. These results indicated that copper continued to be released from these wood products at levels high enough to exceed aquatic life criteria for long periods after installation, and were not simply due to excess surface coating washing off in the first few storms after installation.

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TABLE 3-6 Roof Runoff Analysis—A Literature Summary

Roof Type	Location	Water Quality Parameter								Reference
		Cu (µg/L)	Zn (µg/L)	Pb (µg/L)	Cd (µg/L)	As (µg/L)	pH	NH_4^+ (mg/L)	NO_3^- (mg/L)	
Polyester Tile Flat gravel	Duebendorf, Switzerland	6817 1905 140	2076 360 36	510 172 22	3.1 2.1 0.2					Boller (1997)
Plywood w/ roof paper/tar Rusty galvanized metal Old metal w/Al paint Flat tar surface w/fibrous reflective Al paint New anodized Al	Washington	$166^T/128^D$ $20^T/2^D$ $11^T/7^D$ $25^T/14^D$ $16^T/7^D$	$877^T/909^D$ $12200^T/1190^D$ $1980^T/1610^D$ $297^T/257^D$ $101^T/82^D$	$11^T/<5^D$ $302^T/35^D$ $10^T/<5^D$ $10^T/5^D$ $15^T/<5^D$			4.3 5.9 4.8 4.1 5.9			Good (1993)
Zinc - galvanized Fe	Dunedin City, New Zealand	560 µg/g	5901 µg/g	670 µg/g						Brown & Peake (2006)
Fe-Zn sheets Concrete slate tiles Asbestos cement sheets Aluminum sheets	Ile-Ife, Nigeria						6.77 7.45 7.09 6.68	0.06 0.05 0.06 0.05	1.52 3.34 2.26 6.18	Ademiyi and Olabanji (2005)
Cu panels	Munich, Germany	200–11100					6.7–7.0			Athanasiadis et al. (2006)
Galvanized metals (primarily Galvalume®)	Seattle, WA	10–1400	420–14700	ND						Tobiason (2004)
CCA wood Untreated wood	Florida					1200–1800 2–3				Khan et al. (2006)

Note: D, dissolved; T, total; ND, not detected.
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Traditional unpainted or uncoated hot-dip galvanized steel roof surfaces can also produce very high zinc concentrations. For example, pilot-scale tests by Clark et al. (2008) indicated that zinc roof runoff concentrations were 5 to 30 mg/L throughout the first two years of monitoring of a traditional galvanized metal panel. These are very high values compared to median stormwater values reported in the NSQD of 60 to 300 µg/L for different land uses. Factory-painted aluminum–zinc alloy panels had runoff zinc levels less than 250 µg/L, which were closer to the reported NSQD median values. The authors concluded that traditional galvanized metal roofing contributed the greatest concentrations of many metals and nutrients. In addition, they found that pressure-treated and waterproofed wood contributed substantial copper loads. The potential for nutrient release exists in many of the materials tested (possibly as a result of phosphate washes and binders used in the material's preparation or due to natural degradation).

Other researchers have investigated the effects of industrial rooftop runoff on receiving waters and biota. Bailey et al. (1999) investigated the toxicity to juvenile rainbow trout of runoff from British Columbia sawmills and found that much of the toxicity may have been a result of divalent cations on the industrial site, especially zinc from galvanized roofs.

Effects of Pavement and Pavement Maintenance on Stormwater Quality

Pavement surfaces can also have a strong influence on stormwater runoff quality. For example, concrete is often mixed with industrial waste sludges as a way of disposing of the wastes. However, this can lead to stormwater discharges high in toxic compounds, either due to the additives themselves or due to the mobilization of compounds via the additives. Salaita and Tate (1998) showed that high levels of aluminum, iron, calcium, magnesium, silicon, and sodium were seen in the cement-waste samples. A variety of sands, including waste sands, have been suggested as potential additives to cement and for use as fill in roadway construction. Wiebusch et al. (1998) tested brick sands and found that the higher the concentration of alkaline and alkaline earth metals in the samples, the more easily the heavy metals were released. Pitt et al. (1995) also found that concrete yard runoff had the highest toxicity (using Microtox screening methods) observed from many source areas, likely due to the elevated pH (about 11) from the lime dust washing off from the site.

The components of asphalt have been investigated by Rogge et al. (1997), who found that the majority of the elutable organic mass that could be identified consisted of *n*-alkanes (73 percent), carboxylic acids such as *n*-alkanoic acids (17 percent), and benzoic acids. PAHs and thiaarenes were 7.9 percent of the identifiable mass. In addition, heterocyclic aromatic hydrocarbons containing sulfur (S-PAH), such as dibenzothiophene, were identified at concentration lev-

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els similar to that of phenanthrene. S-PAHs are potentially mutagenic (similar to other PAHs), but due to their slightly increased polarity, they are more soluble in water and more prone to aquatic bioaccumulation.

In addition to the bitumens and asphalts, other compounds are added to paving (and asphaltic roofing) materials. Chemical modifiers are used both to increase the temperature range at which asphalts can be used and to prevent stripping of the asphalt from the binder. A variety of fillers may also be used in asphalt pavement mixtures. The long-term environmental effects of these chemicals in asphalts are unknown. Reclaimed asphalt pavements have also been proposed for use as fill materials for roadways. Brantley and Townsend (1999) performed a series of leaching tests and analyzed the leachate for a variety of organics and heavy metals. Only lead from asphalt pavements reclaimed from older roadways was found to be elevated in the leachate.

Stormwater quality from asphalt-paved surfaces seems to vary with time. Fish kills have been reported when rains occur shortly after asphalt has been installed in parking areas near ponds or streams (Anonymous, 2000; Perez-Rivas, 2000; Kline, 2002). It is expected that these effects are associated with losses of the more volatile and toxic hydrocarbons that are present on new surfaces. It is likely that the concentrations of these materials in runoff decrease as the pavement ages. Toxicity tests conducted on pavements several years old have not indicated any significant detrimental effects, except for those associated with activities conducted on the surface (such as maintenance and storage of heavy equipment; Pitt et al., 1995, 1999). However, pavement maintenance used to "renew" the asphalt surfaces has been shown to cause significant problems, which are summarized below.

A significant source of PAHs in the Austin, Texas, area (and likely elsewhere) has been identified as coal-tar sealants commonly used to "restore" asphalt parking lots and storage areas. Mahler et al. (2005) found that small particles of sealcoat that flake off due to abrasion by vehicle tires have PAH concentrations about 65 times higher than for particles washed off parking lots that are not seal coated. Unsealed parking lots receive PAHs from the same urban sources as do sealed parking lots (e.g., tire particles, leaking motor oil, vehicle exhaust, and atmospheric fallout), and yet the average yield of PAHs from the sealed parking lots was found to be 50 times greater than that from the control lots. The authors concluded that sealed parking lots could be the dominant source of PAHs in watersheds that have seal-coated surfaces, such as many industrial, commercial, and residential areas. Consequently, the City of Austin has restricted the use of parking lot coal-tar sealants, as have several Wisconsin communities.

Stored Materials Exposed to Rain

Although roofing and pavement materials make up a large fraction of the total surface covers and can have significant effects on stormwater quality, leaching of rain through stored materials may also be a significant pollutant

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source at industrial sites. Exposed metals in scrap yards can result in very high concentrations of heavy metals. For example, Table 3-7 summarizes data from three metals recycling facilities/scrap yards in Wisconsin and shows the large fraction of metals that are either dissolved in the runoff or associated with very fine particulate matter. For most of these metals, their greatest abundance is associated with the small particles (<20 μm in diameter), and relatively little is associated with the filterable fraction. These metals concentrations (especially zinc, copper, and lead) are also very high compared to that of most outfall industrial stormwater.

OTHER SOURCES OF URBAN RUNOFF DISCHARGES

Wet weather stormwater discharges from separate storm sewer outfalls are not the only discharges entering receiving waters from these systems. Dry weather flows, snowmelt, and atmospheric deposition all contribute to the pollutant loading of urban areas to receiving waters, and for some compounds may be the largest contributor. Many structural SCMs, especially those that rely on sedimentation or filtration, have been designed to function primarily with stormwater and are not nearly as effective for dry weather discharges, snowmelt, or atmospheric deposition because these nontraditional sources vary considerably in key characteristics, such as the flow rate and volume to be treated, sediment concentrsations and particle size distribution, major competing ions, association of pollutants with particulates of different sizes, and temperature. Information on the treatability of stormwater vs. snowmelt and other nontraditional sources of urban runoff can be found in Pitt and McLean (1986), Pitt et al. (1995), Johnson et al. (2003), and Morquecho (2005).

TABLE 3-7 Metal Concentration Ranges Observed in Scrapyard Runoff

Particle Size	Iron (mg/L)	Aluminum (mg/L)	Zinc (mg/L)
Total	20 – 810	15 – 70	1.6 – 8
< 63 μm diameter	22 – 767	15 – 58	1.5 – 7.6
< 38 μm diameter	21 – 705	15 – 58	1.4 – 7.4
< 20 μm diameter	15 – 534	12 – 50	1.1 – 7.2
< 0.45 μm diameter (filterable fraction)	0.1 – 38	0.1 – 5	0.1 – 6.7
	Copper (mg/L)	**Lead (mg/L)**	**Chromium (mg/L)**
Total	1.1 – 3.8	0.6 – 1.7	0.1 – 1.9
< 63 μm diameter	1.1 – 3.6	0.1 – 1.6	0.1 – 1.6
< 38 μm diameter	1.1 – 3.3	0.1 – 1.6	0.1 – 1.4
< 20 μm diameter	1.0 – 2.8	0.1 – 1.6	0.1 – 1.2
< 0.45 μm diameter (filterable fraction)	0.1 – 0.3	0.1 – 0.3	0.1 – 0.3

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Dry Weather Flows

At many stormwater outfalls, discharges occur during dry weather. These may be associated with discharges from leaking sanitary sewer and drinking water distribution systems, industrial wastewaters, irrigation return flows, or natural spring water entering the system (Figures 3-28 to 3-33). Possibly 25 percent of all separate stormwater outfalls have water flowing in them during dry weather, and as much as 10 percent are grossly contaminated with raw sewage, industrial wastewaters, and so forth (Pitt et al., 1993). These flow contributions can be significant on an annual mass basis, even though the flow rates are relatively small, because they have long duration. This is particularly true in arid areas, where dry weather discharges can occur daily. For example, despite the fact that rain is scarce from May to September in Southern California, an estimated 40 to 90 million liters of discharge flow per day into Santa Monica Bay through approximately 70 stormwater outlets that empty onto or across beaches (LAC DPW, 1985; SMBRP, 1994), such that the contribution of dry weather flow to the total volume of runoff into the bay is about 30 percent (NRC, 1984). Furthermore, in the nearby Ballona Creek watershed, dry weather discharges of trace metals were found to comprise from 8 to 42 percent of the total annual loading (McPherson et al., 2002). Stein and Tiefenthaler (2003) further found that the highest loadings of metals and bacteria in this watershed discharging during dry weather can be attributed to a few specific stormwater drains.

In many cases, stormwater managers tend to overlook the contribution of dry weather discharges, although the EPA's NPDES Stormwater Permit program requires municipalities to conduct stormwater outfall surveys to identify, and then correct, inappropriate discharges into separate storm sewer systems. The role of inappropriate discharges in the NPDES Stormwater Permit program, the developed and tested program to identify and quantify their discharges, and an extensive review of these programs throughout the United States can be found in the recently updated report prepared for the EPA (CWP and Pitt, 2004).



FIGURE 3-28 Washing of vehicle engine and allowing runoff to enter storm drainage system. SOURCE: Robert Pitt, University of Alabama.

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FIGURE 3-29 Contamination of storm drainage with inappropriate disposal of oil. SOURCE: Courtesy of the Center for Watershed Protection.



FIGURE 3-30 Dry weather flows from Toronto industrial area outfall. SOURCE: Pitt and McLean (1986).

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FIGURE 3-31 Sewage from clogged system overflowing into storm drainage system. SOURCE: Robert Pitt, University of Alabama.



FIGURE 3-32 Failing sanitary sewer, causing upwelling of sewage through soil, and draining to gutter and then to storm drainage system. SOURCE: Robert Pitt, University of Alabama.

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FIGURE 3-33 Dye tests to confirm improper sanitary sewage connection to storm drainage system. SOURCE: Robert Pitt, University of Alabama.

Snowmelt

In northern areas, snowmelt runoff can be a significant contributor to the annual discharges from urban areas through the storm drainage system (see Figure 3-34). In locations having long and harsh winters, with little snowmelt until the spring, pollutants can accumulate and be trapped in the snowpack all winter until the major thaw when the contaminants are transported in short-duration events to the outfalls (Jokela, 1990). The sources of the contaminants accumulating in snowpack depend on the location, but they usually include emissions from nearby motor vehicles and heating equipment and industrial activity in the neighborhood. Dry deposition of sulfur dioxide from industrial and power plant smokestacks affects snow packs over a wider area and has frequently been studied because of its role in the acid deposition process (Cadle, 1991). Pollutants are also directly deposited on the snowpack. The sources of directly deposited pollutants include debris from deteriorated roadways, vehicles depositing petroleum products and metals, and roadway maintenance crews applying salt and anti-skid grit (Oberts, 1994). Urban snowmelt, like rain runoff, washes some material off streets, roofs, parking and industrial storage lots, and drainage gutters. However, snowmelt runoff usually has much less energy than striking rain and heavy flowing stormwater. Novotny et al. (1986) found that urban soil ero-

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sion is reduced or eliminated during winter snow-cover conditions. However, erosion of bare ground at construction sites in the spring due to snowmelt can still be very high (Figure 3-35).



FIGURE 3-34 Snowmelt photos. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.



FIGURE 3-35 Construction site in early spring after snowmelt showing extensive sediment transport. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.

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Sources of Contaminants in Snowmelt

Several mechanisms can bring about contamination of snow and snowmelt waters. Initially, air pollutants can be incorporated into snowflakes as they form and fall to the ground. After it falls to the ground and accumulates, the snow can become further contaminated by dry atmospheric deposition, deposition of nearby lost fugitive dust materials (usually blown onto snow packs near roads by passing vehicles), and wash off of particulates from the exposed ground surfaces as it melts and flows to the drainage system.

Snowflakes can remove particulates and gases from the air by in-cloud or below-cloud capture. In-cloud capture of pollutants can occur during snowflake formation as super-cooled cloud water condenses on particles and aerosols that act as cloud condensation nuclei. This is known as nucleation scavenging and is a major pathway for air pollution to be incorporated into snow. Particles and gases may also be scavenged as snowflakes fall to the ground. Gases can also be absorbed as snow falls. Snowflakes are more effective below-cloud scavengers than raindrops because they are bigger and fall slower. Barrie (1991) reports that large snowflakes capture particles in the 0.2- to 0.4-μm-diameter range, not by impaction but by filtering the air that moves through the snow flakes as they fall to the ground.

Most of the contamination of snow in urban areas likely occurs after it lands on the ground. Table 3-8 shows the flow-weighted mean concentrations of pollutants found in undisturbed falling snow compared to snow found in urban snow cover (Bennett et al., 1981). Pitt and McLean (1986) also measured snowpack contamination as a function of distance from a heavily traveled road passing through a park. The contaminants in the snow were at much greater concentrations near the road (the major source of blown contamination on the snow) than farther away. (The pollutant levels in the fresh fallen snow are generally a small fraction of the levels in the snow collected from urban study areas.) Pierstorff and Bishop (1980) also analyzed freshly fallen snow and compared the quality to snow stored at a snow dump site. They concluded that "pollutant levels at the dump site are the result of environmental input occurring after the snow falls." Some pollutants in snowmelt have almost no atmospheric

TABLE 3-8 Comparison of Flow-Weighted Pollutant Concentration Means of Snow Samples from Boulder, Colorado

	Fresh Fallen	High Density Land Use	Low Density Land Use
COD	10	402	54
TS	86	2000	165
SS	16	545	4.5
TKN	0.19	2.69	2
NO_3	0.15	0	0
P	—	0.66	0.017
Pb	—	0.95	—

Note: The units are mg/L. SOURCE: Reprinted, with permission, from Bennett et al. (1981). Copyright 1981 by Water Pollution Control Federation.

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sources. For example, Oliver et al. (1974) found negligible amounts of chlorides in samples of snow from rooftops, indicating that the high chloride level found in the snowmelt runoff water comes almost entirely from surface sources (i.e., road salting). Similar roadside snowpack observations along city park roads by Pitt and McLean (1986) also indicated the strong association of road salt with snowpack chloride levels.

Runoff and Pollutant Loading from Snowmelt

Snowmelt events can exhibit a first flush, in which there are higher concentrations of contaminants at the beginning compared to the total event averaged concentration. The enrichment of the first portion of a snowmelt event by soluble pollutants may be due to snowpack density changes, where water percolation and melt/freeze events that occur in the snowpack cause soluble pollutants to be flushed from throughout the snowpack to concentrate at the bottom of the pack (Colbeck, 1981). This concentrated layer leaves the snowpack as a highly concentrated pulse, as snow melts from the bottom due to warmth from the ground (Oberts, 1994).

When it rains on snow, heavy pollutant loads can be produced because both soluble and particulate pollutants are melted from the snowpack simultaneously. Also, the large volume of melt plus rain can wash off pollutants that have accumulated on various surfaces such as roads, parking lots, roofs, and saturated soil surfaces. The intensity of runoff from a rain-on-snow event can be greater than a summer thunderstorm because the ground is saturated or frozen and the rapidly melting snowpack provides added runoff volume (Oberts, 1994).

Figure 3-36 compares the runoff volumes associated with snowmelts alone to those associated with snowmelts mixed with rain from monitoring at an industrial area in Toronto (Pitt and McLean, 1986). Rain with snowmelt contributes over 80 percent of the total cold-weather event runoff volume.

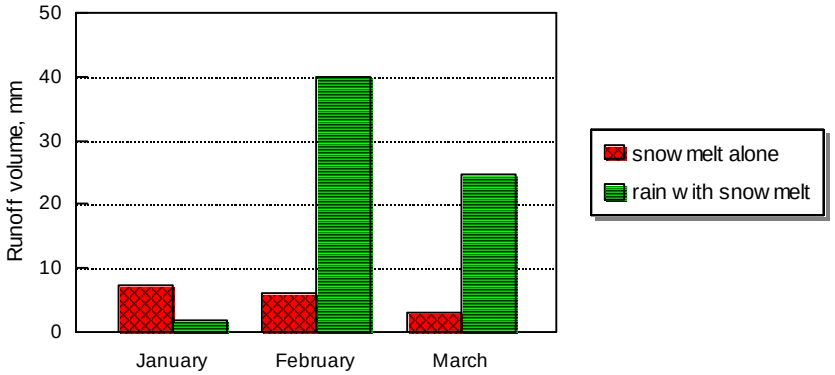

FIGURE 3-36 Runoff volumes for snowmelt events alone and when rain falls on melting snow packs (Toronto industrial area). SOURCE: Pitt and McLean (1986).

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Whether pollutant loadings are higher or lower for snowmelt than for rainfall depends on the particular pollutant and its seasonal prevalence in the environment. For example, the high concentrations of dissolved solids found in snowmelt are usually caused by high chloride concentrations that stem from the amount of de-icing salt used. Figure 3-37 is a plot of the chloride concentrations in the influent to the Monroe Street detention pond in Madison, Wisconsin. Chloride levels are negligible in the non-winter months but increase dramatically when road salting begins in the fall, and remain high through the snow melting period, even extending another month or so after the snowpack in the area has melted. Bennett et al. (1981) found that suspended solids and COD loadings for snowmelt runoff were about one-half of those for rainfall. Nutrients were much lower for snowmelt, while the loadings for lead were about the same for both forms of precipitation. Oberts (1994) reports that much of the annual pollutant yields from event flows in Minneapolis is accounted for by end-of-winter major melts. End-of-winter melts yielded 8 to 20 percent of the total phosphorous and total lead annual load in Minnesota. Small midwinter melts accounted for less than 5 percent of the total loads. Box 3-8 shows mass pollutant discharges for a study site in Toronto and emphasizes the significance of snowmelt discharges on the total annual storm drainage discharges.

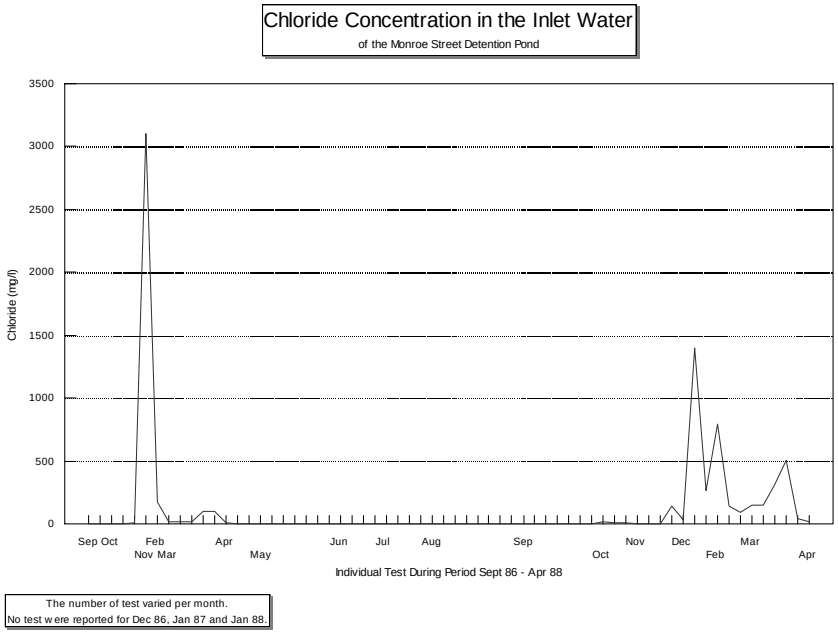

FIGURE 3-37 Monroe Street detention pond chloride concentration of influent (1986–1988). SOURCE: House et al. (1993).

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BOX 3-8
The Contribution of Dry Weather Discharges and Snowmelt to Overall Runoff in Toronto, Ontario

An extensive analysis of all types of stormwater flow—for both dry and wet weather—was conducted in Toronto in the mid-1980s (Pitt and McLean, 1986). The Toronto Area Watershed Management Strategy study included comprehensive monitoring in a residential/commercial area and an industrial area for summer stormwater, warm season dry weather flows, snowmelt, and cold season dry weather flows. In addition to the outfall monitoring, detailed source area sheet flow monitoring was also conducted during rain and snowmelt events to determine the relative magnitude of pollutant sources. Particulate accumulation and wash-off tests were also conducted for a variety of streets in order to better determine their role in contaminant contributions.

Tables 3-9 and 3-10 summarize Toronto residential/commercial and industrial urban runoff median concentrations during both warm and cold weather, respectively. These tables show the relative volumes and concentrations of wet weather and dry weather flows coming from the different land uses. The bacteria densities during cold weather are substantially less than during warm weather, but are still relatively high; similar findings were noted during the NURP studies (EPA, 1983). However, chloride concentrations and dissolved solids are much higher during cold weather. Early spring stormwater events also contain high dissolved solids concentrations. Cold weather runoff accounted for more than half of the heavy metal discharges in the residential/commercial area, while warm weather discharges of zinc were much greater than the cold weather discharges for the industrial area. Warm weather flows were also the predominant sources of phosphorus for the industrial area.

One of the interesting observations is that, at these monitoring locations, warm weather stormwater runoff only contributed about 20 to 30 percent of the total annual flows being discharged from the separate stormwater outfalls. The magnitudes of the base flows were especially surprising, as these monitoring locations were research sites to investigate stormwater processes and were carefully investigated to ensure that they did not have significant inappropriate discharges before they were selected for the monitoring programs.

In comparing runoff from the industrial and residential catchments, Pitt and McLean (1986) observed that concentrations of most constituents in runoff from the industrial watershed were typically greater than the concentrations of the same constituents in the residential runoff. The only constituents with a unit-area yield that were lower in the industrial area were chlorides and total dissolved solids, which was attributed to the use of road deicing salts in residential areas. Annual yields of several constituents (total solids, total dissolved solids, chlorides, ammonia nitrogen, and phenolics) were dominated by cold weather flows, irrespective of the land use.

A comparison of the Toronto sheet flow data from the different land-use areas indicated that the highest concentrations of lead and zinc were found in samples collected from paved areas and roads during both rain runoff and snowmelt (Pitt and McLean, 1986). Fecal coliform values were significantly higher on sidewalks and on, or near, roads during snowmelt sampling, likely because these areas are where dogs would be walked in winter conditions. In warm weather, dog walking would be less concentrated into these areas. The concentrations for total solids from grass or bare open areas were reduced dramatically during snowmelt compared to rain runoff, an indication of the reduced erosion and the

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BOX 3-8 Continued

poor delivery of particulate pollutants during snowmelt periods. Cold weather sheet flow median concentrations of particulate solids for the grass and open areas (80 mg/L) were much less than the TSS concentrations observed during warm weather runoff (250 mg/L) for these same areas. Snowmelt total solids concentrations also increased in areas located near roads due to the influence of road salting on dissolved solids concentrations. In the residential areas, streets were the most significant source of snowmelt solids, while yards and open areas were the major sources of nutrients. Parking and storage areas contrib-

TABLE 3-9 Median Pollutant Concentrations Observed at Toronto Outfalls during Warm Weather[1]

Measured Parameter	Baseflow		Stormwater	
	Residential	*Industrial*	*Residential*	*Industrial*
Stormwater volume (m^3/ha/season)	—	—	950	1500
Baseflow volume (m^3/ha/season)	1700	2100	—	—
Total residue	979	554	256	371
Total dissolved solids	973	454	230	208
Suspended solids	<5	43	22	117
Chlorides	281	78	34	17
Total phosphorus	0.09	0.73	0.28	0.75
Phosphates	<0.06	0.12	0.02	0.16
Total Kjeldahl nitrogen (organic N plus NH_3)	0.9	2.4	2.5	2.0
Ammonia nitrogen	<0.1	<0.1	<0.1	<0.1
Chemical oxygen demand	22	108	55	106
Fecal coliform bacteria (#/100 mL)	33,000	7,000	40,000	49,000
Fecal strep. bacteria (#/100 mL)	2,300	8,800	20,000	39,000
Pseudomonas aeruginosa bacteria (#/100 mL)	2,900	2,380	2,700	11,000
Cadmium	<0.01	<0.01	<0.01	<0.01
Chromium	<0.06	0.42	<0.06	0.32
Copper	0.02	0.05	0.03	0.06
Lead	<0.04	<0.04	<0.06	0.08
Zinc	0.04	0.18	0.06	0.19
Phenolics (μg/L)	<1.5	2.0	1.2	5.1
α-BHC (ng/L)	17	<1	1	3.5
γ-BHC (lindane) (ng/L)	5	<2	<1	<1
Chlordane (ng/L)	4	<2	<2	<2
Dieldrin (ng/L)	4	<5	<2	<2
Pentachlorophenol (ng/L)	280	50	70	705

[1]Values are in mg/L unless otherwise indicated. Warm weather samples were obtained during the late spring, summer, and early fall months when the air temperatures were above freezing and no snow was present.
SOURCE: Pitt and McLean (1986).

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uted the most snowmelt pollutants in the industrial area. An analysis of snow samples taken along a transect of a snowpack adjacent to an industrial road showed that the pollutant levels decreased as a function of distance from the roadway. At distances greater than 3 to 5 meters from the edge of the snowpack, the concentrations were relatively constant. Novotny et al. (1986) sampled along a transect of a snowpack by a freeway in Milwaukee. They also found that the concentration of constituents decreased as the distance from the road increased. Most of the measured constituents, including total solids and lead, were at or near background levels at 30 meters or more from the road.

TABLE 3-10 Median Pollutant Concentrations Observed at Toronto Outfalls during Cold Weather[1]

	Baseflow		**Snowmelt**	
Measured Parameter	*Residential*	*Industrial*	*Residential*	*Industrial*
Stormwater volume (m^3/ha/season)	—	—	1800	830
Base flow volume (m^3/ha/season)	1100	660	—	—
Total residue	2230	1080	1580	1340
Total dissolved solids	2210	1020	1530	1240
Suspended solids	21	50	30	95
Chlorides	1080	470	660	620
Total phosphorus	0.18	0.34	0.23	0.50
Phosphates	<0.05	<0.02	<0.06	0.14
Total Kjeldahl nitrogen (organic N plus NH_3)	1.4	2.0	1.7	2.5
Ammonia nitrogen	<0.1	<0.1	0.2	0.4
Chemical oxygen demand	48	68	40	94
Fecal coliform bacteria (#/100 mL)	9800	400	2320	300
Fecal strep bacteria (#/100 mL)	1400	2400	1900	2500
Pseudomonas aeruginosa bacteria (#/100 mL)	85	55	20	30
Cadmium	<0.01	<0.01	<0.01	0.01
Chromium	<0.01	0.24	<0.01	0.35
Copper	0.02	0.04	0.04	0.07
Lead	<0.06	<0.04	0.09	0.08
Zinc	0.07	0.15	0.12	0.31
Phenolics (mg/L)	2.0	7.3	2.5	15
α-BHC (ng/L)	NA	3	4	5
γ-BHC (lindane) (ng/L)	NA	NA	2	1
Chlordane (ng/L)	NA	NA	11	2
Dieldrin (ng/L)	NA	NA	2	NA
Pentachlorophenol (ng/L)	NA	NA	NA	40

[1]Values are in mg/L unless otherwise indicated. Cold weather samples were obtained during the winter months when the air temperatures were commonly below freezing. Snowmelt samples were obtained during snowmelt episodes and when rain fell on snow.
NA, not analyzed
SOURCE: Pitt and McLean (1986).

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Atmospheric Deposition

The atmosphere contains a diverse array of contaminants, including metals (e.g., copper, chromium, lead, mercury, zinc), nutrients (nitrogen, phosphorus), and organic compounds (e.g., PAHs, polychlorinated biphenyls, pesticides). These contaminants are introduced to the atmosphere by a variety of sources, including local point sources (e.g., power plant stacks) and mobile sources (e.g., motor vehicles), local fugitive emissions (e.g., street dust and wind-eroded materials), and transport from non-local areas. These emissions, composed of gases, small particles (aerosols), and larger particles, become entrained in the atmosphere and subject to a complex series of physical and chemical reactions (Schueler, 1983).

Atmospheric contaminants are deposited on land and water in two ways—termed wet deposition and dry deposition. Wet deposition (or wetfall) involves the sorption and condensation of pollutants to water drops and snowflakes followed by deposition with precipitation. This mechanism dominates the deposition of gases and aerosol particles. Dry deposition (or dryfall) is the direct transfer of contaminants to land or water by gravity (particles) or by diffusion (vapor and particles). Dry deposition occurs when atmospheric turbulence is not sufficient to counteract the tendency of particles to fall out at a rate governed, but not exclusively determined, by gravity (Schueler, 1983).

As atmospheric contaminants deposit, they can exert an influence on stormwater in several ways. Contaminants deposited by wetfall are directly conveyed to stormwater while those in dryfall can be washed off the land surface. For both processes, the atmospheric load of contaminants is strongly influenced by-characteristics such as the amount of impervious surface, the magnitude and proximity of emission sources, wind speed and direction, and precipitation magnitude and frequency (Schueler, 1983). Deposition rates can depend on the type of contaminant and can be site-specific. The relationships between atmospheric deposition and stormwater quality are, however, not well understood and difficult to determine. Following are a few illustrative examples.

Southern California

Several studies have addressed atmospheric deposition in Southern California (e.g., Lu et al., 2003; Harris and Davidson, 2005; Stolzenbach et al., 2007). Stolzenbach et al. and Lu et al. conclude the following *for this region:*

- the major source of contaminants to the atmosphere in this region is associated with resuspended dust, primarily from roads,
- contaminants in resuspended dust may reflect historical as well as current sources and distant as well as local sources,
- atmospheric loadings to the receiving water are primarily the result of chronic daily dry deposition of large particles greater than 10 μm in size on the

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watershed rather than directly on a waterbody,

- significant spatial variability occurs in trace metal mass loadings and deposition fluxes, particularly along transportation corridors along the coast and the mountain slopes of the airshed,
- significant diurnal and seasonal variations occur in the deposition of trace metals, and
- atmospheric deposition of metals is a significant component of contaminant loading to waterbodies in the region relative to other point and nonpoint sources.

Harris and Davidson (2005) have reported that traditional sources of lead to the south coast air basin of California accounted for less than 15 percent of the lead exiting the basin each year. They resolve this difference by considering that lead particles deposited during the years of leaded gasoline use are resuspended as airborne lead at this time, some decades after their original deposition. This result indicates that lead levels in the soil will remain elevated for decades and that resuspension of this lead will remain a major source of atmospheric lead well into the future.

Sabin et al. (2005) assessed the contribution of trace metals (chromium, copper, lead, nickel, and zinc) from atmospheric deposition to stormwater runoff in a small impervious urban catchment in the Los Angeles area. Dry deposition contributed 90 percent or more of the total deposition inside the catchment, indicating the dominance of dry deposition in semi-arid regions such as Los Angeles. Deposition potentially accounted for from 57 to 90 percent of the total trace metals in stormwater in the study area, demonstrating that atmospheric deposition can be an important source of trace metals in stormwater near urban centers.

San Francisco

Dissolved copper is toxic to phytoplankton, the base of the aquatic food chain. Copper and other metals are released in small quantities when drivers depress their brakes. The Brake Pad Partnership (*http://www.suscon.org/brakepad/index/asp*) has conducted studies to determine how much copper is released as wear debris, and how it travels through the air and streets to surface waters. A comprehensive and complex model of copper loads to and of transport and reactions in San Francisco Bay was developed (Yee and Franz, 2005). Objectives were to provide daily loadings of flow, TSS, and copper to the bay and to estimate the relative contribution of brake pad wear debris to copper in the bay. The modeling results (Rosselot, 2006a) indicated that an estimated 47,000 kg of copper was released to the atmosphere in the Bay Area in 2003. Of this amount, 17,000 kg Cu/yr was dry-deposited in subwatersheds; 3,200 kg Cu/yr was wet-deposited in subwatersheds; 1,200 kg Cu/yr was dry-deposited directly to bay waters; and 1,300 kg Cu/yr was wet-deposited directly to bay waters. The remaining 24,000 kg Cu/yr remained airborne until it left the Bay

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Area. The contribution of copper from brake pads to the bay is estimated to range from 10 to 35 percent of the total copper input, with the best estimate being 23 percent (Rosselot, 2006a,b).

Washington, D.C., Metropolitan Area

Schueler (1983) investigated the atmospheric deposition of several contaminants in Washington, D.C., and its surrounding areas in the early 1980s. The contaminants assessed included trace metals (cadmium, copper, iron, lead, nickel, and zinc), nutrients (nitrogen and phosphorus), solids, and organics as measured collectively by BOD and COD. Dryfall solids loading increased progressively from rural to urban sites. A similar trend was observed for total phosphorus, total nitrogen, and trace metal dry deposition rates. Wet deposition rates exhibited few consistent regional patterns.

The relative importance of wet and dry deposition varied considerably with each contaminant and each site. For example, most of the nitrogen was supplied by wet deposition while most of the phosphorus was delivered via dry deposition. If a contaminant is deposited primarily by wet deposition, it is likely that a major fraction of it will be rapidly entrained in urban runoff.

Atmospheric sources were estimated to contribute from 70 to 95 percent of the total nitrogen load to urban runoff and 20 to 35 percent of the total phosphorus load. Overall, atmospheric deposition appeared to be a moderate source of pollutants in urban runoff. However, with the exception of nitrogen, atmospheric deposition was not the major source.

Average annual atmospheric deposition rates suggested a general trend toward greater deposition rates from rural to suburban to urban sites. This pattern was most pronounced for dry deposition. Wet deposition was the most important deposition mechanism for total nitrogen, nitrate, organic nitrogen, COD, copper, and zinc. Dry deposition was most important for most soil-related constituents, such as total solids, iron, lead, total phosphorus, and orthophosphate.

Measurements of rainfall pH showed median values between 4.0 and 4.1 at all stations and during all seasons. Increased mobilization of trace metals from urban surfaces caused by acid rain was noted at several monitoring sites.

***

Relationships between atmospheric deposition rates and the quality of urban stormwater are complex and cannot be generalized regionally or temporally. Site-specific measurements or reliable estimates of (1) contaminant sources, (2) atmospheric particle size and contaminant concentrations, (3) deposition rates and mechanisms, (4) land surface characteristics, (5) local and regional hydrology and meteorology, and (6) contaminant concentrations in stormwater are needed to assess management decisions to improve stormwater quality. Transportation is a major source of metals (lead in gasoline, zinc in tires, copper in

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brake pads). The results of the modeling of copper in San Francisco and its watershed demonstrate the feasibility of modeling the impact of a source, in this case copper input by atmospheric deposition, on water quality in a receiving waterbody.

BIOLOGICAL RESPONSES TO URBANIZATION

As discussed in Chapter 1, the biological integrity of aquatic ecosystems is influenced by five major categories of environmental stressors: (1) chemical, (2) hydrologic, (3) physical (e.g., habitat), (4) biological (e.g., disease, alien species), and (5) energy-related factors (e.g., nutrient dynamics). Recent studies on biological assemblages in urban or urbanizing waters have begun to examine how stormwater stressors limit biological potential along various urban gradients (Horner et al., 2003; Carter and Fend, 2005; Meador et al., 2005; Barbour et al., 2008; Purcell et al., 2009). Advances in biological monitoring and assessment over the past two decades have enabled much of this research. Today, many states and tribes use biological data to directly measure their aquatic life beneficial uses and have developed numeric biocriteria that are institutionalized in their water quality standards. Most of these approaches compare biology and stressors to suites of reference sites (Hughes, 1995; Stoddard et al., 2006), which can vary from near-pristine areas to agricultural landscapes. While this section focuses on streams because of the wealth of data, similar work is being performed on other waterbody types such as wetlands (Mack and Micacchion, 2007) and estuaries, both of which are susceptible to stormwater pollutants such as metals because of their depositional nature (Morrisey et al., 2000).

Aquatic life beneficial uses are based on achieving aquatic *potential* given feasible restorative actions. Because such potential may vary substantially across a region depending on land use and other factors, some states have adopted tiered aquatic life uses (see Box 2-1). The potential of many urban streams is likely to be something less than "biological integrity" (the ultimate goal of the CWA) or even "fishable–swimmable" goals, which are the interim goals of the CWA. Indeed, there is a near-universal, negative association between biological assemblages in streams and increasing urbanization, to the extent that it has been termed the "Urban Stream Syndrome" (Walsh et al., 2005). Recent investigations that have quantified the responses of macroinvertebrates and other biological assemblages along multiple measures of urban/stormwater stressors have discussed how best to set aquatic life goals for urban streams (Booth and Jackson, 1997; Bernhardt and Palmer, 2007). One of the most important contributions to this debate has been the development of the Biological Condition Gradient (BCG) concept by EPA. The BCG is an attempt to anchor and standardize interpretations of biological conditions and to unify biological monitoring results across the United States in order to advance the use of tiered aquatic life beneficial uses. This section summarizes the characteristic biological responses to urban gradients, within the framework of the BCG, and it re-

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views evidence of biological responses within the aforementioned five major categories of environmental stressors.

Biological Condition Gradient

The BCG framework is an ecological model of how structural and functional components of biological assemblages change along gradients of increasing stressors of many kinds (Davies and Jackson, 2006). Ecological systems have some common general attributes related to their structure and function that form the basis for how biological organisms respond to stressors in the environment. Over the past 20 years, development of biological indicators nationwide has taken advantage of these repeatable biological responses to stress; however, state benchmarks often have varied substantially, even between adjacent states. To gain consistency, the EPA convened a national workgroup of EPA Regions, States, and Tribes to develop the BCG—a standardized, nationally applicable model that defines important attributes of biological assemblages and describes how these attributes change along a gradient of increasing stress from pristine environments to severely impaired conditions (Figure 3-38; Davies and Jackson, 2006). The goals of this work were to improve national consistency in the rating and application of biological assessment tools for all types of waterbodies and to provide a baseline for the development of tiered aquatic life uses.

To date, the BCG has been applied to assemblages including aquatic macroinvertebrates, fish, Unionid mussels, and algae in streams, but it could be applied to any organism group in any type of waterbody. The BCG is derived by applying a suite of ten ecological attributes that allows biological condition to be interpreted independently of assessment method (Table 3-11; Davies and Jackson, 2006). The first five attributes focus on taxa sensitivity, an important component of tools such as multimetric indices (e.g., the Index of Biotic Integrity [IBI], the Invertebrate Community Index [ICI]; see Box 2-3) used in the United States and Europe. Many indicator taxa have been widely studied, and, for groups such as fish, historical data often exist. Most states have established lists of tolerant and intolerant species as part of their use of biological indices (Simon and Lyons, 1995). The relatively large literature on species population and distribution changes in response to stressors and landscape condition offers insight into the mechanisms for population shifts, some of which are summarized in this section.

The first two attributes of the BCG relate to those streams that are closest to natural or pristine, with most taxa "as naturally occur." Attribute 1 and 2 taxa are the most sensitive species that typically disappear with even minor stress. Table 3-12 lists some example attribute 1 taxa for four different regions of the United States. Attribute 3 reflects more ubiquitous, but still sensitive, species that can provide information as human influence on the landscape becomes more obvious, but is not yet severe. Attributes 5 and 6 are taxa that increase in abundance and distribution with increasing stress. The organism condition at-

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The Biological Condition Gradient: Biological Response to Increasing Levels of Stress

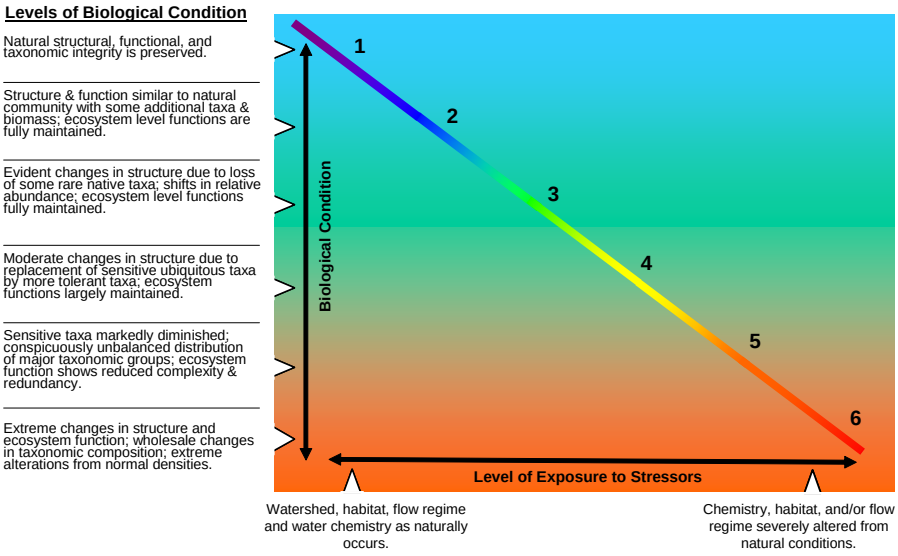

FIGURE 3-38 The Biological Condition Gradient (BCG) and summaries of biological condition along tiers of this gradient. SOURCE: Modified from Davies and Jackson (2006) by EPA.

TABLE 3-11 Ecological attributes that comprise the basis for the BCG

1. Historically documented, sensitive, long-lived or regionally endemic taxa
2. Sensitive-rare taxa
3. Sensitive-ubiquitous taxa
4. Taxa of intermediate tolerance
5. Tolerant taxa
6. Non-native or introduced taxa
7. Organism condition
8. Ecosystem functions
9. Spatial and temporal extent of detrimental effects
10. Ecosystem connectance

SOURCE: EPA (2005).

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TABLE 3-12 Example of Taxa that *Might Serve* as Attribute 1: "Historically Documented, Sensitive, Long-Lived, Regionally Endemic Taxa for Streams in Four Regions of the United States"

State and Taxon	Taxa Representative of Attribute I
Maine	
Mollusks	brook floater (*Alasmodonta varicosa*), triangle floater (*Alasmodonta undulata*), yellow lampmussel (*Lampsilis cariosa*)
Fishes	brook stickleback (*Culaea inconstans*), swamp darter (*Etheostoma fusiforme*)
Washington	
Fishes	steelhead (*Oncorhynchus mykiss*)
Amphibians	spotted frog (*Rana pretiosa*)
Arizona	
Mollusks	spring snails (*Pyrgulopsis* spp.)
Fishes	Gila trout (*Oncorhynchus gilae*), Apache trout (*Oncorhynchus apache*), cutthroat trout (endemic strains) (*Oncorhynchus clarki*)
Amphibians	Chihuahua leopard frog (*Rana chiricahuensis*)
Kansas	
Mollusks†	hickorynut (*Obovaria olivaria*), black sandshell (*Ligumia recta*), ponderous campeloma (*Campeloma crassulum*)
Fishes	Arkansas River shiner (*Notropis girardi*), Topeka shiner (*Notropis topeka*), Arkansas darter (*Etheostoma cragini*), Neosho madtom (*Noturus placidus*), flathead chub (*Platygobio gracilisa*)
Other invertebrates	ringed crayfish (*Orconectes neglectus neglectus*), Plains sand-burrowing mayfly (*Homoeoneuria ammophila*)
Amphibians	Plains spadefood toad (*Spea bombifrans*), Great Plains toad (*Bugo cognatus*), Great Plains narrowmouth toad (*Gastrophryne olivaceae*), Plains leopard frog (*Rana blairi*)

†Although not truly endemic to the central plains, these regionally extirpated mollusks were widely distributed in eastern Kansas prior to the onset of intensive agriculture.
SOURCE: Table 7 from Davies and Jackson (2006). Reprinted, with permission, from Davies and Jackson (2006). Copyright 2006 by Ecological Society of America.

tribute (7) includes the presence of anomalies (e.g., tumors, lesions, eroded fins, etc.) or the presence of large or long-lived individuals in a population. Most natural streams typically have few or incidental rates of "anomalies" associated with disease and stress. Natural waterbodies typically also have the entire range of life stages present, as would be expected. However, as stress is increased, larger individuals may disappear or emigrate, or reproductive failure may occur. Ecosystem function (attribute 8) is very difficult to measure directly (Davies and Jackson, 2006). However, certain functions can be inferred from structural measures common to various multimetric indices, examples of which are listed in Table 3-13. The last two attributes (9 and 10) may be of particular importance with regard to stormwater and urban impacts. Cumulative impacts are a characteristic of urbanization, and biological organisms typically integrate the effects of many small insults to the landscape. Additionally, most natural systems often have strong "connectance," such that aquatic life often has stages that rely on migrating across multiple types or sizes of waterbodies. Urbanized streams can decrease connectance by creating migration blocks, including vertical barriers at road crossings and small dams (Warren and Pardew, 1998).

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TABLE 3-13 Function Ecological Attributes or Process Rates and Their Structural Indicators

Biotic Level and Function or Process	**Structural Indicator**
Individual level	
Fecundity	Maximum individual size, number of eggs
Growth and metabolism	Length/mass (condition)
Morbidity	Percentage anomalies
Population Level	
Growth and fecundity	Density
Mortality	Size- or age-class distribution
Production	Biomass, standing crop, catch per unit effort
Sustainability	Size- or age-class distribution
Migration, reproduction	Presence or absence, density
Community or assemblage level	
Production/respiration ratio, autotrophy vs heterotrophy	Trophic guilds, indicator species
Primary production	Biomass, ash-free dry mass
Ecosystem level	
Connectivity	Degree of aquatic and riparian fragmentation longitudinally, vertically, and horizontally; presence or absence of diadromous and potadromous species

SOURCE: Table 4 from Davies and Jackson (2006). Reprinted, with permission, from Davies and Jackson (2006). Copyright 2006 by Ecological Society of America.

Construction of a BCG creates a conceptual framework for developing stressor–response gradients for particular urban areas. The initial work done to develop the BCG derived a series of six tiers to describe a gradient of biological condition that is anchored in pristine conditions ("as naturally occurs") and that extends to severely degraded conditions (see Figure 3-38). Exercises done by the national work group to derive such a gradient for macroinvertebrates in wadeable streams showed strong consistency in assigning tiers to datasets using the descriptions of taxa for each attribute along these gradients (Davies and Jackson, 2006). Substantial data already exist to populate many of the attributes of the BCG and to provide mechanistic underpinning for the expected directions of change.

The BCG is not a replacement for assessment tools such as the IBI or multivariate predictive models (e.g., RIVPACS approach), but rather a conceptual overlay for characterizing the anchor point-of-reference conditions and a consistent way to communicate biological condition along gradients of stress. As such, it has strong application to understanding stormwater impacts and to communicating where a goal is located along the gradient of biological condition. While most urban goals may be distant from "pristine" or "natural," the BCG process can dispel misconceptions that alternate urban goals are "dead streams" or unsafe in some manner.

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Factors Limiting Aquatic Assemblages in Urban Waters

A slew of recent investigations have quantified the responses of macroinvertebrates and other biological assemblages to multiple measures of urbanization and to stormwater in particular. One important conclusion of some of this work is that declines in the highest biological condition start with low levels of anthropogenic change (e.g., 5 to 25 percent impervious surface); higher levels of urbanization severely alter aquatic conditions (Horner et al., 2003). This has important consequences for protecting sites with the highest biological integrity, as they may be among the most vulnerable. The non-threshold nature of this aquatic response and the typical wedge-shaped response to multiple stressors by aquatic assemblages are discussed in Box 3-9.

BOX 3-9
Non-threshold Nature of the Decline of Biological Assemblages Along Urban Stressor Gradients

Several recent surveys have demonstrated that biological assemblages begin to decline in condition with even low levels of urban disturbance as measured by various gradients of urbanization (e.g., May, 1996; Horner et al., 1997; May et al., 1997; Horner et al., 2003; Moore and Palmer, 2005; Barbour et al., 2008). This box summarizes the work of Horner et al. (2003) in small streams in three regions: Montgomery County, Maryland; Austin, Texas; and the Puget Sound area of Washington. Geographic Information System (GIS) analyses using information such as land use, total impervious area, and riparian land use were used to develop multi-metric Watershed Condition Indices (WCIs) for each region. These in turn were related to fish and macroinvertebrate indices, e.g., benthic IBIs, (B-IBI, all three regions), a fish IBI (F-IBI for Maryland) and an index that was the ratio of the sensitive coho salmon to the more tolerant cutthroat trout in collections for the Puget Sound lowland area.

In each of these areas, no or extremely low urban development, substantial forest cover, and minimal disturbance of riparian zones characterized sites with the highest biological scores, but these conditions did not guarantee high scores because other impacts could limit biology even with these “natural” characteristics. In all three regions, high urbanization and loss of natural cover always led to biological degradation (Figures 3-39 and 3-40). The results of this study were similar to other recent studies such as Barbour et al. (2008) that identify a “wedge-shaped” relationship or a “polygonal” relationship (Carter and Fend, 2005) between urban gradients and biological condition. These types of relationships have also been termed “factor-ceiling” relationships (Thomson et al., 1996). The outer surface of these wedges or polygons reflects where the urban gradients limit biological assemblages, such that points below this surface typically represent sites affected by other stressors (e.g., combined sewer overflows, discharges, etc.). In all of these studies it is easier to predict loss of biological conditions as the urban gradients (e.g., WCI) worsen than it is to ensure high biological integrity at low proportions of urban stress (because some other stressor may still limit aquatic condition).

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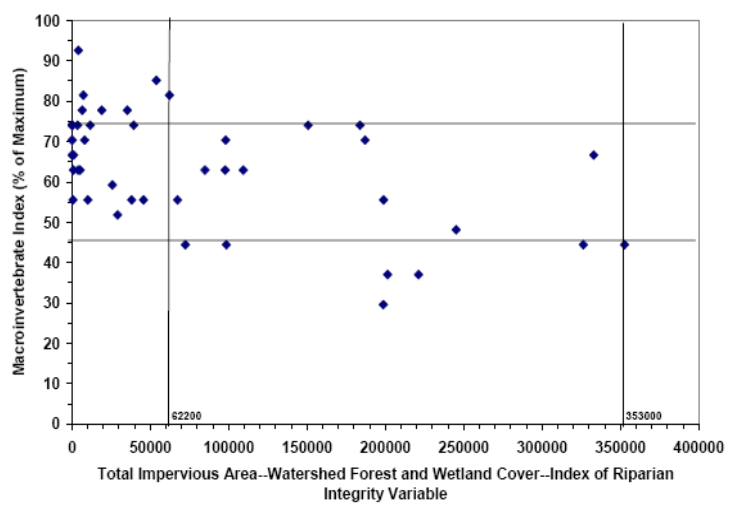
BOX 3-9 Continued



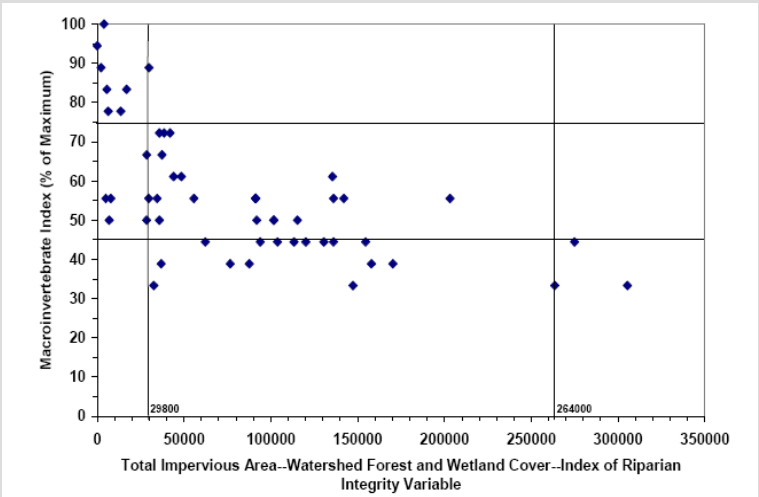


FIGURE 3-39 Plots of a measure of urbanization (TIA + Wetland & Forest Cover + IRI) versus B-IBIs for Austin, Texas (top), and Montgomery County, Maryland (bottom). SOURCE: Horner et al. (2003).

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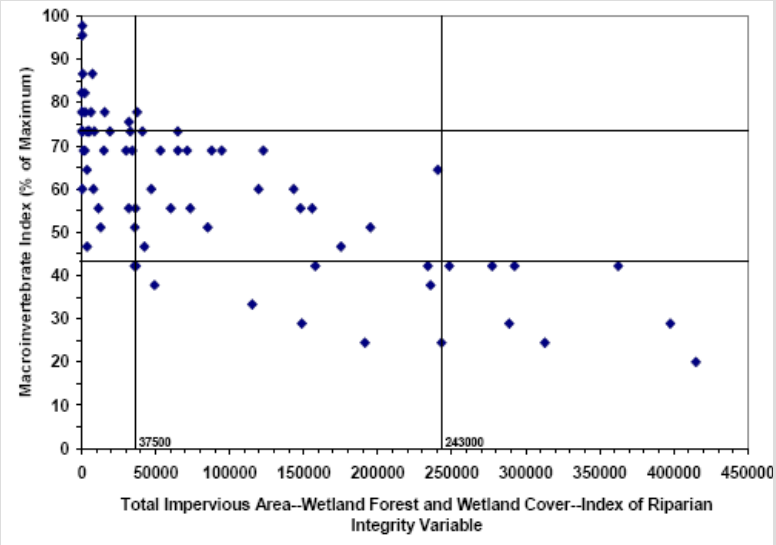
BOX 3-9 Continued



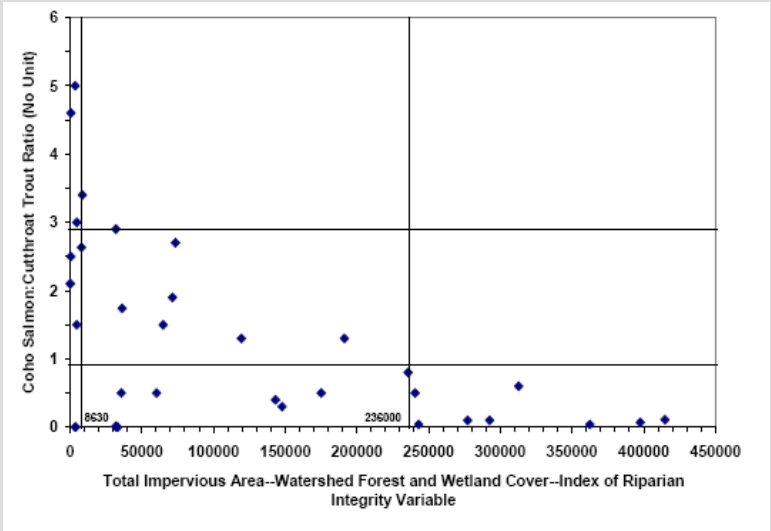


FIGURE 3-40 Plots of a measure of urbanization (TIA + Wetland & Forest Cover + IRI) versus B-IBIs for Puget Sound (top) and versus the ratio of coho salmon to cutthroat trout for Puget Sound (bottom). SOURCE: Horner et al. (2003).

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BOX 3-9 Continued

Horner et al. (2003) also focused on whether structural SCMs could moderate the effects of urbanization on biological assemblages. They made detailed observations of two subbasins in the Puget Sound lowland area, one with a greater degree of stormwater management than the other (although neither had what would be considered comprehensive stormwater management with a focus on water quality issues). As shown in Figure 3-41, at the highest levels of urbanization (triangles), the subbasin with the more extensive use of structural SCMs did have better biological conditions. There was less evidence of biological benefit in the watershed that used SCMs but it had only moderate urbanization and more natural land cover (squares and diamonds). There were no circumstances where high biological condition was observed along with the use of SCMs because high biological condition only occurred where little human alteration was present, and thus SCMs were not used.

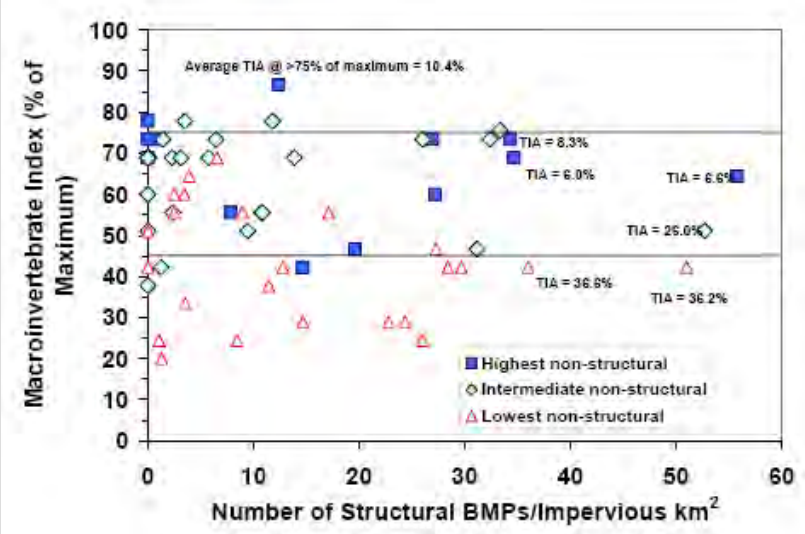

FIGURE 3-41 Macroinvertebrate community index versus structural SCM density with the highest, intermediate, and lowest one-third of natural watershed and riparian cover. The upper and lower horizontal lines represent indices considered to define relatively high and low levels of biological integrity, respectively. SOURCE: Horner et al. (2003).

The sections that follow review the evidence underlying biological responses to each of the major categories of stressors: chemical, hydrologic, physical habitat, biological, and energy-related factors. As will be evident in some of the examples, the stressors themselves can interact (e.g., flow can influence habitat, habitat can influence energy processing, etc.), which increases the complexity of understanding how stormwater affects aquatic ecosystems.

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Biological Responses to Toxic Pollutants

The chemical constituents of natural streams vary widely with climatic region, stream size, soil types, and geological setting. Most small natural streams, outside of unique areas wth naturally occurring toxicants, have very low levels of chemicals considered to be toxicants and have relatively low levels of dissolved and particulate materials in general. This applies to chemicals in the water column and in sediments. Increasing amounts of impervious surface in the watershed typically increase the concentrations of many chemical parameters in runoff derived from urban surfaces (e.g., Porcella and Sorenson, 1980; Sprague et al., 2007).

Stormwater concentrations of these pollutants can be variable and sometimes extreme or "toxic" depending on the timing of flows (e.g., first flush), although concentrations at base flows may not routinely exceed water quality benchmarks (Sprague et al., 2007). Historical deposition of toxics in sediments can also be responsible for extremely high pollutant concentrations within waterbodies, even though the stormwater discharges may no longer be active. These situations have been termed "legacy pollution" and are most commonly associated with urban centers that have a history of industrial production.

Natural constituents such as dissolved materials (e.g., chlorides), particulate material (e.g., fine sediments), nutrients (e.g., phosphorus and nitrogen compounds), as well as a myriad of man-made parameters such as heavy metals and organic chemicals (e.g., hydrocarbons, pesticides and herbicides) have been documented to be increased and at times pervasive in stormwater (Heany and Huber, 1984; Paul and Meyer, 2001; Roy et al., 2003; Gilliom et al., 2006) although specific patterns of concentrations can vary with region and ecological setting (Sprague et al., 2007). Water chemistry impacts can also arise from a complex array of permitted discharges, storm sewer discharges, and combined sewer overflows that are treated to certain limits but at times fail to remove all constituents from flows, especially when associated with storm events (Paul and Meyer, 2001).

Streams in urban settings can have increases in toxicant levels compared to background concentrations. In many instances these cases have been associated with loss of aquatic species and impairment of aquatic life goals (EPA, 2002), which are usually explained in terms of typical lethal responses. The complexity of urban systems with regard to pathways, magnitude, duration, and timing of toxicity as well as possible synergistic or antagonistic effects of mixtures of pollutants argues for a broad approach to characterizing effects including not only toxicity testing, but also novel approaches and direct monitoring of biological assemblages (Burton et al., 1999). What is problematic from a traditional management perspective is that aquatic communities may decline before exceedances of water quality criteria are evident (May et al., 1997; Horner et al., 2003).

The first three BCG attributes focus on populations of species of high to very high sensitivity, most of which are uncommon or absent in waters with any

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substantial level of urbanization. Multi-metric indices such as IBI, which reflect loss of these species, decline at least linearly with increasing urbanization (e.g., Miltner et al., 2004; Meador et al., 2005; Walters et al., 2005). Although toxicity to compounds varies with species, many species of federal and state endangered and threatened aquatic species are more sensitive than "commonly" used test species (Dwyer et al., 2005), such that the loss of aquatic species when toxicant levels exceed criteria are readily explained.

The mechanisms of species population declines in response to chemical contaminants are likely complex and not just limited to direct lethality of the pollutant. Indeed, initial chemical changes may have no "toxic" effects, but rather could change competitive and trophic dynamics by changing primary production and energy dynamics in streams. For example, exposures to aromatic and chlorinated organic compounds from sediments derived from urban areas have been found to increase the susceptibility of salmonids to the bacterial pathogen *Vibrio anguillarum* (Arkoosh et al., 2001). Recent work has found that salmonids show substantial behavioral changes from olfactory degradation related to copper at concentrations as low as 2 μg/L, well below copper water quality criteria and above levels measured in most stormwater-affected streams (Hecht et al., 2007; Sandahl et al., 2007). Salmonid and other fish depend extensively on olfactory cues for feeding, emigration, responding to prey and predators, social and spawning interactions, and other behaviors, such that loss or diminution of such cues may have population-level effects on these species (Sandahl et al., 2007). Copper has been shown to cause olfactory effects on other species (Beyers et al., 2001) and to impair the sensory ability of the fish lateral line (Hernandez et al., 2006), which is nearly ubiquitous in fishes and important for most freshwater species in feeding, schooling, spawning, and other behaviors.

Whole effluent toxicity testing or sediment toxicity testing may misclassify the effects of runoff and effluents in urban settings (Burton et al., 1999). Short-term toxicity tests of stormwater often result in no identified toxicity. However, longer studies (e.g., 30 days) have shown increasing toxicity with time (Masterson and Bannerman, 1994; Ramcheck and Crunkilton, 1995). This suggests that the mechanism of toxicity could be through an ingestion pathway, for example, rather than gill uptake. Metals are often in high concentrations where fine sediments accumulate, and their legacy can extend past the time period of active discharge. Metal concentrations in urban stream sediments have been associated with high rates of fish and invertebrate anomalies such as tumors, lesions, and deformities (Burton, 1992; Ingersoll et al., 1997; Smith et al., 2003).

Biological Responses to Non-Toxicant Chemicals

Non-toxic chemical compounds that occur in stormwater such as nutrients, dissolved oxygen (DO), pH, and dissolved solids as well as physical factors such as temperature can have impacts on aquatic life. The effects of some of these

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compounds (e.g., DO, pH) have been well documented from other impacts (e.g., wastewater, mining), such that nearly all states have developed water quality criteria for these parameters. For example, nutrient enrichment in stormwater runoff has been associated with declines of biological condition in streams (Miltner and Rankin, 1998). Chloride, sulfate, and other dissolved ions that are often elevated in urban areas can have effects on osmoregulation of aquatic organisms and have been associated with loss of species sensitive to dissolved materials such as mayflies (Kennedy et al., 2004). The concentrations of these compounds can vary regionally (Sprague et al., 2007) and with the degree of urbanization.

Water quality criteria for temperature were spurred by the need for thermal permits for industrial and power plant cooling water discharges. There is a very large literature on the importance of water temperature to aquatic organisms; preference, avoidance, and lethal temperature ranges have been derived for many aquatic species (e.g., Brungs and Jones, 1977; Coutant, 1977; Eaton et al., 1995). In addition, temperature is one of the key classification strata for aquatic life, in that streams are routinely classified as cold water, cool water, or warm water based on the geographic and natural settings of waters. The removal of catchment and riparian vegetation and the general increase in surface runoff from impervious, man-made, and heat-capturing surfaces has been associated with increasing water temperatures in urban waterbodies (Wang and Kanehl, 2003; Nelson and Palmer, 2007). A number of researchers have created models to predict in-stream temperatures based on urban characteristics (Krause et al., 2004; Herb et al., 2008).

Hydrologic Influences on Aquatic Life

The importance of "natural" flow regimes on aquatic life has been well documented (Poff et al., 1997; Richter et al., 1997a, 2003). As watersheds urbanize, flow regimes change from little runoff to over 40 to 90 percent of the rainfall becoming surface runoff (Roesner and Bledsoe, 2003). Flow regimes in urban streams typically are very "flashy," with higher and more frequent peak events, compared to undisturbed systems (Poff et al., 1997; Baker et al., 2004) and well as reduced base flows and more frequent desiccation (Bernhardt and Palmer, 2007). Richter et al. (1996) proposed a series of indicators that could be used to measure hydrologic disturbance, many of which have been used in the recent studies identifying the hydrologic effects of stormwater on aquatic biota (Barbour et al., 2008). Pomeroy et al. (2008) did an extensive review of which flow characteristics appear to have the greatest influence on biological metrics and biological integrity. No single measure of flow was found to be significant in all studies; however, important attributes included flow variability and flashiness, flood frequency, flow volume, flow variability, flow timing, and flow duration.

There are a number of mechanisms that may be responsible for the influ-

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ence of flow characteristics on aquatic assemblages. Aquatic species vary dramatically in their swimming performance and behaviors, and species are generally adapted to undisturbed flow regimes in an area. Many low- to moderate-gradient small streams in the United States, for example, have strong connections with their flood-prone areas and often possess habitat features that insulate poor swimming species from episodic natural high flows. Undercut banks, rootwads, oxbows, and backwater habitats all can act as refugia from high flows. Some aquatic species are more or less mobile within the sediments, like certain macroinvertebrates (meiofauna or hyporheos) and fish species such as sculpins and madtoms. Secondary impacts from hydrologic changes such as bank erosion and aggradation of fines can render substrates embedded and prohibit organisms, particularly the meiofauna, from moving vertically within the bottom substrates (Schmid-Araya, 2000). Substrate fining has been documented to occur with increasing urbanization, especially in the early stages of development, which can embed spawning habitats and eliminate or reduce spawning success of fish such as salmonids and minnows (Waters, 1995).

Flood flows can cause mortality in the absence of urbanization. For example, flood flows in streams under natural conditions have been documented as a cause of substantial mortality in young or larval fish such as smallmouth bass (Funk and Fleener, 1974; Lorantas and Kristine, 2004). Increased flashiness from urbanization is likely to exacerbate this effect. Thus, increases in the frequency of peak flows during spring will increase the probability of spawning failure, such that sensitive species may eventually be locally extirpated. In urban areas, culverts and other flow obstructions can create conditions that may preclude re-colonization of upstream reaches because weak-swimming fishes cannot move past flow constrictions or leap past vertical drops caused by artificial structures.

Hydrologic simplification and stream straightening that occur in urban streams, often as a result of increased peak flows or as a local management response, typically remove habitat used as temporary refuges from high flows, such as backwater areas, undercut banks, and rootwads. There is a large literature relating populations of fish and macroinvertebrates to various habitat features of streams, rivers, and wetlands. The first two attributes of the BCG identify taxa that are historically documented, sensitive, long-lived, or regionally endemic taxa or sensitive-rare taxa. Many of these taxa are endangered because of large-scale changes in flow-influenced habitats; that is, threats of extinction often center on habitat degradation that influence spawning, feeding, or other aspects of a species life history (Rieman et al., 1993). In contrast, many of the fish and macroinvertebrate taxa that compose regional lists of tolerant taxa are tolerant to habitat changes related to flow disturbance as well as chemical parameters. Understanding the life history attributes of certain species and how they may change with multiple stressors (Power, 1997) is an important tool for understanding complex responses of aquatic ecosystems to urban stressors.

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Geomorphic and Habitat Influences on Aquatic Life

In natural waters, geomorphic factors and climate, modified by vegetation and land use, constrain the types of physical habitat features likely to occur in streams (Webster and D'Angelo, 1997). For example, very-low-gradient streams may have few riffles and be dominated by woody debris and bank cover, whereas higher gradient waters may have more habitat types formed by rapidly flowing waters (riffles, runs). Aquatic life in streams is influenced directly by the habitat features that are present, such as substrate types, in-stream structures, bank structure, and flow types (e.g., deep-fast vs. shallow-slow).

As discussed previously, human alteration of landscapes, encroachment on riparian areas, and direct channel modifications (e.g., channelization) that acompany urbanization have often resulted in unstable channels, with negative consequences for aquatic habitat. As urbanization has increased, channel density has declined because streams have been piped, dewatered, and straightened (Meyer and Wallace, 2001; Paul and Meyer, 2001). Changes in the magnitude, relative proportions, and timing of sediment and water delivery have resulted in loss of aquatic life and habitat via a wide range of mechanisms, including changes in channel bed materials, increased suspended sediment loads, loss of riparian habitat due to bank erosion, and changes in the variability of flow and sediment transport characteristics relative to aquatic life cycles (Roesner and Bledsoe, 2003). There are still significant gaps in knowledge about how stormwater stressors can affect stream habitat, especially as one moves from the reach scale to the watershed scale. Understanding the stage and trajectory of channel evolution is critical to understanding channel recovery and expected habitat conditions or in choosing effective restoration options (Simon et al., 2007).

Across much of the United States, stream habitats have been altered to the imperilment of aquatic species (Williams et al., 1989; Richter et al., 1997b; Strayer et al., 2004). A study of rapidly urbanizing streams in central Ohio identified the loss of highly and moderately sensitive species as a key factor the decline in the IBI in these streams (Miltner et al., 2004). These streams had historical fish collections when they were primarily influenced by agricultural land use; sampling after the onset of suburban development documented the loss of many of these species attributable to land-use changes and habitat degradation along these urban streams. Along the BCGs that have been developed for streams, most of the species in attributes 1–3 are specialists requiring very specific habitats for spawning, feeding, and refuge. Habitat alteration, either direct or indirect, creates harsh environments that tend to favor tolerant taxa, which would otherwise be in low abundance. Often these tolerant species are characterized by high reproductive potential, generalist feeding behaviors, tolerance to chemical stressors such as low DO, and pioneering strategies that allow rapid recolonization following acute stressful events.

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Altered Energy Pathways in Urban Streams

The pathways of energy flow in streams are an important determinant of aquatic species distributions. In most natural temperate streams, headwaters transform and export energy from stream side vegetation and adjacent land uses into aquatic biomass. The types, amount, and timing of delivery of water, organic material, and debris have important consequences for conditions downstream (Dolloff and Webster, 2000). The energy-transforming aspect of stream ecosystems is difficult to capture directly, so most measures are surrogates, such as the trophic characteristics of assemblages and chemical and physical characteristics consistent with natural energy processes.

An increasingly urban landscape can have a complex array of effects on energy dynamics in streams (Allan, 2004). Loss of riparian areas and changes in riparian vegetation can reduce the supply and quality of coarse organic matter that forms the base of aquatic food webs in most small streams. The reduction in the amount of organic matter with riparian loss is obvious; however, changing species of vegetation (e.g., invasion or planting of exotic species) can affect the quality of organic matter and influence higher trophic levels because, for example, exotic species may have different nutrient values (e.g., C/N ratios, trace chemicals) or process nutrients at a different rate (Royer et al., 1999). Furthermore, native invertebrate taxa may not be adapted to utilize the exotic material (Miller and Boulton, 2005). For example, changes in leaf species in a stream may alter the macroinvertebrate community by favoring species that feed on fast-decaying versus slow-decaying leaves (Smock and MacGregor, 1988; Cummins et al., 1989; Gregory et al., 1991).

Other recent work is examining ways that changes in geomorphology with increasing urbanization can influence trophic structure in streams (Doyle, 2006). Groffman et al. (2005) examined nitrogen processing in stream geomorphic structures such as bars, riffles, and debris dams in suburban and forested areas. Although suburban areas had high rates of production in organic-rich debris dams and gravel bars, higher storm flow effects in urban streams may make these features less stable and able to be maintained (Groffman et al., 2005). Changes in habitat and riparian vegetation may greatly alter trophic patterns of energy transport. For example, local nutrient enrichments combined with reduced riparian vegetation can result in nuisance algal growths in waterbodies that are evidence of simpler energy pathways. Corresponding effects are further water chemistry changes from algal decomposition (e.g.., low DO) or very high algal activity (e.g., high pH) (Ehlinger et al., 2004).

The complexity of energy flow through simple ecosystems is illustrated in Figure 3-42, a “simplified” food web of a headwater stream published by Meyer (1994). The forms in which nutrients are delivered to streams may be more important than actual concentrations as well as the availability of carbon sources essential for nutrient transformation. The nutrient components that form the base of the food web in Figure 3-42 are the FPOM and CPOM boxes. In many natural streams, woody and leafy debris are the most common form of nutrient

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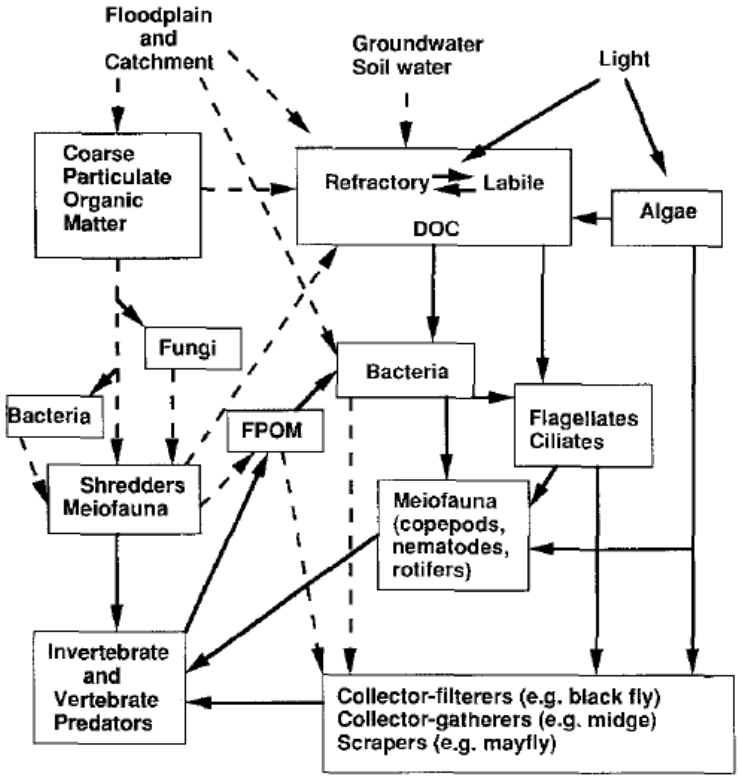

FIGURE 3-42 Simplified diagram of a lotic food web showing sources and major pathways of organic carbon. Dotted lines indicate flows that are a part of the microbial loop in flowing water but not in planktonic systems. SOURCE: Reprinted, with permission, from Meyer (1994). Copyright 1994 by Springer.

input, and changes to urban landscapes often change this to dissolved and finer forms. Urbanization can also reduce the retention of organic debris of streams (Groffman et al., 2005) and the timing of nutrient delivery. Timing can be of crucial importance since species spawning and growth periods may be specifically timed to take advantage of available nutrients.

As important as energy and nutrient dynamics are to stream function, many of the stream characteristics that determine effective energy flow are not typically considered when characterizing stormwater impacts. The best chance for considering these variables and maximizing ecosystem function is through inte-

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grated, biologically based monitoring programs that include urban areas (Barbour et al., 2008) and stressor identification procedures (EPA, 2000) to isolate likely causes of impact and to inform the choices of SCMs.

Biological Interactions in Urban Streams

Streams in urbanized environments often are characterized by fewer native and more alien species than natural streams (DeVivo, 1996; Meador et al., 2005). The influence of exotic species is not always predictable and may be most severe in lentic environments (e.g., wetlands, estuaries) and in riparian zones where various exotic aquatic plants can greatly alter natural systems in both structure and function (Hood and Naiman, 2000). Riley et al. (2005) foundthat the presence of alien aquatic amphibians was positively related to degree of urbanization, as was the absence of certain native amphibian species. In a review of possible reasons for this observation, he suggested that altered flow regimes were responsible. In the arid California streams they studied, flow became more constant with urbanization (i.e., natural streams were generally ephemeral), which allowed invasion by exotic species that can prey on, compete with, or hybridize with native species (Riley et al., 2005). The alteration of stream habitat that accompanies urbanization can also lead to predation by domestic cats and dogs or collection by humans, especially where species (e.g., California newts) are large and conspicuous (Riley et al., 2005).

The effects of specific exotic species on aquatic systems has been observed to vary geographically, although recent work has found correlations between total invasion rate and the number of high-impact exotic species (Ricciardi and Kipp, 2008). This suggests that overall efforts to reduce the importation or spread of all alien species should be helpful.

The Role of Biological Monitoring

The preceding sections illustrate the importance of biological data to understanding the complexities associated with urban and stormwater impacts to waterbodies. Although categories of urban stressors have been discussed individually, these stressors routinely, if not universally, co-occur in urban waterbodies. Their cumulative impacts are best measured with biological tools because the biota integrate the influence of all of these stressors.

Many programmatic aspects of the CWA arose as a response to rather obvious impacts of chemical pollutants that were occurring in surface waters during this time. The initial focus of water quality standards was on developing chemical criteria that could serve as engineering endpoints for waste treatment systems (e.g., NPDES permits). Rather general aquatic life goals for streams and rivers that were suitable for the initial focus of the CWA are now considered insufficient to deal with the complex suite of stressors limiting aquatic systems.

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To that end, refined aquatic life goals and improved biological monitoring are essential for effective water quality management, including stormwater issues (NRC, 2001). Practical biological and physical monitoring tools have even been developed for very small headwater streams (Ohio EPA, 2002; Fritz et al., 2006), which are particularly affected by stormwater because of their prevalence (greater than 95 percent of channels), their relatively high surface-to-volume ratio, their role in nutrient and material processing, and their vulnerability to direct modification such as channelization and piping (Meyer and Wallace, 2001).

Surrogate indicators of stormwater impacts to aquatic life (such as TSS concentrations) have been widely used because direct biological measures were poorly developed and these surrogates were assumed to be important to pollutant delivery to urban streams. However, biological assessment has rapidly advanced in many states and can be readily applied or if needed modified to be sensitive to stormwater stressors (Barbour et al., 2008). As Karr and Chu (1999) warned, the management of complex systems requires measures that integrate multiple factors. Stormwater permitting is no different, and care must be taken to ensure that permitting and regulatory actions retain ecological relevance. Surrogate measures have an essential role in the assessment of individual SCMs; however, this needs to be kept in context with the entire suite of stressors likely to be important to the aquatic life goals in streams.

Stormwater management programs should not necessarily bear the burden of biological monitoring; rather, well-conceived biological monitoring should be the prevue of state and local government agencies (as discussed more extensively in Chapter 6). Refined aquatic life goals developed for all waters, including urban waters, measured with appropriate biological measures, should be the final endpoint for management. The collection of biological data needs to be closely integrated across multiple disciplines in order to be effective. Pomeroy et al. (2008) describe a multidisciplinary approach to study the effects of stormwater in urban settings, and Scholz and Booth (2001) also propose a monitoring approach for urban watersheds. Such efforts are not necessarily easy, and many institutions find pitfalls when trying to integrate scientific information across disciplines (Benda et al., 2002).

EPA water programs, such as the Total Maximum Daily Load (TMDL) program, have been criticized for having too narrow a focus on a limited number of traditional pollutants to the exclusion of important stressors such as hydrology, habitat alteration, and invasive taxa (Karr and Yoder, 2004)—all serious problems associated with stormwater and urbanization. The science has advanced significantly over the past decade so that biological assessment should be an essential tool for identifying stormwater impacts and informing the choice of SCMs in a region or watershed. Although biological responses to stressors in the ambient environment are by their nature correlative exercises, ecological epidemiology principles or "stressor identification" methods can identify likely causative agents of impairment with relatively high certainty in many instances (Suter, 1993, 2006; EPA, 2000). Coupled with other ambient and source moni-

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toring information, biological information can form the basis for an effective stormwater program. As an example, Box 3-10 introduces the Impervious Cover Model (ICM), which was developed using correlative information on the association between impervious cover and biological metrics. The crux of the ICM is that stormwater management is tailored along a readily measureable gradient (impervious cover) that integrates multiple individual stressor categories that would otherwise be overlooked in the traditional pollutant-based approach to stormwater management. Even the form of the ICM (as conceptualized in Figure 3-43) matches that outlined for the BCG (Figure 3-38). Use of the ICM to improve the MS4 stormwater program is discussed in Chapter 6.

Human Health Impacts

Despite the unequivocal evidence of ecosystem consequences resulting from urban stormwater, a formal risk analysis of the human health effects associated with stormwater runoff is not yet possible. This is because (1) many of the most important waterborne pathogens have not been quantified in stormwater, (2) enumeration methods reported in the current literature are disparate and do not account for particle-bound pathogens, and (3) sampling times during storms have not been standardized nor are known to have occurred during periods of human exposure. Individual studies have investigated the runoff impacts on public health in freshwater (Calderon et al., 1991) and marine waters (Haile et al., 1999; Dwight et al,. 2004; Colford et al., 2007). Although these studies provide ample evidence that stormwater runoff can serve as a vector of pathogens with potential health implications (for example, Ahn et al., 2005, found that fecal indicator bacteria concentrations could exceed California ocean bathing water standards by up to 500 percent in surf zones receiving stormwater runoff), it is difficult to draw conclusive inferences about the specific human health impacts from microbial contamination of stormwater. Calderon et al. (1991) concluded that the currently recommended bacterial indicators are ineffective for predicting potential health effects associated with water contaminated by nonpoint sources of fecal pollution. Furthermore, in a study conducted in Mission Bay, California, which analyzed bacterial indicators using traditional and nontraditional methods (chromogenic substrate and quantitative polymerase chain reaction), as well as a novel bacterial indicator and viruses, traditional fecal indicators were not associated with identified human health risks such as diarrhea and skin rash (Colford et al., 2007).

The Santa Monica Bay study (Haile et al., 1999) indicated that the risks of several health outcomes were higher for people who swam at storm-drain locations compared to those who swam farther from the drain. However, the list of health outcomes that were more statistically significant (fever, chills, ear discharge, cough and phlegm, and significant respiratory) did not include highly

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BOX 3-10
The Impervious Cover Model: An Emerging Framework for Urban Stormwater Management

The Impervious Cover Model (ICM) is a management tool that is useful for diagnosing the severity of future stream problems in a subwatershed. The ICM defines four categories of urban streams based on how much impervious cover exists in their subwatershed: *high-quality streams*, *impacted streams, non-supporting streams,* and *urban drainage*. The ICM is then used to develop specific quantitative or narrative predictions for stream indicators within each stream category (see Figure 3-43). These predictions define the severity of current stream impacts and the prospects for their future restoration. Predictions are made for five kinds of urban stream impacts: changes in stream hydrology, alteration of the stream corridor, stream habitat degradation, declining water quality, and loss of aquatic diversity.

The general predictions of the ICM are as follows. Stream segments with less than 10 percent impervious cover (IC) in their contributing drainage area continue to function as **Sensitive Streams**, and are generally able to retain their hydrologic function and support good-to-excellent aquatic diversity. Stream segments that have 10 to 25 percent IC in their contributing drainage area behave as **Impacted Streams** and show clear signs of declining stream health. Most indicators of stream health will fall in the fair range, although some segments may range from fair to good as riparian cover improves. The decline in stream quality is greatest toward the higher end of the IC range. Stream segments that range between 25 and 60 percent subwatershed impervious cover are classified as **Non-Supporting Streams** (i.e., no longer supporting their designated uses in terms of hydrology, channel stability habitat, water quality, or biological diversity). These stream segments become so degraded that any future stream restoration or riparian cover improvements are insufficient to fully recover stream function and diversity (i.e., the streams are so dominated by subwatershed IC that they cannot attain predevelopment conditions). Stream segments whose subwatersheds exceed 60 percent IC are physically altered so that they merely function as a conduit for flood waters. These streams are classified as **Urban Drainage** and consistently have poor water quality, highly unstable channels, and very poor habitat and biodiversity scores. In many cases, these urban stream segments are eliminated altogether by earthworks and/or storm-drain enclosure. Table 3-14 shows in greater detail how stream corridor indicators respond to greater subwatershed impervious cover.

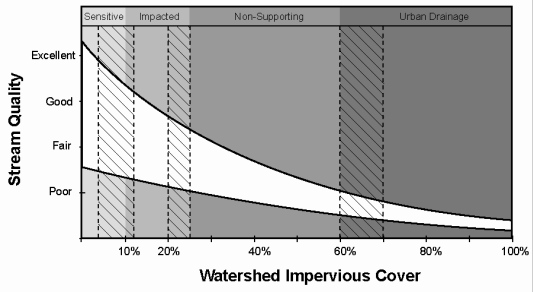

FIGURE 3-43 Changes in Stream Quality with Percent Impervious Cover in the Contributing Watershed. SOURCE: Chesapeake Stormwater Network (2008). Reprinted, with permission, from Chesapeake Stormwater Network (2008). Copyright 2008 by Chesapeake Stormwater Network.

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TABLE 3-14 General ICM Predictions Based on Urban Subwatershed Classification (CWP, 2004):

Prediction	Impacted (IC 11 to 25%) [8]	Non-supporting (IC 26 to 60%)	Urban Drainage (IC > 60%)
Runoff as a Fraction of Annual Rainfall [1]	10 to 20%	25 to 60%	60 to 90%
Frequency of Bankfull Flow per Year [2]	1.5 to 3 per year	3 to 7 per year	7 to 10 per year
Fraction of Original Stream Network Remaining	60 to 90%	25 to 60%	10 to 30%
Fraction of Riparian Forest Buffer Intact	50 to 70%	30 to 60%	Less than 30%
Crossings per Stream Mile	1 to 2	2 to 10	None left
Ultimate Channel Enlargement Ration [3]	1.5 to 2.5 larger	2.5 to 6 times larger	6 to 12 times larger
Typical Stream Habitat Score	Fair, but variable	Consistently poor	Poor, often absent
Increased Stream Warming [4]	2 to 4 °F	4 to 8 °F	8+ °F
Annual Nutrient Load [5]	1 to 2 times higher	2 to 4 times higher	4 to 6 times higher
Wet Weather Violations of Bacteria Standards	Frequent	Continuous	Ubiquitous
Fish Advisories	Rare	Potential risk of accumulation	Should be presumed
Aquatic Insect Diversity [6]	Fair to good	Fair	Very poor
Fish Diversity [7]	Fair to good	Poor	Very poor

[1] Based on annual storm runoff coefficient; ranges from 2 to 5% for undeveloped streams.
[2] Predevelopment bankfull flood frequency is about 0.5 per year, or about one bankfull flood every two years.
[3] Ultimate stream-channel cross-section compared to typical predevelopment channel cross section.
[4] Typical increase in mean summer stream temperature in degrees Fahrenheit, compared with shaded rural stream.
[5] Annual unit-area stormwater phosphorus and/or nitrogen load produced from a rural subwatershed.
[6] As measured by benthic index of biotic integrity. Scores for rural streams range from good to very good.
[7] As measured by fish index of biotic integrity. Scores for rural streams range from good to very good.
[8] IC is not the strongest indicator of stream health below 10% IC, so the sensitive streams category is omitted from this table.
SOURCE: Adapted from Schueler (2004).

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BOX 3-10 Continued

Scientific Support for the ICM

The ICM predicts that hydrological, habitat, water quality, and biotic indicators of stream health first begin to decline sharply at around 10 percent total IC in smaller catchments (Schueler, 1994). The ICM has since been extensively tested in ecoregions around the United States and elsewhere, with more than 200 different studies confirming the basic model for single stream indicators or groups of stream indicators (CWP, 2003; Schueler, 2004). Several recent research studies have reinforced the ICM as it is applied to first- to third-order streams (Coles et al., 2004; Horner et al., 2004; Deacon et al., 2005; Fitzpatrick et al., 2005; King et al., 2005; McBride and Booth, 2005; Cianfrina et al., 2006; Urban et al., 2006; Schueler et al., 2008).

Researchers have focused their efforts to define the specific thresholds where urban stream degradation first begins. There is robust debate as to whether there is a sharp initial threshold or merely a continuum of degradation as IC increases, although the latter is more favored. There is much less debate, however, about the dominant role of IC in defining the hydrologic, habitat, water quality, and biodiversity expectations for streams with higher levels of IC (15 to 60 percent).

Caveats to the ICM

The ICM is a powerful predictor of urban stream quality when used appropriately. The first caveat is that subwatershed IC is defined as total impervious area (TIA) and not effective impervious area (EIA). Second, the ICM should be restricted to first- to third-order alluvial streams with moderate gradient and no major point sources of pollutant discharge. The ICM is most useful in projecting the behavior of numerous stream health indicators, and it is not intended to be accurate for every individual stream indicator. In addition, management practices in the contributing catchment or subwatershed must not be poor (e.g., no deforestation, acid mine drainage, intensive row crops, etc.); just because a subwatershed has less than 10 percent IC does not automatically mean that it will have good or excellent stream quality if past catchment management practices were poor.

ICM predictions are general and may not apply to every stream within the proposed classifications. Urban streams are notoriously variable, and factors such as gradient, stream order, stream type, age of subwatershed development, and past land use can and will make some streams depart from these predictions. Indeed, these “outlier” streams are extremely interesting from the standpoint of restoration. In general, subwatershed IC causes a continuous but variable decline in most stream corridor indicators. Consequently, the severity of individual indicator impacts tends to be greater at the upper end of the IC range for each stream category.

Effects of Catchment Treatment on the ICM

Most studies that investigated the ICM were done in communities with some degree of catchment treatment (e.g., stormwater management or stream buffers). Detecting the effect of catchment treatment on the ICM involves a very complex and difficult paired watershed design. Very few catchments meet the criteria for either full treatment or the lack of it,

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no two catchments are ever really identical, and individual catchments exhibit great variability from year to year. Not surprisingly, the first generation of research studies has produced ambiguous results. For example, seven research studies showed that ponds and wetlands are unable to prevent the degradation of aquatic life in downstream channels associated with higher levels of IC (Galli, 1990; Jones et al., 1996; Horner and May, 1999; Maxted, 1999; MNCPPC, 2000; Horner et al., 2001; Stribling et al., 2001). The primary reasons cited are stream warming (amplified by ponds), changes in organic matter processing, the increased runoff volumes delivered to downstream channels, and habitat degradation caused by channel enlargement.

Riparian forest cover is defined as canopy cover within 100 meters of the stream, and is measured as the percentage of the upstream network in this condition. Numerous researchers have evaluated the relative impact of riparian forest cover and IC on stream geomorphology, aquatic insects, fish assemblages, and various indices of biotic integrity. As a group, the studies suggest that indicator values for urban streams improve when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Booth et al., 2002; Morley and Karr, 2002; Wang et al., 2003; Allan, 2004; Sweeney et al., 2004; Moore and Palmer, 2005; Cianfrina et al., 2006; Urban et al., 2006).

Application of the ICM to other Receiving Waters

Recent research has focused on the potential value of the ICM in predicting the future quality of receiving waters such as tidal coves, lakes, wetlands and small estuaries. The primary work on small estuaries by Holland et al. (2004) [references cited in CWP (2003), Lerberg et al. (2000)] indicates that adverse changes in physical, sediment, and water quality variables can be detected at 10 to 20 percent subwatershed IC, with a clear biological response observed in the range of 20 to 30 percent IC. The primary physical changes involve greater salinity fluctuations, greater sedimentation, and greater pollutant contamination of sediments. The biological response includes declines in diversity of benthic macroinvertebrates, shrimp, and finfish.

More recent work by King et al. (2005) reported a biological response for coastal plain streams at around 21 to 32 percent urban development (which is usually about twice as high as IC). The thresholds for important water quality indicators such as bacterial exceedances in shellfish beds and beaches appears to begin at about 10 percent subwatershed IC, with chronic violations observed at 20 percent IC (Mallin et al., 2001). Algal blooms and anoxia resulting from nutrient enrichment by stormwater runoff also are routinely noted at 10 to 20 percent subwatershed IC (Mallin et al., 2004).

The primary conclusion to be drawn from the existing science is that the ICM does apply to tidal coves and streams, but that the impervious levels associated with particular biological responses appear to be higher (20 to 30 percent IC for significant declines) than for freshwater streams, presumably due to their greater tidal mixing and inputs from nearshore ecosystems. The ICM may also apply to lakes (CWP, 2003) and freshwater wetlands (Wright et al., 2007) under carefully defined conditions. The initial conclusion is that the application of the ICM shows promise under special conditions, but more controlled research is needed to determine if IC (or other watershed metrics) is useful in forecasting receiving water quality conditions.

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BOX 3-10 Continued

Utility of the ICM in Urban Stream Classification and Watershed Management

The ICM is best used as an urban stream classification tool to set reasonable expectations for the range of likely stream quality indicators (e.g., physical, hydrologic, water quality, habitat, and biological diversity) over broad ranges of subwatershed IC. In particular, it helps define general thresholds where water quality standards or biological narrative conditions cannot be consistently met during wet weather conditions (see Table 6-2). These predictions help stormwater managers and regulators to devise appropriate and geographically explicit stormwater management and subwatershed restoration strategies for their catchments as part of MS4 permit compliance. More specifically, assuming that local monitoring data are available to confirm the general predictions of the ICM, it enables managers to manage stormwater within the context of current and future watershed conditions.

credible gastrointestinal illness, which is curious because the vast majority of epidemiological studies worldwide suggests a causal dose-related relationship between gastrointestinal symptoms and recreational water quality measured by bacterial indicator counts (Pruss, 1998). Dwight et al. (2004) found that surfers in an urban environment reported more symptoms than their rural counterparts; however, water quality was not specifically evaluated in that study.

To better assess the relationship between swimming in waters contaminated by stormwater, which have not been influenced by human sewage, and the risk of related illness, the California Water Boards and the City of Dana Point have initiated an epidemiological study. This study will be conducted at Doheny Beach, Orange County, California, which is a beach known to have high fecal indicator bacteria concentrations with no known human source. The project will examine new techniques for measuring traditional fecal indicator bacteria, new species of bacteria, and viruses to determine whether they yield a better relationship to human health outcomes than the indicators presently used in California. The study is expected to be completed in 2010. In addition, the State of California is researching new methods for rapid detection of beach bacterial indicators and ways to bring these methods into regular use by the environmental monitoring and public health communities to better protect human health.

CONCLUSIONS AND RECOMMENDATIONS

The present state of the science of stormwater reflects both the strengths and weaknesses of historic, monodisciplinary investigations. Each of the component disciplines—hydrology, geomorphology, aquatic chemistry, ecology, land use, and population dynamics—have well-tested theoretical foundations and useful predictive models. In particular, there are many correlative studies showing how parameters co-vary in important but complex and poorly understood ways (e.g., changes in fish community associated with watershed road

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density or the percentage of IC). Nonetheless, efforts to create mechanistic links between population growth, land-use change, hydrologic alteration, geomorphic adjustments, chemical contamination in stormwater, disrupted energy flows, and biotic interactions, to changes in ecological communities are still in development. Despite this assessment, there are a number of overarching truths that remain poorly integrated into stormwater management decision making, although they have been robustly characterized and have a strong scientific basis. These are expanded upon below.

There is a direct relationship between land cover and the biological condition of downstream receiving waters. The possibility for the highest levels of aquatic biological condition exists only with very light urban transformation of the landscape. Even then, alterations to biological communities have been documented at such low levels of imperviousness, typically associated with roads and the clearing of native vegetation, that there has been no real "urban development" at all. Conversely, the lowest levels of biological condition are inevitable with extensive urban transformation of the landscape, commonly seen after conversion of about one-third to one-half of a contributing watershed into impervious area. Although not every degraded waterbody is a product of intense urban development, all highly urban watersheds produce severely degraded receiving waters. Because of the close and, to date, inexorable linkage between land cover and the health of downstream waters, stormwater management is an unavoidable offshoot of watershed-based land-use planning (or, more commonly, its absence).

The protection of aquatic life in urban streams requires an approach that incorporates all stressors. Urban Stream Syndrome reflects a multitude of effects caused by altered hydrology in urban streams, altered habitat, and polluted runoff. Focusing on only one of these factors is not an effective management strategy. For example, even without noticeably elevated pollutant concentrations in receiving waters, alterations in their hydrologic regimes are associated with impaired biological condition. Achieving the articulated goals for stormwater management under the CWA will require a balanced approach that incorporates hydrology, water quality, and habitat considerations.

The full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. Permanently increased stormwater volume is only one aspect of an urban-altered storm hydrograph. It contributes to high in-stream velocities, which in turn increase streambank erosion and accompanying sediment pollution of surface water. Other hydrologic changes, however, include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These all can affect both the physical and biological conditions of streams, lakes, and wetlands. Thus, effective hydrologic mitigation for urban development cannot just

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aim to reduce post-development peak flows to predevelopment peak flows.

A single design storm cannot adequately capture the variability of rain and how that translates into runoff or pollutant loadings, and thus is not suitable for addressing the multiple objectives of stormwater management. Of particular importance to the types of problems associated with urbanization is the size of rain events. The largest and most infrequent rains cause near-bankfull conditions and may be most responsible for habitat destruction; these are the traditional "design storms" used to design safe drainage systems. However, moderate-sized rains are more likely to be associated with most of the annual mass discharges of stormwater pollutants, and these can be very important to the eutrophication of lakes and nearshore waters. Water quality standards for bacterial indicators and total recoverable heavy metals are exceeded for almost *every* rain in urban areas. Therefore, the whole distribution of storm size needs to be evaluated for most urban receiving waters because many of these problems coexist.

Roads and parking lots can be the most significant type of land cover with respect to stormwater. They constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in these highly impervious areas because of their close proximity to the variety of pollutants associated with automobiles. This is especially true in areas of the country having mostly small rainfall events (as in the Pacific Northwest). As rainfall amounts become larger, pervious areas in most residential land uses become more significant sources of runoff, sediment, nutrients, and landscaping chemicals. In all cases, directly connected impervious surfaces (roads, parking lots, and roofs that are directly connected to the drainage system) produce the first runoff observed at a storm-drain inlet and outfall because their travel times are the quickest.

Generally, the quality of stormwater from urbanized areas is well characterized, with the common pollutants being sediment, metals, bacteria, nutrients, pesticides, trash, and polycyclic aromatic hydrocarbons. These results come from many thousands of storm events from across the nation, systematically compiled and widely accessible; they form a robust data set of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate pollutant concentrations, which have been shown to vary by land cover and by region across the country. However, characterization data are relatively sparse for individual industrial operations, which makes these sources less amenable to generalized approaches based on reliable assumptions of pollutant types and loads. In addition, industrial operations vary greatly from site to site, such that it may be necessary to separate them into different categories in order to better understand industrial stormwater quality.

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Nontraditional sources of stormwater pollution must be taken into consideration when assessing the overall impact of urbanization on receiving waterbodies. These nontraditional sources include atmospheric deposition, snowmelt, and dry weather discharges, which can constitute a significant portion of annual pollutant loadings from storm systems in urban areas (such as metals in Los Angeles). For example, atmospheric deposition of metals is a very significant component of contaminant loading to waterbodies in the Los Angeles region relative to other point and nonpoint sources. Similarly, much of the sediment found in receiving waters following watershed urbanization can come from streambank erosion as opposed to being contributed by polluted stormwater.

Biological monitoring of waterbodies is critical to better understanding the cumulative impacts of urbanization on stream condition. Over 25 years ago, individual states developed the concept of regional reference sites and developed multi-metric indices to identify and characterize degraded aquatic assemblages in urban streams. Biological assessments respond to the range of non-chemical stressors identified as being important in urban waterways including habitat degradation, hydrological alterations, and sediment and siltation impacts, as well as to the influence of nutrients and other chemical stressors where chemical criteria do not exist or where their effects are difficult to measure directly (e.g., episodic stressors). The increase in biological monitoring has also helped to frame issues related to exotic species, which are locally of critical importance but completely unrecognized by traditional physical monitoring programs.

Epidemiological studies on the human health risks of swimming in freshwater and marine waters contaminated by urban stormwater discharges in temperate and warm climates are needed. Unlike with aquatic organisms, there is little information on the health risks of urban stormwater to humans. Standardized watershed assessment methods to identify the sources of human pathogens and indicator organisms in receiving waters need to be developed, especially for those waters with a contact-recreation use designation that have had multiple exceedances of pathogen or indicator criteria in a relatively short period of time. Given their difficulty and expense, epidemiological studies should be undertaken only after careful characterization of water quality and stormwater flows in the study area.

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4
Monitoring and Modeling

As part of its statement of task, the committee was asked to consider several aspects of stormwater monitoring, including how useful the activity is, what should be monitored and when and where, and how benchmarks should be established. As noted in Chapter 2, the stormwater monitoring requirements under the U.S. Environmental Protection Agency (EPA) stormwater program are variable and generally sparse, which has led to considerable skepticism about their usefulness. This chapter first considers the value of the data collected over the years by municipalities and makes suggestions for improvement. It then does the same for industrial stormwater monitoring, which has lagged behind the municipal separate storm sewer system (MS4) program both in requirements and implementation.

It should be noted upfront that this chapter does not discuss the fine details of MS4 and industrial monitoring that pertain to regulatory compliance—questions such as should the average end of pipe concentrations meet water quality standards, how many exceedances should be allowed per year, or should effluent concentrations be compared to acute or chronic criteria. Individual benchmarks and effluent limits for specific chemicals emanating from specific industries are not provided. The current state of MS4 and industrial stormwater monitoring and the paucity of high quality data are such that it is premature and in many cases impossible to make such determinations. Rather, the chapter suggests both *how* to monitor an individual industry and *how* to determine benchmarks and effluent limits for industrial categories. It suggests how monitoring requirements should be tailored to accommodate the risk level of an individual industrial discharger. Finally, it makes numerous technical suggestions for improving the monitoring of MS4s, building on the data already submitted and analyzed as part of the National Stormwater Quality Database. Policy recommendations about the monitoring of both industries and MS4s are found in Chapter 6.

This chapter's emphasis on monitoring of stormwater should not be interpreted as a disinterest in other types of monitoring, such as biomonitoring of receiving waters, precipitation measurements, or determination of land cover. Indeed, these latter activities are extremely important (they are introduced in the preceding chapter) and they underpin the new permitting program proposed in Chapter 6 (especially biological monitoring). Stormwater management would benefit most substantially from a well-balanced monitoring program that encompasses chemical, biological, and physical parameters from outfalls to receiving waters. Currently, however, decisions about stormwater management are usually made with incomplete information; for example, there are continued recommendations by many that street cleaning will solve a municipality's problems, even when the municipality does not have any information on the sources of the material being removed.

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A second charge to the committee was to define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria. As described in Chapter 3, many processes connect sources of pollution to an effect observed in a downstream receiving water. More and more, these processes can be represented in watershed models, which are the key to linking stormwater sources to effects observed in receiving waters. The latter half of the chapter explores the current capability of models to make such links, including simple models, statistical and conceptual models, and more involved mechanistic models. At the present time, associating a single discharger with degraded in-stream conditions is generally not possible because of the state of both modeling and monitoring of stormwater.

MONITORING OF MS4s

EPA's regulations for stormwater monitoring of MS4s is very limited, in that only the application requirements are stated [see 40 CFR § 122.26(d)]. The regulations require the MS4 program to identify five to ten stormwater discharge outfalls and to collect representative stormwater data for conventional and priority toxic pollutants from three representative storm events using both grab and composite sampling methods. Each sampled storm event must have a rainfall of at least 0.1 inch, must be preceded by at least 72 hours of a dry period, and the rain event must be within 50 percent of the average or median of the per storm volume and duration for the region. While the measurement of flow is not specifically required, an MS4 must make estimates of the event mean concentrations (EMCs) for pollutants discharged from all outfalls to surface waters, and in order to determine EMCs, flow needs to be measured or calculated.

Other than these requirements, the exact type of MS4 monitoring that is to be conducted during the permit term is left to the discretion of the permitting authority. EPA has not issued any guidance on what would be considered an adequate MS4 monitoring program for permitting authorities to evaluate compliance. Some guidance for MS4 monitoring based on desired management questions has been developed locally (for example, see the SCCWRP Technical Report No. 419, SMC 2004, Model Monitoring Program for MS4s in Southern California).

In the absence of national guidance from EPA, the MS4 monitoring programs for Phase I MS4s vary widely in structure and objectives, and Phase II MS4 programs largely do not perform any monitoring at all. The types of monitoring typically contained in Phase I MS4 permits include the (1) wet weather outfall screening and monitoring to characterize stormwater flows, (2) dry weather outfall screening and monitoring under illicit discharge detection and elimination programs, (3) biological monitoring to determine storm water impacts, (4) ambient water quality monitoring to characterize water quality conditions, and (5) stormwater control measure (SCM) effectiveness monitoring.

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The Nationwide Stormwater Quality Database

Stormwater monitoring data collected by a portion of Phase I MS4s has been evaluated for years by the University of Alabama and the Center for Watershed Protection and compiled in a database called the Nationwide Stormwater Quality Database (NSQD). These data were collected in order to describe the characteristics of stormwater on a national level, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas with limited data. The MS4 monitoring data collected over the past ten years from more than 200 municipalities throughout the country have great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. Version 3 of the NSQD is available online at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml. It contains data from more than 8,500 events and 100 municipalities throughout the country. About 5,800 events are associated with homogeneous land uses, while the remainder are for mixed land uses.

The general approach to data collection was to contact EPA regional offices to obtain state contacts for the MS4 data, then the individual municipalities with Phase I permits were targeted for data collection. Selected outfall data from the International BMP Database were also included in NSQD version 3, eliminating any source area and any treated stormwater samples. Some of the older National Urban Runoff Program (NURP) (EPA, 1983) data were also included in the NSQD, along with some data from specialized U.S. Geological Survey (USGS) stormwater monitoring activities in order to better represent nationwide conditions and additional land uses. Because there were multiple sources of information, quality assurance and quality control reviews were very important to verify the correctness of data added to the database, and to ensure that no duplicate entries were added.

The NSQD includes sampling location information such as city, state, land use, drainage area, and EPA Rain Zone, as well as date, season, and rain depth. The constituents commonly measured for in stormwater include total suspended solids (TSS), 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrite plus nitrate (NO_2+NO_3), total copper (Cu), total lead (Pb), and total zinc (Zn). Less information is available for many other constituents (including filterable heavy metals and bacteria). Figure 4-1 is a map showing the EPA Rain Zones in the United States, along with the locations of the communities contributing to the NSQD, version 3. Table 4-1 shows the number of samples for each land use and for each Rain Zone. This table does not show the number of mixed land-use site samples. Rain Zones 8 and 9 have very few samples, and institutional and open-space areas are poorly represented. However, residential, commercial, industrial, and freeway data are plentiful, except for the few Rain Zones noted above.

Land use has an important impact on the quality of stormwater. For example, the concentrations of heavy metals are higher for industrial land-use areas

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TABLE 4-1 Number of Samples per Land Use and EPA Rain Zone

Single Land Use	1	2	3	4	5	6	7	8	9	Total
Commercial	234	484	131	66	42	37	64	0	22	1080
Freeways	0	241	14	0	262	189	28	0	0	734
Industrial	100	327	90	51	83	74	146	0	22	893
Institutional	9	46	0	0	0	0	0	0	0	55
Open Space	68	37	0	18	0	2	0	0	0	125
Residential	294	1470	290	122	105	32	532	7	81	2933
Total	705	2605	525	257	492	334	770	7	125	5820

Note: there are no mixed-use sites in this table. SOURCE: National Stormwater Quality Database.

due to manufacturing processes and other activities that generate these materials. Fecal coliform concentrations are relatively high for residential and mixed residential land uses, and nitrate concentrations are higher for the freeway land use. Open-space land-use areas show consistently low concentrations for the constituents examined. Seasons could also be a factor in the variation of nutrient concentrations in stormwater due to seasonal uses of fertilizers and leaf drop occurring during the fall season. Most studies also report lower bacteria concentrations in the winter than in the summer. Lead concentrations in stormwater have also significantly decreased since the elimination of lead in gasoline (see Figure 2-6). Most of the statistical tests used are multivariate statistical evaluations that compare different constituent concentrations with land use and geographical location. More detailed discussions of the earlier NSQD results are found in various references, including Maestre et al. (2004, 2005) and Pitt et al. (2003, 2004).

How to use the NSQD to Calculate Representative EMC Values

EMC values were initially used during the NURP to describe typical concentrations of pollutants in stormwater for different monitoring locations and land uses. An EMC is intended to represent the average concentration for a single monitored event, usually based on flow-weighted composite sampling. It can also be calculated from discrete samples taken during an event if flow data are also available. Many individual subsamples should be taken throughout most of the event to calculate the EMC for that event. Being an overall average value, an EMC does not represent possible extremes that may occur during an event.

The NSQD includes individual EMC values from about 8,500 separate events. Stormwater managers typically want a representative single value for a land use for their area. As such, they typically evaluate a series of individual

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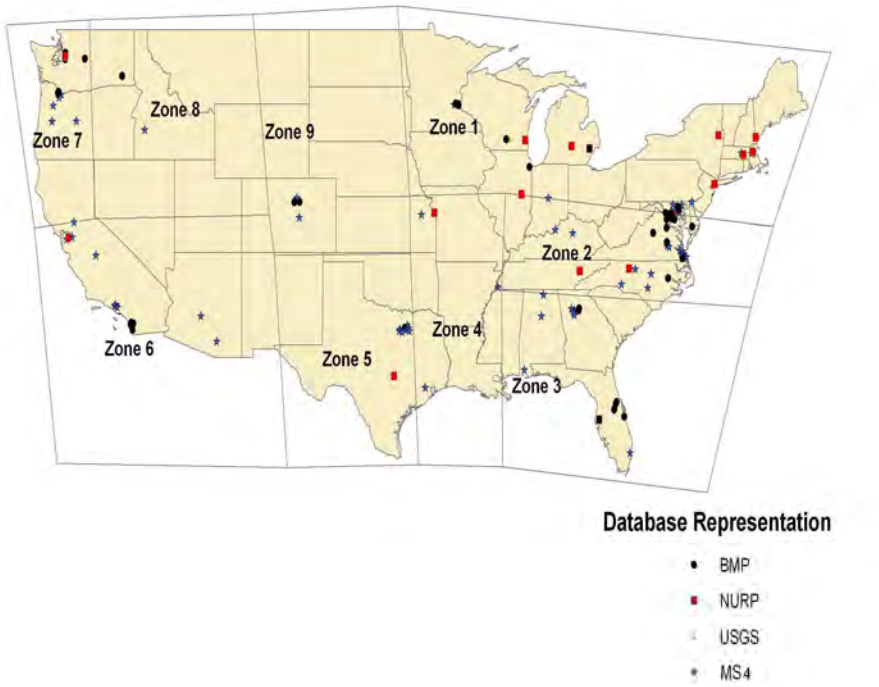

FIGURE 4-1 Sampling Locations for Data Contained in the National Stormwater Quality Database, version 3.

storm EMC values for conditions similar to those representing their site of concern. With the NSQD in a spreadsheet form, it is relatively simple to extract suitable events representing the desired conditions. However, the individual EMC values will likely have a large variability. Maestre and Pitt (2006) reviewed the NSQD data to better explain the variability according to different site and sampling conditions (land use, geographical location, season, rain depth, amount of impervious area, sampling methods, antecedent dry period, etc.). The most common significant factor was land use, with some geographical and fewer seasonal effects observed. As with the original NURP data, EMCs in the NSQD are usually expressed using medians and coefficients of variation to reflect uncertainty, assuming lognormal distributions of the EMC values. Figure 4-2 shows several lognormal probability plots for a few constituents from the NSQD. Probability plots shown as straight lines indicate that the concentrations can be represented by lognormal distributions (see Box 4-1).

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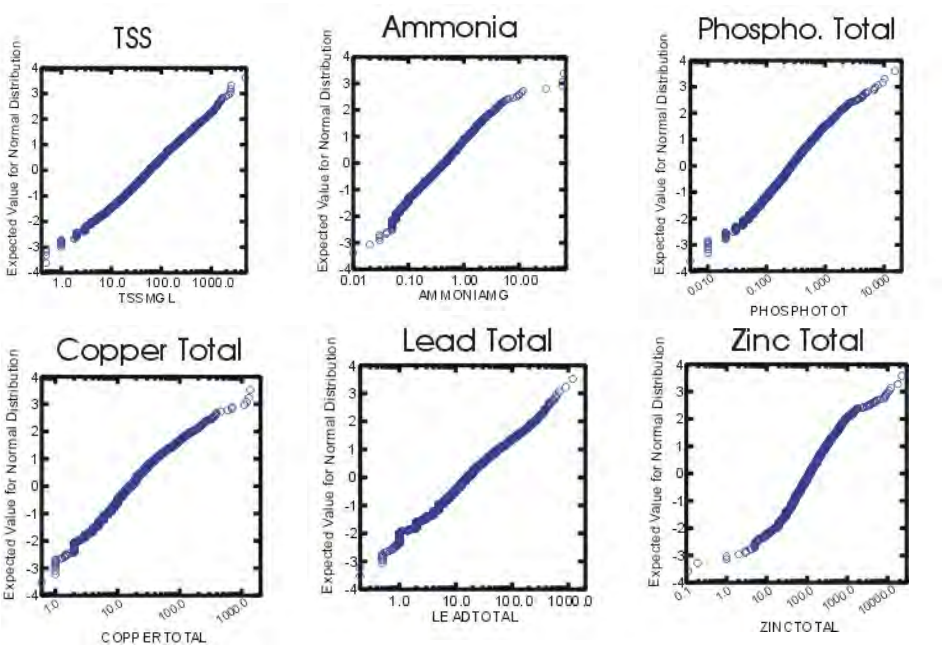

FIGURE 4-2 Lognormal probability plots of stormwater quality data for selected constituents (pooled data from NSQD version 1.1).

Fitting a known distribution is important as it helps indicate the proper statistical tests that may be conducted. Using the *median* EMC value in load calculations, without considering the data variability, will result in smaller mass loads compared to actual monitored conditions. This is due to the medians underrepresenting the larger concentrations that are expected to occur. The use of *average* EMC values will represent the larger values better, although they will still not represent the variability likely to exist. If all of the variability cannot be further explained adequately (such as being affected by rain depth), which would be highly unlikely, then a set of random calculations (such as that obtained using Monte Carlo procedures) reflecting the described probability distribution of the constituents would be the best method to use when calculating loads.

Municipal Monitoring Issues

As described in Chapter 2, typical MS4 monitoring requirements involve sampling during several events per year at the most common land uses in the area. Obviously, a few samples will not result in very useful data due to

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BOX 4-1
Probability Distributions of Stormwater Data

The coefficient of variation (COV) values for many constituents in the NSQD range from unusually low values of about 0.1 (for pH) to highs between 1 and 2. One objective of a data analysis procedure is to categorize the data into separate stratifications, each having small variations in the observed concentrations. The only stratification usually applied is for land use. However, further analyses indicated many differences by geographical area and some differences by season. When separated into appropriate stratifications, the COV values are reduced, ranging between about 0.5 to 1.0. With a reasonable confidence of 95 percent (α= 0.05) and power of 80 percent (β= 0.20), and a suitable allowable error goal of 25 percent, the number of samples needed to characterize these conditions would therefore range from about 25 to 50 (Burton and Pitt, 2002). In a continuing monitoring program (such as the Phase I stormwater National Pollutant Discharge Elimination System [NPDES] permit monitoring effort) characterization data will improve over time as more samples are obtained, even with only a few samples collected each year from each site.

Stormwater managers have generally accepted the assumption of lognormality of stormwater constituent concentrations between the 5th and 95th percentiles. Based on this assumption, it is common to use the log-transformed EMC values to evaluate differences between land-use categories and other characteristics. Statistical inference methods, such as estimation and tests of hypothesis, and analysis of variance, require statistical information about the distribution of the EMC values to evaluate these differences. The use of the log-transformed data usually includes the location and scale parameter, but a lower-bound parameter is usually neglected.

Maestre et al. (2005) conducted statistical tests using NSQD data to evaluate the lognormality assumptions of selected common constituents. It was found in almost all cases that the log-transformed data followed a straight line between the 5th and 95th percentile, as illustrated in Figure 4-3 for total dissolved solids (TDS) in residential areas.

For many statistical tests focusing on the central tendency (such as for determining the concentrations that are to be used for mass balance calculations), this may be a suitable fit. As an example, the model WinSLAMM (Pitt, 1986; Pitt and Voorhees, 1995) uses a Monte Carlo component to describe the likely variability of stormwater source flow pollutant concentrations using either lognormal or normal probability distributions for each constituent. However, if the most extreme values are of importance, such as when dealing with the influence of many non-detectable values on the predicted concentrations, or determining the frequency of observations exceeding a numerical standard, a better description of the extreme values may be important.

The NSQD contains many factors for each sampled event that likely affect the observed concentrations. These include such factors as seasons, geographical zones, and rain intensities. These factors may affect the shape of the probability distribution. The only way to evaluate the required number of samples in each category is by using the power of the test, where power is the probability that the test statistic will lead to a rejection of the null hypothesis (Gibbons and Chakraborti, 2003).

In the NSQD, most of the data were from residential land uses. The Kolmogorov-Smirnov test was used to indicate if the cumulative empirical probability distribution of the residential stormwater constituents can be adequately represented with a lognormal distribution. The number of collected samples was sufficient to detect if the empirical distribu-

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BOX 4-1 Continued

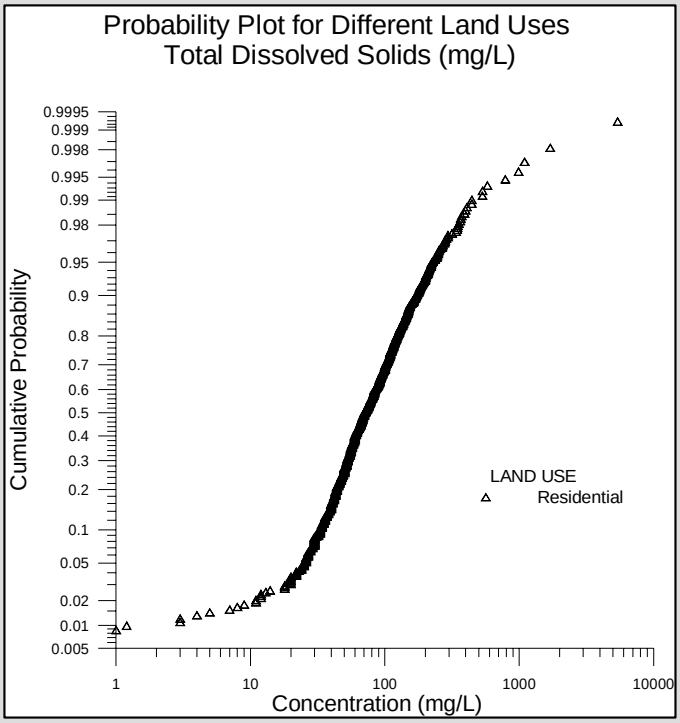

FIGURE 4-3 Probability plot of total dissolved solids in residential land uses (NSQD version 1.1 data).

tion was located inside an interval of width 0.1 above and below the estimated cumulative probability distribution. If the interval was reduced to 0.05, the power varies between 40 and 65 percent. Another factor that must be considered is the importance of relatively small errors in the selected distribution and the problems of false-negative determinations. It may not be practical to collect as many data observations as needed when the distributions are close. Therefore, it is important to understand what types of further statistical and analysis problems may be caused by having fewer samples than optimal. For example, Figure 4-4 (total phosphorus in residential areas) shows that most of the data fall along the straight line (indicating a lognormal fit), with fewer than 10 observations (out of 933) in the tails being outside of the obvious path of the line, or a false-negative rate of about 0.01 (1 percent).

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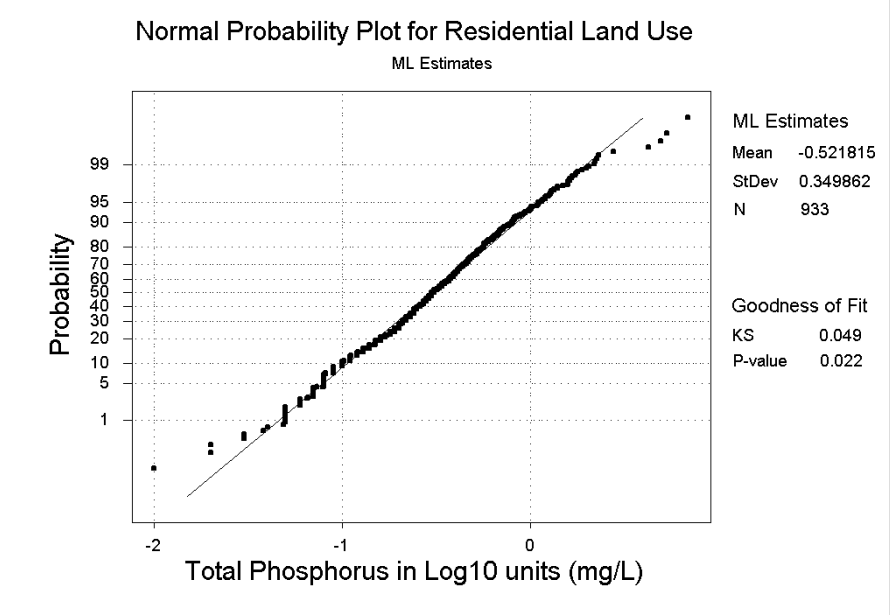

FIGURE 4-4 Normality test for total phosphorus in residential land uses using the NSQD.

Further analyses to compare the constituent concentration distributions to other common probability distributions (normal, lognormal, gamma, and exponential) were also conducted for all land uses by Maestre et al. (2004). Most of the stormwater constituents can be assumed to follow a lognormal distribution with little error. The use of a third parameter in the estimated lognormal distribution may be needed, depending on the number of samples. When the number of samples is large per category (approximately more than 400 samples) the maximum likelihood and the two-parameter lognormal distribution better fit the empirical distribution. For large sample sizes, the L-moments method usually unacceptably truncates the distribution in the lower tail. However, when the sample size is more moderate per category (approximately between 100 and 400 samples), the three-parameter lognormal method, estimated by L-moments, better fits the empirical distribution. When the sample size is small (less than 100 samples, as is common for most stormwater programs), the use of the third parameter does not improve the fit with the empirical distribution and the common two-parameter lognormal distribution produces a better fit than the other two methods. The use of the lognormal distribution also has an advantage over the other distribution types because it can be easily transformed to a normal distribution and the data can then be correctly examined using a wide variety of statistical tests.

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the variability of stormwater characteristics. However, during the period of a five-year permit with three samples per year, about 15 events would be sampled for each land use. While still insufficient for many analyses, this number of data points likely allows the confidence limits to be reasonably calculated for the average conditions. When many sites of the same land use are monitored for a region, substantial data may be collected during a permit cycle. This was the premise of the NSQD where MS4 data were collected for many locations throughout the country. These data were evaluated and various findings made. The following comments are partially based on these analyses, along with additional data sources.

Sampling Technique and Compositing

There are a variety of methods for collecting and compositing stormwater samples that can result in different values for the EMC. The first distinction is the mode of sample collection, either as grab samples or automatic sampling. Obviously, grab sampling is limited by the speed and accuracy of the individuals doing the sampling, and it is personnel intensive. It is for this reason that about 80 percent of the NSQD samples are collected using automatic samplers. Manual sampling has been observed to result in slightly lower TSS concentrations compared to automatic sampling procedures. This may occur, for example, if the manual sampling team arrives after the start of runoff and therefore misses an elevated first flush (if it exists for the site), resulting in reduced EMCs.

A second important concept is how and whether the samples are combined following collection. With *time-based discrete sampling*, **s**amplers (people or machines) are programmed to take an aliquot after a set period of time (usually in the range of every 15 minutes) and each aliquot is put into a separate bottle (usually 1 liter). Each bottle is processed separately, so this method can have high laboratory costs. This is the only method, however, that will characterize the changes in pollutant concentrations during the event. *Time-based composite sampling* refers to samplers being programmed to take an aliquot after a set period of time (as short as every 3 minutes), but then the aliquots are combined into one container prior to analysis (compositing). All parts of the event receive equal weight with this method, but the large number of aliquots can produce a reasonably accurate composite concentration. Finally, *flow-weighted composite sampling* refers to samplers being programmed to collect an aliquot (usually 1 liter) for a set volume of discharge. Thus, more samples are collected during the peak of the hydrograph than toward the trailing edge of the hydrograph. All of the aliquots are composited into one container, so the concentration for the event is weighted by flow.

Most communities calculate their EMC values using flow-weighted composite sample analyses for more accurate mass discharge estimates compared to time-based compositing. This is especially important for areas with a first flush of very short duration, because time-composited samples may overly emphasize

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these higher flows. An automatic sampler with flow-weighted samples, in conjunction with a bed-load sampler, is likely the most accurate sampling method, but only if the sampler can obtain a representative sample at the location (such as sampling at a cascading location, or using an automated depth-integrated sampler) (Clark et al., 2008).

Time- and flow-weighted composite options have been evaluated in residential, commercial, and industrial land uses in EPA Rain Zone 2 and in industrial land uses in EPA Rain Zone 3 for the NSQD data. No significant differences were observed for BOD_5 concentrations using either of the compositing schemes for any of the four categories. TSS and total lead median concentrations in EPA Rain Zone 2 were two to five times higher in concentration when time-based compositing was used instead of flow-based compositing. Nutrients in EPA Rain Zone 2 collected in residential, commercial, and industrial areas showed no significant differences using either compositing method. The only exceptions were for ammonia in residential and commercial land-use areas and total phosphorus in residential areas where time-based composite samples had higher concentrations. Metals were higher when time-based compositing was used in residential and commercial land-use areas. No differences were observed in industrial land-use areas, except for lead. Again, in most cases, mass discharges are of the most importance in order to show compliance with TMDL requirements. Flow-weighted sampling is the most accurate method to obtain these values (assuming sufficient numbers of subsamples are obtained). However, if receiving water effects are associated with short-duration high concentrations, then discrete samples need to be collected and analyzed, with no compositing of the samples during the event. Of course, this is vastly more costly and fewer events are usually monitored if discrete sampling is conducted.

Numbers of Data Observations Needed

The biggest issue associated with most monitoring programs is the number of data points needed. In many cases, insufficient data are collected to address the objectives of the monitoring program with a reasonable amount of confidence and power. Burton and Pitt (2002) present much guidance in determining the amount of data that should be collected. A basic equation that can be used to estimate the number of samples to characterize a set of conditions is as follows:

$$n = [COV(Z_{1-\alpha} + Z_{1-\beta})/(error)]^2$$

where:

n = number of samples needed.

α = false-positive rate ($1-\alpha$ is the degree of confidence; a value of α of 0.05 is usually considered statistically significant, corresponding to a $1-\alpha$ degree

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of confidence of 0.95, or 95%).

β = false-negative rate (1–β is the power; if used, a value of β of 0.2 is common, but it is frequently and improperly ignored, corresponding to a β of 0.5).

$Z_{1-\alpha}$ = Z score (associated with area under a normal curve) corresponding to 1–α; if α is 0.05 (95% degree of confidence), then the corresponding $Z_{1-\alpha}$ score is 1.645 (from standard statistical tables).

$Z_{1-\beta}$ = Z score corresponding to 1–β value; if β is 0.2 (power of 80%), then the corresponding $Z_{1-\beta}$ score is 0.85 (from standard statistical tables); however, if power is ignored and β is 0.5, then the corresponding $Z_{1-\beta}$ score is 0.

error = allowable error, as a fraction of the true value of the mean.

COV = coefficient of variation (sometimes noted as CV), the standard deviation divided by the mean (dataset assumed to be normally distributed).

Figures 4-5 and 4-6 can be used to estimate the sampling effort, based on the expected variability of the constituent being monitored, the allowable error in the calculated mean value, and the associated confidence and power. Figure 4-5 can be used for a single sampling point that is being monitored for basic characterization information, while Figure 4-6 is used for paired sampling when two locations are being compared. Confidence and power are needed to control the likelihood of false negatives and false positives. The sample needs increase dramatically as the difference between datasets becomes small when comparing two conditions with a paired analysis, as shown in Figure 4-6 (above and below an outfall, influent vs. effluent, etc.). Typically, being able to detect a difference of at least about 25 percent (requiring about 50 sample pairs with typical sample variabilities) is a reasonable objective for most stormwater projects. This is especially important when monitoring programs attempt to distinguish test and control conditions associated with SCMs. It is easy to confirm significant differences between influent and effluent conditions at wet detention ponds, as they have relatively high removal rates. Less effective controls are much more difficult to verify, as the sampling program requirements become very expensive.

First-Flush Effects

First flush refers to an assumed elevated load of pollutants discharged in the beginning of a runoff event. The first-flush effect has been observed more often in small catchments than in large catchments (Thompson et al., 1995, cited by WEF and ASCE, 1998). Indeed, in large catchments (>162 ha, 400 acres), the

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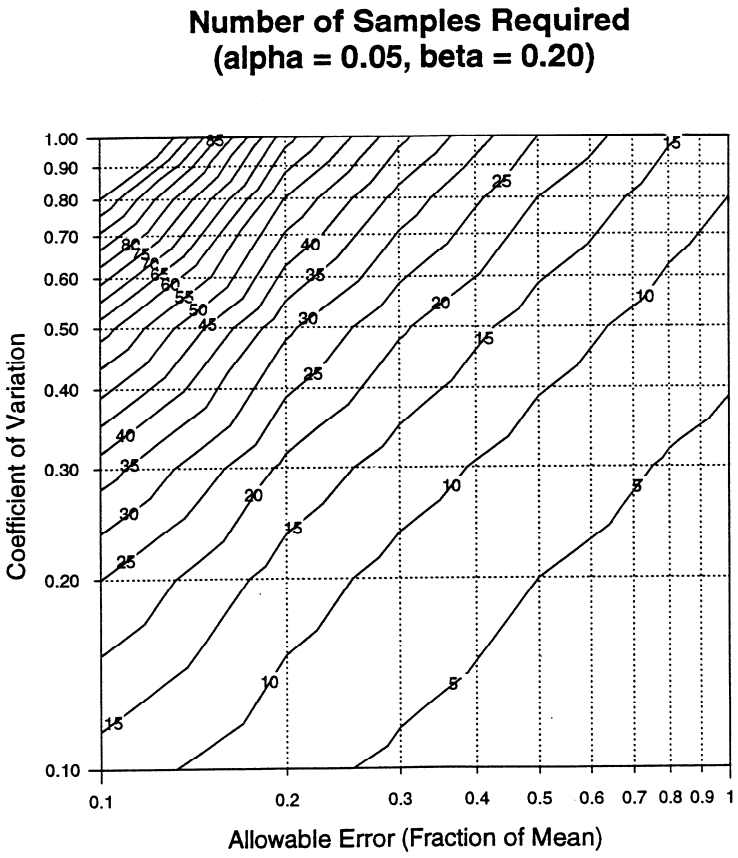

FIGURE 4-5 Number of samples to characterize median (power of 80% and confidence of 95%). SOURCE: Reprinted, with permission from, Burton and Pitt (2002). Copyright 2002 by CRC Press.

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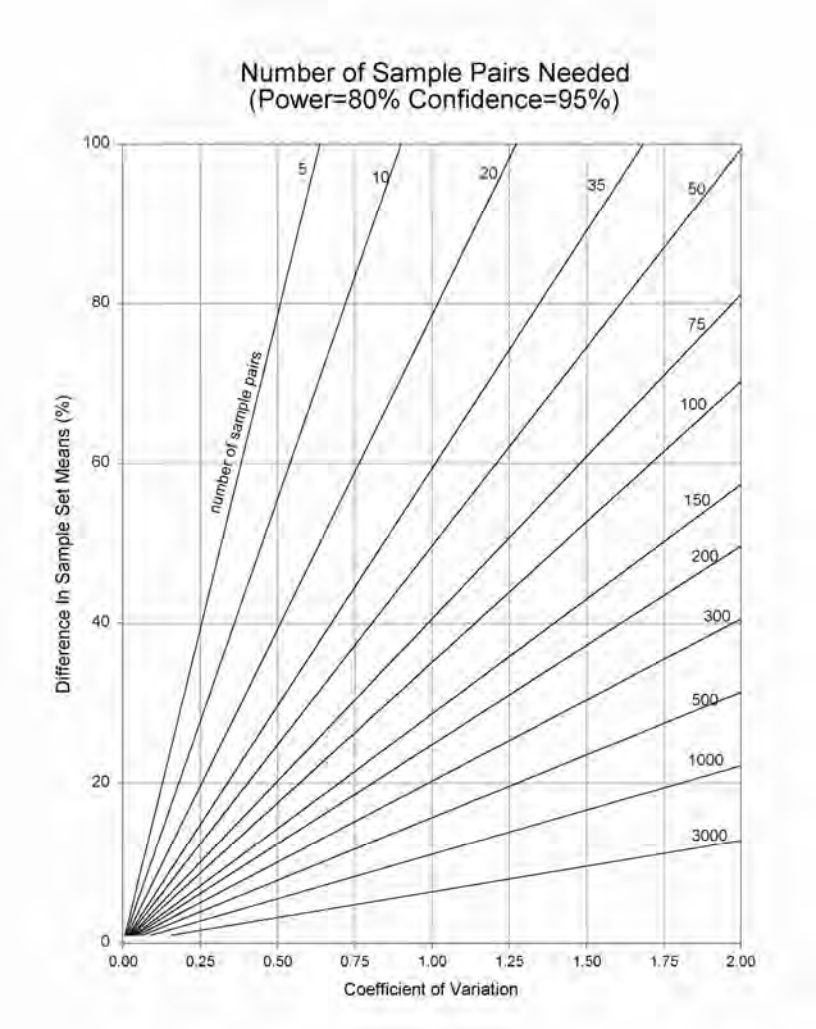

FIGURE 4-6 Number of paired samples needed to distinguish between two sets of observations (power 80% and confidence of 95%). SOURCE: Reprinted, with permission from, Burton and Pitt (2002). Copyright 2002 by CRC Press.

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highest concentrations are usually observed at the times of flow peak (Brown et al., 1995; Soeur et al., 1995). Adams and Papa (2000) and Deletic (1998) both concluded that the presence of a first flush depends on numerous site and rainfall characteristics.

Figure 4-7 is a plot of monitoring data from the Villanova first-flush study (Batroney, 2008) showing the flows, rainfall, TSS concentration, TDS concentration, and TDS and TSS event mean concentrations for the inflow to an infiltration trench. Because of the first-flush effect, a grab sample early in the storm would have over-predicted the TSS event mean concentration of the site, and a later sample would have under-predicted this same value, although for TDS the results would have been similar.

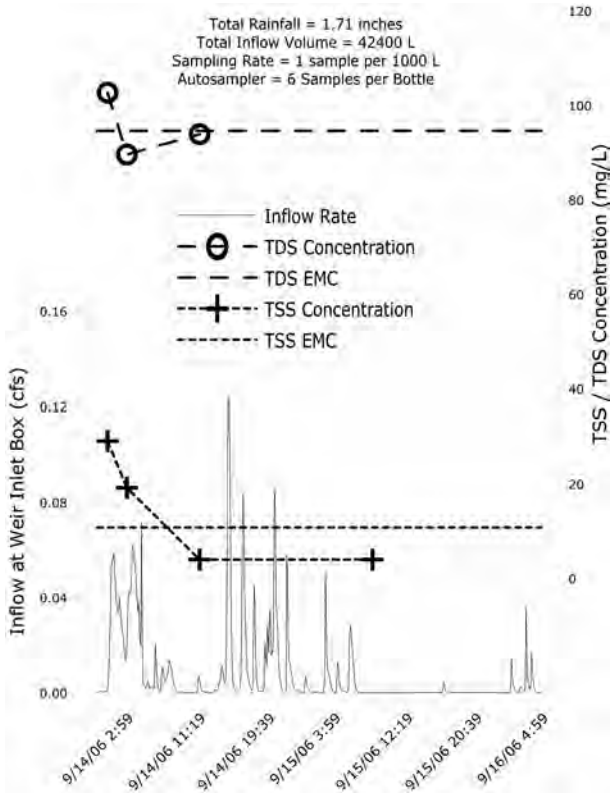

FIGURE 4-7 Villanova first-flush study showing pollutant concentration as a function of inflow rainfall volume. This study collected runoff leaving the top floor of a parking garage. Samples were taken of the runoff in one-quarter-inch increments, up to an inch of rain, and then every inch thereafter. The plot of TSS concentration versus rainfall increment shows a strong first flush for this storm, while the TDS concentration does not. SOURCE: Reprinted, with permission, Batroney (2008). Copyright 2008 by T. Thomas Batroney.

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Figure 4-8 shows data for a short-duration, high-intensity rain in Tuscaloosa, Alabama, that had rain intensities as great a 6 inches per hour for a 10-minute period. The drainage area was a 0.4-ha paved parking lot with some landscaping along the edges. The turbidity plot shows a strong first flush for this event, and the particle size distributions indicate larger particles at the beginning of the event, then becoming smaller as the event progresses, and then larger near the end. Most of the other pollutants analyzed had similar first-flush patterns like the turbidity, with the notable exception of bacteria. Both *E. coli* and enterococci concentrations started off moderately low, but then increased substantially near the end of the rain. Several rains have been monitored at this site so far, and most show a similar pattern with decreasing turbidity and increasing bacteria as the rain continues.

Sample collection conducted for some of the NPDES MS4 Phase I permits required both a grab and a composite sample for each event. A grab sample was to be taken during the first 30 minutes of discharge to capture the first flush, and a flow-weighted composite sample was to be taken for the entire time of discharge (every 15 to 20 minutes for at least three hours or until the event ended). Maestre et al. (2004) examined about 400 paired sets of 30-minute and 3-hour samples from the NSQD, as shown in Table 4-2. Generally, a statistically significant first flush is associated with a median concentration ratio of about 1.4 or greater (the exceptions are where the number of samples in a specific category is much smaller). The largest ratios observed were about 2.5, indicating that for these conditions the first 30-minute flush sample concentrations are about 2.5 times greater than the composite sample concentrations. More of the larger ratios are found for the commercial and institutional land-use categories, where larger paved areas are likely to be found. The smallest ratios are associated with the residential, industrial, and open-space land uses—locations where there may be larger areas of unpaved surfaces.

The data in Table 4-2 were from North Carolina (76.2 percent), Alabama (3.1 percent), Kentucky (13.9 percent), and Kansas (6.7 percent) because most other states' stormwater permits did not require this sampling strategy. The NSQD investigation of first-flush conditions for these data locations indicated that a first-flush effect was not present for all the land-use categories and certainly not for all constituents. Commercial and residential areas were more likely to show this phenomenon, especially if the peak rainfall occurred near the beginning of the event. It is expected that this effect will more likely occur in a watershed with a high level of imperviousness, but even so, the data indicated first flushes for less than 50 percent of the samples for the most impervious areas. This reduced frequency of observed first flushes in areas most likely to have first flushes is probably associated with the varying rain conditions during the different events, including composite samples that did not represent the complete runoff duration.

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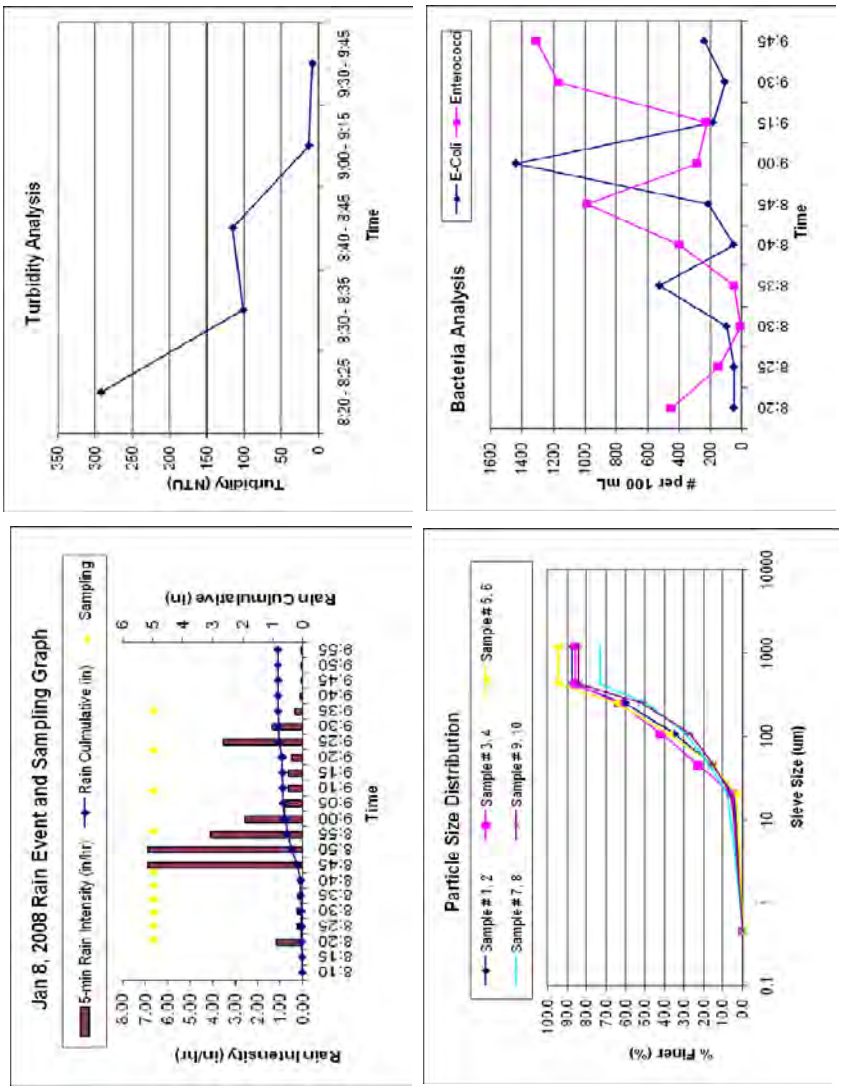

FIGURE 4-8 Pollutant variations during rain period (0.4-ha drainage area, mostly paved parking with small fringe turf area, Tuscaloosa, Alabama). SOURCE: Robert Pitt, University of Alabama.

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TABLE 4-2 Significant First Flush Ratios (First Flush to Composite Median Concentration)

Parameter	Commercial				Industrial				Institutional			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU	11	11	=	1.32			X				X	
COD, mg/L	91	91	≠	2.29	84	84	≠	1.43	18	18	≠	2.73
TSS, mg/L	90	90	≠	1.85	83	83	=	0.97	18	18	≠	2.12
Fecal coliform, col/100mL	12	12	=	0.87			X				X	
TKN, mg/L	93	86	≠	1.71	77	76	≠	1.35			X	
Phosphorus total, mg/L	89	77	≠	1.44	84	71	=	1.42	17	17	=	1.24
Copper, total, µg/L	92	82	≠	1.62	84	76	≠	1.24	18	7	=	0.94
Lead, total, µg/L	89	83	≠	1.65	84	71	≠	1.41	18	13	≠	2.28
Zinc, total, µg/L	90	90	≠	1.93	83	83	≠	1.54	18	18	≠	2.48

Parameter	Open Space				Residential				All Combined			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU			X		12	12	=	1.24	26	26	=	1.26
COD, mg/L	28	28	=	0.67	140	140	≠	1.63	363	363	≠	1.71
TSS, mg/L	32	32	=	0.95	144	144	≠	1.84	372	372	≠	1.60
Fecal coliform, col/100mL			X		10	9	=	0.98	22	21	=	1.21
TKN, mg/L	32	14	=	1.28	131	123	≠	1.65	335	301	≠	1.60
Phosphorus, total, mg/L	32	20	=	1.05	140	128	≠	1.46	363	313	≠	1.45
Copper, total, µg/L	30	22	=	0.78	144	108	≠	1.33	368	295	≠	1.33
Lead, total, µg/L	31	16	=	0.90	140	93	≠	1.48	364	278	≠	1.50
Zinc, total, µg/L	21	21	=	1.25	136	136	≠	1.58	350	350	≠	1.59

Note: n, number of total possible events; sc, number of selected events with detected values; R, result; X, not enough data; =, not enough evidence to conclude that median values are different; ≠, median values are different. "Ratio" is the ratio of the first flush to the full-period sample concentrations.
SOURCE: NSQD, as reported by Maestre et al. (2004).

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Groups of constituents showed different behaviors for different land uses. All the heavy metals evaluated showed higher concentrations at the beginning of the event in the commercial land-use category. Similarly, all the nutrients showed higher initial concentrations in residential land-use areas, except for total nitrogen and orthophosphorus. This phenomenon was not found in the bacterial analyses. None of the land uses showed a higher population of bacteria at the beginning of the event.

The general conclusion from these data is that, in areas having low and generally even-intensity rains, first-flush observations are more common, especially in small and mostly paved areas. As an area increases in size, multiple routing pathways tend to blend the water, and runoff from the more distant locations reaches the outfall later in the event. SCMs located at outfalls in areas having low levels of impervious cover should be selected and sized to treat the complete event, if possible. Preferential treatment of first flushes may only be justified for small impervious areas, but even then, care needs to be taken to prevent undersizing and missing substantial fractions of the event.

Seasonal first flushes refer to larger portions of the annual runoff and pollutant discharges occurring during a short rain season. Seasonal first flushes may be observed in more arid locations where seasonal rainfalls are predominant. As an example, central and southern California can have dry conditions for extended periods, with the initial rains of the season occurring in the late fall. These rains can be quite large and, since they occur after prolonged dry periods, may carry substantial portions of the annual stormwater pollutant load. This is especially pronounced if later winter rains are more mild in intensity and frequent. For these areas, certain types of seasonally applied SCMs may be effective. As an example, extensive street, channel, and inlet cleaning in the late summer and early fall could be used to remove large quantities of debris and leaves from the streets before the first heavy rains occur. Other seasonal maintenance operations benefiting stormwater quality should also be scheduled before these initial rains.

Rain Depth Effects

An issue related to first flushes pertains to the effects of rain depth on stormwater quality. The NSQD contains much rainfall data along with runoff data for most areas of the country. Figure 4-9 contains scatter plots showing concentrations plotted against rain depth for some NSQD data. Although many might assume a correlation between concentrations and rain depth, in fact there are no obvious trends of concentration associated with rain depth. Rainfall energy determines erosion and wash-off of particulates, but sufficient runoff volume is needed to carry the particulate pollutants to the outfalls. Different travel times from different locations in the drainage areas results in these materials arriving at different times, plus periods of high rainfall intensity (that increase pollutant wash-off and movement) occur randomly throughout the storm. The

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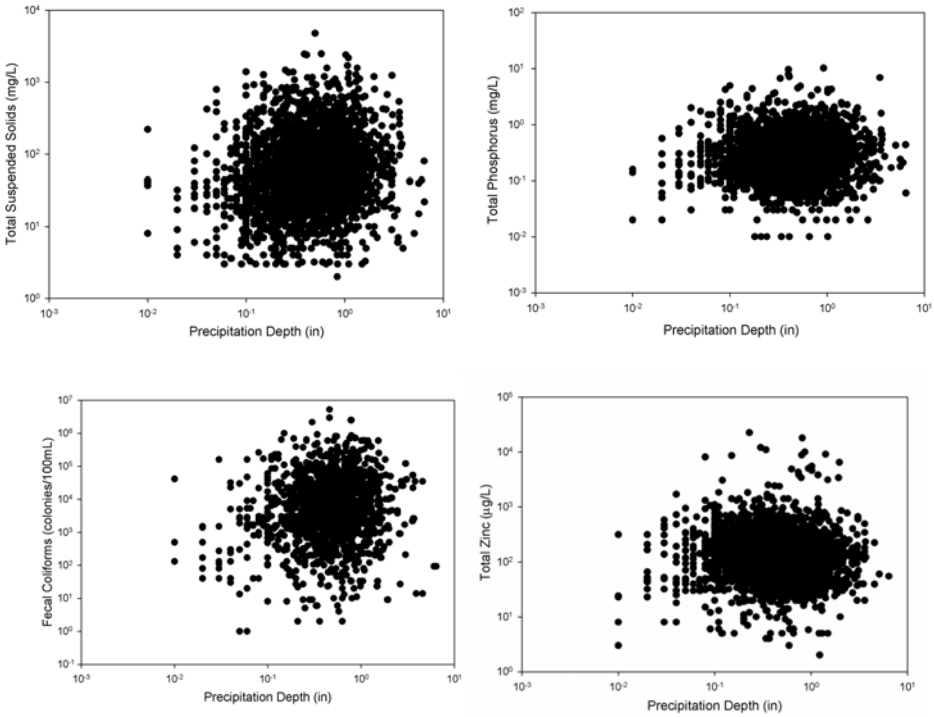

FIGURE 4-9 Examples of scatter plots by precipitation depth. SOURCE: NSQD.

resulting outfall stormwater concentration patterns for a large area having various surfaces is therefore complex and rain depth is just one of the factors involved.

Reported Monitoring Problems

A number of monitoring problems were described in the local Phase I community MS4 annual monitoring reports that were summarized as part of assembling the NSQD. About 58 percent of the communities described monitoring problems. Problems were mostly associated with obtaining reliable data for the targeted events. These problems increased costs because equipment failures had to be corrected and sampling excursions had to be rescheduled. One of the basic sampling requirements was to collect three samples every year for each

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of the land-use stations. These samples were to be collected at least one month apart during storm events having at least 0.1-inch rains, and with at least 72 hours from the previous 0.1-inch storm event. It was also required (when feasible) that the variance in the duration of the event and the total rainfall not exceed the median rainfall for the area. About 47 percent of the communities reported problems meeting these requirements. In many areas of the country, it was difficult to have three storm events per year with these characteristics. Furthermore, the complete range of site conditions needs to be represented in the data-collection effort; focusing only on a narrow range of conditions limits the representativeness of the data.

The second most frequent problem, reported by 26 percent of the communities, concerned backwater tidal influences during sampling, or that the outfall became submerged during the event. In other cases, it was observed that there was flow under the pipe (flowing outside of the pipe, in the backfill material, likely groundwater), or sometimes there was no flow at all. These circumstances all caused contamination of the collected samples, which had to be discarded, and prevented accurate flow monitoring. Greater care is obviously needed when locating sampling locations to eliminate these problems.

About 12 percent of the communities described errors related to malfunctions of the sampling equipment. When reported, the equipment failures were due to incompatibility between the software and the equipment, clogging of the rain gauges, and obstruction in the sampling or bubbler lines. Memory losses in the equipment recording data were also periodically reported. Other reported problems were associated with lighting, false starts of the automatic sampler before the runoff started, and operator error due to misinterpretation of the equipment configuration manual.

The reported problems suggest that the following changes should be made. First, the rain gauges need to be placed close to the monitored watersheds. Large watersheds cannot be represented with a single rain gauge at the monitoring station. In all cases, a standard rain gauge needs to supplement a tipping bucket rain gauge, and at least three rain gauges should be used in the research watersheds. Second, flow-monitoring instrumentation also needs to be used at all water quality monitoring stations. The lack of flow data greatly hinders the value of the chemical data. Third, monitoring needs to cover the complete storm duration. Automatic samplers need to be properly programmed and maintained to handle very short to very long events. It is unlikely that manual samplers were able to initiate sampling near the beginning of the events, unless they were deployed in anticipation of an event later in the day. A more cost-effective and reliable option would be to have semi-permanent monitoring stations at the various locations with sampling equipment installed in anticipation of a monitored event. Most monitoring agencies operated three to five land-use stations at one time. This number of samplers, and flow equipment, could have been deployed in anticipation of an acceptable event and would not need to be continuously installed in the field at all sampling locations.

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Non-Detected Analyses

Left-censored data involve observations that are reported as below the limits of detection, whereas right-censored data involve above-range observations. Unfortunately, many important stormwater measurements (such as for filtered heavy metals) have large fractions of undetected values. These incomplete data greatly hinder many statistical tests. To estimate the problems associated with censored values, it is important to identify the probability distributions of the data in the dataset and the level of censoring. As discussed previously, most of the constituents in the NSQD follow a lognormal distribution. When the frequencies of the censored observations were lower than 5 percent, the means, standard deviations, and COVs were almost identical to the values obtained when the censored observations were replaced by half of the detection limit. As the percentage of nondetected values increases, replacing the censored observation by half of the detection limit instead of estimating them using Cohen's maximum likelihood method produced lower means and larger standard deviations. Replacing the censored observations by half of the detection limit is not recommended for levels of censoring larger than 15 percent. Because the Cohen method uses the detected observations to estimate the nondetected values, it is not very accurate, and therefore not recommended, when the percentage of censored observations is larger than 40 percent (Burton and Pitt, 2002). In this case, summaries should only be presented for the detected observations, with clear notations stating the level of nondetected observations.

The best method to eliminate problems associated with left-censored data is to use an appropriate analytical method. By keeping the nondetectable level below 5 percent, there are many fewer statistical analysis problems and the value of the datasets can be fully realized. Table 4-3 summarizes the recommended minimum detection limits for various stormwater constituents to obtain manageable nondetection frequencies (< 5 percent), based on the NSQD data observations. Some of the open-space stormwater measurements (lead, and oil and grease, for example) would likely have greater than 5 percent nondetections, even with the detection limits shown. The detection limits for filtered heavy metals should also be substantially less than shown on this table.

Seasonal Effects

Another factor that some believe may affect stormwater quality is the season when the sample was obtained. If the few samples collected for a single site were all collected in the same season, the results may not be representative of the whole year. The NPDES sampling protocols were designed to minimize this effect by requiring the three samples per year to be separated by at least one month. The few samples still could be collected within a single season, but not within the same week. Seasonal variations for residential fecal coliform data are shown in Figure 4-10 for NSQD data for all residential areas. These data were

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TABLE 4-3 Suggested Analytical Detection Limits for Stormwater Monitoring Programs to Obtain Less Than 5 Percent Nondetections

Parameter	Residential, Commercial, Industrial, Freeway		Open Space	
Conductivity	20	μS/cm	20	μS/cm
Hardness	10	mg/L	10	mg/L
Oil and grease	0.5	mg/L	0.5	mg/L
TDS	10	mg/L	10	mg/L
TSS	5	mg/L	1	mg/L
BOD_5	2	mg/L	1	mg/L
COD	10	mg/L	5	mg/L
Ammonia	0.05	mg/L	0.01	mg/L
$NO_2 + NO_3$	0.1	mg/L	0.05	mg/L
TKN	0.2	mg/L	0.2	mg/L
Dissolved P	0.02	mg/L	0.01	mg/L
Total P	0.05	mg/L	0.02	mg/L
Total Cu	2	μg/L	2	μg/L
Total Pb	3	μg/L (residential μg/L)	1	μg/L
Total Ni	2	μg/L	1	μg/L
Total Zn	20	μg/L (residential 10 μg/L)	5	μg/L

SOURCE: Maestre and Pitt (2005).

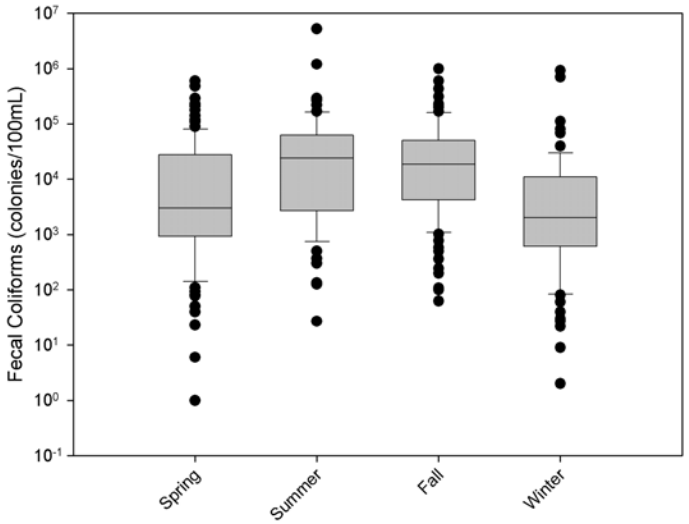

FIGURE 4-10 Fecal coliform concentrations in stormwater by season. SOURCE: NSQD.

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the only significant differences in concentration by season for any constituent measured. The bacteria levels are lowest during the winter season and highest during the summer and fall (a similar conclusion was obtained during the NURP data evaluations).

Recommendations for MS4 Monitoring Activities

The NSQD is an important tool for the analysis of stormwater discharges at outfalls. About a fourth of the total existing information from the NPDES Phase I program is included in the database. Most of the statistical analyses in this research were performed for residential, commercial, and industrial land uses in EPA Rain Zone 2 (the area of emphasis according to the terms of the EPA-funded research). Many more data are available from other stormwater permit holders that are not included in this database. Acquiring these additional data for inclusion in the NSQD is a recommended and cost-effective activity and should be accomplished as additional data are also being obtained from ongoing monitoring projects.

The use of automatic samplers, coupled with bed-load samplers, is preferred over manual sampling procedures. In addition, flow monitoring and on-site rainfall monitoring need to be included as part of all stormwater characterization monitoring. The additional information associated with flow and rainfall data will greatly enhance the usefulness of the much more expensive water quality monitoring. Flow monitoring must also be correctly conducted, with adequate verification and correct base-flow subtraction methods applied. A related issue frequently mentioned by the monitoring agencies is the lack of on-site precipitation information for many of the sites. Using regional rainfall data from locations distant from the monitoring location is likely to be a major source of error when rainfall factors are being investigated.

Many of the stormwater permits only required monitoring during the first three hours of the rain event. This may have influenced the EMCs if the rain event continued much beyond this time. Flow-weighted composite monitoring should continue for the complete rain duration. Monitoring only three events per year from each monitoring location requires many years before statistically adequate numbers of observations are obtained. In addition, it is much more difficult to ensure that such a small fraction of the total number of annual events is representative. Also, there is minimal value in obtaining continued data from an area after sufficient information is obtained. It is recommended that a more concentrated monitoring program be conducted for a two- or three-year period, with a total of about 30 events monitored for each site, covering a wide range of rain conditions. Periodic checks can be made in future years, such as repeating concentrated monitoring every 10 years or so (and for only 15 events during the follow-up surveys).

Finally, better watershed area descriptions, especially accurate drainage-area delineations, are needed for all monitored sites. While the data contained in

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the NSQD are extremely useful, future monitoring information obtained as part of the stormwater permit program would be greatly enhanced with these additional considerations.

MONITORING OF INDUSTRIES INCLUDING CONSTRUCTION

The various industrial stormwater monitoring requirements of the EPA Stormwater Program have come under considerable scrutiny since the program's inception. Input to the committee at its first meeting conveyed the strong sense that monitoring as it is being done is nearly useless, is burdensome, and produces data that are not being utilized. The requirements consist of the following. All industrial sectors covered under the Multi-Sector General Permit (MSGP) must conduct visual monitoring four times a year. This visual monitoring is performed by collecting a grab sample within the first hour of stormwater discharge and observing its characteristics qualitatively (except for construction activities—see below). A subset of MSGP industries are required to perform analytical monitoring for benchmark pollutant parameters (see Table 2-5) four times in year 2 of permit coverage and again in year 4 if benchmarks are exceeded in year 2. A benchmark sample is collected as a grab sample within the first hour of stormwater discharge after a rainfall event of 0.1 inch or greater and with an interceding dry period of at least 72 hours. An even smaller subset of MSGP industries that are subject to numerical effluent guidelines under 40 C.F.R. must, in addition, collect grab samples of their stormwater discharge after every discharge event and analyze it for specific pollutant parameters as specified in the effluent guidelines (see Table 2-6). There is no monitoring requirement for stormwater discharges from construction activity in the Construction General Permit. There is only an elective requirement that the construction site be visually inspected within 24 hours after the end of a storm event that is 0.5 inch or greater, if inspections are not performed weekly.

EPA selected the benchmark analytical parameters for industry subsectors to monitor using data submitted by industrial groups in 1993 as part of their group applications. The industrial groups were required to sample a minimum of 10 percent of facilities within an industry group for pH, TSS, BOD_5, oil and grease, COD, TKN, nitrate plus nitrite nitrogen, and total phosphorous. Each sampling facility within a group collected a minimum of one grab sample within the first 30 minutes of discharge and one flow-weighted composite sample. Other nonconventional pollutants such as fecal coliform bacteria, iron, and cobalt were analyzed only if the industry group expected it to be present. Similarly, toxic pollutants such as lead, copper, and zinc were not sampled but rather self-identified only if expected to be present in the stormwater discharge. As a result of the self-directed nature of these exercises, the data submitted with the group applications were often incomplete, inconsistent, and not representative of the potential risk posed by the stormwater discharge to human health and aquatic

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life. EPA has not conducted or funded independent investigations and has relied solely on the data submitted by industry groups to determine which pollutant parameters are appropriate for the analytical monitoring of an industry subsector. Thus, there are glaring deficiencies; for example, the only benchmark parameter for asphalt paving and roofing materials is TSS, even though current science shows that the most harmful pollutants in stormwater discharges from the asphalt manufacturing industry are polycyclic aromatic hydrocarbons (compare Table 2-5 with Mahler et al., 2005).

Aside from the suitability of benchmark parameters is the fact the too few samples are collected to sufficiently characterize the variability of pollutant concentrations associated with industrial facilities within a sector. This is discussed in detail in Box 4-2, which describes one of the few efforts to collect and analyze data from the benchmark monitoring of industries done in Southern California. EPA has not requested a nationwide effort to compile these data, as was done for the MS4 program, although this could potentially lead to average effluent concentrations by industrial sector that could be used for a variety of purposes, including more considerate regulations. Finally, the compliance monitoring that is presently being conducted under the MSGP is of limited usefulness because it is being done to comply with effluent guidelines that have not been updated to reflect the best available technology relevant to pollutants of most concern. All of these factors have led to an industrial stormwater monitoring program that is not very useful for the purposes of reducing stormwater pollution from industries or informing operators on which harmful pollutants to expect from their sites.

Industrial-Area Monitoring Issues

Monitoring at industrial sites has some unique issues that must be overcome. The most important aspect for any monitoring program is understanding and specifying the objectives of the monitoring program and developing and following a detained experimental design to allow these objectives to be met. The following discussion is organized around the reasons why monitoring at industrial sites may be conducted.

Regional Monitoring of Many Facilities

An important monitoring objective would be regional monitoring to calibrate and verify stormwater quality models, to randomly verify compliance at facilities not normally requiring monitoring, and to establish benchmarks for compliance. As shown in Box 4-2, haphazard monitoring throughout an area would require a very large effort, and would still likely result in large errors in the expected data. It is recommended that a regional stormwater authority coordinate regional monitoring as part of the MS4 monitoring requirements, possibly

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BOX 4-2
The Plight of Industrial Stormwater Data

Unlike the data collected by municipalities and stored in the NSQD, the benchmark monitoring data collected by permitted industries are not compiled or analyzed on a national basis. However, there has been at least one attempt to compile these data on a more local basis. California required that industrial facilities submit their benchmark monitoring data over a nine-year period, and it was subsequently analyzed by Michael Stenstrom and colleagues at UCLA (Stenstrom and Lee, 2005; Lee et al., 2007). The collected data were for such parameters as pH, turbidity, specific conductance, oil and grease (or total organic carbon), and several metals. There are more than 6,000 industries covered under the California general permit, each of which was to have collected two grab samples per year for a limited number of parameters. Whether these data were collected each year and for each industry was highly variable.

The analysis of the data from Los Angeles and Ventura counties revealed that stormwater monitoring data are not similar to the types of data that the environmental engineering field is used to collecting, in particular wastewater data. Indeed, as shown in Figure 4-11, stormwater data are many orders of magnitude more variable than drinking water and wastewater data. The coefficients of variation for municipal and industrial stormwater were almost two orders of magnitude higher than for drinking water and wastewater, with the industrial stormwater data being particularly variable. This variability comes from various sources, including intrinsic variability given the episodic nature of storm events, analytical methods that are more variable when applied to stormwater, and sampling technique problems and error.

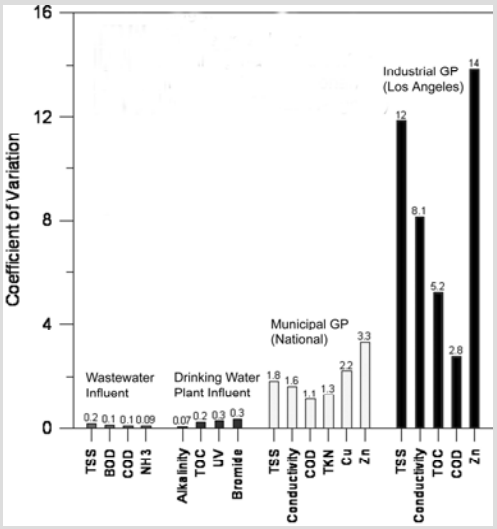

FIGURE 4-11 A comparison of data from four sources: wastewater influent, drinking water plant effluent, municipal stormwater, and industrial stormwater. SOURCE: Reprinted, with permission, from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

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BOX 4-2 Continued

This enormous variability means that it is extremely difficult to make meaningful statements. For example, it was impossible, using different analyses, to correlate certain chemical pollutants with certain industries. Furthermore, although the data revealed that there are exceedances of benchmark values for certain parameters (Al, Cu, Fe, Pb, and Zn in particular), the data are not of sufficient quantity or quality to identify problem polluters. Finally, there were also large numbers of outliers (that is, samples whose concentrations were well above the 75th percentile range).

Because of these large coefficients of variation, greater numbers of samples are needed to be able to say there is a significant difference between samples. As shown in Figure 4-12 using COD and a 50 percent difference in means as an example, one would need six data points to tell the difference between two wastewater influents, 80 data points if one had municipal stormwater data, and around 1,000 data points for industrial stormwater. These numbers obviously eclipse what is required under all states' MSGPs.

For drinking water treatment, monitoring is done to ensure the quality of the product, while for wastewater, there is a permit that requires the plant to meet a specific quality of water. Unlike these other areas of water resources, there are few incentives that might compel an industry to increase its frequency of stormwater monitoring. As a result, industries are less invested in the process and rarely have the expertise needed to carry out self-monitoring.

Permitted industries are not required to sample flow. However, Stenstrom and colleagues used Los Angeles rainfall data (see Figure 4-13) as a surrogate for flow and demonstrated that there is a seasonal first-flush phenomenon occurring in early fall. That is, samples taken after a prolonged dry spell will have higher pollutant concentrations. There are always high concentrations of contaminants during the first rainfall because contaminants have had time to accumulate since the previous rainfall. This is important because EPA asks the industrial permittees to collect data from the first rainfall, such that they may end up overestimating the mass emissions for the year. Furthermore, it shows that numeric limits for grab samples would be risky because the measured data are highly affected by the timing of the storm.

The controversy about numeric limits for industrial stormwater dischargers has existed for more than ten years in California. A recent expert panel concluded that in some cases, numeric limits are appropriate (for construction, but not for municipalities). Stenstrom's recommendations are that industrial monitoring should be either ended or upgraded (for competent industries). If upgraded, it should include more types of monitored parameters, a sampling method with a lower coefficient of variation, real-time monitoring as opposed to grab samples, more quality assurance/quality control, and web-based reporting. A fee-based program with a subset of randomly selected industries may be better than requiring every industry to sample. Stenstrom and Lee (2005) suggest who might do this monitoring if the industry does not have the necessary trained personnel. There is concern that the California water boards are too understaffed to administer such programs and respond to high emitters.

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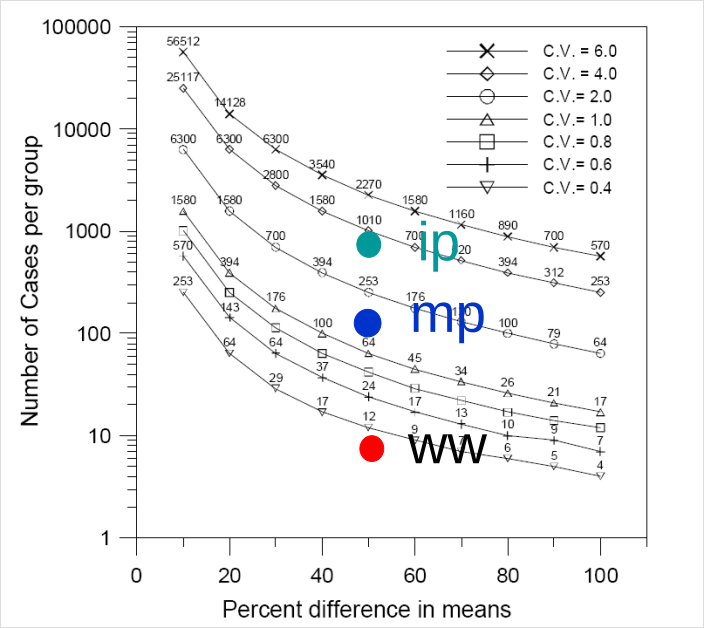

FIGURE 4-12 Number of cases needed to detect a certain percentage difference in the means, using COD as an example. SOURCE: Reprinted, with permission, from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

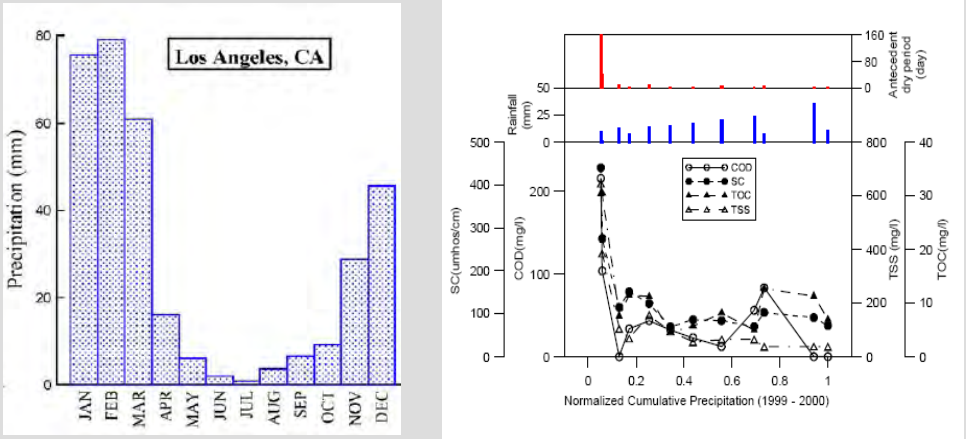

FIGURE 4-13 Annual precipitation in Los Angeles (left) and seasonal first flushes of various contaminants (right). SOURCE: Reprinted, with permission, from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

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even at the state level covering several Phase I municipalities. A coordinated effort would be most cost-effective with the results compiled for a specific objective. The general steps in this effort would include the following.

(1) Compiling available regional stormwater quality data and comparing the available data to the needs (such as calibration of a regional model; verifying compliance of facilities not requiring monitoring; and establishing regional benchmarks). This may include expanding the NSQD for the region to include all of the collected data, plus examination of data collected as part of other specialized monitoring activities. These objectives will result in different data needs, so it is critical that the uses of the data are identified before sampling plans are established.

(2) Identifying monitoring opportunities as part of other on-going activities that can be expanded to also meet data gaps for these specific objectives. It is important to understand the time frame for the monitoring and ensure that it will meet the needs. As an example, current NPDES stormwater monitoring only requires a few events to be sampled per year at a facility. It may take many years before sufficient data are obtained unless the monitoring effort is accelerated.

(3) Preparing an experimental design that identifies the magnitude of the needed data, considering the allowable errors in the results, and carrying out the sampling program. Different types of data may have varying data quality objectives, depending on their use. It may be possible to truncate some of the monitoring when a sufficient understanding is obtained.

A regionally calibrated and verified model can be used to review development plans and proposed SCMs for new facilities. When suitably integrated with receiving-water modeling tools, a stormwater model can also be used to develop discharge objectives and numeric discharge limits that are expected to meet regulatory requirements. Eventually, it may be possible to couple watershed stormwater models with regional receiving water assessments and beneficial use studies. Haphazard monitoring of a few events each year will be very difficult to correlate with regional receiving water objectives, while a calibrated and verified watershed model, along with receiving water assessments, will result in a much more useful tool and understanding of the local problems.

Regional monitoring can also be targeted to categories of industries that were previously determined to be of low priority. This monitoring activity would randomly target a specific number of these facilities for monitoring to verify the assumption that they are of low priority and are still carrying out the minimum management practices. This activity would also quantify the discharges from these facilities and the performance of the minimum controls. If the discharges are excessive when compared to the initial assumptions, or the management practices being used are not adequate, then corrective actions would be instigated. A single category of specific industries could be selected for any one year, and a team from the regional stormwater management author-

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ity could randomly select and monitor a subset of these facilities. An efficient experimental design would need to be developed based on expected conditions, but it is expected that from 10 to 15 such facilities would be monitored for at least a year in a large metropolitan area that has a Phase I stormwater permit, or even state-wide.

Regional monitoring is also necessary to more accurately establish benchmarks for numeric permits. Geographical location, along with land use, is normally an important factor affecting stormwater quality. Receiving water impacts and desired beneficial uses also vary greatly for different locations. It is therefore obvious that compliance benchmarks also be established that consider these regional differences. This could be a single statewide effort if the state agency has the permit authority and if the state has minimal receiving water and stormwater variations. However, in most cases, significant variations occur throughout the state and separate monitoring activities would be needed for each region. In the simplest case, probability distributions of stormwater discharge quality can be developed for different discharge categories and the benchmarks would be associated with a specific probability value. In some cases, an overall distribution may be appropriate, and only the sites having concentrations greater than the benchmark value would need to have additional treatment. In all cases, a basic level of stormwater management should be expected for all sites, but the benchmark values would identify sites where additional controls are necessary. The random monitoring of sites not requiring extensive monitoring could be used to identify and adjust the basic levels of control needed for all categories of stormwater dischargers.

Identification of Critical Source Areas Associated with Specific Industrial Operations

The objective of this monitoring activity would be to identify and characterize critical source areas for specific industries of concern. If critical source areas can be identified, targeted control or treatment can be much more effective than relying only on outfall monitoring. Many of the treatment strategies for industrial sites involve pollution prevention, ranging from covering material or product storage areas to coating galvanized metal. Other treatment strategies involve the use of highly effective treatment devices targeting a small area, such as filters used to treat zinc in roof runoff or lamella plate separators for pretreatment of storage yard runoff before wet pond treatment. Knowledge of the characteristics of the runoff from the different areas at a facility is needed in order to select and design the appropriate treatment methods.

Box 4-3 is a case study of one such group monitoring effort—for a segment of the telecommunications industry targeting a specific maintenance practice. Instead of having each telecommunication company throughout the country conduct a detailed monitoring program for individual stormwater permits associated with maintenance efforts, many of the companies joined together under an

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BOX 4-3
Monitoring to Support a General Stormwater Group Permit Application for the Telecommunications Industry

This monitoring program was conducted to support a group permit application for the telecommunications industry, specifically to cover maintenance operations associated with pumping water out of communications manholes that is then discharged into the storm drainage system. Under federal and state environmental statues, the generator (owner or operator) is responsible for determining if the discharged water needs treatment. The work performed under this project covered characterization, prevention, and treatment methods of water found in manholes.

The objective of this project was to develop a test method to quickly evaluate water in manholes and then to recommend on-site treatment and preventative methods. To meet the telecommunication industry needs, the evaluating tests of water found in manholes need to be simple, quick, inexpensive, field applicable, and accurate indicators of contaminated conditions. The on-site treatment methods must be cost-effective and quickly reduce the concentrations of the contaminant of concern to acceptable levels before the water from manholes is discharged, to result in a safe environment for workers.

A sampling effort was conducted by Pitt et al. (1998) to characterize the quality of the water and sediment found in manholes. More than 700 water samples and 300 sediment samples were analyzed over a three-year period, representing major land-use, age, season, and geographical factors from throughout the United States. The samples were analyzed for a wide range of common and toxic constituents. The statistical procedures identified specific relationships between these main factor categories and other manhole characteristics. Part of the project was to evaluate many field analytical methods. Finally, research was also conducted to examine possible water treatment methods for water being pumped from telecommunication manholes.

Summary of Sampling Effort and Strategy

The objective of the monitoring program was to characterize telecommunication manhole water and sediment. Important variables affecting the quality of these materials were also determined. A stratified random sampling design was followed, with the data organized in a full 2^4 factorial design, with repeated sampling of the same manholes for each season. The goal for the minimum number of samples per strata was ten. This sampling effort enabled the determination of errors associated with the results, which was expected to be less than 25 percent. In addition, this level of effort enabled comparison tests to be made outside of the factorial design. Table 4-4 lists the constituents that were evaluated for each of the sample types.

The immense amount of data collected during this project and the adherence to the original experimental design enabled a comprehensive statistical evaluation of the data. Several steps in data analysis were performed, including:

- exploratory data analyses (mainly probability plots and grouped box plots),
- simple correlation analyses (mainly Pearson correlation matrices and associated scatter plots),
- complex correlation analyses (mainly cluster and principal component analyses, plus Kurskal-Wallis comparison tests), and

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• model building (based on complete 2^4 factorial analyses of the most important factors).

The toxicity screening tests (using the Azur Microtox® method) conducted on both unfiltered and filtered water samples from telecommunication manholes indicated a wide range of toxicity, with no obvious trends for season, land use, or age. About 60 percent of the samples were not considered toxic (less than an I25 light reduction of 20 percent, the light reduction associated with phosphorescent bacteria after a 25-minute exposure to undiluted samples), about 20 percent were considered moderately toxic, while about 10 percent were considered toxic (light reductions of greater than 40 percent), and 10 percent were considered highly toxic (light reductions of greater than 60 percent). Surprisingly, samples from residential areas generally had greater toxicities than samples from commercial and industrial areas. Samples from newer areas were also more toxic than those from older areas. Further statistical tests of the data indicated that the high toxicity levels were likely associated with periodic high concentrations of salt (in areas using de-icing salt), heavy metals (especially filterable zinc, with high values found in most areas), and pesticides (associated with newer residential areas).

TABLE 4-4 Constituents Examined in Water and Sediment from Telecommunication Manholes

Constituent	Unfiltered Water	Filtered Water	Sediment
Solids, volatile solids, COD, Cu, Pb, and Zn	X	X	X
Turbidity, color, and toxicity (Microtox screening method)	X	X	
pH, conductivity, hardness, phosphate, nitrate, ammonia, boron, fluoride, potassium, and detergents	X		
Odor, color, and texture			X
E. coli, enterococci, particle size, and chromium	Selected		
Metal scan (ICP)			Selected
PAHs, phenols (GC/MSD), and pesticides	X	Selected	Selected

SOURCE: Modified from Pitt et al. (1998).

Concentrations of copper, lead, and zinc were evaluated in almost all of the water samples, and some filtered samples were also analyzed for chromium. From 470 to 548 samples (75 to 100 percent of all unfiltered samples analyzed) had detectable concentrations of these metals. Filterable lead concentrations in the water were as high as 160 μg/L, while total lead concentrations were as high as 810 μg/L. Zinc values in filtered and unfiltered samples were as high as about 3,500 μg/L. Some of the copper concentrations were also high in both filtered and unfiltered samples (as high as 1,400 μg/L). Chromium concentrations as high as 45 μg/L were also detected.

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BOX 4-3 Continued

About 300 sediment samples were analyzed and reviewed for heavy metals. An ICP/MS was used to obtain a broad range of metals with good detection limits. The following list shows the median observed concentrations for some of the constituents found in the sediments (expressed as milligrams of the constituent per kilogram of dry sediment):

Aluminum	14,000 mg/kg
COD	85,000 mg/kg
Chromium	<10 mg/kg
Copper	100 mg/kg
Lead	200 mg/kg
Strontium	35 mg/kg
Zinc	1,330 mg/kg

Geographical area had the largest effect on the data observations, while land use, season, and age influenced many fewer parameters. The most obvious relationship was found for high dissolved solids and conductivity associated with winter samples from snowmelt areas. The high winter concentrations slowly decreased with time, with the lowest concentrations noted in the fall. Another important observation was the common association between zinc and toxicity. Residential-area samples generally had larger zinc concentrations than the samples from commercial and industrial areas. Samples from the newest areas also had higher zinc concentrations compared to samples from older areas. No overall patterns were observed for zinc concentrations in sediment samples obtained from manholes. Other constituents (especially nutrients and pesticides) were also found to have higher concentrations in water collected from manholes in newer residential areas. Very few organic toxicants were found in the water samples, but sediment sample organic toxicant concentrations appeared to be well correlated to sediment texture and color. About 10 to 25 percent of the sediment samples had relatively large concentrations of organics. Bacteria analyses indicated some relatively high bacteria counts in a small percentage of the samples. Bacteria were found in lower amounts during sampling periods that were extremely hot or extremely cold. Pacific Northwest samples also had the lowest bacteria counts.

The data were used to develop and test predictive equations based on site conditions. These models were shown to be valid for most of the data, but the highest concentrations were not well predicted. Therefore, special comparisons of many site conditions were made for the manholes having water with the highest concentrations of critical constituents for comparison to the other locations. It was interesting to note that about half of the problem manholes were repeated samples from the same sites (after complete pumping), but at different seasons, indicating continuous problems and not discrete incidents. In addition, the problem manholes were found for all areas of the country and for most rain conditions. Water clarity and color, along with sediment texture, were found to be significant factors associated with the high concentrations of other constituents, while land use was also noted as a significant factor. These factors can be used to help identify problem manholes, but the rates of false positives and false negatives were found to be high. Therefore, these screening criteria can be used to identify more likely problematic manholes, but other methods (such as confirmation chemical analyses) are also needed to identify those that could not be identified using these simpler methods.

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BOX 4-3 Continued

The field analytical test methods worked reasonably well, but had much higher detection limits than advertised, limiting their usefulness. Due to the complexity and time needs for many of these on-site analyses, it is usually more effective to analyze samples at a central facility. For scheduled maintenance operations, a crew could arrive at the site before the maintenance time to collect samples and have them analyzed before the maintenance crew arrives. For emergency repairs, it is possible to pump the collected water into a tank truck for later analyses, treatment, and disposal.

The treatment scenario developed and tested is relatively rapid and cheap and can be used for all operations, irrespective of screening analyses. Chemical addition (using ferric chloride) to the standing water in the manhole was found to reduce problematic levels of almost all constituents to low levels. Slow pumping from the water surface over about a 15- to 30-minute period, with the discharged water then treated in 20-µm cartridge filters, allows the manhole to be entered and the repairs made relatively rapidly, with the water safely discharged. The remaining several inches of water in the bottom of the manhole, along with the sediment, can be removed at a later time for proper disposal.

SOURCE: Pitt et al. (1998).

industrial trade group to coordinate the monitoring and to apply for a group permit. This was a significant effort that was conducted over several years and involved the participation of many regional facilities throughout the nation. This coordinated effort spread the cost over these different participants, and also allowed significant amounts of data to be collected, control practices to be evaluated, and the development of screening methods that allow emergency maintenance operations of the telecommunication system to proceed in a timely manner. The experimental design of this monitoring program allowed an efficient examination of factors affecting stormwater discharges from these operations. This enabled the efficient implementation of effective control programs that targeted specific site and operational characteristics. Although the total cost for this monitoring program was high, it was much less costly than if each individual company had conducted their own monitoring. In addition, this group effort resulted in much more useful information for the industry as a whole.

Outfall Monitoring at a Single Industrial Facility for Permit Compliance and to Demonstrate Effectiveness of Control Practices

Sampling at an individual facility results in outfall data that can be compared to pre-control conditions and numeric standards. There are many guidance documents and reports available describing how to monitor stormwater at an outfall. Two comprehensive sources that describe stormwater monitoring procedures include the handbook written by Burton and Pitt (2002) and a recent guidance report prepared by Shaver et al. (2007). There are a number of basic

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components that need to be included for an outfall characterization monitoring effort, many which have been described in this report. These include the following:

- rainfall monitoring in the drainage area (rate and depth, at least at two locations).
- flow monitoring at the outfall (calibrated with known flow or using dye dilution methods).
- flow-weighted composite sampler, with sampler modified to accommodate a wide range of rain events.
- recommended use of water quality sonde to obtain high-resolution and continuous measurements of such parameters as turbidity, conductivity, pH, oxidation reduction potential, dissolved oxygen (DO), and temperature.
- preparation of adequate experimental design that quantifies the needed sampling effort to meet the data quality objectives (adequate numbers of samples in all rain categories and seasons).
- selection of constituents that meet monitoring objectives. In addition, the analytical methods must be appropriately selected to minimize "nondetected" values.
- monitoring station maintenance must also be conducted appropriately to ensure reliable sample collection. Sampling plan must also consider sample retrieval, sample preparation and processing, and delivery to the analytical laboratory to meet quality control requirements.

Burton and Pitt (2002) describe these monitoring components in detail, along with many other monitoring elements of potential interest (e.g., receiving water biological, physical, and chemical monitoring, including sediment and habitat studies), and include many case studies addressing these components, along with basic statistical analyses and interpretation of the collected data. Box 4-4 provides a detailed example of industrial stormwater monitoring at individual sites in Wisconsin.

In general, monitoring of industries should be tailored to their stormwater pollution potential, considering receiving water uses and problems. There are a number of site survey methods that have been developed to rank industry by risk that mostly rely on visual inspections and information readily available from regional agencies. The Center for Watershed Protection developed a hot-spot investigation procedure that is included in the Urban Subwatershed Restoration Manual No. 11 (Wright et al., 2005). This site survey reconnaissance method ranks each site according to its likely stormwater pollutant discharge potential. A detailed field sheet is used when surveying each site to assist with the visual inspections. Cross and Duke (2008) developed a methodology, described in greater detail in Chapter 6, to visually assess industrial facilities based on the level of activities exposed to stormwater. They devised four categories—Category A, no activities exposed to stormwater; Category B, low intensity; Category C, medium intensity; and Category D, high intensity—and tested this

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BOX 4-4
Wisconsin's Monitoring of Industrial Stormwater

The State of Wisconsin also uses a site assessment method to rank industrial operations into three tiers, mostly based on their standard industrial codes. This system groups facilities by industry and how likely they are to contaminate stormwater. The general permits differ in monitoring requirements, inspection frequency, plan development requirements, and the annual permit fee. The Tier 1 general permit covers the facilities that are considered "heavy" industries, such as paper manufacturing, chemical manufacturing, petroleum refining, ship building/repair, and bulk storage of coal, minerals, and ores. The monitoring required of these facilities is presented in this box. The Tier 2 general permit covers facilities that are considered "light" industries and includes such sites as furniture manufacturing, printing, warehousing, and textiles. Facilities with no discharge of contaminated stormwater are in the Tier 3 category and include sites that have no outdoor storage of materials or waste products.

In accordance with the Wisconsin MSGP, Tier 1 industries are required to perform an annual chemical stormwater sampling at each outfall for those residual pollutants listed in the industry's stormwater pollution prevention plan. The one runoff event selected for sampling must occur between March and November and the rainfall depth must be at least 0.1 inch. At least 72 hours must separate the sampled event and the previous rainfall of 0.1 inch. The concentration of the pollutant must represent a composite of at least three grab samples collected in the first 30 minutes of the runoff event. There is concern about the value of collecting so few samples from just one storm each year.

To evaluate how well this sampling protocol characterizes pollutant concentrations in industrial runoff, the Wisconsin Department of Natural Resources partnered with the USGS to collect stormwater samples from three Tier 2 industrial sites (Roa-Espinosa and Bannerman, 1994). Seven runoff events were monitored at each site, and the samples were collected using five different sampling methods, including (1) flow-weighted composites, (2) time-based discrete samples, (3) time-based composites, (4) a composite of discrete samples from first 30 minutes, and (5) time-based composite sheet flow samples. The first three methods have been described previously. For the composite of discrete samples from the first 30 minutes, the sampler is programmed to take an aliquot after a set period of time (usually every 5 minutes) and the aliquots are combined into one container. The sampler stops collecting samples after 30 minutes. For many sites the samples are collected manually, so there is a high probability the sample does not represent the first 30 minutes of the event. For the time-based composite sheet flow samples, a sheet flow sampler is programmed to take an aliquot of sheet flow after a set period of time (usually about every 5 to 15 minutes). All the aliquots are deposited in one bottle beneath the surface of the ground. All of the parts of the hydrograph receive equal weight in the final concentration, but the larger number of aliquots makes for a reasonably accurate composite concentration. This method is unique in that it can be placed near the source of concern. Automatic samplers were used for the first four methods, while sheet flow samplers designed by the USGS were used for the fifth method (Bannerman et al., 1993). Samples were collected during the entire event. All the automatic samplers had to be installed at a location with concentrated flow, such as an outfall pipe, while the sheet flow samplers could be installed in the pavement near a potential source, such as a material storage area.

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BOX 4-4 Continued

The time-based discrete, time-based composite, first-30-minute composite, and sheet flow samples were analyzed for COD, total recoverable copper, total recoverable lead, total recoverable zinc, TSS, total solids, and hardness. In addition to these constituents, the flow-weighted composite samples were analyzed for antimony, arsenic, beryllium, chromium, ammonia-N, nitrate plus nitrite, TKN, and TP. All the analysis was done at the State Laboratory of Hygiene in Madison, Wisconsin, and the data are stored in the USGS's QWDATA database.

The number of samples collected during a runoff event varied greatly among the five types of sampling. By design, the median number of samples collected for the first 30 minutes was three. Limits on the funds available for laboratory cost limited the time-based discrete sampling to about six per storm. Since they are not restricted by laboratory cost, the composites can be based on more sub-samples during a storm. Thus, the median numbers of sub-samples collected for the flow-weighted composite and time-based composite were 13 and 24, respectively. The time-based composite sheet flow sample could not document the number of samples it collected, but it was set to collect a sample every few minutes.

To judge the accuracy of the sampling methods, one method had to be selected as the most representative of the concentration and load affecting the receiving water. Because a relatively large number of samples are collected and the timing of the sampling is weighted by volume, the flow-weighted composite concentrations were used as the best representation of the quality of the industrial runoff. Concentrations in water samples collected by the time-based composite method compared very well to those collected by the flow-weighted composite method, especially if the time-based composite resulted in 20 sub-samples or more. This was not true for the discrete sampling method, because many fewer sub-samples were used to represent changes across the hydrograph. The time-based composite sheet flow sampler produced concentrations slightly higher than the time-based composite samplers collecting water in the concentrated flow. Concentrations from the sheet flow sampler are probably not diluted by other source areas such as the roof.

Concentrations of total recoverable zinc and TSS collected in the first 30 minutes of the event were usually two to three times higher than the flow-weighted composite samples. For many of the events, the highest concentration of these constituents occurred in the first 10 minutes of the event. Although the concentrations might be higher in the first part of the event, the earlier parts of the event might only represent one third or less of the total runoff volume. Thus, using the concentrations from the first 30 minutes of the event could greatly overestimate the constituent load from the site.

Along with accuracy, the selection of an appropriate sampling method must consider cost and the criteria for installing the sampling equipment. To measure flow, the site must have a location where the flow is concentrated, such as a pipe or well-defined channel, and the runoff is just coming from the site. Out of 474 sites evaluated for this project, only 14 met the criteria for an accurate flow measurement. A few more sites might be suitable for using an automatic sampler without flow measurements, but the number of sites would still be limited. Sheet flow samplers can be used on most sites, since they are simply installed in the pavement near the source of concern.

For each sampling method, approximate costs were determined including equipment, installation of equipment, and the analysis of one sample (Table 4-5). Collecting the samples and processing the data should also be included, but they were not because this cost is highly variable. Flow-weighted composite and time-based discrete sampling had the highest cost. Flow measurements made the composite sampling more expensive, while the laboratory cost of analyzing six discrete samples increased the cost of the time-based

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TABLE 4-5 Cost of Using Different Sampling Methods in 1993 Dollars

Method	Estimated Cost for Equipment, Installation, and Analysis of One Sample
Flow-weighted composite	$16,052
Time-based discrete	$22,682
Time-based composite	$5,920
First-30-minutes (automatic sampler)	$6,000
First-30-minutes (grab sample)	$1,800[1]
Time-based composite sheet flow sampler	$2,889

[1]Cost of laboratory analysis only. SOURCE: Reprinted, with permission, from Roa-Espinosa and Bannerman (1994). Copyright 1994 by the American Society of Civil Engineers.

discrete method. It should be noted that hand grab samples could be used to collect the discrete samples in the first 30 minutes at lower cost, although this depends strongly on the skill of the person collecting the sample. The sheet flow sampler could be the most cost effective approach to sampling an industrial site.

A determination must be made of how many runoff events should be sampled in order to accurately characterize a site's water quality. As shown in Table 4-6, representing a site with the results from one storm can be very misleading. Concentrations in Table 4-6 were collected by the flow-weighted composite method. The geometric means of EMCs from five or more events were very different than the lowest or highest concentration observed for the set of storms. The chances of observing an extreme value by sampling just one event is increased by selecting a sampling method designed to collect a limited number of sub-samples, such as the first-30-minutes method. Too few storms were monitored in this project to properly evaluate the variability in the EMCs, but sufficient changes occur between the zinc and TSS geometric means in Table 4-6 to suggest that a compliance monitoring schedule should include a minimum of five events be sampled each year.

To overcome the high COV observed for municipal stormwater data collected in Wisconsin, EMCs should be determined for about 40 events (Selbig and Bannerman, 2007; Horwatich et al., 2008). The 40 event mean concentrations would probably represent the long-range distribution of rainfall depths, and there would be sufficient data available to perform some trend analysis, such as evaluating the benefits of an SCM implemented at an industrial site. Monitoring 40 events each year, however, would be too costly for an annual compliance monitoring schedule for each industrial site.

Results from this project indicate that the stormwater monitoring required at industrial sites cannot adequately characterize the quality of runoff from an industrial site. Only collecting samples from the first 30 minutes of a storm is probably an overestimate of the concentration, and a load calculated from this concentration would exaggerate the impact of the site on the receiving waters. Time- and flow-based composite sampling would be much better methods for monitoring a site if there are locations to operate an automatic sampler. For sites without such a location, the time-based composite sheet flow sampler offers the best results at the least cost. Given all the variability in concentrations between runoff events, the annual monitoring schedule for any site should include sampling multiple storms.

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BOX 4-4 Continued

TABLE 4-6 Effects of Including a Different Number of Events in the Geometric Mean Calculation for Zinc and TSS[a]

Number of Events	Total Recoverable Zinc	Total Suspended Solids
	AC Rochester	
1 (Lowest Concentration)	57	8
1 (Highest Concentration)	150	84
3	76	24
5	91	36
	PPG Industries	
1 (Lowest Concentration)	140	32
1 (Highest Concentration)	330	49
3	153	57
6	186	53
	Warman International	
1 (Lowest Concentration)	68	17
1 (Highest Concentration)	140	56
3	67	15
5	81	26
7	74	19

[a]Samples were collected using the flow-weighted composite method. SOURCE: Reprinted, with permission, from Roa-Espinosa and Bannerman (1994). Copyright 1994 by the American Society of Civil Engineers.

scheme by examining many southern Florida industrial facilities. About 25 percent of the facilities surveyed that were officially included in the stormwater permit program had no stormwater exposure (Category A), but very few had submitted the necessary application to qualify for an exception under the "no exposure" rule. Slightly more than half of the of the surveyed facilities were included in the "no exposure" and "low exposure" categories, obviously deserving less attention compared to the higher impact categories.

Recommendations for Industrial Stormwater Monitoring

Suitable industrial monitoring programs can be implemented for different categories of industrial activities. The following is one such suggestion, based on the likely risks associated with stormwater discharges from each type of facility.

No Exposure to Industrial Activities and Other Low-Risk Industrial Operations

For sites having limited stormwater exposure to industrial operations, such as no outdoor storage of materials or waste products, basic monitoring would

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not normally be conducted. However, roof runoff (especially if galvanized metals are used) and large parking areas need to be addressed under basic stormwater regulations dealing with these common sources of contaminants and the large amounts of runoff that may be produced. Simple SCM guidance manuals can be used to select and size any needed controls for these sites, based on the areas of concern at the facility. For these facilities, simple visual inspections with no monitoring requirements may be appropriate to ensure compliance with the basic stormwater regulations. A regionally calibrated stormwater quality model can be used to evaluate these basic stormwater conditions and to calculate the expected benefits of control measures. Periodic random monitoring of sites in this category should be conducted to verify the small magnitude of discharges from these sites and the performance of SCMs.

Medium-Risk Industrial Operations

For "medium-intensity" industry facilities, site inspections and modeling should be supplemented with suitable outfall monitoring to ensure compliance. As noted in Box 4-2, there can be a tremendous amount of variability in industrial runoff characteristics. However, the dataset described in that example was a compilation of data from many different types of facilities, with no separation by industrial type. Even different facilities in a single industrial group may have highly variable runoff characteristics. However, a single facility has much less variability, and reasonable monitoring strategies can be developed for compliance purposes. As noted in Box 4-4, about 40 samples were expected to be needed for each site in that example. With typical permit periods of five years, this would require that less than ten samples per year (more than the three samples per year currently obtained at many locations) be collected in order to determine the EMC for the site for comparison to allowable discharge conditions. Obviously, the actual number of samples needed is dependent on the variability of the runoff characteristics and the allowable error, as described elsewhere. After about 10 to 15 storms have been monitored for a site, it would be possible to better estimate the total number of samples actually needed based on the data quality objectives. If the monitoring during the permit period indicated excessive stormwater discharges, then the SCMs are obviously not adequate and would need improvement. The permit for the next five-year period could then be modified to reflect the need for more stringent controls, and suitable fines accessed if the facility was not in compliance. It is recommended that absolute compliance not be expected in the industrial permits, but that appropriate benchmarks be established that allow a small fraction of the monitored events to exceed the goals. This is similar to discharge permit requirements for combined sewers, and for air quality regulations, where a certain number of excessive periods are allowed per year.

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High-Risk Industrial Facilities

For "high-risk" industrial sites of the most critical nature, especially if noncompliance may cause significant human and environmental health problems, visual inspections and site modeling should be used in conjunction with monitoring of each event during the permit period. Because of the potential danger associated with noncompliance, the most stringent and robust controls would be required, and frequent monitoring would be needed to ensure compliance. If noncompliance was noted, immediate action would be needed to improve the discharge conditions. This is similar to industrial and municipal NPDES monitoring requirements for point sources.

MODELING TO LINKING SOURCES OF POLLUTION TO EFFECTS IN RECEIVING WATERS

Stormwater permitting is designed to regulate dischargers, develop information, and reduce the level of stormwater pollutants and impact on receiving waterbodies. An important assumption is that the level of understanding of the stormwater system, through a combination of monitoring and modeling, is sufficient to associate stormwater discharges with receiving waterbody impacts. Impairment of waterbodies can occur for a variety of physical, chemical, and biological reasons, often with a complex combination of causes. The ambient water quality of a receiving waterbody, which may result in a determination of impairment, is itself a function of the total mass loading of pollutant; dilution with stream discharge or standing waterbody volume; the capacity of the aquatic ecosystem to assimilate, transform, or disperse the pollutant; and transport out of the waterbody. In addition to the chemical and physical attributes of the water, impairment may also be characterized by degraded biologic structure or geomorphic form of the waterbody (e.g., channel incision in urban areas). Interactions between multiple pollutant loadings, long turnover and residence times, saturation effects, and cascading feedbacks with biological communities complicate the apparent response of waterbodies to pollutant discharge. This is particularly important when considering cumulative watershed effects, in which interactions between stressors and long-term alteration of watershed conditions may contribute to threshold responses of a waterbody to continued loading or alteration. Under these conditions, simple "loading-response" relations are often elusive and require consideration of historical and local watershed conditions.

As an example, pollutant loading at high stream flow or into strong tidally flushed systems may be advected downstream or into the coastal ocean without building up significant concentrations, while pollutant loading at low flow may not be effectively transported and dispersed and may build up to harmful concentrations. In the former case the pollutant may be rapidly transported out of the local waterbody, but may impact a more distant, downstream system. In addition, certain pollutants, such as inorganic nitrogen, may be discharged into

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surface waters and subsequently transformed and removed from the water column into vegetation or outgassed (e.g., volatilized or denitrified) into the atmosphere under certain ecosystem conditions. Sediment and other pollutants may be stored for long time periods in alluvial or lacustrine deposits, and then remobilized long after the initial loading into a stream reach or standing waterbody in response to extreme climate events, land-use change, reservoir management, or even reductions in the pollutant concentrations in the water column. Consequently, long lags may exist between the actual discharge of the sediment (and any pollutants adsorbed or otherwise stored within the deposits) and their contribution to waterbody impairment. Therefore, understanding the fate of pollutants, particularly nonconservative forms, may require consideration of the full ecosystem cycling and transport of the material over long time periods.

Impairment of waterbodies can be assessed on the basis of biological indicators, as discussed in Chapter 2. As organisms and communities respond to multiple stressors, it is not always clear what the direct or indirect effects of any specific pollutant discharge is, or how that may be exacerbated by correlated or interacting activity in the watershed. The association of specific types of impairment with surrounding land use implicitly accounts for these interactions but does not provide a mechanistic understanding of the linkage sufficient to specify effective remedial activity. However, much progress has been made in determining toxic effects of certain contaminants on different aquatic species assemblages (see, e.g., Shaver et al., 2007) and on quantifying impacts of land use on flow duration curves, EMCs, and loading rates for a number of pollutants (Maestre and Pitt, 2005). For the latter effort, it has been shown that there is large variability within land-use categories, both as a function of specific SCMs and of innate differences due to historical legacies, climate, and hydrogeology.

A protocol linking pollutants in stormwater discharges to ambient water quality criteria should be based on conservation of mass, in which the major inputs, outputs, transformations, and stores of the pollutant can be quantified. Indeed, these are the components of hydrologic and watershed models used to simulate the fate and transport of stormwater and its pollutants. SCMs that improve ambient water quality criteria are designed to act on one or more of these mass balance terms. A number of these measures act to reduce the magnitude of a stormwater source (e.g., porous pavement), while others are designed to absorb or dissipate a pollutant within a hydrologic flowpath downstream from a source (e.g., rain garden, detention pond, stream restoration). The latter requires some consideration of the flowpath from the source to the receiving waterbody. Therefore, determining the major sources, sinks, and transformations of the pollutant should be the first step in this procedure. For a number of pollutants there may be very few potential sources, while for others there may be multiple significant sources. The spatial diversity of these sources and sinks may also range from uniform distribution to “hot spot” patterns that are difficult to detect and quantify. Many stormwater models work effectively with sources, but are not structured to follow the transport or transformation of pollutants from source to waterbody along hydrologic flowpaths.

Figure 4-14 shows the drainage area of Jordan Lake, an important regional

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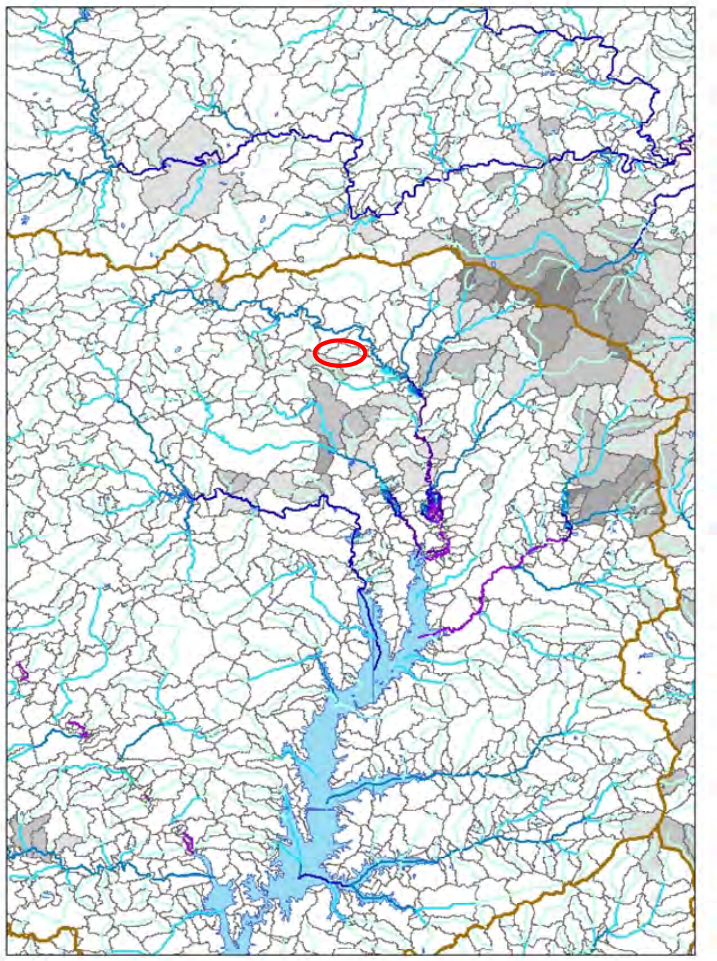

FIGURE 4-14 The drainage area to Jordan Lake, a major drinking water reservoir in the Triangle area of North Carolina, is under nutrient-sensitive rules, requiring reductions in total nitrogen and phosphorus. Drainage flowlines and catchment areas are from NHDplus, and are shaded according to their percentage of industrial and commercial land cover from the NLCD. The area outlined in black is a small urban catchment, detailed in Figure 4-15, and comprised of a wooded central region, surrounded by residential and institutional land use. SOURCE: Data from the NHD+.

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drinking water source in the Triangle area of North Carolina. Catchment areas are shaded to relate the percentage of industrial and commercial land cover, according to the National Land Cover Database (NLCD). Figure 4-15 shows a small tributary within the Jordan Lake watershed in Chapel Hill (outlined in Figure 4-14) with a high-resolution image of all impervious surfaces overlain on the topographically defined surface flowpath network. Each of the distributed sources of stormwater is routed through a flowpath consisting of other pervious and impervious segments, within which additions, abstractions, and transformations of water and pollutants occur depending on weather, hydrologic, and ecosystem conditions. The cumulative delivery and impact of all stormwater sources include the transformations occurring along the flowpaths, which could include specific SCMs such as detention or infiltration facilities or simply infiltration or transformations in riparian areas or low-order streams. The riparian area may be bypassed depending on stormwater concentration or piping, and it may have various levels of effectiveness on reducing pollutants depending on geomorphic, ecosystem, and hydrologic conditions. The ability of a stormwater model to capture these types of effects is a key property influencing its ability to associate a stormwater source with a waterbody outcome.

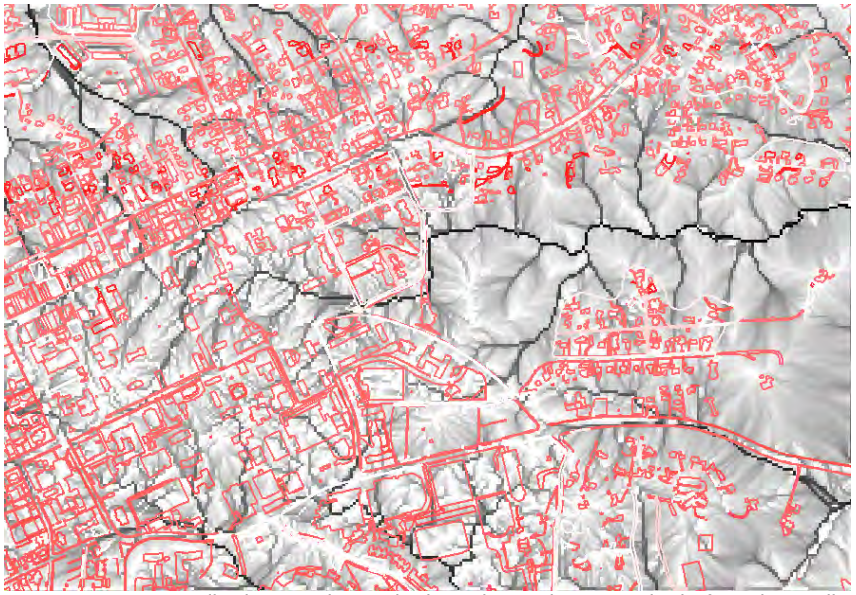

FIGURE 4-15 A small urban catchment in the Lake Jordan watershed of North Carolina with distributed sources of impervious surface (buildings and roads) stormwater arranged within the full surface drainage flowpath system. Stormwater from each source is routed down surface and subsurface flowpaths to the nearest tributary and out the drainage network, with additions and abstractions of water and pollutants along each flowpath segment. SOURCE: Data from the NHD^{+}.

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This section discusses the fundamentals of stormwater modeling and the capabilities of commonly used models. Much of this information is captured in a summary table at the end of the section (Table 4-7). The models included are the following:

- The Rational Method, or $Q = C*I*A$, where Q is the peak discharge for small urban catchments, A is the catchment area, I is the rainfall intensity, and C is a rainfall-runoff coefficient.
- The Simple Method, which classifies stormwater generation and impact regimes by the percent impervious cover
- TR-20 and TR-55
- The Generalized Watershed Loading Function (GWLF)
- Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (P8)
- Model for Urban Stormwater Improvement Conceptualization (MUSIC)
- Stormwater Management Model (SWMM)
- Source Loading and Management Model (WinSLAMM)
- Soil and Water Assessment Tool (SWAT)
- Hydrologic Simulation Program–Fortran (HSPF)
- Western Washington Hydrologic Model
- Chesapeake Bay Watershed Model (CBWM)

Fundamentals of Stormwater Models

Stormwater models are designed to evaluate the impacts of a stormwater discharge on a receiving waterbody. In order to do this, the model must have the capability of describing the nature of the source term (volumes, constituents), transport and transformation to the receiving waterbody, and physical, chemical, and biological interaction with the receiving water body and ecosystem. No model can mechanistically reproduce all of these interactions because of current limitations in available data, incomplete understanding of all processes, and large uncertainties in model and data components. Computer resources, while rapidly advancing, still limit the complexity of certain applications, especially as spatial data become increasingly available and it is tempting to model at ever-increasing resolution and comprehensiveness. Therefore, models must make a set of simplifying assumptions, emphasizing more reliable and available data, while attempting to retain critical processes, feedbacks, and interactions. Models are typically developed for a variety of applications, ranging from hydraulic design for small urban catchments to urban and rural pollutant loading at a range of watershed scales.

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An evaluation of the current state of stormwater modeling should say much about our ability to link pollutant sources with effects in receiving waters. Both stormwater models and models supporting the evaluation of SCM design and effectiveness are based on simulating a mass budget of water and specific pollutants. The detail of mass flux, transformation, and storage terms vary depending on the scale and purpose of the application, level of knowledge regarding the primary processes, and available data. In many cases, mechanisms of transformation may be either poorly understood or may be dependent on detailed interactions. As an example, nitrogen-cycle transformations are sensitive to very short temporal and spatial conditions, termed "hot spots" and "hot moments" relative to hydrologic flowpaths and moisture conditions (McClain et al., 2003).

Stormwater runoff production and routing are common components of these models. All models include an approach to estimate the production of stormwater runoff from one or more zones in the watershed, although runoff routing from the location(s) of runoff production to a point or waterbody is not always included explicitly. Major divisions between approaches are found in the representation of the watershed "geography" in terms of patterns and heterogeneity, and in runoff production and routing. Some stormwater models do not consider the effects of routing from a runoff source to a local waterbody directly, but may attempt to reproduce net impacts at larger scales through the use of unit hydrograph theory to estimate peak flows, and delivery ratios or stormwater control efficiency factors to estimate export to a waterbody.

There are a number of different approaches and paradigms used in stormwater models that include varying degrees of watershed physical, biological, and chemical process detail, as well as spatial and temporal resolution and the representation of uncertainty in model estimates. A number of researchers have written about the nature of watershed models (e.g., Beven, 2001; Pitt and Vorhees, 2002). At present, many hydrologic and stormwater models have become so complex, with multiple choices for different components, that standard descriptions apply only to specific components of the models. The following discussion is generalized; most models fit the descriptions only to certain degrees or only under specific conditions in which they are operated.

Lumped Versus Distributed Approaches

Central to the design of watershed models is the concept of a "control volume," which is a unit within which material and energy contents and balances are defined, with boundaries across which material and energy transport occurs. Control volumes can range from multiple subsurface layers and vegetation canopy layers bounded in three dimensions to a full watershed. Lumped models ignore or average spatial heterogeneity and patterns of watershed conditions, representing all control volumes, and the stores, sources, and sinks of water and pollutants in a vertically linked set of conceptual components, such as surface interception, unsaturated and saturated subsurface zones, and a single stream or

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river reach. For example, SWAT or HSPF are conceptually lumped at the scale of subwatersheds (e.g., the level of geography in Figure 4-14) and do not show any spatial patterns at higher resolutions (e.g., Figure 4-15) than these units. While multiple land-use/soil combinations may be represented, these models do not represent the connectivity of the land segments (e.g., which land segments drain into which land segments) and assume all unique land segment types drain directly to a stream.

Distributed models include some scheme to represent spatial heterogeneity of the watershed environment pertinent to stormwater generation, including land cover, soils, topography, meteorological inputs, and stream reach properties distributed through a set of linked control volumes. Control volumes representing land elements, including vertically linked surface and subsurface stores, are connected by a representation of water and pollutant lateral routing through a network of flowpaths that may be predefined or set by the dynamics of surface, soil, and saturated zone water storage. The land elements may be grid cells in a regular lattice, or irregular elements (e.g., triangles) with the pattern adapted to variations in land surface characteristics or hydraulic gradients.

A number of models are intermediate between lumped and distributed, with approaches such as lumping at the subwatershed scale, incorporating statistical distributions of land element types within subwatersheds but without explicit pattern representation, or lumping some variables and processes (such as groundwater storage and flux), while including distributed representation of topography and land cover. Thus, within the model SLAMM (Pitt and Vorhees, 2002), the catchment is described in sufficient detail to summarize the breakdown of different drainage sequences. As an example, roof area will be broken down to the proportion that drains to pervious areas and to directly connected impervious areas. An important distinction is that there is no routing of the output of one land element into another, such that there is no drainage sequence that may significantly modify the stormwater runoff from its source to the stream. Implicitly, all land elements drain directly into a stream, although a loss rate or delivery ratio can be specified.

The choice of a more lumped or distributed model is often dependent on available data and overall complexity of the model. Simpler, lumped models may be preferred in the absence of sufficient data to effectively parameterize a distributed approach, or for simplicity and computational speed. However, fully lumped models may be limited in their ability to represent spatial dependency, such as the development and dynamics of riparian zones, or the effects of SCM patterns and placement. As there is typically an irreducible level of spatial heterogeneity in land surface characteristics down to very small levels below the resolution of individual flow elements, we note that all models lump at some scale (Beven, 2000).

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Mechanistic Versus Conceptual Process Representation

Mechanistic, or process-based, approaches attempt to reproduce key stormwater transport and transformation processes with more physically, chemically, or biologically based detail, while conceptual models represent fluxes between stores and transformations with aggregate, simplified mathematical forms. No operational models are built purely from first principles, so the distinction between mechanistic and conceptual process basis is one of degree.

The level of sampling necessary to support detailed mechanistic models, as well as remaining uncertainty in physicochemical processes active in heterogeneous environments typically limits the application of first-principle methods. The development or application of more mechanistic approaches is currently limited by available measurements, which require both time and resources to adequately carry out. Unfortunately, modeling and monitoring have often been mutually exclusive in terms of budgets, although it is necessary for both to be carefully planned and integrated. A new generation of sensors and a more rigorous and formal sampling protocol for existing methods will be necessary to advance beyond the current practice.

At present, most operational hydrologic and transport models are based on a strong set of simplifying assumptions regarding active processes and/or the spatial variation of sources, sinks, and stores in the watershed. Runoff production can be computed by a range of more mechanistic to more conceptual or empirical methods. More mechanistic methods include estimation of infiltration capacities based on soil hydraulic properties and moisture conditions, excess runoff production, and hydraulic routing over land surfaces into and through a stream-channel network. More conceptual approaches use a National Resources Conservation Service (NRCS) curve number approach (see Box 4-5) and unit hydrograph methods to estimate runoff volume and time of concentration. Pollutant concentrations or loads are often estimated on the basis of look-up tables using land use or land cover. Land use- or land cover-specific EMC or unit area loading for pollutants can be developed directly from monitoring data or from local, regional, or national databases. The NSQD statistically summarizes the results of a large number of stormwater monitoring projects (as discussed previously in this chapter). The effects of SCM performance (typically percent removal) can be estimated from similar databases (e.g., www.bmpdatabase.org). A set of models, such as SWAT, incorporate fairly detailed descriptions of nutrient cycling as an alternative to using EMC, requiring more detailed inputs of soil, crop, and management information. Unfortunately, the detailed biogeochemistry of this and similar models is typically not matched by the hydrology, which remains lumped at individual Hydrologic Response Unit (HRU) levels using NRCS curve number methods, although options exist to incorporate more mechanistic infiltration excess runoff.

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BOX 4-5
NRCS Technical Release 55

NRCS methods to estimate runoff volumes and flows have been popular since the early 1950s (Rallison, 1980). Fundamentally they can be broken into the separation of runoff from the rainfall volume (Curve Number Method), the pattern of runoff over time (dimensionless unit hydrograph), and their application within computer simulation models. In the late 1970s these components were packaged together in a desktop hydrology method known as Technical Release 55 (TR-55). TR-55 became the primary model used by the majority of stormwater designers, and there is considerable confusion over the terms used to describe what aspects of the NRCS methods are in use.

The NRCS Curve Number Method was first derived in the 1950s for prediction of runoff from ungauged agricultural areas. It relates two summation ratios, that of runoff to rainfall and that of moisture retained to maximum potential retention. Two statistically based relations were developed to drive the ratio, the first of which is based on a "curve number" which depicts the soil type, land cover, and initial moisture content. The second or initial abstraction is defined as the volume of losses that occur prior to the initiation of runoff, and is also related to the curve number. Data were used to derive curve numbers for each soil type and cover as shown in Figure 4-16 (Rallison, 1980).

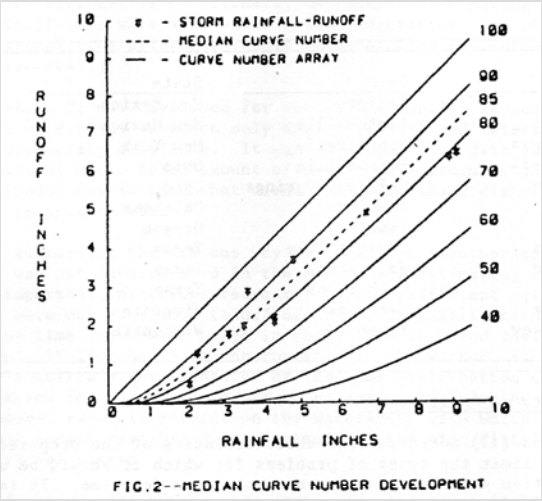

FIGURE 4-16 Development of curve number from collected data. SOURCE: Reprinted, with permission, from Rallison (1980). Copyright 1980 by the American Society of Civil Engineers.

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The Curve Number method is a very practical method that gives "average" runoff results from a watershed and is used in many models (WIN TR-55, TR-20, SWMM, GWLF, HEC-HMS, etc.). Caution has to be exercised when using it for smaller urbanizing storm events. For example, past practice was to average curve numbers for developments for pavement and grass based on percent imperviousness. While this works well for large storms, for smaller storms it gives erroneous answers through violation of the initial abstraction relationship. Current state manuals (MDE, 2000; PaDEP, 2006) do not allow paved- and unpaved-area curve numbers to be averaged. When applied to continuous simulation models (such as in SWMM or GWLF), it requires an additional method to recover the capacity to remove runoff because the soil capacity to infiltrate water is restored over time.

The NRCS Dimensionless Unit Hydrograph has also evolved over many years and simply creates a temporal pattern from the runoff generated from the curve number method. This transformation is based upon the time of concentration, defined as the length of time the water takes to travel from the top to the bottom of the watershed. The dimensionless curve ensures that conservation of mass is maintained. The main purpose of this method is to estimate how long it takes the runoff generated by the curve number to run off the land and produce discharge at the watershed outlet.

The NRCS curve number and dimensionless unit hydrograph were first incorporated in the Soil Conservation Service (SCS) TR-20 hydrologic computer model developed in the 1960s. As most stormwater professionals did not have access to mainframes, SCS put together TR-55, which created a hand or calculator method to apply the curve number and dimensionless unit hydrograph. In order to create this hand method, many runs were generated using TR-20 to develop patterns for different times of concentration. The difficulty with using the original TR-55 in the modern era is that the simplifications to the hydrograph development do not allow the benefits of SCMs to be easily accounted for.

The use of the term TR-55 has been equated with the curve number method; this has created confusion, especially when it is included in municipal code. Further clouding the issue, there are two types of TR-55 computer models available. One is based on the original, outdated, simplified hand method, and the other (Win TR-55) returns to the more appropriate application of the curve number and dimensionless hydrograph methods. In either case, the focus of these models is on single event hydrology and cannot easily incorporate or demonstrate the benefits of the wide range of structural and nonstructural SCMs. Note that the curve number and dimensionless unit hydrograph methods are incorporated in many continuous flow models, including SWMM and GWLF, as the basis of runoff generation and runoff timing.

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Deterministic Versus Stochastic Methods

Deterministic models are fully determined by their equation sets, initial and boundary conditions, and forcing meteorology. There are no components that include random variation. In a stochastic model, at least one parameter or variable is drawn from a probability distribution function such that the same model set-up (initial and boundary conditions, meteorology, parameter sets) will have randomly varying results. The advantage of the latter approach is the ability to generate statistical variability of outcomes, reflecting uncertainty in parameters, processes, or any other component. In fact, any deterministic model can be operated in a stochastic manner by sampling parameter values from specified probability distributions.

It is recognized that information on the probability distribution of input parameters may be scarce. For situations with limited information on parameter values, one option is to assume a uniform distribution that brackets a range of values of the parameter reported in the literature. This would at least be a start in considering the impacts of the variability of model inputs on outputs. A thorough discussion on methods for incorporating uncertainty analysis into model evaluation is provided in Chapter 14 of Ramaswami et al. (2005). It should be noted that the ability to generate probability distribution information on stormwater outcomes requires a potentially large number of model runs, which may be difficult for detailed mechanistic and distributed models that have large computational loads.

Continuous Versus Event-Based Approaches

Another division between modeling approaches is the time domain of the simulation. Event-based models limit simulation time domains to a storm event, covering the time of rainfall and runoff generation and routing. Initial conditions need to be estimated on the basis of antecedent moisture or precipitation conditions. For catchments in which runoff is dominated by impervious surfaces, this is a reasonable approach. In landscapes dominated by variable source area runoff dynamics in which runoff is generated from areas that actively expand and contract on the basis of soil moisture conditions, a fuller accounting of the soil moisture budget is required. Furthermore, event-based modeling is inappropriate for water quality purposes because it will not reproduce the full distribution of receiving water problems. Continuous models include simulation of a full time domain composed of storm and inter-storm periods, thus tracking soil moisture budgets up to and including storm events.

Outfall Models

After beneficial use impairments are recognized, cause-and-effect relation-

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ships need to be established and restorative discharge goals need to be developed. Models are commonly used to calculate the expected discharges for different outfalls affecting the receiving water in a community. All of the models shown in Table 4-7 can calculate outfall discharge quantities, although some may only give expected average annual discharge. Models calculate these discharges using a variety of processes, but all use an urban hydrology component to determine the runoff quantity and various methods to calculate the quality of the runoff. The runoff quantity is multiplied by the pollutant concentration in the outfall to obtain the mass discharges of the different pollutants. The outfall mass discharge from the various outfalls in the area can then be compared to identify the most significant outfalls that should be targeted for control.

The most common hydrology "engines" in simple stormwater models are the NRCS curve number method or a simple volumetric runoff coefficient—R_v, the ratio of runoff to rainfall—for either single rainfall events or the total annual rainfall depth. Runoff quality in the simple models is usually calculated based on published EMCs for similar land uses in the same geographical area. More complex models may use build-up and wash-off of pollutants from impervious surfaces in a time series or they may derive pollutant concentrations from more detailed biogeochemical cycling mechanisms, including atmospheric deposition and other inputs (e.g., fertilizer). Some models use a combination of these processes depending on the area considered, and others offer choices to the model user. Again, these processes all need local calibration and verification to reduce the likely uncertainty associated with the resultant calculated discharge conditions.

Source Area

When the outfalls are ranked according to their discharges of the pollutants of importance, further detailed modeling can be conducted to identify sources of the significant pollutants within the outfall drainage area. Lumped parameter models cannot be used, as the model parameters vary within the drainage area according to the different source areas. Distributed area models can be used to calculate contributions from different source areas within the watershed area. This information can then be used to rank the land uses and source area contributions. In-stream responses can be calculated if the land-area models are linked to appropriate receiving-water models.

Need for Coupling Models

As urban areas become increasingly extensive and heterogeneous, including a gradient of dense urban to forest and agricultural areas, linkage and coupling of models to develop feedback and interactions (e.g., impacts of urban runoff hydraulics with stream scour and sedimentation, mixed with agricultural nutrient

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and sediment production on receiving waterbodies) is a critical area that requires more development. In general, stormwater models were designed to track and predict discharges from sources by surface water flowpaths into receiving waterbodies, such that infiltration was considered to be a loss (or retention) of water and its constituents. To fully evaluate catchment-scale impacts of urbanization on receiving waterbodies, the infiltration term needs to be considered a source term for the groundwater, and a groundwater component or model needs to be coupled to complete the surface–subsurface hydrologic interactions and loadings to the waterbody.

Finally, each of the models may or may not incorporate explicit consideration of SCM performance based on design, implementation and location within the catchment. As discussed in the next chapter, SCM models can range from simple efficiency factors (0–1 multipliers on source discharge) to more detailed treatment of physical, chemical, and biological transport and transformations.

Linking to Receiving-Water Models

Specific problems for urban receiving waters need to be identified through comprehensive field monitoring and modeling. Monitoring can identify current problems and may identify the stressors of importance (see Burton and Pitt [2002] for tools to evaluate receiving water impairments). However, monitoring cannot predict conditions that do not yet exist and for other periods of time that are not represented at the time of monitoring. Modeling is therefore needed to gain a more comprehensive understanding of the problem. In small-scale totally urbanized systems, less complex receiving-water models are needed. However, as the watershed becomes more complex and larger with multiple land uses, the receiving-water models also need to become more complex. Complex receiving-water models need to include transport and transformations of the pollutants of concern, for example. Examples of models shown on the comparison table that include receiving-water processes are MUSIC and HSPF. Other models (such as WinSLAMM) provide direct data links to external receiving-water models. Calibration and verification of important receiving-water processes that are to be implemented in a model can be very expensive and time consuming, and still result in substantial uncertainty.

Model Calibration and Verification

Calibration is the process where model parameters are adjusted to minimize the difference between model output and field measurements, with an aim of keeping model parameters within a range of values reported in the literature. Model *verification*, similar to model validation, is used to mean comparison between calibrated model results using part of a data set as input and results from application of the calibrated model using a second (independent) part of

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the data set as input. Oreskes et al. (1994) present the viewpoint that no model can really be verified; at best, verification should be taken to mean that a model is consistent with a physical system under a given set of comparison data. This is not synonymous with saying that the model can reliably represent the real system under any set of conditions. In general, the water quantity aspects of stormwater modeling are easier to calibrate and verify than the water quality aspects, in part because there are more water quantity data available and because chemical transformations are more complex to simulate. A thorough discussion of the broad topic of model evaluation is provided by several excellent texts on this subject, including Schnoor (1996) and Ramaswami et al. (2005).

Models in Practice Today

Table 4-7 presents a set of models used for stormwater evaluation that range in complexity from first-generation stormwater models making use of simple empirical land cover/runoff and loading relations to more detailed and information-demanding models. The columns in Table 4-7 provide an abbreviated description of some of the attributes of these models—common usage, typical application scales, the degree of model complexity, some data requirements (for the hydrologic component), whether the model addresses groundwater, and whether the model has the ability to simulate SCMs. Models capable of simulating a water quality component require EMC data, with some models also having a simple build-up/wash-off approach to water quality simulation (e.g., SWMM, WinSLAMM, and MUSIC) and others simulating more complex geochemistry (e.g., SWAT and HSPF). The set of columns in Table 4-7 is not meant to be exhaustive in describing the models, which is why websites are provided for comprehensive model descriptions and data requirements.

In addition to the models listed in Table 4-7, a representative set of emerging research models that are not specifically designed for stormwater, but may offer some advantages for specific uses, are also described below. In general, it is important that models that integrate hydrologic, hydraulic, meteorologic, water quality, and biologic processes maintain balance in their treatment of process details. Both model design and data collection should proceed in concert and should be geared toward evaluating and diagnosing the consistency of model or coupled model predictions and the uncertainty attached to each component and the integrated modeling system. The models should be used in a manner that produces both best estimates of stormwater discharge impacts on receiving waterbodies, as well as the level of uncertainty in the predictions.

The Rational Method is a highly simplified model widely used to estimate peak flows for in sizing storm sewer pipes and other low level drainage pathways. The method assumes a constant rainfall rate (intensity), such that the runoff rate will increase until the time at which all of the drainage area contributes to flow at its outlet (termed the *time of concentration*). The product of the drainage area and rainfall intensity is considered to be the input flow rate to the

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drainage area under consideration; the ratio of the input flow rate to an outflow discharge rate is termed the runoff coefficient. Runoff coefficients for a variety of land surface types and slopes have been compiled in standard tables (see e.g., Chow et al., 1988). The outflow is determined by multiplying inflow (rainfall intensity times drainage area) by the runoff coefficient for the land-surface type. As pointed out by Chow et al. (1988), this method is often criticized owing to its simplified approach, so its use is limited to stormwater inlet and piping designs.

The Simple Method estimates stormwater pollutant loads for urban areas, and it is most valuable for assessing and comparing the relative stormwater pollutant load changes of different land use and stormwater management scenarios. It requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater pollutant concentrations (as defined by the EMC), and annual precipitation. The subwatershed can be broken up into specific land uses, such that annual pollutant loads are calculated for each type of land use. Stormwater pollutant concentrations are usually estimated from local or regional data, or from national data sources. The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as $L = 0.226\ R \times C \times A$, where L = annual load (lbs), R = annual runoff (inches), C = pollutant concentration (mg/l), and A = area (acres).

Of slightly increased complexity are those models initially developed decades ago by the Soil Conservation Service, now the NRCS of the U.S. Department of Agriculture (USDA). NRCS Technical Releases (TR) 20 and 55 are widely used in many municipalities, despite the availability of more rigorous, updated stormwater models. Box 4-5 provides an overview of the NRCS TR-55 assumptions and approaches.

A number of watershed models that are used for stormwater assessment are lumped, conceptual forms, with varying levels of process simplification and spatial patterns aggregated at the subwatershed level, with aspatial statistical distribution of land types as described above. The GWLF model (Haith and Shoemaker, 1987) is an example of this type of approach, using simple land use-based EMC with NRCS curve number estimates of runoff within a watershed context. GWLF is a continuous model with simplified upper- and lower-zone subsurface water stores, and a simple linear aquifer to deliver groundwater flow. EMCs are assigned or calibrated for subsurface and surface flow delivery, while sediment erosion and delivery are computed with the use of the Universal Soil Loss Equation and delivery coefficients. The methods are easily linked to a Geographical Information System (GIS), which provides land-use composition at the subwatershed level and develops estimates of runoff and loading that are typically used to estimate annual loading. AVGWLF links GWLF with ArcView and is used as a planning- or screening-level tool. A recent example of AVGWLF for nutrient loading linked to a simple stream network nutrient decay model for the development of a TMDL for a North Carolina water supply area is given in Box 4-6.

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BOX 4-6
The B. Everett Jordan Lake GWLF Watershed Model Development

Jordan Lake is a regionally important water supply reservoir at the base of the 1,686-square-mile Haw watershed in North Carolina (see Figure 4-17). It is considered a nutrient-sensitive waterbody. Officials are now in the process of implementing watershed goals to reduce nitrogen and phosphorus, with the reduction goals differentiated by geographic location within the basin. In support of the development of these rules as part of a TMDL effort, the North Carolina Division of Water Quality commissioned a water quality modeling study (Tetra Tech, 2003). The modeling effort was needed to support the evaluation of nutrient reduction strategies in different parts of the watershed relative to Jordan Lake, which requires both a model of nutrient loading, as well as river transport and transformation. Given data and resource restrictions, a more detailed model was not considered feasible. As GWLF does not support nutrient transformations in the stream network, the model was used in conjunction with a method to decay nutrient source loading by river transport distance to the lake. A spreadsheet model was designed to take as input GWLF estimates of seasonal loads for 14-digit hydrologic unit code (HUC) subbasins of the Haw, and to reduce the loads by river miles between the subwatershed and Jordan Lake. The GWLF loading model was calibrated to observations in small subwatersheds within the Haw using HRUs developed from soil and NLCD land classes, updated with additional information from county GIS parcel databases and the 2000 Census. This information was used to estimate subwatershed impervious surface cover, fertilizer inputs, runoff curve numbers, soil water capacity, and vegetation cover to adjust evapotranspiration rates. Wastewater disposal (sewer or septic) was estimated on the basis of urban service boundaries. GWLF was used to provide loading estimates, using limited information on soil and groundwater nutrient concentrations, and calibrated delivery ratios. In-stream loss was based on a first-order exponential decay function of river travel time to Jordan Lake, with the decay coefficient generated by estimates of residence time in the river network, and upstream/downstream nutrient loads following non-linear regression methods used in SPARROW (Alexander et al., 2000). Further adjustments based on impoundment trapping of sediment and associated nutrient loads were carried out for larger reservoirs in the Haw. The results provided estimates of both loading and transport efficiency to Jordan Lake, with estimates of relative effectiveness of sectoral loading reductions in different parts of the watershed.

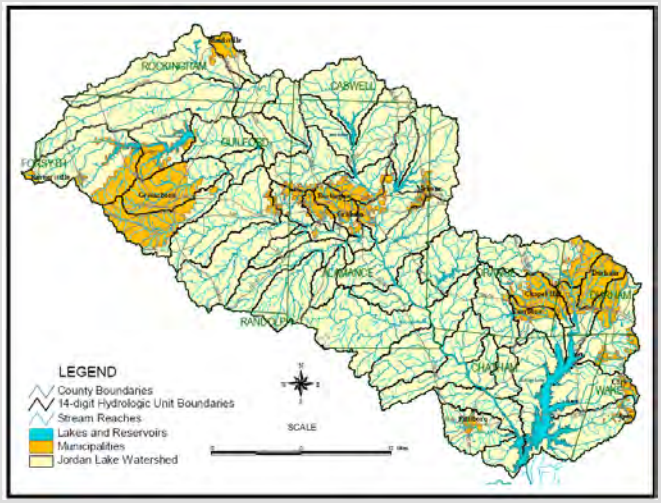

FIGURE 4-17 14 digit HUCs draining to Jordan Lake in the Haw River watershed of North Carolina. SOURCE: Tetra Tech (2003).

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P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds) is a curve number-based model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds, originally developed to help design and evaluate nutrient control in wet detention ponds (Palmstrom and Walker, 1990; http://wwwalker.net/p8/). Continuous water-balance and mass-balance calculations are performed and consist of the following elements: watersheds, devices, particle classes, and water quality components. Continuous simulations use hourly rainfall and daily air temperature time series. The model was initially calibrated to predict runoff quality typical of that measured under NURP (EPA, 1983). SCMs in P8 include detention ponds (wet, dry, extended), infiltration basins, swales, and buffer strips. Groundwater and baseflows are also included in the model using linear reservoir processes.

MUSIC is a part of the Catchment Modelling Toolkit (www.toolkit.net.au) developed by the Cooperative Research Center for Catchment Hydrology in Australia (Wong et al., 2001). The model concentrates on the quality and quantity of urban stormwater, including detailed accounting of multiple SCMs acting within a treatment train and life-cycle costing. It employs a simplified rainfall–runoff model (Chiew and McMahon, 1997) based on impervious area and two moisture stores (shallow and deep). TSS, total nitrogen, and total phosphorus are based on EMCs, sampled from lognormal distributions. The model does not contain detailed hydraulics required for routing or sizing of SCMs, and it is designed as a planning tool.

EPA's SWMM has the capability of simulating water quantity and quality for a single storm event or for continuous runoff. The model is commonly used to design and evaluate storm, sanitary, and combined sewer systems. SWMM accounts for hydrologic processes that produce runoff from urban areas, including time-varying rainfall, evaporation, snow accumulation and melting, depression storage, infiltration into soil, percolation to groundwater, interflow between groundwater and the drainage system, and nonlinear reservoir routing of overland flow. Spatial variability is modeled by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between subcatchments, or between entry points of a drainage system. SWMM can also be used to estimate the production of pollutant loads associated with runoff for a number of user-defined water quality constituents. Transport processes include dry-weather pollutant buildup over different land uses, pollutant wash-off from specific land uses, direct contribution of rainfall deposition, and the action of such SCMs as street cleaning, source control, and treatment in storage units, among others.

Watershed models such as SWAT (Arnold et al., 1998) or HSPF (Bicknell et al., 1997, 2005) have components based on similar land-use runoff and loading factors, but also incorporate options to utilize detailed descriptions of interception, infiltration, runoff, routing, and biogeochemical transformations. Both models are based on hydrologic models that were developed prior to the availability of detailed digital spatial information on watershed form and use concep-

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tual control volumes that are not spatially linked. HRUs are based on land use, soils, and vegetation (and crop) type, among other characteristics, and are considered uniformly distributed through a subbasin. Within each HRU, simplified representations of soil upper and lower zones, or unsaturated and saturated components, are vertically integrated with a conceptual groundwater storage-release component. There is no land surface routing and all runoff from a land element is considered to reach the river reach, with some delivery ratio if appropriate for sediment and other constituents. Like GWLF, the models are typically not designed to estimate loadings from individual dischargers, but are used to help guide and develop TMDL for watersheds. SWAT and HSPF are integrated within the EPA BASINS system (http://www.epa.gov/waterscience/basins) with GIS tools designed to use available spatial data to set up and parameterize simulations for watersheds within the United States. Examples of combining one of these models, typically designed for larger-scale applications (such as the area shown in Figure 4-14) with more site-specific models such as SLAMM or SWMM, are given in Box 4-7.

BOX 4-7
Using SWAT and WinSLAMM to Predict Phosphorus Loads in the Rock River Basin, Wisconsin

Wisconsin Administrative Code NR 217 states that wastewater treatment facilities in Wisconsin must achieve an effluent concentration of 1 mg/L for phosphorus. Alternative limits are allowed if it can be demonstrated that achieving the 1 mg/L limit will not "result in an environmentally significant improvement in water quality" (NR 217.04(2)(b)1). In response to NR 217, a group of municipal wastewater treatment facilities formed the Rock River Partnership (RRP) to assess water quality management issues (Kirsch, 2000). The RRP and the Wisconsin Department of Natural Resources funded a study to seek water quality solutions across all media, and not just pursue additional reductions from point sources. A significant portion of the study required a modeling effort to determine the magnitude of various nutrient sources and determine potential reductions through the implementation of global SCMs.

The Rock River Basin covers approximately 9,530 square kilometers and lies within the glaciated portion of south central and eastern Wisconsin (Figure 4-18). The Rock River and its numerous tributaries thread their way through this landscape that spreads over 10 counties inhabited by more than 750,000 residents. There are 40 permitted municipalities in the watershed, representing 4 percent of the land area, and they are served by 57 sewage treatment plants. Urban centers include Madison, Janesville, and Beloit as well as smaller cities such as Waupun, Watertown, Oconomowoc, Jefferson, and Beaver Dam. Although the basin is experiencing rapid growth, it is still largely rural in character with agriculture using nearly 75 percent of the land area. Crops range from continuous corn and corn–soybean rotations in the south to a mix of dairy, feeder operations, and cash cropping in the north. The basin enjoys a healthy economy with a good balance of agricultural, industrial, and service businesses.

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BOX 4-7 Continued

The focus of the modeling was to construct an intermediate-level macroscale model to better quantify phosphorus loads from point and nonpoint sources throughout the basin. The three goals of the modeling effort were to (1) estimate the average annual phosphorus load, (2) estimate the relative contribution of phosphorus loads from both nonpoint (urban and agricultural) and point sources, and (3) estimate changes in average annual phosphorus loads from the application of global SCMs and point source controls.

SWAT was selected for the agricultural analysis and WinSLAMM was selected to develop phosphorus loads for the urban areas. WinSLAMM was selected to make estimates of stormwater loads, because it is already calibrated in Wisconsin for stormwater volumes and pollutant concentrations. Outputs of phosphorus loads from WinSLAMM were used as input to SWAT. One output of SWAT was a total nonpoint phosphorus load based on agricultural loads calculated in SWAT and stormwater loads estimated by WinSLAMM.

SWAT was calibrated with data from 23 USGS gauging stations in the Rock River Basin. Hydrology was balanced first on a yearly basis looking at average annual totals, then monthly to verify snowfall and snowmelt routines, and then daily. Daily calibration was conducted to check crop growth, evapotranspiration, and daily peak flows. Crop yields predicted by SWAT were calibrated to those published in the USDA Agricultural Statistics.

Under current land-use and management conditions, the model predicted an average annual load of approximately 1,680,000 pounds of total phosphorus for the basin with 41 percent from point sources and 59 percent from nonpoint sources. Less than 10 percent of the annual phosphorus load is generated by the urban areas in the watershed. Evaluation of various SCM scenarios shows that with implementation of NR 217 (applicable point source effluent at 1 mg/L) and improvement in tillage practices and nutrient management practices, total phosphorus can be reduced across the basin by approximately 40 percent. It is important to note that the nonpoint management practices that were analyzed were limited to two options: modifications in tillage practices, and adoption of recommended nutrient application rates. No other management practices (i.e., urban controls, riparian buffer strips, etc.) were simulated. Urban controls were not included because the urban areas contributed a relatively small percentage of the total phosphorus load. Thus, loadings depicted by SWAT under these management scenarios do not necessarily represent the lowest attainable loads. Results suggest that a combination of point and nonpoint controls will be required to attain significant phosphorus reductions.

The CBWM is a detailed watershed model that is extended from HSPF as a base, but includes additional components to incorporate stormwater controls at the land segment level. HSPF is operated for a number of subbasins, and each subbasin model includes different land segments based on land cover and soil units as aspatial, lumped distribution functions, but also includes representation of SCMs and (large) stream routing. Model implementation at the scale of the full Chesapeake Bay watershed requires fairly coarse-grained land partitioning. A threshold of 100 cfs mean annual flow is used to represent streams and rivers, and the one-to-one mapping of land segment to river reach produces large, heterogeneous land segments as the basic runoff-producing zones. SCMs are implemented either at the field or runoff production unit as distinct land segment types in terms of management or land cover, or as “edge-of-field” reductions of runoff or pollutant loads. The latter are assigned as static efficiency factors irrespective of flow conditions or season, with all SCMs within a land segment integrated into a single weighted efficiency value.

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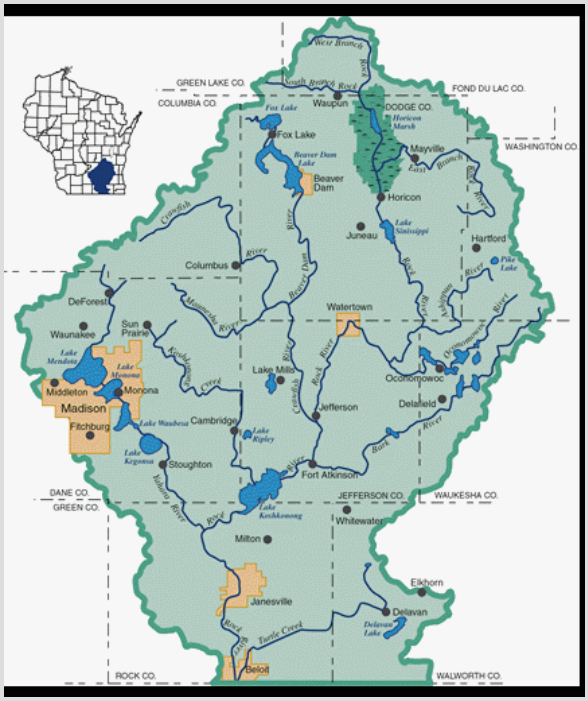

FIGURE 4-18 Rock River Basin, Wisconsin. SOURCE: Reprinted, with permission, from Kirsch (2000). Copyright 2000 by American Society for Biological and Agricultural Engineers.

SLAMM is designed for complex, urban catchments and is used as a planning tool to assess both stormwater and pollutant runoff production and the capability of specific stormwater control strategies to reduce stormwater discharges from urban sources. It is specifically designed to capture the most significant distributed and sequential drainage effects of variable source areas in urban catchments (Pitt and Vorhees, 2002) and is based on detailed descriptions of the catchment composition, including both type and relative position (drainage sequence) of land elements. The model is dependent on high-resolution classification or description of the catchment that has become increasingly available in urban areas over the past two decades, and comprehensive field assessment of runoff and pollutant loading from different urban land elements. SLAMM uses continuous simulation for some aspects, such as the build up of street pollutant loads between storms, while using event-based simulation for runoff. The description of build-up and wash-off is a critical component in urban stormwater models applied to areas with substantial impervious surfaces and is a good example of the need to match detailed and rigorous field sampling in

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order to adequately describe and represent dominant processes. Details of measurement and model representation for build-up and wash-off of contaminants are given in Box 4-8.

Potential New Applications of Coupled Distributed Models

The advent of high-resolution digital topographic and land-cover data over the past two decades has fueled a significant shift in runoff modeling towards "spatially explicit" simulations that distinguish and connect runoff producing elements in a detailed flow routing network. While models developed prior to the availability of high-resolution data or based on older paradigms developed in the absence of this information required spatial and conceptual lumping of control volumes, more recently developed distributed models may contain control volumes linked in multiple vertical layers (soil and aquifer elements) and laterally from a drainage divide to the stream, including stream-channel and riparian segments. A set of models has been developed and applied to stormwater generation using this paradigm that can be applied at the scale of residential neighborhoods, resolving land cover and topography at the parcel level. These models also vary in terms of their emphasis, with some models better representing coupled surface water–groundwater interactions, water, carbon and nutrient cycling, or land–atmosphere interactions. Boyer et al. (2006) have recently reviewed a set of hydrologic and ecosystem models in terms of their ability to simulate sources, transport, and transformation of nitrogen within terrestrial and aquatic ecosystems. Data and information requirements are typically high, and the level of process specificity may outstrip the available information necessary to parameterize the integrated models. However, an emphasis is placed on providing mechanistic linkage and feedbacks between important surface, subsurface, atmospheric, and ecosystem components. Examples of these models include the Distributed Hydrology Soil Vegetation model (DHSVM, Wigmosta et al., 1994); the Regional Hydro-Ecologic Simulation System (RHESSys, Band et al., 1993; Tague and Band, 2004); ParFlow-Common Land Model (CLM, Maxwell and Miller, 2007); the Penn State Integrated Hydrologic Model (PIHM, Qu and Duffy, 2007); the Soil Moisture Distribution and Routing (SMDR) model (Easton et al., 2007); and that of Xiao et al. (2007).

One advantage of integrating surface and subsurface flow systems within any of these model structures is the ability to incorporate different SCMs by specifying characteristics of specific locations within the flow element networks linked to the subsurface drainage. Examples can include alteration of surface detention storage and release curves to simulate detention ponds, or soil depth, texture, vegetation, and drainage release for rainfall gardens. The advantage of this approach is the tight coupling of these SCM features with the connected surface and subsurface drainage systems, allowing the direct incorporation of the SCM as sink or source terms within the flowpath network. Burgess et al. (1998) effectively demonstrated that suburban lawns can become the major

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BOX 4-8
Build-up and Wash-off of Contaminants from Impervious Surfaces

The accumulation and wash-off of street particulates have been studied for many years (Sartor and Boyd, 1972; Pitt, 1979, 1985, 1987) and are important considerations in many stormwater models, such as SWMM, HSPF, and SLAMM, that require information pertaining to the movement of pollutants over land surfaces. Accumulation rates are usually obtained through trial and error during calibration, with little, if any, actual direct measurements. Furthermore, those direct measurements that have been made are often misapplied in modeling applications, resulting in unreasonable model predictions.

Historically, streets have been considered the most important directly connected impervious surface. Therefore, much early research was directed toward measuring the processes on these surfaces. Although it was eventually realized that other surfaces can also be significant pollutant sources (see Pitt et al., 2005a,b for reviews), additional research to study accumulation and wash-off for these other areas has not been conducted, such that the following discussion is focused on street dirt accumulation and wash-off.

Accumulation of Particulates on Street Surfaces

The permanent storage component of street surface particulates is a function of street texture and condition and is the quantity of street dust and dirt that cannot be removed naturally by rain or wind, or by street cleaning equipment. It is literally trapped in the texture of the street. The street dirt loading at any time is this initial permanent loading plus the accumulation amount corresponding to the exposure period, minus the resuspended material removal by wind and traffic-induced turbulence.

One of the first research studies to attempt to measure street dirt accumulation was conducted by Sartor and Boyd (1972). Field investigations were conducted between 1969 and 1971 in several cities throughout the United States and in residential, commercial, and industrial land-use areas. Figure 4-19 is a plot of the 26 test area measurements collected from different cities, but separated by the three land uses. The data are the accumulated solids loading plotted against the number of days since the street had been cleaned by the municipal street cleaning operation or a “significant” rain. There is a large amount of variability. The street cleaning and this rain were both assumed to remove all of the street dirt; hence, the curves were all forced through zero loading at zero days.

A more thorough study was conducted in San Jose, California by Pitt (1979), during which the measured street dirt loading for a smooth street was also found to be a function of time. As shown in Figure 4-20, both accumulation rates and increases in particle size of the street dirt increase as time between street cleaning lengthens. However, it is also evident that there is a substantial residual loading on the streets immediately after the street cleaning, which differs substantially from the assumption of Sartor and Boyd that rains reduce street dirt to zero.

The San Jose study also investigated the role of different street textures, which resulted in very different street dirt loadings. Although the accumulation and deposition rates are quite similar, the initial loading values (the permanent storage values) are very different, with greater amounts of street dirt trapped by the coarser (oil and screens) pavement. Street cleaning and rains are not able to remove this residual material. The early, uncorrected Sartor and Boyd accumulation rates that ignored the initial loading values were almost ten times the corrected values that had reasonable “initial loads.”

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BOX 4-8 Continued

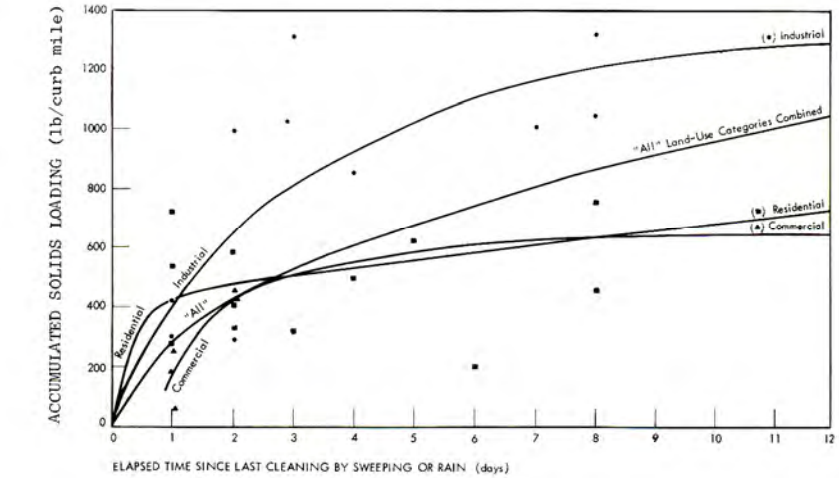

FIGURE 4-19 Accumulation curves developed during early street cleaning research. SOURCE: Sartor and Boyd (1972).

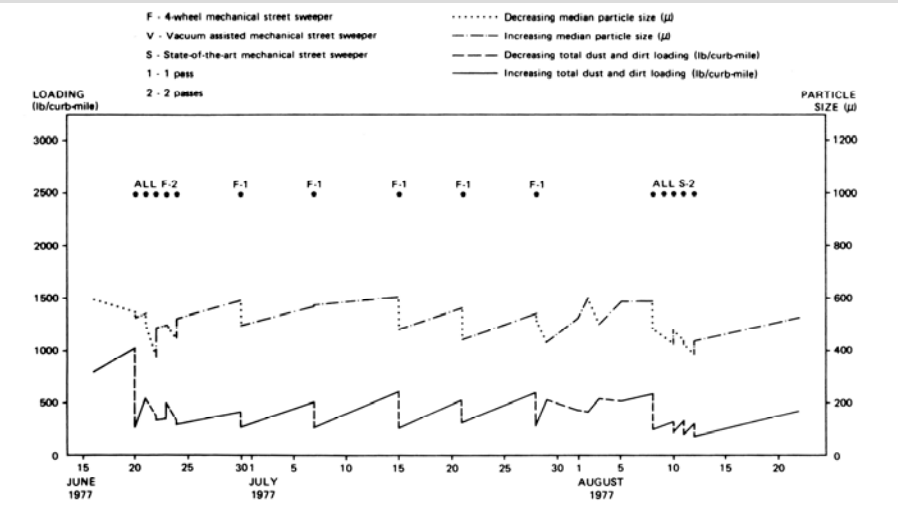

FIGURE 4-20 Street dirt accumulation and particle size changes on good asphalt streets in San Jose, California. SOURCE: Pitt (1979).

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Finally, it was found that, at very long accumulation periods relative to the rain frequency, the wind losses (fugitive dust) may approximate the deposition rate, resulting in very little increases in loading. In Bellevue, Washington, with inter-event rain periods averaging about three days, steady loadings were observed after about one week (Pitt, 1985). However, in Castro Valley, California, the rain inter-event periods were much longer (ranging from about 20 to 100 days), and steady loadings were never observed (Pitt and Shawley, 1982).

Taking many studies into account (Sartor and Boyd 1972—corrected; Pitt, 1979, 1983, 1985; Pitt and Shawley, 1982; Pitt and Sutherland, 1982; Pitt and McLean, 1986), the most important factors affecting the initial loading and maximum loading values have been found to be street texture and street condition, and not land use. When data from many locations are studied, it is apparent that smooth streets have substantially less loadings at any accumulation period compared to rough streets for the same land use. Very long accumulation periods relative to the rain frequency result in high street dirt loadings. However, during these conditions the wind losses of street dirt (as fugitive dust) may approximate the deposition rate, resulting in relatively constant street dirt loadings.

Wash-off of Street Surface Pollutants

Wash-off of particulates from impervious surfaces is dependent on the available supply of particulates on the surface that can be removed by rains, the rain energy available to loosen the material, and the capacity of the runoff to transport the loosened material. Observations of particulate wash-off during controlled tests have resulted in empirical wash-off models. The earliest controlled street dirt wash-off experiments were conducted by Sartor and Boyd (1972) to estimate the percentage of the available particulates on the streets that would wash off during rains of different magnitudes. Sartor and Boyd fitted their data to an exponential curve, as shown in Figure 4-21 (accumulative wash-off curves for several particle sizes). The empirical equation that they developed, $N = N_o\, e^{-kR}$, is only sensitive to the total rain depth up to the time of interest and the initial street dirt loading.

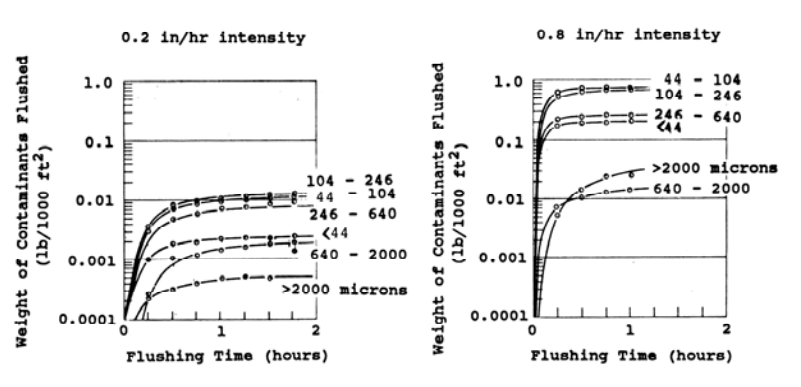

FIGURE 4-21 Street dirt wash-off during high-intensity rain tests. SOURCE: Sartor and Boyd (1972).

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BOX 4-8 Continued

There are several problems with this approach. First, these figures did not show the total street dirt loading that was present before the wash-off tests. Most modelers have assumed that the asymptotic maximum shown was the total "before-rain" street dirt loading; that is, the N_o factor has been assumed to be the total initial street loading, when in fact it is only the portion of the total street load available for wash-off (the maximum asymptotic wash-off load observed during the wash-off tests). The actual total street dirt loadings were several times greater than the maximum wash-off amounts observed. STORM and SWMM now use an availability factor (*A*) for particulate residue as a calibration procedure in order to reduce the wash-off quantity for different rain intensities (Novotny and Chesters, 1981). Second, the proportionality constant, *k*, was found by Sartor and Boyd to be slightly dependent on street texture and condition, but was independent of rain intensity and particle size. The value of this constant is usually taken as 0.18/mm, assuming that 90 percent of the particulates will be washed from a paved surface in one hour during a 13 mm/h rain. However, Alley (1981) fitted this model to watershed outfall runoff data and found that the constant varied for different storms and pollutants for a single study area. Novotny examined "before" and "after" rain-event street particulate loading data using the Milwaukee NURP stormwater data (Bannerman et al., 1983) and found almost a three-fold difference between the proportionality constant value for fine (<45 μm) and medium-sized particles (100 to 250 μm). Jewell et al. (1980) also found large variations in outfall "fitted" values for different rains compared to the typical default value. They stressed the need to have local calibration data before using the exponential wash-off equation, as the default values can be very misleading. The exponential wash-off equation for impervious areas is justified, but wash-off coefficients for each pollutant would improve its accuracy. The current SWMM5 version discourages the use of accumulation and wash-off functions due to lack of data, and the misinterpretation of available data.

It turns out that particle dislodgement and transport characteristics at impervious areas can be directly measured using relatively simple wash-off tests. The Bellevue, Washington, urban runoff project (Pitt, 1985) included about 50 pairs of street dirt loading observations close to the beginnings and ends of rains to determine the differences in loadings that may have been caused by the rains. The observations were affected by rains falling directly on the streets, along with flows and particulates originating from non-street areas. When all the data were considered together, the net loading difference was about 10 to 13 g/curb-m removed, which amounted to a street dirt load reduction of about 15 percent. Large reductions in street dirt loadings for the small particles were observed during these Bellevue rains. Most of the weight of solid material in the runoff was concentrated in fine particle sizes (<63 μm). Very few wash-off particles greater than 1,000 μm were found; in fact, street dirt loadings increased for the largest sizes, presumably due to settled erosion materials. Urban runoff outfall particle size analyses in Bellevue (Pitt, 1985) resulted in a median particle size of about 50 μm; similar results were obtained in the Milwaukee NURP study (Bannerman et al., 1983). The results make sense because the rain energy needed to remove larger particles is much greater than for small particles.

In order to clarify street dirt wash-off, Pitt (1987) conducted numerous controlled wash-off tests on city streets in Toronto. The experimental factors examined included rain intensity, street texture, and street dirt loading. The differences between available and total street dirt loads were also related to the experimental factors. The runoff flow quantities were also carefully monitored to determine the magnitude of initial and total rain water losses on impervious surfaces. The test setup was designed and tested to best represent actual rainfall conditions, such as rain intensities (3 mm/h) and peak rain intensities (12 mm/h). The kinetic energies of the "rains" during these tests were therefore comparable to actual rains under investigation. Figure 4-22 shows the asymptotic wash-off values observed in the tests, along with the measured total street dirt loadings. The maximum asymptotic values are the "available" street dirt loadings (N_o). As can be seen, the measured

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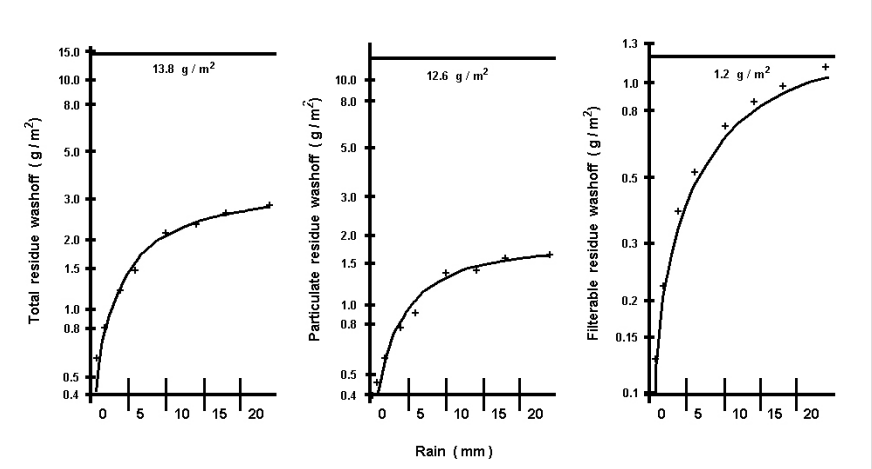

FIGURE 4-22 Wash-off plots for high rain intensity, dirty street, and smooth street test, showing the total street dirt loading. SOURCE: Pitt (1987).

total loadings are several times larger than these "available" loading values. For example, the asymptotic available total solids value for the high-intensity rain–dirty street–smooth street test was about 3 g/m^2 while the total load on the street for this test was about 14 g/m^2, or about five times the available load. The differences between available and total loadings for the other tests were even greater, with the total loads typically about ten times greater than the available loads. The total loading and available loading values for dissolved solids were quite close, indicating almost complete wash-off of the very small particles.

The availability factor (the ratio of the available loading, N_0, to the total loading) depended on the rain intensity and the street roughness, such that wash-off was more efficient for the higher rain energy and smoother pavement tests. The worst case was for a low rain intensity and rough street, where only about 4.5 percent of the street dirt would be washed from the pavement. In contrast, the high rain intensities on the smooth streets were more than four times more efficient in removing street dirt (20 percent removal).

A final important consideration in calculating wash-off of street dirt during rains is the carrying capacity of the flowing water to transport sediment. If the calculated wash-off is greater than the carrying capacity (such as would occur for relatively heavy street dirt loads and low to moderate rain intensities), then the carrying capacity is limiting. For high rain intensities, the carrying capacity is likely sufficient to transport most or all of the wash-off material. Figure 4-23 shows the maximum wash-off amounts (g/m^2) for the different tests conducted on smooth streets plotted against the rain intensity (mm/h) used for the tests (data from Sartor and Boyd, 1972, and Pitt, 1987). Wash-off limitations for rough streets would be more restrictive.

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BOX 4-8 Continued

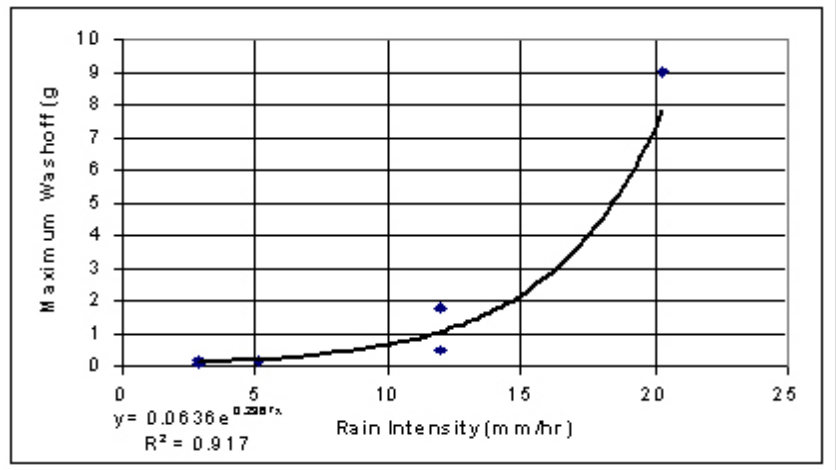

FIGURE 4-23 Maximum wash-off capacity for smooth streets (based on measurements of Sartor and Boyd, 1972; Pitt, 1987). If the predicted wash-off, using the previous "standard" wash-off equations, is smaller than the values shown in this figure, then those values can be used directly. However, if the predicted wash-off is greater than the values shown in this figure, then the values in the figure should be used.

Accumulation and Wash-off Summary

This discussion summarized street particulate wash-off observations obtained during special wash-off tests, along with associated street dirt accumulation measurements. The objectives of these tests were to identify the significant rain and street factors affecting particulate wash-off and to develop appropriate wash-off models. The controlled wash-off experiments identified important relationships between "available" and "total" particulate loadings and the significant effects of the test variables on the wash-off model parameters. Past modeling efforts have typically ignored or misused this relationship to inaccurately predict the importance of street particulate wash-off. The available loadings were almost completely washed off streets during rains of about 25 mm (as previously assumed). However, the fraction of the total loading that was available was at most only 20 percent of the total loading, and averaged only 10 percent, with resultant actual wash-offs of only about 9 percent of the total loadings.

In many model applications, total initial loading values (as usually measured during field studies) are used in conjunction with model parameters as the available loadings, resulting in predicted wash-off values that are many times larger than observed. This has the effect of incorrectly assuming greater pollutant contributions originating from streets and less from other areas during rains. This in turn results in inaccurate estimates of the effectiveness of different source area urban runoff controls. Although streets can be important sources of runoff and stormwater pollutants, their significance varies greatly depending on the land use and rainfall pattern. They are much more important sources in areas having relatively mild rains (e.g., the Pacific Northwest), where contaminants from other potential sources are not effectively transported to the storm drainage system.

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source of stormwater in seasonally wet conditions (Seattle), while Cuo et al. (2008) have explored the modification of DHSVM to include detention SCMs. Xiao et al. (2007) explicitly integrated and evaluated parcel scale SCM design and efficiency into their model. Wang et al. (2008) integrated a canopy interception model with a semi-distributed subsurface moisture scheme (TOPMODEL) to evaluate the effectiveness of urban tree canopy interception on stormwater production, utilizing a detailed spatial dataset of urban tree cover. Band et al. (2001) and Law (2003) coupled a water-, carbon-, and nitrogen-cycling model to a distributed water routing system modified from DHSVM to simulate nitrogen cycling and export in a high-spatial-resolution representation of forested and suburban catchments. While these models have the potential to directly link stormwater generation with specific dischargers, the challenge of scaling to larger watersheds remains. SMDR (Easton et al., 2007) has recently been used to integrate rural and urban stormwater production, including dissolved phosphorus source and transport in New York State.

Alternatives to mass budget-based models include fully statistical approaches such as simple regressions based on watershed land use and population (e.g., Boyer et al., 2002); nonlinear regression using detailed watershed spatial data and observed loads to estimate retention parameters and loading of nutrients, sediment, and other pollutants (e.g., Smith et al., 1997; Brakebill and Preston, 1999; Schwarz et al., 2006); and Bayesian chain models (e.g., Reckhow and Chapra, 1999; Borsuk et al., 2001). These models have the advantage of being data-based, and therefore capable of assimilating observations as they become available to update water quality probabilities, but also lack a process basis that might support management intervention. A major debate exists within the literature as to the relative advantages of detailed process-based models that may not have inadequate information for parameterization, and the more empirical, data-based approaches.

Limitations in Extending Stormwater Models to Biological Impacts

The mass budget approach may be successful in developing the physical and chemical characteristics of the receiving waterbody in terms of the flow (or stage) duration curve, the distribution of concentrations over time, and the integrated pollutant storage and flux (load) terms. However, the biological status of the waterbody requires a link between the physical and chemical conditions, primary productivity, and trophic system interactions. Progressing from aquatic ecosystem productivity to trophic systems includes increasingly complex ecological processes such as competition, herbivory, predation, and migration. To date, mechanistic linkage between flow path hydraulics, biogeochemistry, and the ecological structure of the aquatic environment has not been developed. Instead, habitat suitability for different communities is identified through empirical sampling and analysis, with the implicit assumption that, as relative

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TABLE 4-7 Example Mathematical Models That Have Been or Can Be Used in Stormwater Modeling

Model	Common Use	Typical Scale	Complexity	Data Requirements	Ground-water	SCM	Reference
Rational Method	Urban hydraulic design—peak flow	Small	Simple	Land cover, rainfall intensity, T_c	None	None	Standard hydrology text
Simple Method	Urban annual runoff, loads	Small to medium	Simple	Impervious surface cover, land use, annual rainfall	None	None	http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm
TR-20 TR-55	Rural/urban runoff production for simple stormwater models, hydraulic design	Small to medium	Simple to medium	Land use, soil texture, T_c	None	Pond sizing for hydraulic benefits and others through CN modification	http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models
GWLF	Rural/urban runoff, pollutant loading	Medium to watershed	Simple to medium	Land use, soil texture, precipitation time series	Simple linear reservoir	Runoff reduction with CN modification	Haith and Shoemaker (1987) http://www.avgwlf.psu.edu/overview.htm
P8	Urban runoff, pollutant loading	Small to large	Simple to medium	Land use, soil texture, precipitation time series, SCM type and sizing	Simple linear reservoir	Runoff reduction with CN modification, ponds (evaluation and sizing), infiltration, street cleaning	Palmstrom and Walker (1990) http://www.wwwalker.net/p8/
MUSIC	Urban runoff, pollutant loading, hydraulic design, simple receiving water	Small to large	Medium to complex	Land use, soil texture, precipitation/PET? time series, drainage system details, SCM type and sizing	Simple linear reservoir	Comprehensive evaluation of SCM systems	Wong (2000) (proprietary) http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit.woa/wa/productDetails?productID=1000000

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SWMM	Urban runoff, pollutant loading, hydraulic design	Small to large	Medium to complex	Land use, soil texture, meteorological time series, drainage system details, SCM type and sizing	Simple linear reservoir?	Infiltration practices, ponds, street cleaning	http://www.epa.gov/ednnrmrl/models/swmm
PCSWMM	Same as above	Same as above	Same as above	Same as above	Same as above	Enhanced SCM compared to SWMM	(proprietary) http://www.computationalhydraulics.com/Software/PCSWMM.NET
WinSLAMM	Urban runoff, pollutant loads	Small to large	Intermediate	Land cover, land use, development characteristics, soil texture, compaction, rainfall event time series, monthly PET, monthly water evaporation, SCM type and sizing	Mounding under infiltration controls	Comprehensive evaluation of SCM systems	(proprietary) http://www.winslamm.com/prod01.htm
SWAT	Rural runoff, loading	Medium to watershed	Intermediate	Land cover/land use, soil texture, precipitation, temperature, humidity, solar radiation time or PET series	Simple subbasin reservoir	Impoundments, agricultural conservation practices, nutrient management, buffers	http://www.epa.gov/waterscience/BASINS/bsnsdocs.html#swat
HSPF	Comprehensive watershed evaluation, receiving water dynamics	Medium to watershed	Complex	Land cover/land use, soil texture, precipitation, temperature, humidity, solar radiation or PET time series	Subbasin reservoir	Infiltration, ponds	Bicknell et al. (2005) http://www.epa.gov/ceampubl/swater/hspf/index.htm http://www.epa.gov/waterscience/BASINS/bsnsdocs.html#hspf
WWHM	HSPF engine with regional modifications,	Puget Sound	Complex	Same as above	Same as above	Enhanced infiltration, ponds (from HSPF)	http://www.ecy.wa.gov/programs/wq/stormwater/wwhm_training/index.html.
CBWM	HSPF engine with regional modifications,	Chesapeake Bay Watershed	Complex	Same as above	Same as above	Enhanced infiltration, ponds (from HSPF)	http://www.chesapeakebay.net/phase5.htm

Note: CN, curve number

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habitat suitability changes, transitions will occur between species or assemblages. These methods may work well at the base of the trophic system (algae, phytoplankton) and for specific conditions such as DO limitations on fish communities, but the impacts of low to moderate concentrations of pollutants on aquatic ecosystems may still be poorly understood. A critical assumption in these and similar models (e.g., ecological community change resulting from physical changes to the watershed or climate) is the substitution of space for time. More detailed understanding of the mechanisms leading to a shift in ecological communities and interactions with the physical environment is necessary to develop models of transient change, stability of the shifts, and feedback to the biophysical environment.

Given these limitations, it should be noted that statistical databases on species tolerance to a range of aquatic conditions have been compiled that will allow the development of habitat suitability mapping as a mechanism for (1) targeting ecosystem restoration, (2) determining vulnerable sites (for use in application of the Endangered Species Act), and (3) assessing aquatic ecosystem impairment and "best use" relative to reference sites.

***

Stormwater models have been developed to meet a range of objectives, including small-scale hydraulic design (e.g., siting and sizing a detention pond), estimation of potential contributions of stormwater pollutants from different land covers and locations using empirically generated EMC, and large watershed hydrology and gross pollutant loading. The ability to associate a given discharger with a particular waterbody impairment is limited by the scale and complexity of watersheds (i.e., there maybe multiple discharge interactions); by the ability of a model to accurately reproduce the distribution function of discharge events and their cumulative impacts (as opposed to focusing only on design storms of specific return periods); and by the availability of monitoring data of sufficient number and design to characterize basic processes (e.g., build-up/wash-off), to parameterize the models, and to validate model predictions.

In smaller urban catchments with few dominant dischargers and significant impervious area, current modeling capabilities may be sufficient to associate the cumulative impact of discharge to waterbody impairment. However, many impaired waterbodies have larger, more heterogeneous stormwater sources, with impacts that are complex functions of current and past conditions. The level of sampling that would be necessary to support linked model calibration and verification using current measurement technologies is both time-consuming and expensive. In order to develop a more consistent capability to support stormwater permitting needs, there should be increased investment in improving model paradigms, especially the practice and methods of model linkage as described above, and in stormwater monitoring. The latter may require investment in a new generation of sensors that can sample at temporal resolutions that can adjust to characterize low flow and the dynamics of storm flow, but are sufficiently

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inexpensive and autonomous to be deployed in multiple locations from distributed sources to receiving waterbodies of interest. Finally, as urban areas extend to encompass progressively lower-density development, the interactions of surface water and groundwater become more critical to the cumulative impact of stormwater on impaired waterbodies.

EPA needs to ensure continuous support and development of their water quality models and spatial data infrastructure. Beyond this, a set of distributed watershed models has been developed that can resolve the location and position of parcels within hydrologic flow fields; these are being modified for use as urban stormwater models. These models avoid the pitfalls of lumping, but they require much greater volumes of spatial data, provided by current remote sensing technology (e.g., lidar, airborne digital optical and infrared sensors) as well as the emerging set of in-stream sensor systems. While these methods are not yet operational or widespread, they should be further investigated and tested for their capabilities to support stormwater management.

CONCLUSIONS AND RECOMMENDATIONS

This chapter addresses what might be the two weakest areas of the stormwater program—monitoring and modeling of stormwater. The MS4 and particularly the industrial stormwater monitoring programs suffer from (1) a paucity of data, (2) inconsistent sampling techniques, (3) a lack of analyses of available data and guidance on how permittees should be using the data to improve stormwater management decisions, and (4) requirements that are difficult to relate to the compliance of individual dischargers. The current state of stormwater modeling is similarly limited. Stormwater modeling has not evolved enough to consistently say whether a particular discharger can be linked to a specific waterbody impairment, although there are many correlative studies showing how parameters co-vary in important but complex and poorly understood ways (see Chapter 3). Some quantitative predictions can be made, particularly those that are based on well-supported causal relationships of a variable that responds to changes in a relatively simple driver (e.g., modeling how a runoff hydrograph or pollutant loading change in response to increased impervious land cover). However, in almost all cases, the uncertainty in the modeling and the data, the scale of the problems, and the presence of multiple stressors in a watershed make it difficult to assign to any given source a specific contribution to water quality impairment. More detailed conclusions and recommendations about monitoring and modeling are given below.

Because of a ten-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized. These results come from many thousands of storm events, systematically compiled and widely accessible; they form a robust dataset of utility to theoreticians and practitioners alike. These data make it possible to

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accurately estimate the EMC of many pollutants. Additional data are available from other stormwater permit holders that were not originally included in the database and from ongoing projects, and these should be acquired to augment the database and improve its value in stormwater management decision-making.

Industry should monitor the quality of stormwater discharges from certain critical industrial sectors in a more sophisticated manner, so that permitting authorities can better establish benchmarks and technology-based effluent guidelines. Many of the benchmark monitoring requirements and effluent guidelines for certain industrial subsectors are based on inaccurate and old information. Furthermore, there has been no nationwide compilation and analysis of industrial benchmark data, as has occurred for MS4 monitoring data, to better understand typical stormwater concentrations of pollutants from various industries. The absence of accurate benchmarks and effluent guidelines for critical industrial sectors discharging stormwater may explain the lack of enforcement by permitting authorities, as compared to the vigorous enforcement within the wastewater discharge program.

Industrial monitoring should be targeted to those sites having the greatest risk associated with their stormwater discharges. Many industrial sites have no or limited exposure to runoff and should not be required to undertake extensive monitoring. Visual inspections should be made, and basic controls should be implemented at these areas. Medium-risk industrial sites should conduct monitoring so that a sufficient number of storms are measured over the life of the permit for comparison to regional benchmarks. Again, visual inspections and basic controls are needed for these sites, along with specialized controls to minimize discharges of the critical pollutants. Stormwater from high-risk industrial sites needs to be continuously monitored, similar to current point source monitoring practices. The use of a regionally calibrated stormwater model and random monitoring of the lower-risk areas will likely require additional monitoring.

Continuous, flow-weighted sampling methods should replace the traditional collection of stormwater data using grab samples. Data obtained from too few grab samples are highly variable, particularly for industrial monitoring programs, and subject to greater uncertainly because of experimenter error and poor data-collection practices. In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications. It should be replaced by more accurate and frequent continuous sampling methods that are flow weighted. Flow-weighted composite monitoring should continue for the duration of the rain event. Emerging sensor systems that provide high temporal resolution and real-time estimates for specific pollutants should be further investigated, with the aim of providing lower costs and more extensive monitoring systems to sample both streamflow and constituent loads.

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Flow monitoring and on-site rainfall monitoring need to be included as part of stormwater characterization monitoring. The additional information associated with flow and rainfall data greatly enhance the usefulness of the much more expensive water quality monitoring. Flow monitoring should also be correctly conducted, with adequate verification and correct base-flow subtraction methods applied. Using regional rainfall data from locations distant from the monitoring location is likely to be a major source of error when rainfall factors are being investigated. The measurement, quality assurance, and maintenance of long-term precipitation records are both vital and nontrivial to stormwater management.

Whether a first flush of contaminants occurs at the start of a rainfall event depends on the intensity of rainfall, the land use, and the specific pollutant. First flushes are more common for smaller sites with greater imperviousness and thus tend to be associated with more intense land uses such as commercial areas. Even though a site may have a first flush of a constituent of concern, it is still important that any SCM be designed to treat as much of the runoff from the site as possible. In many situations, elevated discharges may occur later in an event associated with delayed periods of peak rainfall intensity.

Stormwater runoff in arid and semi-arid climates demonstrates a seasonal first-flush effect (i.e., the dirtiest storms are the first storms of the season). In these cases, it is important that SCMs are able to adequately handle these flows. As an example, early spring rains mixed with snowmelt may occur during periods when wet detention ponds are still frozen, hindering their performance. The first fall rains in the southwestern regions of the United States may occur after extended periods of dry weather. Some SCMs, such as street cleaning targeting leaf removal, may be more effective before these rains than at other times of the year.

Watershed models are useful tools for predicting downstream impacts from urbanization and designing mitigation to reduce those impacts, but they are incomplete in scope and typically do not offer definitive causal links between polluted discharges and downstream degradation. Every model simulates only a subset of the multiple interconnections between physical, chemical, and biological processes found in any watershed, and they all use a grossly simplified representation of the true spatial and temporal variability of a watershed. To speak of a "comprehensive watershed model" is thus an oxymoron, because the science of stormwater is not sufficiently far advanced to determine causality between all sources, resulting stressors, and their physical, chemical, and biological responses. Thus, it is not yet possible to create a protocol that mechanistically links stormwater dischargers to the quality of receiving waters. The utility of models with more modest goals, however, can still be high—as long as the questions being addressed by the model are in fact relevant and important to the functioning of the watershed to which that model is being applied, and sufficient data are available to calibrate the model for the processes

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included therein.

EPA needs to ensure that the modeling and monitoring capabilities of the nation are continued and enhanced to avoid losing momentum in understanding and eliminating stormwater pollutant discharges. There is a need to extend, develop, and support current modeling capabilities, emphasizing (1) the impacts of flow energy, sediment transport, contaminated sediment, and acute and chronic toxicity on biological systems in receiving waterbodies; (2) more mechanistic representation (physical, chemical, biological) of SCMs; and (3) coupling between a set of functionally specific models to promote the linkage of source, transport and transformation, and receiving water impacts of stormwater discharges. Stormwater models have typically not incorporated interactions with groundwater and have treated infiltration and recharge of groundwater as a loss term with minimal consideration of groundwater contamination or transport to receiving waterbodies. Emerging distributed modeling paradigms that simulate interactions of surface and subsurface flowpaths provide promising tools that should be further developed and tested for applications in stormwater analysis.

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5
Stormwater Management Approaches

A fundamental component of the U.S. Environmental Protection Agency's (EPA) Stormwater Program, for municipalities as well as industries and construction, is the creation of stormwater pollution prevention plans. These plans invariably document the stormwater control measures that will be used to prevent the permittee's stormwater discharges from degrading local waterbodies. Thus, a consideration of these measures—their effectiveness in meeting different goals, their cost, and how they are coordinated with one another—is central to any evaluation of the Stormwater Program. This report uses the term stormwater control measure (SCM) instead of the term best management practice (BMP) because the latter is poorly defined and not specific to the field of stormwater.

The committee's statement of task asks for an evaluation of the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality. As discussed in the last two chapters, the state of the science has yet to reveal the mechanistic links that would allow for a full assessment of that relationship. However, enough is known to design systems of SCMs, on a site scale or local watershed scale, to lessen many of the effects of urbanization. Also, for many regulated entities the current approach to stormwater management consists of choosing one or more SCMs from a preapproved list. Both of these facts argue for the more comprehensive discussion of SCMs found in this chapter, including information on their characteristics, applicability, goals, effectiveness, and cost. In addition, a multitude of case studies illustrate the use of SCMs in specific settings and demonstrate that a particular SCM can have a measurable positive effect on water quality or a biological metric. The discussion of SCMs is organized along the gradient from the rooftop to the stream. Thus, pollutant and runoff prevention are discussed first, followed by runoff reduction and finally pollutant reduction.

HISTORICAL PERSPECTIVE ON STORMWATER CONTROL MEASURES

Over the centuries, SCMs have met different needs for cities around the world. Cities in the Mesopotamian Empire during the second millennium BC had practices for flood control, to convey waste, and to store rain water for household and irrigation uses (Manor, 1966) (see Figure 5-1). Today, SCMs are considered a vital part of managing flooding and drainage problems in a city. What is relatively new is an emphasis on using the practices to remove pollutants from stormwater and selecting practices capable of providing groundwater recharge. These recent expectations for SCMs are not readily accepted and re-

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quire an increased commitment to the proper design and maintenance of the practices.

With the help of a method for estimating peak flows (the Rational Method, see Chapter 4), the modern urban drainage system came into being soon after World War II. This generally consisted of a system of catch basins and pipes to prevent flooding and drainage problems by efficiently delivering runoff water to the nearest waterbody. However, it was soon realized that delivering the water too quickly caused severe downstream flooding and bank erosion in the receiving water. To prevent bank erosion and provide more space for flood waters, some stream channels were enlarged and lined with concrete (see Figure 5-2). But while hardening and enlarging natural channels is a cost-effective solution to erosion and flooding, the modified channel increases downstream peak flows and it does not provide habitat to support a healthy aquatic ecosystem.



FIGURE 5-1 Cistern tank, Kamiros, Rhodes (ancient Greece, 7th century BC). SOURCE: Robert Pitt, University of Alabama.

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FIGURE 5-2 Concrete channel in Lincoln Creek, Milwaukee, Wisconsin. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.

Some way was needed to control the quantity of water reaching the end of pipes during a runoff event, and on-site detention (Figure 5-3) became the standard for accomplishing this. Ordinances started appearing in the early 1970s, requiring developers to reduce the peaks of different size storms, such as the 10-year, 24-hour storm. The ordinances were usually intended to prevent future problems with peak flows by requiring the installation of flow control structures, such as detention basins, in new developments. Detention basins can control peak flows directly below the point of discharge and at the property boundary. However, when designed on a site-by-site basis without taking other basins into account, they can lead to downstream flooding problems because volume is not reduced (McCuen, 1979; Ferguson, 1991; Traver and Chadderton, 1992; EPA, 2005d). In addition, out of concerns for clogging, openings in the outlet structure of most basins are generally too large to hold back flows from smaller, more frequent storms. Furthermore, low-flow channels have been constructed or the basins have been graded to move the runoff through the structure without delay to prevent wet areas and to make it easier to mow and maintain the detention basin.

Because of the limitations of on-site detention, infiltration of urban runoff to control its volume has become a recent goal of stormwater management. Without stormwater infiltration, municipalities in wetter regions of the country can expect drops in local groundwater levels, declining stream base flows (Wang et al., 2003a), and flows diminished or stopped altogether from springs feeding wetlands and lakes (Leopold, 1968; Ferguson, 1994).

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FIGURE 5-3 On-site detention. SOURCE: Tom Schueler, Chesapeake Stormwater Network, Inc.

The need to provide volume control marked the beginning of low-impact development (LID) and conservation design (Arendt, 1996; Prince George's County, 2000), which were founded on the seminal work of landscape architect Ian McHarg and associates decades earlier (McHarg and Sutton, 1975; McHarg and Steiner, 1998). The goal of LID is to allow for development of a site while maintaining as much of its natural hydrology as possible, such as infiltration, frequency and volume of discharges, and groundwater recharge. This is accomplished with infiltration practices, functional grading, open channels, disconnection of impervious areas, and the use of fewer impervious surfaces. Much of the LID focus is to manage the stormwater as close as possible to its source—that is, on each individual lot rather than conveying the runoff to a larger regional SCM. Individual practices include rain gardens (see Figure 5-4), disconnected roof drains, porous pavement, narrower streets, and grass swales. In some cases, LID site plans still have to include a method for passing the larger storms safely, such as a regional infiltration or detention basin or by increasing the capacity of grass swales.

Infiltration has been practiced in a few scattered locations for a long time. For example, on Long Island, New York, infiltration basins were built starting in 1930 to reduce the need for a storm sewer system and to recharge the aquifer, which was the only source of drinking water (Ferguson, 1998). The Cities of Fresno, California, and El Paso, Texas, which faced rapidly dropping groundwater tables, began comprehensive infiltration efforts in the 1960s and 1970s. In the 1980s Maryland took the lead on the east coast by creating an ambitious

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FIGURE 5-4 Rain Garden in Madison, Wisconsin. SOURCE: Roger Bannerman, Wisconsin Department of Natural Resources.

statewide infiltration program. The number of states embracing elements of LID, especially infiltration, has increased during the 1990s and into the new century and includes California, Florida, Minnesota, New Jersey, Vermont, Washington, and Wisconsin.

Evidence gathered in the 1970s and 1980s suggested that pollutants be added to the list of things needing control in stormwater (EPA, 1983). Damages caused by elevated flows, such as stream habitat destruction and floods, were relatively easy to document with something as simple as photographs. Documentation of elevated concentrations of conventional pollutants and potentially toxic pollutants, however, required intensive collection of water quality samples during runoff events. Samples collected from storm sewer pipes and urban streams in the Menomonee River watershed in the late 1970s clearly showed the concentrations of many pollutants, such as heavy metals and sediment, were elevated in urban runoff (Bannerman et al., 1979). Levels of heavy metals were especially high in industrial-site runoff, and construction-site erosion was calculated to be a large source of sediment in the watershed. This study was followed by the National Urban Runoff Program, which added more evidence about the high levels of some pollutants found in urban runoff (Athayde et al., 1983; Bannerman et al., 1983).

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With new development rapidly adding to the environmental impacts of existing urban areas, the need to develop good stormwater management programs is more urgent than ever. For a variety of reasons, the greatest potential for stormwater management to reduce the footprint of urbanization is in the suburbs. These areas are experiencing the fastest rates of growth, they are more amenable to stormwater management because buildings and infrastructure are not yet in place, and costs for stormwater management can be borne by the developer rather than by taxpayers. Indeed, most structural SCMs are applied to new development rather than existing urban areas. Many of the most innovative stormwater programs around the country are found in the suburbs of large cities such as Seattle, Austin, and Washington, D.C. When stormwater management in ultra-urban areas is required, it entails the retrofitting of detention basins and other flow control structures or the introduction of innovative below-ground structures characterized by greater technical constraints and higher costs, most of which are charged to local taxpayers.

Current-day SCMs represent a radical departure from past practices, which focused on dealing with extreme flood events via large detention basins designed to reduce peak flows at the downstream property line. As defined in this chapter, SCMs now include practices intended to meet broad watershed goals of protecting the biology and geomorphology of receiving waters in addition to flood peak protection. The term encompasses such diverse actions as using more conventional practices like basins and wetland to installing stream buffers, reducing impervious surfaces, and educating the public.

REVIEW OF STORMWATER CONTROL MEASURES

Stormwater control measures refer to what is defined by EPA (1999) as "a technique, measure, or structural control that is used for a given set of conditions to manage the quantity and improve the quality of stormwater runoff in the most cost-effective manner." SCMs are designed to mitigate the changes to both the quantity and quality of stormwater runoff that are caused by urbanization. Some SCMs are engineered or constructed facilities, such as a stormwater wetland or infiltration basin, that reduce pollutant loading and modify volumes and flow. Other SCMs are preventative, including such activities as education and better site design to limit the generation of stormwater runoff or pollutants.

Stormwater Management Goals

It is impossible to discuss SCMs without first considering the goals that they are expected to meet. A broadly stated goal for stormwater management is to reduce pollutant loads to waterbodies and maintain, as much as possible, the natural hydrology of a watershed. On a practical level, these goals must be made specific to the region of concern and embedded in the strategy for that

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region. Depending on the designated uses of the receiving waters, climate, geomorphology, and historical development, a given area may be more or less sensitive to both pollutants and hydrologic modifications. For example, goals for groundwater recharge might be higher in an area with sandy soils as compared to one with mostly clayey soils; watersheds in the coastal zone may not require hydrologic controls. Ideally, the goals of stormwater management should be linked to the water quality standards for a given state's receiving waters. However, because of the substantial knowledge gap about the effect of a particular stormwater discharge on a particular receiving water (see Chapter 3 conclusions), surrogate goals are often used by state stormwater programs in lieu of water quality standards. Examples include credit systems, mandating the use of specific SCMs, or achieving stormwater volume reduction. Credit systems might be used for practices that are known to be productive but are difficult to quantify, such as planting trees. Specific SCMs might be assumed to remove a percent of pollutants, for example 85 percent removal of total suspended solids (TSS) within a stormwater wetland. Reducing the volume of runoff from impervious surfaces (e.g., using an infiltration device) might be assumed to capture the first flush of pollutants during a storm event. Before discussing specific state goals, it is worth understanding the broader context in which goals are set.

Trade-offs Between Stormwater Control Goals and Costs

The potentially substantial costs of implementing SCMs raise a number of fundamental social choices concerning land-use decisions, designated uses, and priority setting for urban waters. To illustrate some of these choices, consider a hypothetical urban watershed with three possible land-cover scenarios: 25, 50, and 75 percent impervious surface. A number of different beneficial uses could be selected for the streams in this watershed. At a minimum, the goal may be to establish low-level standards to protect public health and safety. To achieve this, sufficient and appropriate SCMs might be applied to protect residents from flooding and achieve water quality conditions consistent with secondary human contact. Alternatively, the designated use could be to achieve the physical, chemical, and/or biological conditions sufficient to provide exceptional aquatic habitat (e.g., a high-quality recreational fishery). The physical, biological, and chemical conditions supportive of this use might be similar to a reference stream located in a much less disturbed watershed. Achieving this particular designated use would require substantially greater resources and effort than achieving a secondary human contact use. Intermediate designated uses could also be imagined, including improving ambient water quality conditions that would make the water safe for full-body emersion (primary human contact) or habitat conditions for more tolerant aquatic species.

Figure 5-5 sketches what the marginal (incremental) SCM costs (opportunity costs) might be to achieve different designated uses given different amounts of impervious surface in the watershed. The horizontal axis orders potential

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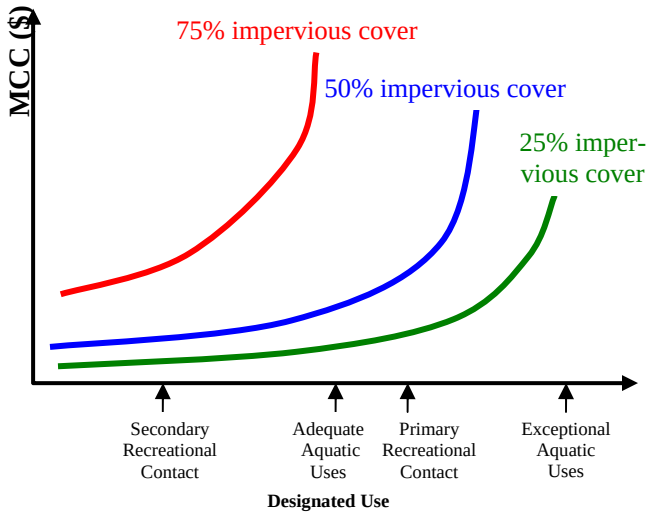

FIGURE 5-5 Cost of achieving designated uses in a hypothetical urban watershed. MCC is the marginal control cost, which represents the incremental costs to achieve successive expansion of designated uses through SCMs. The curves are constructed on the assumption that the lowest cost combination of SCMs would be implemented at each point on the curve.

designated uses in terms of least difficult to most difficult to achieve. The three conceptual curves represent the SCM costs under three different impervious surface scenarios. The relative positions of the cost curves indicate that achieving any specific designated use will be more costly in situations with a higher percentage of the watershed in impervious cover. All cost curves are upward sloping, reflecting the fact that incremental improvements in designated uses will be increasingly costly to achieve. The cost curves are purely conceptual, but nonetheless might reasonably reflect the relative costs and direction of change associated with achieving specific designated uses in different watershed conditions.

The locations of the cost curves suggest that in certain circumstances not all designated uses can be achieved or can be achieved only at an extremely high cost. For example, the attainment of exceptional aquatic uses may be unachievable in areas with 50 percent impervious surface even with maximum application of SCMs. In this illustration, the cost of achieving even secondary human contact use is high for areas with 75 percent impervious surfaces. In such highly urbanized settings, achievement of only adequate levels of aquatic uses could be exceedingly high and strain the limits of what is technically achievable. Finally, the existing and likely expected future land-use conditions have significant im-

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plications for what is achievable and at what cost. Clearly land-use decisions have an impact on the cost and whether a use can be achieved, and thus they need to be included in the decision process. The trade-off between costs and achieving specific designated uses can change substantially given different development patterns.

The purpose of Figure 5-5 is not to identify the precise location of the cost curves or to identify thresholds for achieving specific designated uses. Rather, these concepts are used to illustrate some fundamental trade-offs that confront public and private investment and regulatory decisions concerning stormwater management. The general relationships shown in Figure 5-5 suggest the need for establishing priorities for investments in stormwater management and controls, and connecting land usage and watershed goals. Setting overly ambitious or costly goals for urban streams may result in the perverse consequence of causing more waters to fail to meet designated uses. For example, consider efforts to secure ambitious designated uses in highly developed areas or in an area slated for future high-density development. Regulatory requirements and investments to limit stormwater quantity and quality through open-space requirements, areas set aside for infiltration and water detention, and strict application of maximum extent practicable controls have the effect of both increasing development costs and diminishing land available for residential and commercial properties. Policies designed to achieve exceedingly costly or infeasible designated uses in urban or urbanizing areas could have the net consequence of shifting development (and associated impervious surface) out into neighboring areas and watersheds. The end result might be minimal improvements in "within-watershed" ambient conditions but a decrease in designated uses (more impairments) elsewhere. In such a case, it might be sound water quality policy to accept higher levels of impervious surface in targeted locations, more stormwater-related impacts, and less ambitious designated uses in urban watersheds in order to preserve and protect designated uses in other watersheds.

Setting unrealistic or unachievable water quality objectives in urban areas can also pose political risks for stormwater management. The cost and difficulty of achieving ambitious water quality standards for urban stream goals may be understood by program managers but pursued nonetheless in efforts to demonstrate public commitment to achieving high-quality urban waters. Yet, promising what cannot be realistically achieved may act to undermine public support for urban stormwater programs. Increasing costs without significant observable improvements in ambient water conditions or achievement of water quality standards could ultimately reduce public commitment to the program. Thus, there are risks of "setting the bar" too high, or not coordinating land use and designated stream uses.

The cost of setting the bar too low can also be significant. Stormwater requirements that result in ineffective stormwater management will not achieve or maintain the desired water uses and can result in impairments. Loss of property, degraded waters, and failed infrastructure are tangible costs to the public (Johnston et al., 2006). Streambank rehabilitation costs can be severe, and loss of con-

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fidence in the ability to meet stormwater goals can result.

The above should not be construed as an argument for or against devoting resources to SCMs; rather, such decisions should be made with an open and transparent acknowledgment and understanding of the costs and consequences involved in those decisions.

Common State Stormwater Goals

Most states do not and have never had an overriding water quality objective in their stormwater program, but rather have used engineering criteria for SCM performance to guide stormwater management. These criteria can be loosely categorized as:

- Erosion and sedimentation control,
- Recharge/base flow,
- Water quality,
- Channel protection, and
- Flooding events.

The SCMs used to address these goals work by minimizing or eliminating increases in stormwater runoff volume, peak flows, and/or the pollutant load carried by stormwater.

The criteria chosen by any given state usually integrate state, federal, and regional laws and regulations. Areas of differing climates may emphasize one goal over another, and the levels of control may vary drastically. Contrast a desert region where rainwater harvesting is extremely important versus a coastal region subject to hurricanes. Some areas like Seattle have frequent smaller volume rainfalls—the direct opposite of Austin, Texas—such that small volume controls would be much more effective in Seattle than Austin. Regional geology (karst) or the presence of Brownfields may affect the chosen criteria as well.

The committee's survey of State Stormwater Programs (Appendix C) reflects a wide variation in program goals as reflected in the criteria found in their SCM manuals. Some states have no specific criteria because they do not produce SCM manuals, while others have manuals that address every category of criteria from flooding events to groundwater recharge. Some states rely upon EPA or other states' or transportation agencies' manuals. In general, soil and erosion control criteria are the most common and often exist in the absence of any other state criteria. This wide variation reflects the difficulties that states face in keeping up with rapidly changing information about SCM design and performance.

The criteria are ordered below (after the section on erosion and sediment control) according to the size of the storm they address, from smallest to most extreme. The criteria can be expressed in a variety of ways, from a simple requirement to control a certain volume of rainfall or runoff (expressed as a depth)

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to the size of a design storm to more esoteric requirements, such as limiting the time that flow can be above a certain threshold. The volumes of rainfall or runoff are based on statistics of a region's daily rainfall, and they approximate one another as the percentage of impervious cover increases. Design storms for larger events that address channel protection and flooding are usually based on extreme event statistics and tend to represent a temporal pattern of rainfall over a set period, usually a day. Finally, it should be noted that the categories are not mutually exclusive; for example, recharge of groundwater may enhance water quality via pollutant removal during the infiltration process.

Erosion and Sedimentation Control. This criterion refers to the prevention of erosion and sedimentation of sites during construction and is focused at the site level. Criteria usually include a barrier plan to prevent sedimentation from leaving the site (e.g., silt fences), practices to minimize the potential erosion (phased construction), and facilities to capture and remove sediment from the runoff (detention). Because these measures are considered temporary, smaller extreme events are designated as the design storm than what typically would be used if flood control were the goal.

Recharge/Base Flow. This criterion is focused on sustaining the preconstruction hydrology of a site as it relates to base flow and recharge of groundwater supplies. It may also include consideration of water usage of the property owners and return through septic tanks and tile fields. The criterion, expressed as a volume requirement, is usually to capture around 0.5 to 1.0 inch of runoff from impervious surfaces depending on the climate and soil type of the region. (For this range of rainfall, very little runoff occurs from grass or forested areas, which is why runoff from impervious surfaces is used as the criterion.)

Water Quality. Criteria for water quality are the most widespread, and are usually crafted as specific percent removal for pollutants in stormwater discharge. Generally, a water quality criterion is based on a set volume of stormwater being treated by the SCM. The size of the storm can run from the first inch of rainfall off impervious surfaces to the runoff from the one-year, 24-hour extreme storm event. It should be noted that the term "water quality" covers a wide range of groundwater and surface water pollutants, including water temperature and emerging contaminants.

Many of the water quality criteria are surrogates for more meaningful parameters that are difficult to quantify or cannot be quantified, or they reflect situations where the science is not developed enough to set more explicit goals. For example, the Wisconsin state requirement of an 80 percent reduction in TSS in stormwater discharge does not apply to receiving waters themselves. However, it presumes that there will be some water quality benefits in receiving waters; that is, phosphorus and fecal coliform might be captured by the TSS requirement. Similarly water quality criteria may be expressed as credits for good practices, such as using LID, street sweeping, or stream buffers.

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Channel Protection. This criterion refers to protecting channels from accelerated erosion during storm events due to the increased runoff. It is tied to either the presumed "channel-forming event"—what geomorphologists once believed was the storm size that created the channel due to erosion and deposition—or to the minimum flow that accomplishes any degree of sediment transport. It is generally defined as somewhere between the one- and five-year, 24-hour storm event or a discharge level typically exceeded once to several times per year. Some states require a reduction in runoff volume for these events to match preconstruction levels. Others may require that the average annual duration of flows that are large enough to erode the streambank be held the same on an annual basis under pre- and postdevelopment conditions.

It is not uncommon to find states where a channel protection goal will be written poorly, such that it does not actually prevent channel widening. For example, MacRae (1997) presented a review of the common "zero runoff increase" discharge criterion, which is commonly met by using ponds designed to detain the two-year, 24-hour storm. MacRae showed that stream bed and bank erosion occur during much lower events, namely mid-depth flows that generally occur more than once a year, not just during bank-full conditions (approximated by the two-year event). This finding is entirely consistent with the well-established geomorphological literature (e.g., Pickup and Warner, 1976; Andrews, 1984; Carling, 1988; Sidle, 1988). During monitoring near Toronto, MacRae found that the duration of the geomorphically significant predevelopment mid-bankfull flows increased by more than four-fold after 34 percent of the basin had been urbanized. The channel had responded by increasing in cross-sectional area by as much as three times in some areas, and was still expanding.

Flooding Events. This criterion addresses public safety and the protection of property and is applicable to storm events that exceed the channel capacity. The 10- through the 100-year storm is generally used as the standard. Volume-reduction SCMs can aid or meet this criterion depending on the density of development, but usually assistance is needed in the form of detention SCMs. In some areas, it may be necessary to reduce the peak flow to below preconstruction levels in order to avoid the combined effects of increased volume, altered timing, and a changed hydrograph. It should be noted that some states do not consider the larger storms (100-year) to be a stormwater issue and have separate flood control requirements.

Each state develops a framework of goals, and the corresponding SCMs used to meet them, which will depend on the scale and focus of the stormwater management strategy. A few states have opted to express stormwater goals within the context of watershed plans for regions of the state. However, the setting of goals on a watershed basis is time-consuming and requires study of the watersheds in question. The more common approach has been to set generic or minimal controls for a region that are not based on a watershed plan. This has been done in Maryland, Wisconsin (see Box 5-1), and Pennsylvania (see Box 5-2). This strategy has the advantage of more rapid implementation of

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BOX 5-1
Wisconsin Statewide Goal of TSS Reduction for Stormwater Management

To measure the success of stormwater management, Wisconsin has statewide goals for sediment and flow (Wisconsin DNR, 2002). A lot is known about the impacts of sediment on receiving waters, and any reduction is thought to be beneficial. Flow can be a good indicator of other factors; for example, reducing peak flows will prevent bank erosion.

Developing areas in Wisconsin are required to reduce the annual TSS load by 80 percent compared to no controls (Wisconsin DNR, 2002). Two flow-rated requirements for developing areas are in the administrative rules. One is that the site must maintain the peak flow for the two-year, 24-hour rainfall event. Second, the annual infiltration volume for postdevelopment must be within 90 percent of the predevelopment volumes for residential land uses; the number for non-residential is 60 percent. Both of these flow control goals are thought to also have water quality benefits.

The goal for existing urban areas is an annual reduction in TSS loads. Municipalities must reduce their annual TSS loads by 20 percent, compared to no controls, by 2008. This number is increased to 40 percent by 2013. All of these goals were partially selected to be reasonable based on cost and technical feasibility.

BOX 5-2
Volume-Based Stormwater Goals in Pennsylvania

Pennsylvania has developed a stormwater *Best Management Practices* manual to support the Commonwealth's Storm Water Management Act. This manual and an accompanying sample ordinance advocates two methods for stormwater control based on volume, termed Control Guidance (CG) 1 and 2. The first (CG-1) requires that the runoff volume be maintained at the two-year, 24-hour storm level (which corresponds to approximately 3.5 inches of rainfall in this region) through infiltration, evapotranspiration, or reuse. This criterion addresses recharge/base flow, water quality, and channel protection, as well as helping to meet flooding requirements.

The second method (CG-2) requires capture and removal of the first inch of runoff from paved areas, with infiltration strongly recommended to address recharge and water quality issues. Additionally, to meet channel protection criteria, the second inch is required to be held for 24 hours, which should reduce the channel-forming flows. (This is an unusual criterion in that it is expressed as what an SCM can accomplish, not as the flow that the channel can handle.) Peak flows for larger events are required to be at preconstruction levels or less if the need is established by a watershed plan. These criteria are the starting point for watershed or regional plans, to reduce the effort of plan development. Some credits are available for tree planting, and other nonstructural practices are advocated for dissolved solids mitigation. See http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/stormwatermanagement/default.htm.

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some SCMs because watershed management plans are not required. In order to be applicable to all watersheds in the state, the goals must target common pollutants or flow modification factors where the processes are well known. It must also be possible for these goals to be stated in National Pollutant Discharge Elimination System (NPDES) permits. Many states have selected TSS reduction, volume reduction, and peak flow control as generic goals. A generic goal is not usually based on potentially toxic pollutants, such as heavy metals, due to the complexity of their interaction in the environment, the dependence on the existing baseline conditions, and the need for more understanding on what are acceptable levels. The difficulty with the generic approach is that specific watershed issues are not addressed, and the beneficial uses of waters are not guaranteed.

One potential drawback of a strategy based on a generic goal coupled to the permit process is that the implementation of the goal is usually on a site-by-site basis, especially for developing areas. Generic goals may be appropriate for certain ubiquitous watershed processes and are clearly better than having no goals at all. However, they do not incorporate the effects of differences in past development and any unique watershed characteristics; they should be considered just a good starting point for setting watershed-based goals.

Role of SCMs in Achieving Stormwater Management Goals

One important fundamental change in SCM design philosophy has come about because of the recent understanding of the roles of smaller storms and of impervious surfaces. This is demonstrated by Box 3-4, which shows that for the Milwaukee area more than 50 percent of the rainfall by volume occurs in storms that have a depth of less then 0.75 inch. If extreme events are the only design criteria for SCMs, the vast majority of the annual rainfall will go untreated or uncontrolled, as it is smaller than the minimum extreme event. This relationship is not the same in all regions. For example, in Austin, Texas, the total yearly rainfall is smaller than in Milwaukee, but a large part of the volume occurs during larger storm events, with long dry periods in between.

The upshot is that the design strategy for stormwater management, including drainage systems and SCMs, should take a region's rainfall and associated runoff conditions into account. For example, an SCM chosen to capture the majority of the suspended solids, recharge the baseflow, reduce streambank erosion, and reduce downstream flooding in Pennsylvania or Seattle (which have moderate and regular rainfall) would likely not be as effective in Texas, where storms are infrequent and larger. In some areas, a reduction in runoff volume may not be sufficient to control streambank erosion and flooding, such that a second SCM like an extended detention stormwater wetland may be needed to meet management goals.

Finally, as discussed in greater detail in a subsequent section, SCMs are most effective from the perspective of both efficiency and cost when stormwater

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management is incorporated in the early planning stages of a community. Retrofitting existing development with SCMs is much more technically difficult and costly because the space may not be available, other infrastructure is already installed, or utilities may interfere. Furthermore, if the property is on private land or dedicated as an easement to a homeowners association, there may be regulatory limitations to what can be done. Because of these barriers, retrofitting existing urban areas often depends on engineered or manufactured SCMs, which are more expensive in both construction and operation.

Stormwater Control Measures

SCMs reduce or mitigate the generation of stormwater runoff and associated pollutants. These practices include both "structural" or engineered devices as well as more "nonstructural measures" such as land-use planning, site design, land conservation, education, and stewardship practices. Structural practices may be defined as any facility constructed to mitigate the adverse impacts of stormwater and urban runoff pollution. Nonstructural practices, which tend to be longer-term and lower-maintenance solutions, can greatly reduce the need for or increase the effectiveness of structural SCMs. For example, product substitution and land-use planning may be key to the successful implementation of an infiltration SCM. Preserving wooded areas and reducing street widths can allow the size of detention basins in the area to be reduced.

Table 5-1 presents the expansive list of SCMs that are described in this chapter. For most of the SCMs, each listed item represents a class of related practices, with individual methods discussed in greater detail later in the chapter. There are nearly 20 different broad categories of SCMs that can be applied, often in combination, to treat the quality and quantity of stormwater runoff. A primary difference among the SCMs relates to which stage of the development cycle they are applied, where in the watershed they are installed, and who is responsible for implementing them.

The development cycle extends from broad planning and zoning to site design, construction, occupancy, retrofitting, and redevelopment. As can be seen, SCMs are applied throughout the entire cycle. The scale at which the SCM is applied also varies considerably. While many SCMs are installed at individual sites as part of development or redevelopment applications, many are also applied at the scale of the stream corridor or the watershed or to existing municipal stormwater infrastructure. The final column in Table 5-1 suggests who would implement the SCM. In general, the responsibility for implementing SCMs primarily resides with developers and local stormwater agencies, but planning agencies, landowners, existing industry, regulatory agencies, and municipal separate storm sewer system (MS4) permittees can also be responsible for implementing many key SCMs.

In Table 5-1, the SCMs are ordered in such a way as to mimic natural systems as rain travels from the roof to the stream through combined application of

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TABLE 5-1 Summary of Stormwater Control Measures—When, Where, and Who

Stormwater Control Measure	When	Where	Who
Product Substitution	Continuous	National, state, regional	Regulatory agencies
Watershed and Land-Use Planning	Planning stage	Watershed	Local planning agencies
Conservation of Natural Areas	Site and watershed planning stage	Site, watershed	Developer, local planning agency
Impervious Cover Minimization	Site planning stage	Site	Developer, local review authority
Earthwork Minimization	Grading plan	Site	Developer, local review authority
Erosion and Sediment Control	Construction	Site	Developer, local review authority
Reforestation and Soil Conservation	Site planning and construction	Site	Developer, local review authority
Pollution Prevention SCMs for Stormwater Hotspots	Post-construction or retrofit	Site	Operators and local and state permitting agencies
Runoff Volume Reduction—Rainwater harvesting	Post-construction or retrofit	Rooftop	Developer, local planning agency and review authority
Runoff Volume Reduction—Vegetated	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Runoff Volume Reduction—Subsurface	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Peak Reduction and Runoff Treatment	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Runoff Treatment	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Aquatic Buffers and Managed Floodplains	Planning, construction and post-construction	Stream corridor	Developer, local planning agency and review authority, landowners
Stream Rehabilitation	Postdevelopment	Stream corridor	Local planning agency and review authority

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TABLE 5-1 Continued

Stormwater Control Measure	When	Where	Who
Municipal Housekeeping	Postdevelopment	Streets and stormwater infrastructure	MS4 Permittee
Illicit Discharge Detection and Elimination	Postdevelopment	Stormwater infrastructure	MS4 Permittee
Stormwater Education	Postdevelopment	Stormwater infrastructure	MS4 Permittee
Residential Stewardship	Postdevelopment	Stormwater infrastructure	MS4 Permittee

Note: Nonstructural SCMs are in italics.

a series of practices throughout the entire development site. This order is upheld throughout the chapter, with the implication that no SCM should be chosen without first considering those that precede it on the list.

Given that there are 20 different SCM groups and a much larger number of individual design variations or practices within each group, it is difficult to authoritatively define the specific performance or effectiveness of SCMs. In addition, our understanding of their performance is rapidly changing to reflect new research, testing, field experience, and maintenance history. The translation of these new data into design and implementation guidance is accelerating as well. What is possible is to describe their basic hydrologic and water quality objectives and make a general comparative assessment of what is known about their design, performance, and maintenance as of mid-2008. This broad technology assessment is provided in Table 5-2, which reflects the committee's collective understanding about the SCMs from three broad perspectives:

- Is widely accepted design or implementation guidance available for the SCM and has it been widely disseminated to the user community?
- Have enough research studies been published to accurately characterize the expected hydrologic or pollutant removal performance of the SCM in most regions of the country?
- Is there enough experience with the SCM to adequately define the type and scope of maintenance needed to ensure its longevity over several decades?

Affirmative answers to these three questions are needed to be able to reliably quantify or model the ability of the SCM, which is an important element in defining whether the SCM can be linked to improvements in receiving water quality. As will be discussed in subsequent sections of this chapter, there are many SCMs for which there is only a limited understanding, particularly those that are nonstructural in nature.

The columns in Table 5-2 summarize several important factors about each SCM, including the ability of the SCM to meet hydrologic control objectives

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and water quality objectives, the availability of design guidance, the availability of performance studies, and whether there are maintenance protocols. The hydrologic control objectives range from complete prevention of stormwater flow to reduction in runoff volume and reduction in peak flows. The column on water quality objectives describes whether the SCM can prevent the generation of, or remove, contaminants of concern in stormwater.

The availability of design guidance tends to be greatest for the structural practices. Some but not all nonstructural practices are of recent origin, and communities lack available design guidance to include them as an integral element of local stormwater solutions. Where design guidance is available, it may not yet have been disseminated to the full population of Phase II MS4 communities.

TABLE 5-2 Current Understanding of Stormwater Control Measure Capabilities

SCM	Hydrologic Control Objectives	Water Quality Objectives	Available Design Guidance	Performance Studies Available	Defined Maintenance Protocols
Product Substitution	NA	Prevention	NA	Limited	NA
Watershed and Land-Use Planning	All objectives	Prevention	Available	Limited	Yes
Conservation of Natural Areas	Prevention	Prevention	Available	None	Yes
Impervious Cover Minimization	Prevention and reduction	Prevention	Available	Limited	No
Earthwork Minimization	Prevention	Prevention	Emerging	Limited	Yes
Erosion and Sediment Control	Prevention and reduction	Prevention and removal	Available	Limited	Yes
Reforestation and Soil Conservation	Prevention and reduction	Prevention and removal	Emerging	None	No
Pollution Prevention SCMs for Hotspots	NA	Prevention	Emerging	Very few	No
Runoff Volume Reduction—Rainwater harvesting	Reduction	NA	Emerging	Limited	Yes
Runoff Volume Reduction—Vegetated (Green Roofs, Bioretention, Bioinfiltration, Bioswales)	Reduction and some peak attenuation	Removal	Available	Limited	Emerging
Runoff Volume Reduction—Subsurface (Infiltration Trenches, Pervious Pavements)	Reduction and some peak attenuation	Removal	Available	Limited	Yes

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TABLE 5-2 Continued

SCM	Hydrologic Control Objectives	Water Quality Objectives	Available Design Guidance	Performance Studies Available	Defined Maintenance Protocols
Peak Reduction and Runoff Treatment (Stormwater Wetlands, Dry/Wet Ponds)	Peak attenuation	Removal	Available	Adequate	Yes
Runoff Treatment (Sand Filters, Manufactured Devices)	None	Removal	Emerging	Adequate—sand filters Limited—manufactured devices	Yes
Aquatic Buffers and Managed Floodplains	NA	Prevention and removal	Available	Very few	Emerging
Stream Rehabilitation	NA	Prevention and removal	Emerging	Limited	Unknown
Municipal Housekeeping (Street Sweeping/ Storm-Drain Cleanouts)	NA	Removal	Emerging	Limited	Emerging
Illicit Discharge Detection/ Elimination	NA	Prevention and removal	Available	Very few	No
Stormwater Education	Prevention	Prevention	Available	Very few	Emerging
Residential Stewardship	Prevention	Prevention	Emerging	Very few	No

Note: Nonstructural SCMs are in italics.

Key:		
Hydrologic Objective	Water Quality Objective	Available Design Guidance?
Prevention: Prevents generation of runoff **Reduction:** Reduces volume of runoff **Treatment:** Delays runoff delivery only **Peak Attenuation**: Reduction of peak flows through detention	**Prevention**: Prevents generation, accumulation, or wash-off of pollutants and/or reduces runoff volume **Removal:** Reduces pollutant concentrations in runoff by physical, chemical, or biological means	**Available:** Basic design or implementation guidance is available in most areas of the country are readily available **Emerging:** Design guidance is still under development, is missing in many parts of the country, or requires more performance data
Performance Data Available?	Defined Maintenance Protocol?	Notes:
Very Few: Handful of studies, not enough data to generalize about SCM performance **Limited:** Numerous studies have been done, but results are variable or inconsistent **Adequate**: Enough studies have been done to adequately define performance	**No:** Extremely limited understanding of procedures to maintain SCM in the future **Emerging:** Still learning about how to maintain the SCM **Yes**: Solid understanding of maintenance for future SCM needs	**NA:** Not applicable for the SCM

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The column on the availability of performance data is divided into those SCMs where enough studies have been done to adequately define performance, those SCMs where limited work has been done and the results are variable, and those SCMs where only a handful of studies are available. A large and growing number of performance studies are available that report the efficiencies of structural SCMs in reducing flows and pollutant loading (Strecker et al., 2004; ASCE, 2007; Schueler et al., 2007; Selbig and Bannerman, 2008). Many of these are compiled in the Center for Watershed Protection's National Pollutant Removal Performance Database for Stormwater Treatment Practices (http://www.cwp.org/Resource_Library/Center_Docs/SW/bmpwriteup_092007_v3.pdf), in the International Stormwater BMP Database (http://www.bmpdatabase.org/Docs/Performance%20Summary%20June%202008.pdf), and by the Water Environment Research Foundation (WERF, 2008). In cases where there is incomplete understanding of their performance, often information can be gleaned from other fields including agronomy, forestry, petroleum exploration, and sanitary engineering. Current research suggests that it is not a question if whether structural SCMs "work" but more of a question of to what degree and with what longevity (Heasom et al., 2006; Davis et al., 2008; Emerson and Traver, 2008). There is considerably less known about the performance of nonstructural practices for stormwater treatment, partly because their application has been uneven around the country and it remains fairly low in comparison to structural stormwater practices.

Finally, defined maintenance protocols for SCMs can be nonexistent, emerging, or fully available. SCMs differ widely in the extent to which they can be considered permanent solutions. For those SCMs that work on the individual site scale on private property, such as rain gardens, local stormwater managers may be reluctant to adopt such practices due to concerns about their ability to enforce private landowners to conduct maintenance over time. Similarly, those SCMs that involve local government decisions (such as education, residential stewardship practices, zoning, or street sweeping) may be less attractive because governments are likely to change over time.

The following sections contain more detailed information about the individual SCMs listed in Tables 5-1 and 5-2, including the operating unit processes, the pollutants treated, the typical performance for both runoff and pollutant reduction, the strengths and weaknesses, maintenance and inspection requirements, and the largest sources of variability and uncertainty.

Product Substitution

Product substitution refers to the classic pollution prevention approach of reducing the emissions of pollutants available for future wash-off into stormwater runoff. The most notable example is the introduction of unleaded gasoline, which resulted in an order-of-magnitude reduction of lead levels in stormwater runoff in a decade (Pitt et al., 2004a,b). Similar reductions are expected with the

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phase-out of methyl tert-butyl ether (MTBE) additives in gasoline. Other examples of product substitution are the ban on coal-tar sealants during parking lot renovation that has reduced PAH runoff (Van Metre et al., 2006), phosphorus-free fertilizers that have measurably reduced phosphorus runoff to Minnesota lakes (Barten and Johnson, 2007), the painting of galvanized metal surfaces, and alternative rooftop surfaces (Clark et al., 2005). Given the importance of coal power plant emissions in the atmospheric deposition of nitrogen and mercury, it is possible that future emissions reductions for such plants may result in lower stormwater runoff concentrations for these two pollutants.

The level of control afforded by product substitution is quite high if major reductions in emissions or deposition can be achieved. The difficulty is that these reductions require action in another environmental regulatory arena, such as air quality, hazardous waste, or pesticide regulations, which may not see stormwater quality as a core part of their mission.

Watershed and Land-Use Planning

Communities can address stormwater problems by making land-use decisions that change the location or quantity of impervious cover created by new development. This can be accomplished through zoning, watershed plans, comprehensive land-use plans, or Smart Growth incentives.

The unit process that is managed is the amount of impervious cover, which is strongly related to various residential and commercial zoning categories (Cappiella and Brown, 2000). Numerous techniques exist to forecast future watershed impervious cover and its probable impact on the quality of aquatic resources (see the discussion of the Impervious Cover Model in Chapter 3; CWP, 1998a; MD DNR, 2005). Using these techniques and simple or complex simulation models, planners can estimate stormwater flows and pollutant loads through the watershed planning process and alter the location or intensity of development to reduce them.

The level of control that can be achieved by watershed and land-use planning is theoretically high, but relatively few communities have aggressively exercised it. The most common application of downzoning has been applied to watersheds that drain to drinking water reservoirs (Kitchell, 2002). The strength of this practice is that it has the potential to directly address the underlying causes of the stormwater problem rather than just treating its numerous symptoms. The weakness is that local decisions on zoning and Smart Growth are reversible and often driven by other community concerns such as economic development, adequate infrastructure, and transportation. In addition, powerful consumer and market forces often have promoted low-density sprawl development. Communities that use watershed-based zoning often require a compelling local environmental goal, since state and federal regulatory authorities have traditionally been extremely reluctant to interfere with the local land-use and zoning powers.

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Conservation of Natural Areas

Natural-area conservation protects natural features and environmental resources that help maintain the predevelopment hydrology of a site by reducing runoff, promoting infiltration, and preventing soil erosion. Natural areas are protected by a permanent conservation easement prescribing allowable uses and activities on the parcel and preventing future development. Examples include any areas of undisturbed vegetation preserved at the development site, including forests, wetlands, native grasslands, floodplains and riparian areas, zero-order stream channels, spring and seeps, ridge tops or steep slopes, and stream, wetland, or shoreline buffers. In general, conservation should maximize contiguous area and avoid habitat fragmentation.

While natural areas are conserved at many development sites, most of these requirements are prompted by other local, state, and federal habitat protections, and are not explicitly designed or intended to provide runoff reduction and stormwater treatment. To date, there are virtually no data to quantify the runoff reduction and/or pollutant removal capability of specific types of natural area conservation, or the ability to explicitly link them to site design.

Impervious Cover Reduction

A variety of practices, some of which fall under the broader term "better site design," can be used to minimize the creation of new impervious cover and disconnect or make more permeable the hard surfaces that are needed (Nichols et al., 1997; Richman, 1997; CWP, 1998a). A list of some common impervious cover reduction practices for both residential and commercial areas is provided below.

Elements of Better Site Design: Single-Family Residential

- Maximum residential street width
- Maximum street right-of-way width
- Swales and other stormwater practices can be located within the right-of-way
- Maximum cul-de-sac radius with a bioretention island in the center
- Alternative turnaround options such as hammerheads are acceptable if they reduce impervious cover
- Narrow sidewalks on one side of the street (or move pedestrian pathways away from the street entirely)
- Disconnect rooftops from the storm-drain systems
- Minimize driveway length and width and utilize permeable surfaces
- Allow for cluster or open-space designs that reduce lot size or setbacks in exchange for conservation of natural areas
- Permeable pavement in parking areas, driveways, sidewalks, walkways, and patios

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Elements of Better Site Design: Multi-Family Residential and Commercial

- Design buildings and parking to have multiple levels
- Store rooftop runoff in green roofs, foundation planters, bioretention areas, or cisterns
- Reduce parking lot size by reducing parking demand ratios and stall dimensions
- Use landscaping areas, tree pits, and planters for stormwater treatment
- Use permeable pavement over parking areas, plazas, and courtyards

CWP (1998a) recommends minimum or maximum geometric dimensions for subdivisions, individual lots, streets, sidewalks, cul-de-sacs, and parking lots that minimize the generation of needless impervious cover, based on a national roundtable of fire safety, planning, transportation and zoning experts. Specific changes in local development codes can be made using these criteria, but it is often important to engage as many municipal agencies that are involved in development as possible in order to gain consensus on code changes.

At the present time, there is little research available to define the runoff reduction benefits of these practices. However, modeling studies consistently show a 10 to 45 percent reduction in runoff compared to conventional development (CWP, 1998b,c, 2002). Several monitoring studies have documented a major reduction in stormwater runoff from development sites that employ various forms of impervious cover reduction and LID in the United States and Australia (Coombes et al., 2000; Philips et al., 2003; Cheng et al., 2005) compared to those that do not.

Unfortunately, better site design has been slowly adopted by local planners, developers, designers, and public works officials. For example, although the project pictured in Figure 5-6 has been very successful in terms of controlling stormwater, the better-site-design principles used have not been widely adopted in the Seattle area. Existing local development codes may discourage or even prohibit the application of environmental site design practices, and many engineers and plan reviewers are hesitant to embrace them. Impervious cover reduction must be incorporated at the earliest stage of site layout and design to be effective, but outdated development codes in many communities can greatly restrict the scope of impervious cover reduction (see Chapter 2). Finally, the performance and longevity of impervious cover reduction are dependent on the infiltration capability of local soils, the intensity of development, and the future management actions of landowners.

Earthwork Minimization

This source control measure seeks to limit the degree of clearing and grading on a development site in order to prevent soil compaction, conserve soils, prevent erosion from steep slopes, and protect zero-order streams. This is accomplished by (1) identifying key soils, drainage features, and slopes to protect

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FIGURE 5-6 110th Street, Seattle, part of the Natural Drainage Systems Project. This location exhibits several elements of impervious cover reduction. In particular, vegetated swales were installed and curbs and gutters removed. There are sidewalks on only one side of the street, and they are separated from the road by the swales. The residences' rooftops have been disconnected from the storm-drain systems and are redirected into the swales. SOURCE: Seattle Public Utilities.

and then (2) establishing a limit of disturbance where construction equipment is excluded. This element is an important, but often under-utilized component of local erosion and sediment control plans.

Numerous researchers have documented the impact of mass grading, clearing, and the passage of construction equipment on the compaction of soils, as measured by increase in bulk density, declines in soil permeability, and increases in the runoff coefficient (Lichter and Lindsey, 1994; Legg et al., 1996; Schueler, 2001a,b; Gregory et al., 2006). Another goal of earthwork minimization is to protect zero-order streams, which are channels with defined banks that emanate from a hollow or ravine with convergent contour lines (Gomi et al., 2002). They represent the uppermost definable channels that possess temporary or intermittent flow. Functioning zero-order channels provide major watershed functions, including groundwater recharge and discharge (Schollen et al., 2006; Winter, 2007), important nutrient storage and transformation functions (Bernot and Dodds, 2005; Groffman et al., 2005), storage and retention of eroded hillslope sediments (Meyers, 2003), and delivery of leaf inputs and large woody debris. Compared to high-order network streams, zero-order streams are disproportionately disturbed by mass grading, enclosure, or channelization (Gomi et al., 2002; Meyer, 2003).

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The practice of earthwork minimization is not widely applied across the country. This is partly due to the limited performance data available to quantify its benefits, and the absence of local or national design guidance or performance benchmarks for the practice.

Erosion and Sediment Control

Erosion and sediment control predates much of the NPDES stormwater permitting program. It consists of the temporary installation and operation of a series of structural and nonstructural practices throughout the entire construction process to minimize soil erosion and prevent off-site delivery of sediment. Because construction is expected to last for a finite and short period of time, the design standards are usually smaller and thus riskier (25-year versus the 100-year storm). By phasing construction, thereby limiting the exposure of bare earth at any one time, the risk to the environment is reduced significantly.

The basic practices include clearing limits, dikes, berms, temporary buffers, protection of drainage-ways, soil stabilization through hydroseeding or mulching, perimeter controls, and various types of sediment traps and basins. All plans have some component that requires filtration of runoff crossing construction areas to prevent sediment from leaving the site. This usually requires a sediment collection system including, but not limited to, conventional settling ponds and advanced sediment collection devices such as polymer-assisted sedimentation and advanced sand filtration. Silt fences are commonly specified to filter distributed flows, and they require maintenance and replacement after storms as shown in Figure 5-7. Filter systems are added to inlets until the streets are paved and the surrounding area has a cover of vegetation (Figure 5-8). Sedimentation basins (Figure 5-9) are constructed to filter out sediments through rock filters, or are equipped with floating skimmers or chemical treatment to settle out pollutants. Other common erosion and sediment control measures include temporary seeding and rock or rigged entrances to construction sites to remove dirt from vehicle tires (see Figure 5-10).

Control of the runoff's erosive potential is a critical element. Most erosion and sediment control manuals provide design guidance on the capacity and ability of swales to handle runoff without eroding, on the design of flow paths to transport runoff at non-erosive velocities, and on the dissipation of energy at pipe outlets. Examples include rock energy dissipaters, level spreaders (see Figure 5-11), and other devices.

Box 5-3 provides a comprehensive list of recommended construction SCMs. The reader is directed to reviews by Brown and Caraco (1997) and Shaver et al. (2007) for more information. Although erosion and sediment control practices are temporary, they require constant operation and maintenance during the complicated sequence of construction and after major storm events. It is exceptionally important to ensure that practices are frequently inspected and repaired and that sediments are cleaned out. Erosion and sediment control are

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FIGURE 5-7 A functioning silt fence (top) and an improperly maintained silt fence (bottom). SOURCES: Top, EPA NPDES Menu of BMPs (available at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=56) and, bottom, Robert Traver, Villanova University.



FIGURE 5-8 Sediment filter left in place after construction. SOURCE: Robert Traver, Villanova University.

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FIGURE 5-9 Sediment basin. SOURCE: EPA NPDES Menu of BMPs (available at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&vew=specific&bmp=56).



FIGURE 5-10 Rumble strips to remove dirt from vehicle tires. SOURCE: Laura Ehlers, National Research Council.

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FIGURE 5-11 Level spreader. SOURCE: Robert Traver, Villanova University.

BOX 5-3
Recommended Construction Stormwater Control Measures

1. As the top priority, emphasize construction management SCMs as follows:
   - Maintain existing vegetation cover, if it exists, as long as possible.
   - Perform ground-disturbing work in the season with smaller risk of erosion, and work off disturbed ground in the higher risk season.
   - Limit ground disturbance to the amount that can be effectively controlled in the event of rain.
   - Use natural depressions and planning excavation to drain runoff internally and isolate areas of potential sediment and other pollutant generation from draining off the site, so long as safe in large storms.
   - Schedule and coordinate rough grading, finish grading, and erosion control application to be completed in the shortest possible time overall and with the shortest possible lag between these work activities.

2. Stabilize with cover appropriate to site conditions, season, and future work plans. For example:
   - Rapidly stabilize disturbed areas that could drain off the site, and that will not be worked again, with permanent vegetation supplemented with highly effective temporary erosion controls until achievement of at least 90 percent vegetative soil cover.
   - Rapidly stabilize disturbed areas that could drain off the site, and that will not be worked again for more than three days, with highly effective temporary erosion controls.
   - If at least 0.1 inch of rain is predicted with a probability of 40 percent or more, before rain falls stabilize or isolate disturbed areas that could drain off the site, and that are being actively worked or will be within three days, with measures that will prevent or minimize transport of sediment off the property.

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BOX 5-3 Continued

3. As backup for cases where all of the above measures are used to the maximum extent possible but sediments still could be released from the site, consider the need for sediment collection systems including, but not limited to, conventional settling ponds and advanced sediment collection devices such as polymer-assisted sedimentation and advanced sand filtration.

4. Specify emergency stabilization and/or runoff collection (e.g., using temporary depressions) procedures for areas of active work when rain is forecast.

5. If runoff can enter storm drains, use a perimeter control strategy as backup where some soil exposure will still occur, even with the best possible erosion control (above measures) or when there is discharge to a sensitive waterbody.

6. Specify flow control SCMs to prevent or minimize to the extent possible:
- Flow of relatively clean off-site water over bare soil or potentially contaminated areas;
- Flow of relatively clean intercepted groundwater over bare soil or potentially contaminated areas;
- High velocities of flow over relatively steep and/or long slopes, in excess of what erosion control coverings can withstand; and
- Erosion of channels by concentrated flows, by using channel lining, velocity control, or both.

7. Specify stabilization of construction entrance and exit areas, provision of a nearby tire and chassis wash for dirty vehicles leaving the site with a wash water sediment trap, and a sweeping plan.

8. Specify construction road stabilization.

9. Specify wind erosion control.

10. Prevent contact between rainfall or runoff and potentially polluting construction materials, processes, wastes, and vehicle and equipment fluids by such measures as enclosures, covers, and containments, as well as berming to direct runoff.

widely applied in many communities, and most states have some level of design guidance or standards and specifications. Nonetheless, few communities have quantified the effectiveness of a series of construction SCMs applied to an individual site, nor have they clearly defined performance benchmarks for individual practices or their collective effect at the site. In general, there has been little monitoring in the past few decades to characterize the performance of construction SCMs, although a few notable studies have been recently published (e.g., Line and White, 2007). Box 5-4 describes the effectiveness of filter fences and filter fences plus grass buffers to reduce sediment loadings from construction activities and the resulting biological impacts.

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BOX 5-4
Receiving Water Impacts Associated with Construction Site Discharges

The following is a summary of a recent research project that investigated in-stream biological conditions downstream of construction sites having varying levels of erosion controls (none, the use of filter fences, and filter fences plus grass buffers) for comparison. The project title is *Studies to Evaluate the Effectiveness of Current BMPs in Controlling Stormwater Discharges from Small Construction Sites* and was conducted for the Alabama Water Resources Research Institute, Project 2001AL4121B, by Drs. Robert Angus, Ken Marion, and Melinda Lalor of the University of Alabama at Birmingham. The initial phase of the project, described below, was completed in 2002 (Angus et al., 2002). While this case study is felt to be representative of many sites across the United States, there are other examples of where silt fences have been observed to be more effective (e.g., Barrett et al., 1998).

Methods

This study was conducted in the upper Cahaba River watershed in north central Alabama, near Birmingham. The study areas had the following characteristics. (1) Topography and soil types representative of the upland physiographic regions in the Southeast (i.e., southern Appalachian and foothill areas); thus, findings from this study should be relevant to a large portion of the Southeast. (2) The rainfall amounts and intensities in this region are representative of many areas of the Southeast and (3) the expanding suburbs of the Birmingham metropolitan area are rapidly encroaching upon the upper Cahaba River and its tributaries. Stormwater runoff samples were manually collected from sheet flows above silt fences, and from points below the fence within the vegetated buffer. Water was sampled during "intense" (≥1 inch/hour) rain events. The runoff samples were analyzed for turbidity, particle size distribution (using a Coulter Counter Multi-Sizer IIe), and total solids (dissolved solids plus suspended/non-filterable solids). Sampling was only carried out on sites with properly installed and well-maintained silt fences, located immediately upgrade from areas with good vegetative cover.

Six tributary or upper mainstream sites were studied to investigate the effects of sedimentation from construction sites on both habitat quality and the biological "health" of the aquatic ecosystem (using benthic macroinvertebrates and fish). EPA's Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers was used to assess the habitat quality at the study sites. Each site was assessed in the spring to evaluate immediate effects of the sediment, and again during the following late summer or early fall to evaluate delayed effects.

Results

Effectiveness of Silt Fences. Silt fences were found to be better than no control measures at all, but not substantially. The mean counts of small particles (<5 μm) below the silt fences were about 50 percent less than that from areas with no erosion control measures, even though the fences appeared to be properly installed and in good order. However, the variabilities were large and the difference between the means was not statistically significant. For every variable measured, the mean values of samples taken below silt fences were significantly higher ($p < 0.001$) than samples collected from undisturbed vegetated control sites collected nearby and at the same time. These data therefore indicate that silt fences are only marginally effective at reducing soil particulates in runoff water.

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Effectiveness of Filter Fences with Vegetated Buffers. Runoff samples were also collected immediately below filter fences, and below filter fences after flow over buffers having 5, 10, and 15 feet of dense (intact) vegetation. Mean total solids in samples collected below silt fences and a 15-foot-wide vegetated buffer zone were about 20 percent lower, on average, than those samples collected only below the silt fence. The installation of filter fences above an intact, good vegetated buffer removes sediment from construction site runoff more effectively than with the use of filter fences alone.

Biological Metrics Sensitive to Sedimentation Effects (Fish). Analysis of the fish biota indicates that various metrics used to evaluate the biological integrity of the fish community also are affected by highly sedimented streams. As shown in Figure 5-12, the overall composition of the population, as quantified by the Index of Biotic Integrity (IBI) is lower; the proportion and biomass of darters, a disturbance-sensitive group, is lower; the proportion and biomass of sunfish is higher; the Shannon-Weiner diversity index is lower; and the number of disturbance-tolerant species is higher as mean sediment depth increases.

Benthic Macroinvertebrates. A number of stream benthic macroinvertebrate community characteristics were also found to be sensitive to sedimentation. Metrics based on these characteristics differ greatly between sediment-impacted and control sites (Figure 5-13). Some of the metrics that appear to reflect sediment-associated stresses include the Hilsenhoff Biotic Index (HBI), a variation of the EPT index (percent EPT minus Baetis), and the Sorensen Index of Similarity to a reference site. The HBI is a weighted mean tolerance value; high HBI values indicate sites dominated by disturbance-tolerant macroinvertebrate taxa. The EPT% index is the percent of the collection represented by organisms in the generally disturbance-sensitive orders *Ephemeroptera, Plecoptera,* and *Trichoptera*. Specimens of the genus *Baetis* were not included in the index as they are relatively disturbance-tolerant. The HBI and the EPT indices also show positive correlations to several other measures of disturbance, such as percent of the watershed altered by development.

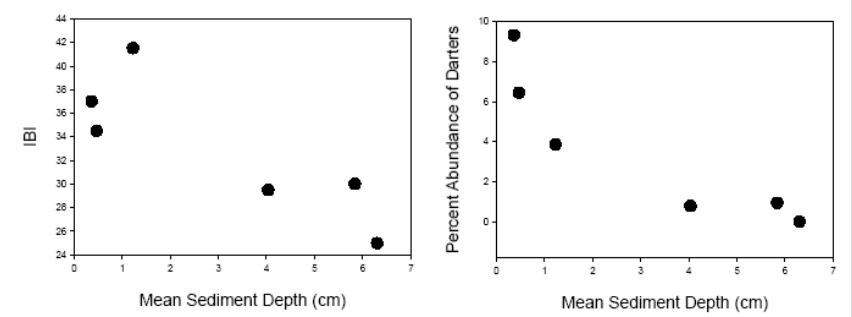

FIGURE 5-12 Association between two fish metrics and amount of stream sediment. NOTE: The IBI is based on numerous characteristics of the fish population. The percent relative abundance of darters is the percentage of darters to all the fish collected at a site. SOURCE: Angus et al. (2002).

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BOX 5-4 Continued

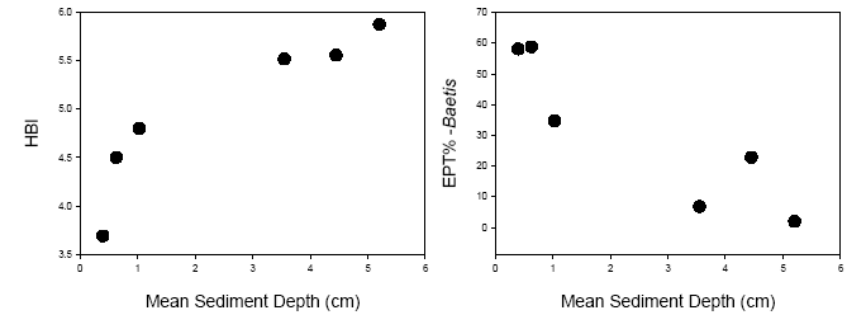

FIGURE 5-13 Associations between two macroinvertebrate metrics and the amount of stream sediment. SOURCE: Angus et al. (2002).

Reforestation and Soil Compost Amendments

This set of practices seeks to improve the quality of native vegetation and soils present at the site. Depending on the ecoregion, this may involve forest, prairie, or chapparal plantings, tilling, and amending compacted soils to improve their hydrologic properties.

The goal is to maintain as much predevelopment hydrologic function at a development site as possible by retaining canopy interception, duff/soil layer interception, evapotranspiration, and surface infiltration. The basic methods to implement this practice are described in Cappiella et al. (2006), Pitt et al. (2005), Chollak and Rosenfeld (1998), and Balusek (2003).

At this time, there are few monitoring data to assess the degree to which land reforestation or soil amendments can improve the quality of stormwater runoff at a particular development site, apart from the presumptive watershed research that has shown that forests with undisturbed soils have very low rates of surface runoff and extremely low levels of pollutants in runoff (Singer and Rust, 1975; Johnson et al., 2000; Chang, 2006). More data are needed on the hydrologic properties of urban forests and soils whose ecological functions are stressed or degraded by the urbanization process (Pouyat et al., 1995, 2007).

Pollution Prevention SCMs for Stormwater Hotspots

Certain classes of municipal and industrial operations are required to maintain a series of pollution prevention practices to prevent or minimize contact of pollutants with rainfall and runoff. Pollution prevention practices involve a wide range of operational practices at a site related to vehicle repairs, fueling, washing and storage, loading and unloading areas, outdoor storage of materials, spill prevention and response, building repair and maintenance, landscape and

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turf management, and other activities that can introduce pollutants into the stormwater system (CWP, 2005). Training of personnel at the affected area is needed to ensure that industrial and municipal managers and employees understand and implement the correct stormwater pollution prevention practices needed for their site or operation.

Examples of municipal operations that may need pollution prevention plans include public works yards, landfills, wastewater treatment plants, recycling and solid waste transfer stations, maintenance depots, school bus and fleet storage and maintenance areas, public golf courses, and ongoing highway maintenance operations. The major industrial categories that require stormwater pollution prevention plans were described in Table 2-3. Both industrial and municipal operations must develop a detailed stormwater pollution prevention plan, train employees, and submit reports to regulators. Compliance has been a significant issue with this program in the past, particularly for small businesses (Duke and Augustenberg, 2006; Cross and Duke, 2008) Recently filed investigations of stormwater hotspots indicate many of these operations are not fully implementing their stormwater pollution prevention plans, and a recent GAO report (2007) indicates that state inspections and enforcement actions are extremely rare.

The goal of pollution prevention is to prevent contact of rainfall or stormwater runoff with pollutants, and it is an important element of the post-construction stormwater plan. However, with the exception of a few industries such as auto salvage yards (Swamikannu, 1994), basic research is lacking on how much greater event mean concentrations are at municipal and industrial stormwater hotspots compared to other urban land uses. In addition, little is presently known about whether aggressive implementation of stormwater pollution prevention plans actually can reduce stormwater pollutant concentrations at hot spots.

Runoff Volume Reduction—Rainwater Harvesting

A primary goal of stormwater management is to reduce the volume of runoff from impervious surfaces. There are several classes of SCMs that can achieve this goal, including rainwater harvesting systems, vegetated SCMs that evapotranspirate part of the volume, and infiltration SCMs. For all of these measures, the amount of runoff volume to be captured depends on watershed goals, site conditions including climate, upstream nonstructural practices employed, and whether the chosen SCM is the sole management measure or part of a treatment train. Generally, runoff-volume-reduction SCMs are designed to handle at least the first flush from impervious surfaces (1 inch of rainfall). In Pennsylvania, control of the 24-hour, two-year storm volume (about 8 cm) is considered the standard necessary to protect stream-channel geomorphology, while base flow recharge and the first flush can be addressed by capturing a much smaller volume of rain (1–3 cm). Where both goals must be met, the designer is permitted to either oversize the volume reduction device to control the

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larger volume, or build a smaller device and use it in series with an extended detention basin to protect the stream geomorphology (PaDEP, 2006). Some designers have reported that in areas with medium to lower percentage impervious surfaces they are able to control up to the 100-year storm by enlarging runoff-volume-reduction SCMs and using the entire site. In retrofit situations, capture amounts as small as 1 cm are a distinct improvement. It should be noted that there are important, although indirect, water quality benefits of all runoff-volume-reduction SCMs—(1) the reduction in runoff will reduce streambank erosion downstream and the concomitant increases in sediment load, and (2) volume reductions lead to pollutant load reductions, even if pollutant concentrations in stormwater are not decreased.

Rainwater harvesting systems refer to use of captured runoff from roof tops in rain barrels, tanks, or cisterns (Figures 5-14 and 5-15). This SCM treats runoff as a resource and is one of the few SCMs that can provide a tangible economic benefit through the reduction of treated water usage. Rainwater harvesting systems have substantial potential as retrofits via the use of rain barrels or cisterns that can replace lawn or garden sprinkling systems. Use of this SCM to provide gray water within buildings (e.g., for toilet flushing) is considerably more complicated due to the need to construct new plumbing and obtain the necessary permits.



FIGURE 5-14 Rainwater harvesting tanks at a Starbucks in Austin, Texas. SOURCE: Laura Ehlers, National Research Council.

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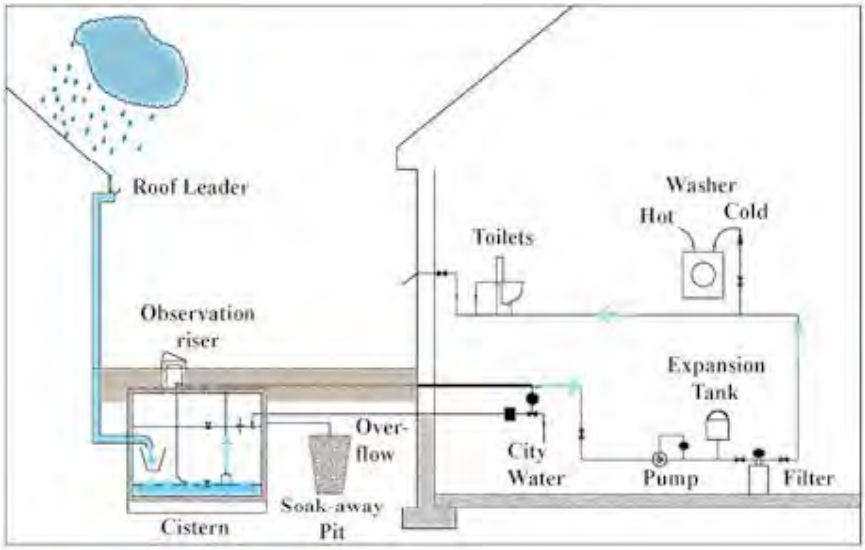

FIGURE 5-15 A Schematic of rainwater harvesting. SOURCE: PaDEP (2006).

The greatest challenge with these systems is the need to use the stored water and avoid full tanks, since these cannot be responsive in the event of a storm. That is, these SCMs are effective only if the captured runoff can be regularly used for some grey water usage, like car washing, toilet flushing, or irrigation systems (golf courses, landscaping, nurseries). In some areas it might be possible to use the water for drinking, showering, or washing, but treatment to potable water quality would be required. Sizing of the required storage is dependent on the climate patterns, the amount of impervious cover, and the frequency of water use. Areas with frequent rainfall events require less storage as long as the water is used regularly, while areas with cold weather will not be able to utilize the systems for irrigation in the winter and thus require larger storage.

One substantial advantage of these systems is their ability to reduce water costs for the user and the ability to share needs. An example of this interaction is the Pelican Hill development in Irvine, California, where excess runoff from the streets and houses is collected in enormous cisterns and used for watering of a nearby golf course. Furthermore, compared to other SCMs, the construction of rainwater harvesting facilities provide a long-term benefit with minimal maintenance cost, although they do require an upfront investment for piping and storage tanks.

Coombes et al. (2000) found that rainwater harvesting achieved a 60 to 90 percent reduction in runoff volume; in general, few studies have been conducted to determine the performance of these SCMs. It should be noted that rainwater harvesting systems do collect airborne deposition and acid rain.

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Runoff Volume Reduction—Vegetated

A large and very promising class of SCMs includes those that use infiltration and evapotranspiration via vegetation to reduce the volume of runoff. These SCMs also directly address water quality of both surface water and groundwater by reducing streambank erosion, capturing suspended solids, and removing other pollutants from stormwater during filtration through the soil (although the extent to which pollutants are removed depends on the specific pollutant and the local soil chemistry). Depending on their design, these SCMs can also reduce peak flows and recharge groundwater (if they infiltrate). These SCMs can often be added as retrofits to developed areas by installing them into existing lawns, rights of way, or traffic islands. They can add beauty and property value.

Flow volume is addressed by this SCM group by first capturing runoff, creating a temporary holding area, and then removing the stored volume through infiltration and evapotranspiration. Examples include bioswales, bioretention, rain gardens, green roofs, and bioinfiltration. Swales refer to grassy areas on the side of the road that convey drainage. These were first designed to move runoff away from paved areas, but can now be designed to achieve a certain contact time with runoff so as to promote infiltration and pollutant removal (see Figure 5-16). Bioretention generally refers to a constructed sand filter with soil and vegetation growing on top to which stormwater runoff from impervious surfaces is directed (Figure 5-17). The original rain garden or bioretention facilities were constructed with a fabric at the bottom of the prepared soil to prevent infiltration and instead had a low-level outflow at the bottom. Green roofs (Figure 5-18) are very similar to bioretention SCMs. They tend to be populated with a light expanded shale-type soil and succulent plants chosen to survive wet and dry periods. Finally, bioinfiltration is similar to bioretention but is better engineered to achieve greater infiltration (Figure 5-19). All of these devices are usually at the upper end of a treatment train and designed for smaller storms, which minimizes their footprint and allows for incorporation within existing infrastructure (such as traffic control devices and median strips). This allows for distributed treatment of the smaller volumes and distributed volume reduction.

These SCMs work by capturing water in a vegetated area, which then infiltrates into the soil below. They are primarily designed to use plant material and soil to evapotranspirate the runoff over several days. A shallow depth of ponding is required, since the inflows may exceed the possible infiltration ability of the native soil. This ponding is maintained above an engineered sandy soil mixture and is a surface-controlled process (Hillel, 1998). Early in the storm, the soil moisture potential creates a suction process that helps draw water into the SCM. This then changes to a steady rate that is “practically equal to the saturated hydraulic conductivity” of the subsurface (Hillel, 1998). The hydrologic design goal should be to maximize the volume of water that can be held in the soil, which necessitates consideration of the soil hydraulic conductivity (which varies with temperature), climate, depth to groundwater, and time to drain.

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FIGURE 5-16 Vegetated swale. SOURCE: PaDEP (2006).



FIGURE 5-17 Bioretention during a storm event at the University of Maryland. SOURCE: Reprinted, with permission, from Davis et al. (2008). Copyright 2008 by the American Society of Civil Engineers.

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FIGURE 5-18 City Hall in the center of Chicago's downtown was retrofitted with a green roof to reduce the heat island effect, remove airborne pollutants, and attenuate stormwater flows as a demonstration of innovative stormwater management in an ultra-urban setting. SOURCE: Courtesy of the Conservation Design Forum.



FIGURE 5-19 Retrofit bioinfiltration at Villanova University immediately following a storm event. SOURCE: Robert Traver, Villanova University.

Usually these devices are designed to empty between 24 and 72 hours after a storm event. In some cases (usually bioretention), these SCMs have an underdrain.

The choice of vegetation is an important part of the design of these SCMs. Many sites where infiltration is desirable have highly sandy soils, and the vegetation has to be able to endure both wet and dry periods. Long root growths are desired to promote infiltration (Barr Engineering Co., 2001), and plants that attract birds can reduce the insect population. Bioretention cells may be wet for

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longer periods than bioinfiltration sites, requiring different plants. Denser plantings or "thorns" may be needed to avoid the destruction caused by humans and animals taking shortcuts through the beds.

The pollutant removal mechanism operating for volume-reduction SCMs are different for each pollutant type, soil type, and volume-reduction mechanism. For bioretention and SCMs using infiltration, the sedimentation and filtration of suspended solids in the top layers of the soil are extremely efficient. Several studies have shown that the upper layers of the soil capture metals, particulate nutrients, and carbon (Pitt, 1996; Deschesne et al., 2005; Davis et al., 2008). The removal of dissolved nutrients from stormwater is not as straightforward. While ammonia is caught by the top organic layer, nitrate is mobile in the soil column. Some bioretention systems have been built to hold water in the soil for longer periods in order to create anaerobic conditions that would promote denitrification (Hunt and Lord, 2006a). Phosphorus removal is related to the amount of phosphorus in the original soil. Some studies have shown that bioretention cells built with agricultural soils increased the amount of phosphorus released. Chlorides pass through the system unchecked (Ermilio and Traver, 2006), while oils and greases are easily removed by the organic layer. Hunt et al. (2008) have reported in studies in North Carolina that the drying cycle appears to kill off bacteria. Temperature is not usually a concern as most storms do not overflow these devices. Green roofs collect airborne deposition and acid rain and may export nutrients when they overflow. However, this must be tempered by the fact that in larger storms, most natural lands would produce nutrients.

A group of new research studies from North America and Australia have demonstrated the value of many of these runoff-volume-reduction practices to replicate predevelopment hydrology at the site. The results from 10 recent studies are given in Table 5-3, which shows the runoff reduction capability of bioretention. As can be seen, the reduction in runoff volume achieved by these practices is impressive—ranging from 20 to 99 percent with a median reduction of about 75 percent. Box 5-5 discusses the excellent performance of the bioswales installed during Seattle's natural drainage systems project (see also Horner et al., 2003; Jefferies, 2004; Stagge, 2006). Bioinfiltration has been less studied, but one field study concluded that close to 30 percent of the storm volume was able to be removed by bioinfiltration (Sharkey, 2006). A very recent case study of bioinfiltration is provided in Box 5-6, which demonstrates that the capture of small storms through these SCMs is extremely effective in areas where the majority of the rainfall falls in smaller storms.

The strengths of vegetated runoff-volume-reduction SCMs include the flexibility to utilize the drainage system as part of the treatment train. For example, bioswales can replace drainage pipes, green roofs can be installed on buildings, and bioretention can replace parking borders (Figure 5-27), thereby reducing the footprint of the stormwater system. Also, through the use of swales and reducing pipes and inlets, costs can be offset. Vegetated systems are more tolerant of the TSS collected, and their growth cycle maintains pathways for

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TABLE 5-3 Volumetric Runoff Reduction Achieved by Bioretention

Bioretention Design	Location	Runoff Reduction	Reference
Infiltration	CT	99%	Dietz and Clausen (2006)
	PA	86%	Ermilio and Traver (2006)
	FL	98%	Rushton (2002)
	AUS	73%	Lloyd et al. (2002)
Underdrain	ONT	40%	Van Seters et al. (2006)
	Model	30%	Perez-Perdini et al. (2005)
	NC	40 to 60%	Smith and Hunt (2007)
	NC	20 to 29%	Sharkey (2006)
	NC	52 to 56%	Hunt et al. (2008)
	MD	52 to 65%	Davis et al. (2008)

BOX 5-5
Bioswale Case Study 110th Street Cascade, Seattle, Washington

A recent example of the ability of SCMs to accomplish a variety of goals was illustrated for water quality swales in Seattle, Washington. As part of its Natural Drainage Systems Project, the City of Seattle retrofitted several blocks of an urban residential neighborhood with curbside vegetated swales. On NW 110th Street, the two-block-long system was developed as a cascade, due to the steep slope (6 percent). Twelve stepped, in-series biofilters were installed between properties and the road, each of which contains a storage area and an overflow weir. During rain events, the cells were designed to fill before emptying into the cell downstream. The soils in the bottom of each cell were over one foot thick and consisted of river rocks overlain by a swale mix. Native plants were chosen to vegetate the sides of the swale.



Extensive flow and water quality sampling occurred during 2003–2006 at the inflow and outflow of the biofilters as well as at references points elsewhere in the neighborhood that are not served by the new SCMs. Perhaps the most profound observation was that almost 50 percent of all rainfall flowing into the cascade was infiltrated, resulting in a corresponding reduction in runoff. Indeed, the cascade discharged measurable flow only during 49 of 235 storm events during the period. Depending on preceding conditions, the cascade was able to retain all of the flow for storms up to 1 inch in magnitude. In addition to the reduction in runoff affected by the swales, they also achieved significant peak flow reduction, as shown in Figure 5-20. Many peak flow rates were entirely dampened, even those where the inflow peak rate was as high as 0.7 cfs.

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BOX 5-5 Continued

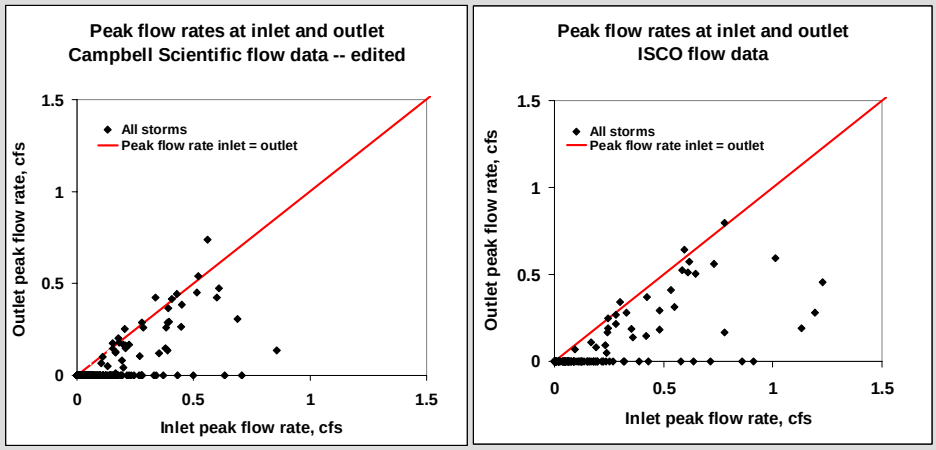

FIGURE 5-20 Peak flow rates at the inlet and outlet of the cascade, as measured by two different devices: Campbell Scientific (left) and ISCO (right). SOURCE: Horner and Chapman (2007).

Water quality data were also extremely encouraging, as shown in Table 5-4. For total suspended solids, influent concentration of 94 mg/L decreased to 29 mg/L at the outlet of the cascade. Similar percent removals were observed for total copper, total phosphorus, total zinc, and total lead (see Table 5-4). Soluble phosphorus concentrations tended to increase from the inflow of the cascade to the outflow.

TABLE 5-4 Typical Outflow Quality from the 110th Street Cascade.

Pollutant	Range (mg/L)
Total Suspended Solids	10–40
Total Nitrogen	0.6–1.4
Total Phosphorus	0.09–0.23
Soluble Reactive Phosphorus	0.02–0.05
Total Copper	0.004–0.008
Dissolved Copper	0.002–0.005
Total Zinc	0.04–0.11
Dissolved Zinc	0.02–0.06
Total Lead	0.002–0.007
Dissolved Lead	<0.001
Motor Oil	0.11–0.33

SOURCE: Horner and Chapman (2007).

Taking both measured concentrations and volume reduction into account, the cascade reduced the mass loadings for the contaminants by 60 percent to greater than 90 percent. As shown in Table 5-5, pollutants associated with sediments were reduced to the greatest extent, while dissolved pollutants were less readily removed.

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BOX 5-5 Continued

TABLE 5-5 Pollutant Mass Loading Reductions at 110th Street Cascade.

Pollutant	Percent Reduction (90% Confidence Interval)
Total Suspended Solids	84 (72–92)
Total Nitrogen	63 (53–74)
Total Phosphorus	63 (49–74)
Total Copper	83 (77–88)
Dissolved Copper	67 (50–78)
Total Zinc	76 (46–85)
Dissolved Zinc	55 (21–70)
Total Lead	90 (84–94)
Motor Oil	92 (86–97)

SOURCE: Horner and Chapman (2007).

This level of performance was compared to other parts of the neighborhood treated with conventional ditch and pipe systems. The concentrations of almost all pollutants at the outlet of the 100th Cascade was significantly lower than a corresponding outlet at 120th Street. Furthermore, the ability of this SCM to attenuate peak flows and reduce runoff was remarkable.

BOX 5-6
SCM Evaluation Through Monitoring: Villanova Bioinfiltration SCM

The Bioinfiltration Traffic Island located on the campus of Villanova University in Southeastern Pennsylvania is part of the Villanova Urban Stormwater Partnership (VUSP) BMP Demonstration Park (see Figure 5-21). Originally funded through the Pennsylvania Growing Greener Program, and now through the State's 319 nonpoint source monitoring program, the site has been monitored continuously since soon after it was constructed in 2001. This monitoring has lead to a wealth of information about the performance and monitoring needs of infiltration SCMs.



FIGURE 5-21 Villanova Bioinfiltration Traffic Island SCM. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

The SCM is a retrofit of an existing curb-enclosed traffic island in the parking lot of a university dormitory complex. The original grass area was dug out to approximately six feet. The soil removed during the excavation was then mixed with sand onsite to create a 50 percent sand–soil mixture. This soil mixture was then placed back into the excavation to

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BOX 5-6 Continued

a depth of approximately four feet, leaving a surface depression that is an average of two feet deep. Care was taken during construction to prevent any compaction of either the soil mixture or the undisturbed soil below. Placement of the mixed soil is shown in Figure 5-22.



FIGURE 5-22 Placement of the mixed soil in the basin. Notice the construction equipment being kept away from the basin to avoid potential compaction of the sub-base. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

During construction two curb cuts were created to direct runoff into the SCM. Creation of one of the cuts entailed filling and paving over an existing stormwater inlet to redirect the runoff that previously entered the stormwater drainage system of the parking lot. Another existing inlet was used to collect and redirect runoff into the SCM. Plants were chosen based on their ability to thrive in both extreme wet and dry conditions; the species chosen are commonly found on sand dunes where similar wet/dry conditions may exist.

The contributing watershed is approximately 50,000 square feet and is 52 percent impervious surfaces. The design goal of the SCM was for it to temporarily store the first inch of runoff. The one-inch capture depth is based on an analysis of local historical rainfall data showing that capture of the first inch of each storm would account for approximately 96 percent of the annual rainfall. This capture depth would therefore also account for the majority of the annual pollutant load coming from the drainage area.

Continuous monitoring over multiple years has increased our understanding of how this type of structure operates and its benefits. For example, Heasom et al. (2006) was able to produce a continuous hydrologic flow model of the site based on season. Figure 5-23 shows the variability of the infiltration rate on a seasonal basis, and the relationship between infiltration and temperature (Emerson and Traver, 2008). This work has also shown no statistical change in performance over the five-year monitoring period.

When examining the yearly performance of the site from a surface water standpoint, it is easily shown that on a regular basis approximately 50 to 60 percent of the runoff that reaches the site is removed from the surface waters, and 80 to 85 percent of the rainfall is infiltrated (Figure 5-24).

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BOX 5-6 Continued

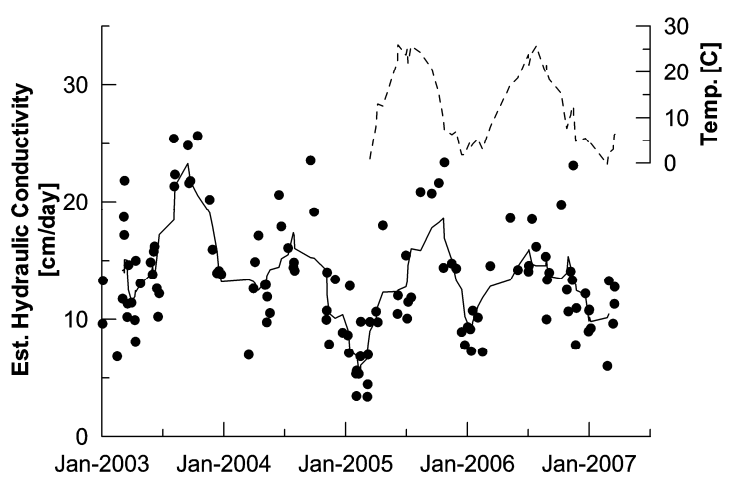

FIGURE 5-23 Seasonal Infiltration Rate. SOURCE: Reprinted, with permission, from Emerson and Traver (2008). Copyright 2008 by Journal of Irrigation and Drainage Engineering.

The performance of the SCM during individual storm events was examined in 2005. Out of 77 rainfall events, overflow was recorded for only seven events. Generally overflow did not occur for rainfalls less than 1.95 inches except for one occasion. As the bowl volume is much less than this value, substantial infiltration must be occurring during the storm event. When one extreme 6-inch storm was recorded (Figure 5-25), it was surprising to note that infiltration occurred all during the storm event, as did some unexpected peak flow reduction. What is even more impressive is to examine the reduction in the duration of flows, which is directly related to downstream channel erosion (Figure 5-26). Clearly the bioinfiltration SCM exceeded its design goals.

Research on this site is currently examining water quality benefits and groundwater interactions. When evaluating the pollutant removal of bioinfiltration, it is critical to consider flow volumes and pollutant levels together. For example, during many of the overflow events, there were higher nutrient levels leaving the SCM than entering due to the plants contained within the SCM. However, when the runoff volume reduction is considered, the total nitrogen and phosphorus removed from the influent is impressive (Davis et al., 2008). Water quality studies of the infiltrated water are still incomplete but generally show some conversion of nitrate to nitrite, and high chlorides from snow melt chemicals moving through the system. Nutrient levels are relatively low in the samples at the 8-foot depth.

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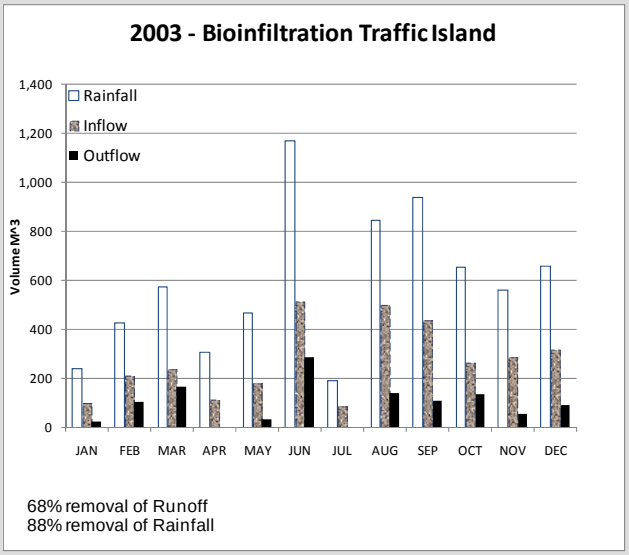

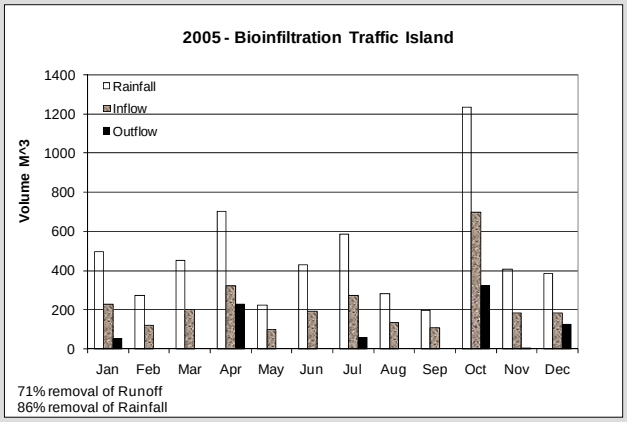

FIGURE 5-24 2003 Performance and 2005 Performance. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

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BOX 5-6 Continued

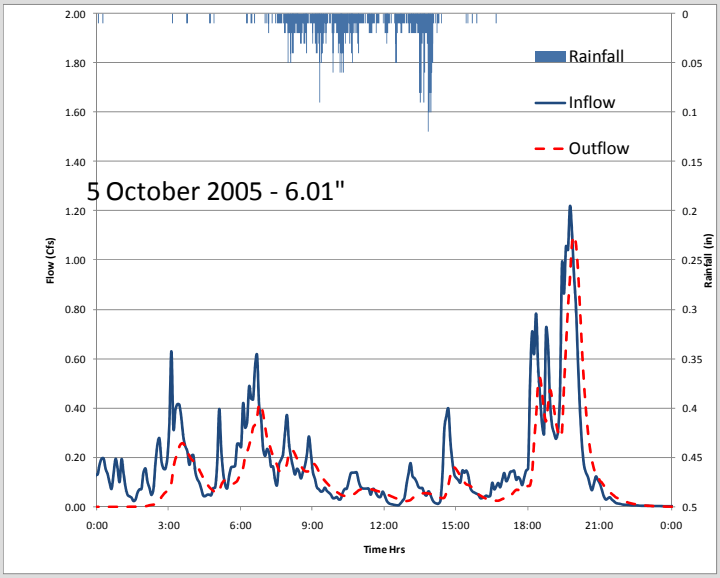

FIGURE 5-25 October 2005 extreme storm event. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

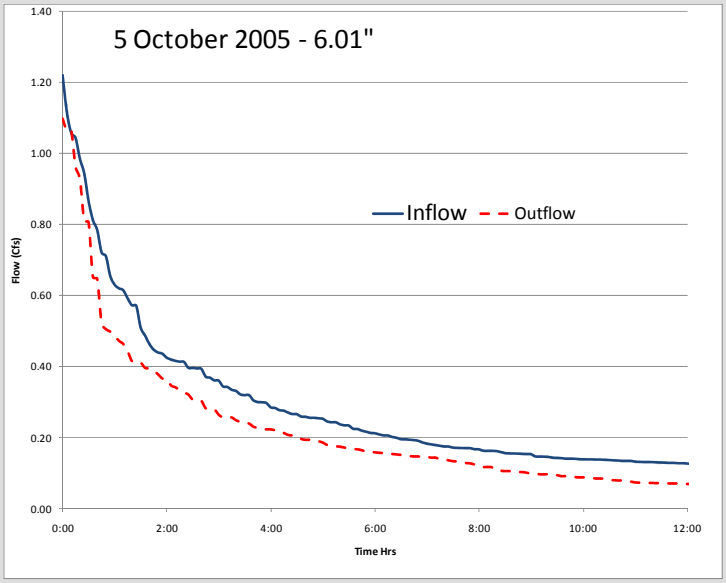

FIGURE 5-26 Flow duration curves, October 2005. SOURCE: Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

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FIGURE 5-27 North Carolina Retrofit Bioretention SCMs. SOURCE: Robert Traver, Villanova University.

infiltration and prevents clogging. Freeze–thaw cycles also contribute to pathway maintenance. The aesthetic appeal of vegetated SCMs is also a significant strength.

Weaknesses include the dependence of these SCMs on native soil infiltration and the need to understand groundwater levels and karst geology, particularly for those SCMs designed to infiltrate. For bioinfiltration and bioretention, most failures occur early on and are caused by sedimentation and construction errors that reduce infiltration capacity, such as stripping off the topsoil and compacting the subsurface. Once a good grass cover is established in the contributing area, the danger of sedimentation is reduced. Nonetheless, the need to prevent sediment from overwhelming these structures is critical. The longevity of these SCMs and their vulnerability to toxic spills are a concern (Emerson and Traver, 2008), as is their failure to reduce chlorides. Finally, in areas where the land use is a hot spot, or where the SCM could potentially contaminate the groundwater supply, bioretention, non-infiltrating bioswales, and green roofs may be more suitable than infiltration SCMs.

The role of infiltration SCMs in promoting groundwater recharge deserves additional consideration. Although this is a benefit of infiltration SCMs in regions where groundwater levels are dropping, it may be undesirable in a few limited scenarios. For example, in the arid southwest contributions to base flow from irrigation have turned some dry ephemeral stream systems into perennial streams that support the growth of dense vegetation, which may be less desirable habitat for certain riparian species (like the Arroyo toad in Southern California). Infiltration SCMs could contribute to changing the flow regime in cases such as these. In most urban areas, there is so much impervious cover that it would be

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difficult to "overinfiltrate." Nonetheless, the use of infiltration SCMs will change local subsurface hydrology, and the ramifications of this—good and bad—should be considered prior to their installation.

Maintenance of vegetated runoff-volume-reduction SCMs is relatively simple. A visit after a rainstorm to check for plant health, to check sediment buildup, and to see if the water is ponded can answer many questions. Maintenance includes trash pickup and seasonal removal of dead grasses and weeds. Sediment removal from pretreatment devices is required. Depending on the pollutant concentrations in the influent, the upper layer of organic matter may need to be removed infrequently to maintain infiltration and to prevent metal and nutrient buildup.

At the site level, the chief factors that lead to uncertainty are the infiltration performance of the soil, particular for the limiting subsoil layer, and how to predict the extent of pollutant removal. Traditional percolation tests are not effective to estimate the infiltration performance; rather, testing hydraulic conductivity is required. Furthermore, the infiltration rate varies depending on temperature and season (Emerson and Traver, 2008). Basing measurements on percent removal of pollutants is extremely misleading, since every site and storm generates different levels of pollutants. The extent of pollutant removal depends on land use, time between storms, seasons, and so forth. These factors should be part of the design philosophy for the site. Finally, it should also be pointed out that climate is a factor determining the effectiveness of some of these SCMs. For example, green roofs are more likely to succeed in areas having smaller, more frequent storms (like the Pacific Northwest) compared to areas subjected to less frequent, more intense storms (like Texas).

Runoff Volume Reduction—Subsurface

Infiltration is the primary runoff-volume-reduction mechanism for subsurface SCMs, such that much of the previous discussion is relevant here. Thus, like vegetated SCMs, these SCMs provide benefits for groundwater recharge, water quality, stream channel protection, peak flow reduction, capture of the suspended solids load, and filtration through the soil (Ferguson, 2002). Because these systems can be built in conjunction with paved surfaces (i.e., they are often buried under parking lots), the amount of water captured, and thus stream protection, may be higher than for vegetated systems. They also have lower land requirements than vegetated systems, which can be an enormous advantage when using these SCMs during retrofitting, as long as the soil is conducive to infiltration.

Similar to vegetated SCMs, this SCM group works primarily by first capturing runoff and then removing the stored volume through infiltration. The temporary holding area is made either of stone or using manufactured vaults. Examples include pervious pavement, infiltration trenches, and seepage pits (see Figures 5-28, 5-29, 5-30, 5-31, and 5-32). As with vegetated SCMs, a shallow

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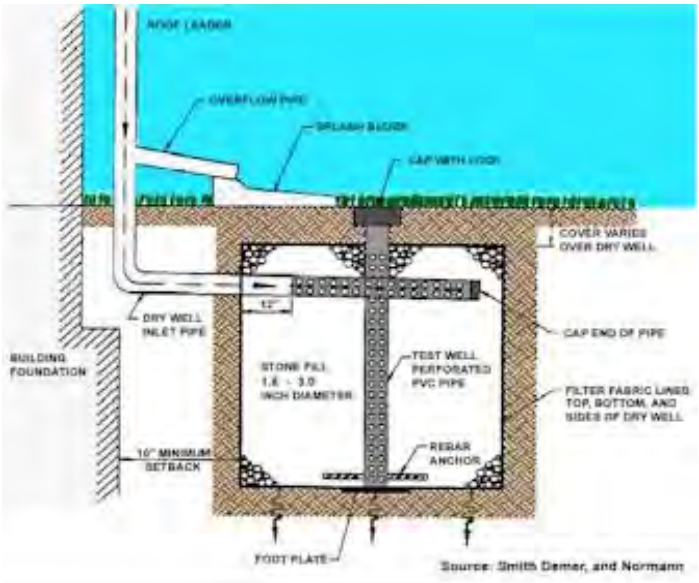

FIGURE 5-28 Schematic of a seepage pit. SOURCE: PaDEP (2006).



FIGURE 5-29 Porous asphalt. SOURCE: PaDEP (2006).

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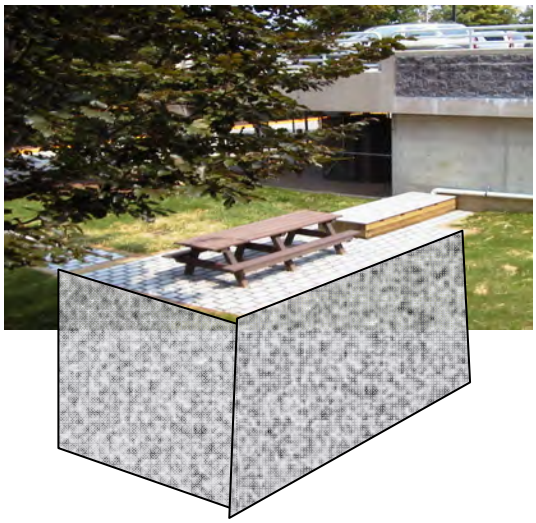

FIGURE 5-30 A retrofitted infiltration trench at Villanova University. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

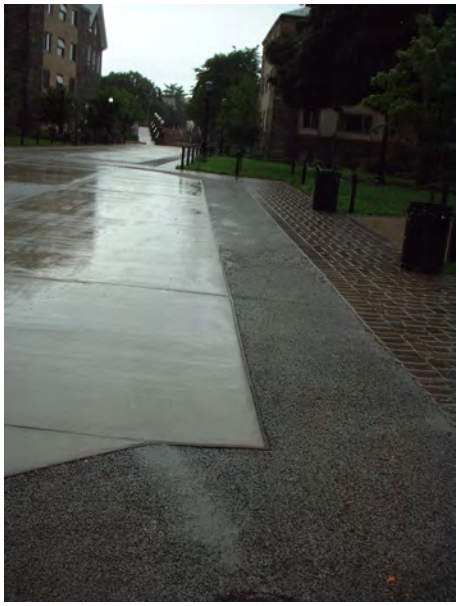

FIGURE 5-31 Pervious concrete at Villanova University. SOURCE: Reprinted, with permission from Villanova University. Copyright by VUSP.

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FIGURE 5-32 A small office building conversion at the edge of downtown Denver included the replacement of a portion of the site's parking with modular block porous pavement underlain by an 18-inch layer of crushed rock. Rainfall on the porous pavement and roof runoff for most storm events are contained in the reservoir created by the crushed rock. The pavement infiltrates runoff from most storm events for one-third of the impervious area on the half-acre site. SOURCE: Courtesy of Wenk Associates.

depth of ponding is required, since the inflows may exceed the possible infiltration ability of the native soil. In this case, the ponding is maintained within a rock bed under a porous pavement or in an infiltration trench. These devices are usually designed to empty between 24 and 72 hours after the storm event.

The infiltration processes operating for these subsurface SCMs are similar to those for the vegetated devices previously discussed. Thus, much like for

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vegetated systems, the level of control achieved depends on the infiltration ability of the native soils, the percent of impervious surface area in the contributing watershed, land use contributing to the pollutant loadings, and climate. A large number of recent studies have found that permeable pavement can reduce runoff volume by anywhere from 50 percent (Rushton, 2002; Jefferies, 2004; Bean et al., 2007) to as much as 95 percent or greater (van Seters et al., 2006; Kwiatkowski et al., 2007). Box 5-7 describes the success of a recent retrofitting of asphalt with pervious pavement at Villanova University.

The strengths of subsurface runoff-volume-reduction SCMs are similar to those of their vegetated counterparts. Additional attributes include their ability to be installed under parking areas and to manage larger volumes of rainfall. These SCMs typically have few problems with safety or vector-borne diseases because of their subsurface location and storage capacity, and they can be very aesthetically pleasing. The potential of permeable pavement could be particularly far-reaching if one considers the amount of impervious surface in urban areas that is comprised of roads, driveways, and parking lots.

The weaknesses of these SCMs are also similar to those of vegetated systems, including their dependence on native soil infiltration and the need to understand groundwater levels and karst geology. Simply estimating the soil hydraulic conductivity can have an error rate of an order of magnitude. Specifically for subsurface systems that use geotextiles (not permeable pavement), there is a danger of TSS being compressed against the bottom of the geotextile, preventing infiltration. There are no freeze–thaw cycles or vegetated processes that can reopen pathways, so the control of TSS is even more critical to their life span. In most cases (permeable pavement is an exception), pretreatment is required, except for the cleanest of sources (like a slate roof). Typically, manufactured devices, sediment forebays, or grass strips are part of the design of subsurface SCMs to capture the larger sediment particles.

The maintenance of subsurface runoff-volume-reduction SCMs is relatively simple but critical. If inspection wells are installed, a visit after a rainstorm will check that the volume is captured, and later that it has infiltrated. Porous surfaces should undergo periodic vacuum street sweeping when a sediment source is present. Pretreatment devices require sediment removal. The difficulty with this class of SCMs is that, if a toxic spill occurs or maintenance is not proactive, there are no easy corrective measures other than replacement.

Low-Impact Development. LID refers primarily to the use of small, engineered, on-site stormwater practices to treat the quality and quantity of runoff at its source. It is discussed here because the SCMs that are thought of as LID—particularly vegetated swales, green roofs, permeable pavement, and rain gardens—are all runoff-volume-reduction SCMs. They are designed to capture the first portion of a rainfall event and to treat the runoff from a few hundred square meters of impervious cover.

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BOX 5-7
Evaluation Through Monitoring: Villanova Pervious Concrete SCM

Villanova University's Stormwater Research and Demonstration Park is home to a pervious concrete infiltration site (Figure 5-33). The site, formerly a standard asphalt paved area, is located between two dormitories. The area was reconstructed in the summer of 2002 and outfitted with three infiltration beds overlain with pervious concrete. Usage of the site consists primarily of pedestrian traffic with some light automobile traffic. The pervious concrete site is designed to infiltrate small-volume storms (1 to 2 inches). Roof top runoff is directly piped to the rock bed under the concrete. For these smaller events, there is essentially no runoff from the site.



FIGURE 5-33 Villanova University pervious concrete retrofit site. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

The pervious concrete is outlined with decorative pavers that divide the pervious concrete into three separate sections as seen in Figure 5-33. Underneath these three sections are individual storage beds. Since the site lies on a significant slope it was necessary to create earthen dams that isolate each storage area. At the top of each dam there is an overflow pipe which connects the storage area with the next one downstream. The final storage bed has an overflow that connects to the existing storm sewer. The beds are approximately 4 feet deep and are filled with stone, producing about 40 percent void space within the beds. A geotextile pervious liner was laid down to separate the storage beds from the undisturbed soil below (Figure 5-34). The primary idea was to avoid any upward migration of the in-situ soil, which could possibly reduce the capacity of the beds over time.

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BOX 5-7 Continued



FIGURE 5-34 Infiltration bed under construction. Pervious concrete has functionality and workability similar to that of regular concrete. However, the pervious concrete mix lacks the sand and other fine particles found in regular concrete. This creates a significant amount of void space which allows water to flow relatively unobstructed through the concrete. This site was the first attempt at creating a pervious concrete SCM in the area, and there were construction and material problems. Since that time the industry has matured, and a second site on campus constructed in 2007 has not had any significant difficulties. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

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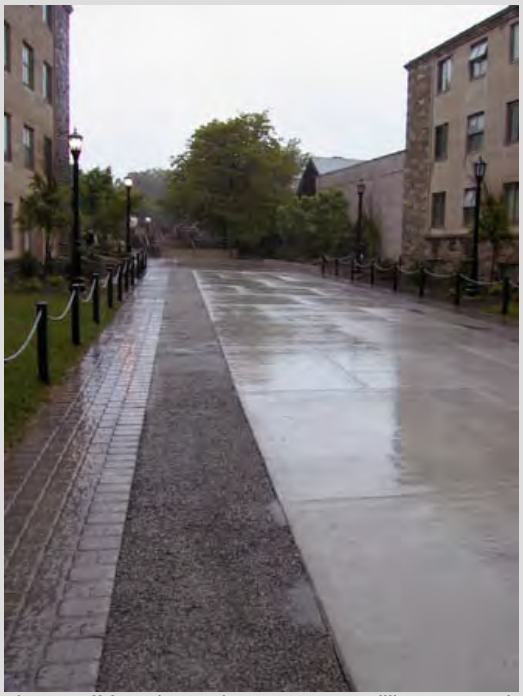

Note the runoff from impervious concrete spilling over to the pervious concrete. SOURCE: Robert Traver, Villanova University

Continuous monitoring of the site over a number of years has considerably increased our understanding of infiltration. Similar to the bioinfiltration site (Box 5-6), the infiltration rate of permeable concrete does vary as a function of temperature (Braga et al., 2007; Emerson and Traver, 2008), and the SCM volume reduction is impressive. As shown in Figure 5-35, over 95 percent of the yearly rainfall was infiltrated with minimal overflow. Besides hydrologic plots, water quality plots also show the benefits of permeable concrete (Kwiatkowski et al., 2007). Because over 95 percent of the runoff is infiltrated, well over 95 percent of the pollutant mass is also removed. Figure 5-36 shows the level of copper extracted from lysimeters buried under the rock bed and surrounding grass. The plot is arranged in quartiles, with readings in milligrams per liter. Lysimeter samples from under the surrounding grass and one foot and four feet under the infiltration bed all report almost no copper, compared to samples taken from the port in the rock bed and from the gutters draining the roof tops.

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BOX 5-7 Continued

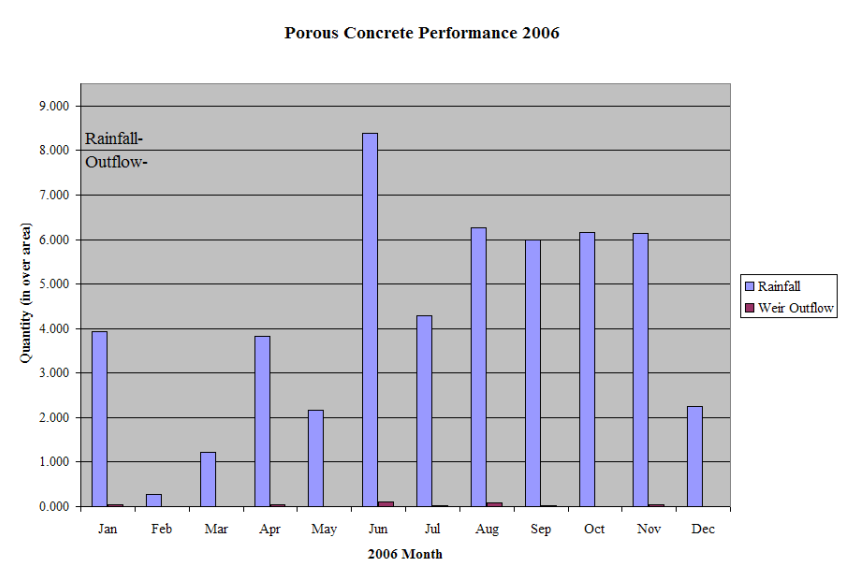

FIGURE 5-35 Rainfall and corresponding outflow from the weir of the SCM. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

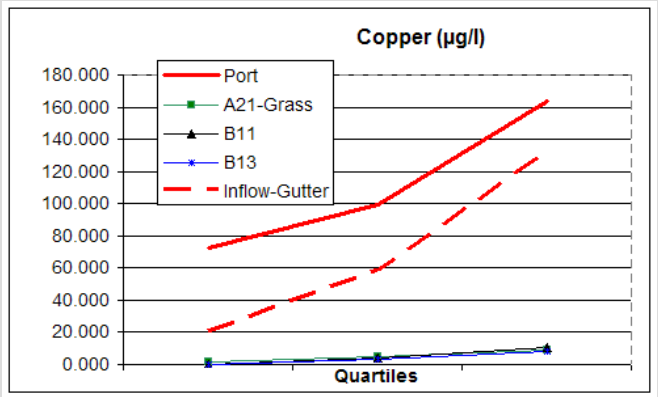

FIGURE 5-36 Copper measured at various locations. The three quartiles correspond to the 25th, 50th, and 75th percentile value of all data collected. A21 is a lysimeter location under the surrounding grass, while B11 and B13 refer to locations that are one foot and four feet under the infiltration bed, respectively. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

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As discussed earlier, several studies have measured the runoff volume reduction of individual LID practices. Fewer studies are available on whether multiple LID practices, when used together, have a cumulative benefit at the neighborhood or catchment scale. Four monitoring studies have clearly documented a major reduction in runoff from developments that employ LID and Better Site Design (see Box 5-8) compared to those that do not. In addition, six studies have documented the runoff reduction benefits of LID at the catchment or watershed scale using a modeling approach (Alexander and Heaney, 2002; Stephens et al., 2002; Holman-Dodds et al., 2003; Coombes, 2004; Hardy et al., 2004; Huber et al., 2006).

Peak Flow Reduction and Runoff Treatment

After efforts are made to prevent the generation of pollutants and to reduce the volume of runoff that reaches stormwater systems, stormwater management focuses on the reduction of peak flows and associated treatment of polluted runoff. The main class of SCMs used to accomplish this is extended detention basins, versions of which have dominated stormwater management for decades. These include a wide variety of ponds and wetlands, including wet ponds (also known as retention basins), dry extended detention ponds (as known as detention basins), and constructed wetlands. By holding a volume of stormwater runoff for an extended period of time, extended detention SCMs can achieve both water quality improvement and reduced peak flows. Generally the goal is to hold the flows for 24 hours at a minimum to maximize the opportunity of settling, adsorption, and transformation of pollutants (based on past pollutant removal studies) (Rea and Traver, 2005). For smaller storm events (one- to two-year storms), this added holding time also greatly reduces the outflows from the SCM to a level that the stream channel can handle. Most wet ponds and stormwater wetlands can hold a "water quality" volume, such that the flows leaving in smaller storms have been held and "treated" for multiple days. Extended detention dry ponds greatly reduce the outflow peaks to achieve the required residence times.

Usually extended detention devices are lower in the treatment train of SCMs, if not at the end. This is both due to their function (they are designed for larger events) and because the required water sources and less permeable soils needed for these SCMs are more likely to be found at the lower areas of the site. Some opportunities exist to naturalize dry ponds or to retrofit wet ponds into stormwater wetlands but it depends on their site configuration and hydrology. Stormwater wetlands are shown in Figures 5-40 and 5-41. A wet pond and a dry extended detention basin are shown in Figures 5-42 and 5-43.

Simple ponds are little more than a hole in the ground, in which stormwater is piped in and out. Dry ponds are meant to be dry between storms, whereas wet ponds have a permanent pool throughout the year. Detention basins reduce peak flows by restricting the outflows and creating a storage area. Depending on the

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BOX 5-8
Jordan Cove—An LID Watershed Project

LID refers to the use of a system of small, on-site SCMs to counteract increases in flow and pollution following development and to control smaller runoff events. Although some studies are available that measure the runoff volume reduction of individual LID practices, fewer studies are available on whether multiple LID practices, when used together, have a cumulative benefit at the neighborhood or catchment scale. Of those listed in Table 5-6, Jordan Cove is the most extensively studied, as it was monitored for ten years as part of a paired watershed study that included a site with no SCMs and a site with traditional (detention) SCMs. The watersheds were monitored during calibration, construction, and post-construction periods. The project consisted of 12 lots, and the SCMs used were bioretention, porous pavements, no-mow areas, and education for the homeowners (Figure 5-37).

TABLE 5-6 Review of Recent LID Monitoring Research on a Catchment Scale

Location	Practices	Runoff Reduction
Jordan Cove, USA Dietz and Clausen (2008)	Permeable pavers, bioretention, grass swales, education	84%
Somerset Heights, USA Cheng et al. (2005)	Grass swale, bioretention, and roof-top disconnection	45%
Figtree Place, Australia Coombes et al. (2000)	Rain tanks, infiltration trenches, swales	100%



FIGURE 5-37 Jordan Cove LID subdivision. SOURCE: Reprinted, with permission, from Clausen (2007). Copyright 2007 by John Clausen.

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Figure 5-38 (right panel) displays the hydrograph from a post-construction storm comparing the LID, traditional, and control watersheds. Note that the traditional watershed shows the delay and peak reduction from the detention basins, while the LID watershed has almost no runoff. The LID watershed was found to reduce runoff volume by 74 percent by increasing infiltration over preconstruction levels.

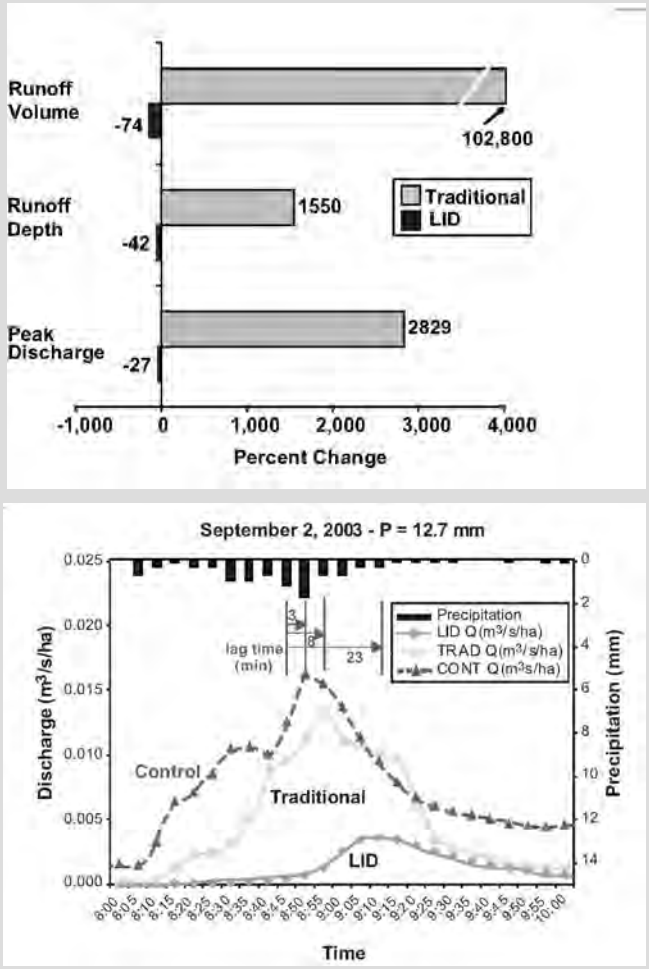

FIGURE 5-38. Significant changes in runoff volume (m^3/week), runoff depth (cm/week) and peak discharge (m^3/sec/week) after construction was completed (top panel). Hydrograph of all three subdivisions in the project, showing the larger volume and rate of runoff from the traditional and control subdivisions, as compared to the LID (bottom panel). SOURCE: Reprinted, with permission, from Clausen (2007). Copyright 2007 by John Clausen.

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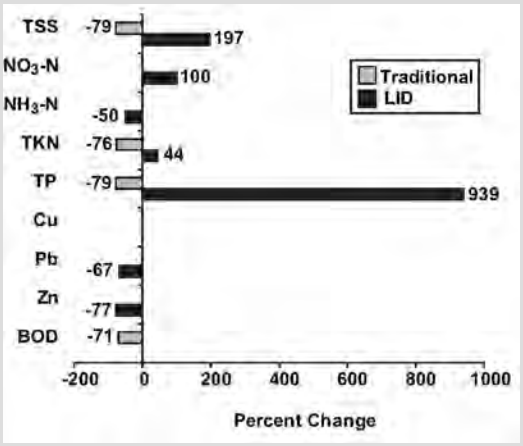
BOX 5-8 Continued

Comparisons of nutrient and metal concentrations and total export in the surface water shows the value of the LID approach as well as the significance of the reduction in runoff volume. Figure 5-39 shows the changes in pollutant concentration and mass export before and after construction for the traditional and LID subdivisions. Note that concentrations of TSS and nutrients are increased in the LID subdivision (left-hand panel); this is because swales and natural systems are used in place of piping as a "green" drainage system and because only larger storms leave the site. The right-hand panel shows how the large reduction in runoff achieved through infiltration can dramatically reduce the net export of pollutants from the LID watershed.



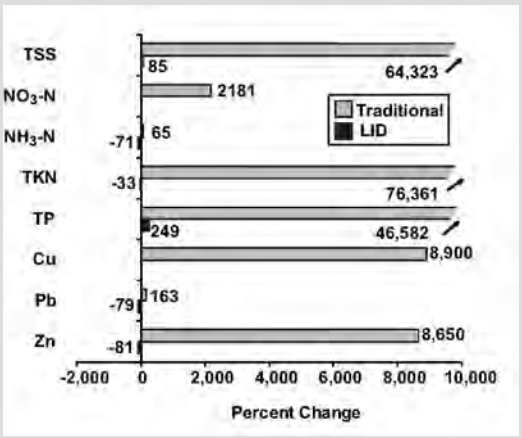


FIGURE 5-39 Significant changes in pollutant concentration, after construction was completed (top). Units are mg/L for NO_3-N, NH_3-N, TKN, TP, and BOD, and µg/L for Cu, Pb, and Zn. Significant changes in mass export (kg/ha/year) after construction was completed (bottom). SOURCE: Reprinted, with permission, from Clausen (2007). Copyright 2007 by John Clausen.

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FIGURE 5-40 Constructed wetland. SOURCE: PaDEP (2006).



FIGURE 5-41 Retrofitted stormwater wetland at Villanova University. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.



FIGURE 5-42 Wet pond. SOURCE: PaDEP (2006).

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FIGURE 5-43 Dry extended detention pond. SOURCE: PaDEP (2006).

detention time, outflows can be reduced to levels that do not accelerate erosion, that protect the stream channel, and that reduce flooding.

The flow normally enters the structure through a sediment forebay (Figure 5-44), which is included to capture incoming sediment, remove the larger particles through settling, and allow for easier maintenance. Then a meandering path or cell structure is built to "extend" and slow down the flows. The main basin is a large storage area (sometimes over the meandering flow paths). Finally, the runoff exits through an outflow control structure built to retard flow.

Wet ponds, stormwater wetlands, and (to a lesser extent) dry extended detention ponds provide treatment. The first step in treatment is the settling of larger particles in the sediment forebay. Next, for wet ponds a permanent pool of water is maintained so that, for smaller storms, the new flows push out a volume that has had a chance to interact with vegetation and be "treated." This volume is equivalent to an inch of rain over the impervious surfaces in the drainage area. Thus, what exits the SCM during smaller storm events is baseflow contributions and runoff that entered during previous events. For dry extended detention ponds, there is no permanent pool and the outlet is instead greatly restricted. For all of these devices, vegetation is considered crucial to pollutant removal. Indeed, wet ponds are designed with an aquatic bench around the edges to promote contact with plants. The vegetation aids in reduction of flow velocities, provides growth surfaces for microbes, takes up pollutants, and provides filtering (Braskerud, 2001).

The ability of detention structures to achieve a certain level of control is size related—that is, the more peak flow reduction or pollutant removal required, the more volume and surface area are needed in the basin. Because it is not simply the peak flows that are important, but also the duration of the flows that cause damage to the stream channels (McCuen, 1979; Loucks et al., 2005),

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FIGURE 5-44 Villanova University sediment forebay. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

some detention basins are currently sized and installed in series with runoff-volume-reduction SCMs.

The strength of extended detention devices is the opportunity to create habitats or picturesque settings during stormwater management. The weaknesses of these measures include large land requirements, chloride buildup, possible temperature effects, and the creation of habitat for undesirable species in urban areas. There is a perception that these devices promote mosquitoes, but that has not been found to be a problem when a healthy biological habitat is created (Greenway et al., 2003). Another drawback of this class of SCMs is that they often have limited treatment capacity, in that they can reduce pollutants in stormwater only to a certain level. These so-called irreducible effluent concentrations have been documented mainly for ponds and stormwater wetlands, as well as sand filters and grass channels (Schueler, 1998). Finally, it should be noted that either a larger watershed (10–25 acres; CWP, 2004) or a continuous water source is needed to sustain wet ponds and stormwater wetlands.

Maintenance requirements for extended detention basins and wetlands include the removal of built-up sediment from the sediment forebay, harvesting of grasses to remove accumulated nutrients, and repair of berms and structures after storm events. Inspection items relate to the maintenance of the berm and sediment forebay.

While the basic hydrologic function of extended detention devices is well known, their performance on a watershed basis is not. Because they do not significantly reduce runoff volume and are designed on a site-by-site basis using synthetic storm patterns, their exclusive use as a flood reduction strategy at the

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watershed scale is uncertain (McCuen, 1979; Traver and Chadderton, 1992). Much of this variability is reduced when they are coupled with volume reduction SCMs at the watershed level. Pollutant removal is effected by climate, short-circuiting, and by the schedule of sediment removal and plant harvesting. Extreme events can resuspend captured sediments, thus reintroducing them into the environment. Although there is debate, it seems likely that plants will need to be harvested to accomplish nutrient removal (Reed et al., 1998).

Runoff Treatment

As mentioned above, many SCMs associated with runoff volume reduction and extended detention provide a water quality benefit. There are also some SCMs that focus primarily on water quality with little peak flow or volume effect. Designed for smaller storms, these are usually based on filtration, hydrodynamic separation, or small-scale bioretention systems that drain to a subsequent receiving water or other device. Thus, often these SCMs are used in conjunction with other devices in a treatment train or as retrofits under parking lots. They can be very effective as pretreatment devices when used "higher up" in the watershed than infiltration structures. Finally, in some cases these SCMs are specifically designed to reduce peak flows in addition to providing water quality benefits by introducing elements that make them similar to detention basins; this is particularly the case for sand filters.

The sand filter is relied on as a treatment technology in many regions, particular those where stream geomorphology is less of a concern and thus peak flow control and runoff volume reduction are not the primary goals. These devices can be effective at removing suspended sediments and can extend the longevity and performance of runoff-volume-reduction SCMs. They are also one of the few urban retrofits available, due to the ability to implement them within traditional culvert systems. Figures 5-45 and 5-46 show designs for the Austin sand filter and the Delaware sand filter.

Filters use sand, peat, or compost to remove particulates, similar to the processes used in drinking water plants. Sand filters primarily remove suspended solids and ammonia nitrogen. Biological material such as peat or compost provides adsorption of contaminants such as dissolved metals, hydrocarbons, and other organic chemicals. Hydrodynamic devices use rotational forces to separate the solids from the flow, allowing the solids to settle out of the flow stream. There is a recent class of bioretention-like manufactured devices that combine inlets with planters. In these systems, small volumes are directed to a soil planter area, with larger flows bypassing and continuing down the storm sewer system. In any event, for manufactured items the user needs to look to the manufacturer's published and reviewed data to understand how the device should be applied.

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FIGURE 5-45 Austin sand filter. SOURCE: Robert Traver, Villanova University.



FIGURE 5-46 Delaware sand filter. SOURCE: Tom Schueler, Chesapeake Stormwater Network.

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The level of control that can be achieved with these SCMs depends entirely on sizing of the device based on the incoming flow and pollutant loads. Each unit has a certified removal rate depending on inflow to the SCM. Also all units have a maximum volume or rate of flow they can treat, such that higher flows are bypassed with no treatment. Thus, the user has to determine what size unit is needed and the number to use based on the area's hydrologic cycle and what criteria are to be met.

With the exception of some types of sand filters, the strengths of water quality SCMs are that they can be placed within existing infrastructure or under parking lots, and thus do not take up land that may be used for other purposes. They make excellent choices for retrofit situations. For filters, there is a wealth of experience from the water treatment community on their operations. For all manufactured devices there are several testing protocols that have been set up to validate the performance of the manufactured devices (the sufficiency of which is discussed in Box 5-9). Weaknesses of these devices include their cost and maintenance requirements. Regular maintenance and inspection at a high level are required to remove captured pollutants, to replace mulch, or to rake and remove the surface layer to prevent clogging. In some cases specialized equipment (vacuum trucks) is required to remove built-up sediment. Although the underground placement of these devices has many benefits, it makes it easy to neglect their maintenance because there are no signs of reduced performance on the surface. Because these devices are manufactured, the unit construction cost is usually higher than for other SCMs. Finally, the numerous testing protocols are confusing and prevent more widespread applications.

The chief uncertainty with these SCMs is due to the lack of certification of some manufactured devices. There is also concern about which pollutants are removed by which class of device. For example, hydrodynamic devices and sand filters do not address dissolved nutrients, and in some cases convert suspended pollutants to their dissolved form. Both issues are related to the false perception that a single SCM must be found that will comprehensively treat stormwater. Such pressures often put vendors in a position of trying to certify that their devices can remove all pollutants. Most often, these devices can serve effectively as part of a treatment train, and should be valued for their incremental contributions to water quality treatment. For example, a filter that removes sediment upstream of a bioinfiltration SCM can greatly prolong the life of the infiltration device.

Aquatic Buffers and Managed Floodplains

Aquatic buffers, sometimes also known as stream buffers or riparian buffers, involve reserving a vegetated zone adjacent to streams, shorelines, or wetlands as part of development regulations or as an ordinance. In most regions of the country, the buffer is managed as forest, although in arid or semi-arid

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BOX 5-9
Insufficient Testing of Proprietary Stormwater Control Measures

Manufacturers of proprietary SCMs offer a service that can save municipalities time and money. Time is saved by the ability of the manufactures to quickly select a model matching the needs of the site. A city can minimize the cost of buying the product by requiring the different manufacturers to submit bids for the site. All the benefits of the service will have no meaning, however, if the cities cannot trust the performance claims of the different products. Because the United States does not have, at this time, a national program to verify the performance of proprietary SCMs, interested municipalities face a high amount of uncertainty when they select a product. Money could be wasted on products that might have the lowest bid, but do not achieve the water quality goals of the city or state.

The EPA's Environmental Technology Verification (ETV) program was created to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The Wet Weather Flow Technologies Pilot was established as part of the ETV program to verify commercially available technologies used in the abatement and control of urban stormwater runoff, combined sewer overflows, and sanitary sewer overflows. Ten proprietary SCMs were tested under the ETV program (see Figure 5-47), and the results of the monitoring are available on the National Sanitation Foundation International website. Unfortunately, the funding for the ETV program was discontinued before all the stormwater products could be tested. Without a national testing program some states have taken a more regional approach to verifying the performance of proprietary practices, while most states do not have any type of verification or approval program.

The Washington Department of Ecology has supported a testing protocol called Technology Assessment Protocol–Ecology that describes a process for evaluating and reporting on the performance and appropriate uses of emerging SCMs. California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia have sponsored a testing program called Technology Acceptance and Reciprocity Partnership (TARP), and a number of products are being tested in the field. The State of Wisconsin has prepared a draft technical standard (1006) describing methods for predicting the site-specific reduction efficiency of proprietary sedimentation devices. To meet the criteria in the standard the manufacturers can either use a model to predict the performance of the practice or complete a laboratory protocol designed to develop efficiency curves for each product. Although none of these state or federal verification efforts have produced enough information to sufficiently reduce the uncertainty in selection and sizing of proprietary SCMs, many proprietary practices are being installed around the country, because of the perceived advantage of the service being provided by the manufacturers and the sometimes overly optimistic performance claims.

All those involved in stormwater management, including the manufacturers, will have a much better chance of implementing a cost-effective stormwater program in their cities if the barriers to a national testing program for proprietary SCMs are eliminated. Two of the barriers to the ETV program were high cost and the transferability of the results. Also, the ETV testing did not produce results that could be used in developing efficiency curves for the product. A new national testing program could reduce the cost by using laboratory testing instead of field testing. Each manufacturer would only have to do one series of tests in the lab and the results would be applicable to the entire country. The laboratory

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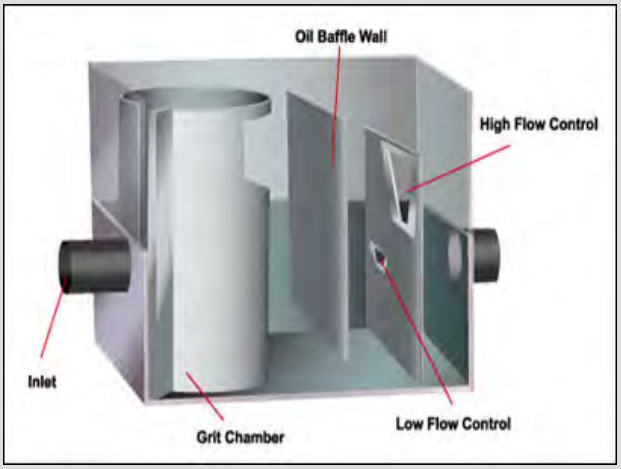
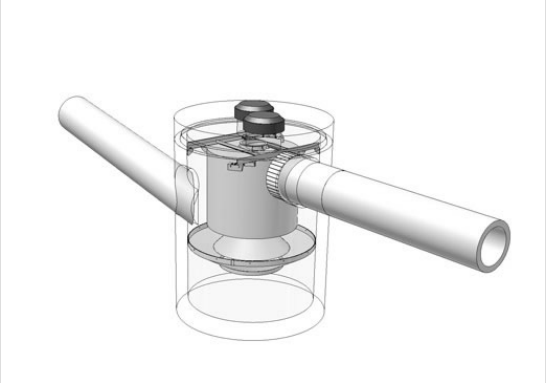
BOX 5-9 Continued

protocol in the Wisconsin Technical Standard 1006 provides a good example of what should be included to evaluate each practice over a range of particle sizes and flows. These types of laboratory data could also be used to produce efficiency curves for each practice. It would be relatively easy for state and local agencies to review the benefits of each installation if the efficiency curves were incorporated into urban runoff models, such as WinSLAMM or P8.



Stormwater 360 Hydrodynamic Separator. SOURCE: EPA (2005c).



Downstream Defender. SOURCE: Available online at http://epa.gov/Region1/assistance/ ceitts/stormwater/techs/downstreamdefender.html

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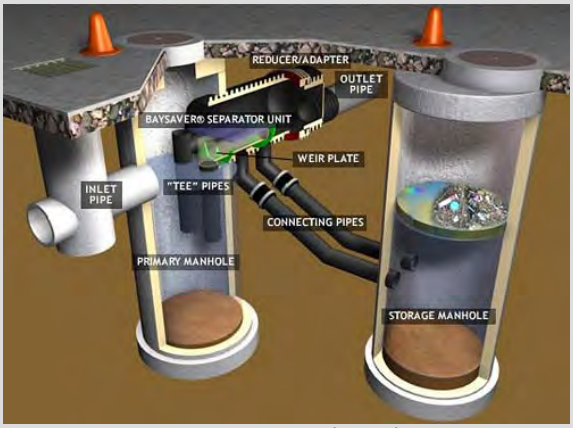
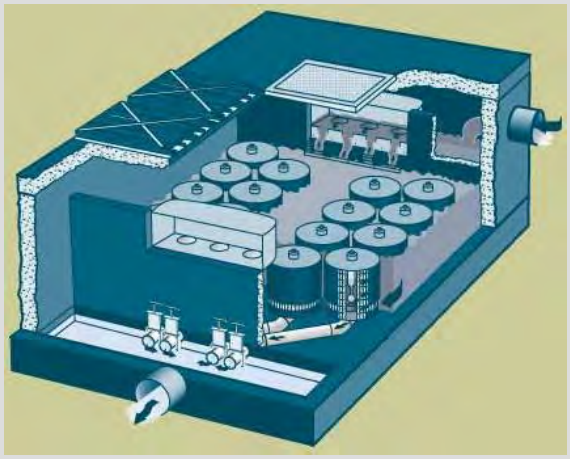


Bay Seperator. SOURCE: EPA (2005a).



Stormfilter. SOURCE: EPA (2005b).

FIGURE 5-47 Proprietary Manufactured Devices tested by the ETV Program.

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regions it may be managed as prairie, chapparal, or other cover. When properly designed, buffers can both reduce runoff volumes and provide water quality treatment to stormwater.

The performance of urban stream buffers cannot be predicted from studies of buffers installed to remove sediment and nutrients from agricultural areas (Lowrance and Sheridan, 2005). Agricultural buffers have been reported to have high sediment and nutrient removal because they intercept sheet flow or shallow groundwater flow in the riparian zone. By contrast, urban stream buffers often receive concentrated surface runoff or may even have a storm-drain pipe that short-circuits the buffer and directly discharges into the stream. Consequently, the pollutant removal capability of urban stream buffers is limited, unless they are specifically designed to distribute and treat stormwater runoff (NRC, 2000). This involves the use of level spreaders, grass filters, and berms to transform concentrated flows into sheet flow (Hathaway and Hunt, 2006). Such designed urban stream buffers have been applied widely in the Neuse River basin to reduce urban stormwater nutrient inputs to this nitrogen-sensitive waterbody.

The primary benefit of buffers is to help maintain aquatic biodiversity within the stream. Numerous researchers have evaluated the relative impact of riparian forest cover and impervious cover on stream geomorphology, aquatic insects, fish assemblages, and various indexes of biotic integrity. As a group, the studies suggest that indicator values for urban stream health increase when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Goetz et al., 2003; Wang et al., 2003b; McBride and Booth, 2005; Moore and Palmer, 2005). The width of the buffer is also important for enhancing its stream protection benefits, and it ranges from 25 to 200 feet depending on stream order, protection objectives, and community ordinances. At the present time, there are no data to support an optimum width for water quality purposes. The beneficial impact of riparian forest cover is less detectable when watershed impervious cover exceeds 15 percent, at which point degradation by stormwater runoff overwhelms the benefits of the riparian forest (Roy et al., 2005, 2006; Walsh et al., 2007).

Maintenance, inspection, and compliance for buffers can be a problem. In most communities, urban stream buffers are simply a line on a map and are not managed in any significant way after construction is over. As such, urban stream buffers are prone to residential encroachment and clearing, and to colonization by invasive plants. Another important practice is to protect, preserve, or otherwise manage the ultimate 100-year floodplain so that vulnerable property and infrastructure are not damaged during extreme floods. Federal Emergency Management Agency (FEMA), state, and local requirements often restrict or control development on land within the floodway or floodplain. In larger streams, the floodway and aquatic buffer can be integrated together to achieve multiple social objectives.

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Stream Rehabilitation

While not traditionally considered an SCM, certain stream rehabilitation practices or approaches can be effective at recreating stream physical habitat and ecosystem function lost during urbanization. When combined with effective SCMs in upland areas, stream rehabilitation practices can be an important component of a larger strategy to address stormwater. From the standpoint of mitigating stormwater impacts, four types of urban stream rehabilitation are common:

- Practices that stabilize streambanks and/or prevent channel incision/enlargement can reduce downstream delivery of sediments and attached nutrients (see Figure 5-48). Although the magnitude of sediment delivery from urban-induced stream-channel enlargement is well documented, there are very few published data to quantify the potential reduction in sediment or nutrients from subsequent channel stabilization.

- Streams can be hydrologically reconnected to their floodplains by building up the profile of incised urban streams using grade controls so that the channel and floodplain interact to a greater degree. Urban stream reaches that have been so rehabilitated have increased nutrient uptake and processing rates, and in particular increased denitrification rates, compared to degraded urban streams prior to treatment (Bukavecas, 2007; Kaushal et al., 2008). This suggests that urban stream rehabilitation may be one of many elements that can be considered to help decrease loads in nutrient-sensitive watersheds.

- Practices that enhance in-stream habitat for aquatic life can improve the expected level of stream biodiversity. However, Konrad (2003) notes that improvement of biological diversity of urban streams should still be considered an experiment, since it is not always clear what hydrologic, water quality, or habitat stressors are limiting. Larson et al. (2001) found that physical habitat improvements can result in no biological improvement at all. In addition, many of the biological processes in urban stream ecosystems remain poorly understood, such as carbon processing and nutrient uptake.

- Some stream rehabilitation practices can indirectly increase stream biodiversity (such as riparian reforestation, which could reduce stream temperatures, and the removal of barriers to fish migration).

It should be noted that the majority of urban stream rehabilitation projects undertaken in the United States are designed for purposes other than mitigating the impacts of stormwater or enhancing stream biodiversity or ecosystem function (Bernhardt et al., 2005). Most stream rehabilitation projects have a much narrower design focus, and are intended to protect threatened infrastructure,

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FIGURE 5-48 Three photographs illustrate stream rehabilitation in Denver. The top picture is a creek that has eroded in its bed due to urbanization. The middle picture shows a portion of the stabilized creek immediately after construction. Check structures, which keep the creek from cutting its bed, are visible in the middle distance. The bottom image shows the creek just upstream of one of the check structures two years after stabilization. The thickets of willows established themselves naturally. The only revegetation performed was to seed the area for erosion control. SOURCE: Courtesy of Wenk Associates.

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naturalize the stream corridor, achieve a stable channel, or maintain local bank stability (Schueler and Brown, 2004). Improvements in either biological health or the quality of stormwater runoff have rarely been documented.

Unique design models and methods are required for urban streams, compared to their natural or rural counterparts, given the profound changes in hydrologic and sediment regime and stream–floodplain interaction that they experience (Konrad, 2003). While a great deal of design guidance on urban stream rehabilitation has been released in recent years (FISRWG, 2000; Doll and Jennings, 2003; Schueler and Brown, 2004), most of the available guidance has not yet been tailored to produce specific outcomes for stormwater mitigation, such as reduced sediment delivery, increased nutrient processing, or enhanced stream biodiversity. Indeed, several researchers have noted that many urban stream rehabilitation projects fail to achieve even their narrow design objectives, for a wide range of reasons (Bernhardt and Palmer, 2007; Sudduth et al., 2007). This is not surprising given that urban stream rehabilitation is relatively new and rarely addresses the full range of in-stream alteration generated by watershed-scale changes. This shortfall suggests that much more research and testing are needed to ensure urban stream habilitation can meet its promise as an emerging SCM.

Municipal Housekeeping (Street Sweeping and Storm-Drain Cleanouts)

Phase II NPDES stormwater permits specifically require municipal good housekeeping as one of the six minimum management measures for MS4s. Although EPA has not presented definitive guidance on what constitutes “good housekeeping”, CWP (2008) outlines ten municipal operations where housekeeping actions can improve the quality of stormwater, including the following:

- municipal hotspot facility management,
- municipal construction project management,
- road maintenance,
- street sweeping,
- storm-drain maintenance,
- stormwater hotline response,
- landscape and park maintenance ,
- SCM maintenance, and
- employee training.

The overarching theme is that good housekeeping practices at municipal operations provide source treatment of pollutants before they enter the storm-drain system. The most frequently applied practices are street sweeping (Figure 5-49) and sediment cleanouts of sumps and storm-drain inlets. Most communities

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FIGURE 5-49 Vacuum street sweeper at Villanova University. SOURCE: Robert Traver, Villanova University.

conduct both operations at some frequency for safety and aesthetic reasons, although not specifically for the sake of improving stormwater quality (Law et al., 2008).

Numerous performance monitoring studies have been conducted to evaluate the effect of street sweeping on the concentration of stormwater pollutants in downstream storm-drain pipes (see Pitt, 1979; Bender and Terstriep, 1994; Brinkman and Tobin, 2001; Zarrielo et al., 2002; Chang et al., 2005; USGS, 2005; Law et al., 2008). The basic finding is that regular street sweeping has a low or limited impact on stormwater quality, depending on street conditions, sweeping frequency, sweeper technology, operator training, and on-street parking. Sweeping will always have a limited removal capability because rainfall events frequently wash off pollutants before the sweeper passes through, and only some surfaces are accessible to the sweeper, thus excluding sidewalk, driveways, and landscaped areas. Frequent sweeping (i.e., weekly or monthly) has a moderate capability to remove sediment, trash and debris, coarse solids, and organic matter.

Fewer studies have been conducted on the pollutant removal capability of frequent sediment cleanout of storm-drain inlets, most in regions with arid climates (Lager et al., 1977; Mineart and Singh, 1994; Morgan et al., 2005). These studies have shown some moderate pollutant removal if cleanouts are done on a monthly or quarterly basis. Most communities, however, report that they clean out storm drains on an annual basis or in response to problems or drainage complaints (Law, 2006).

Frequent sweeping and cleanouts conducted on the dirtiest streets and storm

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drains appear to be the most effective way to include these operations in the stormwater treatment train. However, given the uncertainty associated with the expected pollutant removal for these practices, street sweeping and storm-drain cleanout cannot be relied on as the sole SCMs for an urban area.

Illicit Discharge Detection and Elimination

MS4 communities must develop a program to detect and eliminate illicit discharges to their storm-drain system as a stormwater NPDES permit condition. Illicit discharges can involve illegal cross-connections of sewage or washwater into the storm-drain system or various intermittent or transitory discharges due to spills, leaks, dumping, or other activities that introduce pollutants into the storm-drain system during dry weather. National guidance on the methods to find and fix illicit discharges was developed by Brown et al. (2004). Local illicit discharge detection and elimination (IDDE) programs represent an ongoing and perpetual effort to monitor the network of pipes and ditches to prevent pollution discharges.

The water quality significance of illicit discharges has been difficult to define since they occur episodically in different parts of a municipal storm drain system. Field experience in conducting outfall surveys does indicate that illicit discharges may be present at 2 to 5 percent of all outfalls at any given time. Given that pollutants are being introduced into the receiving water during dry weather, illicit discharges may have an amplified effect on water quality and biological diversity.

Many communities indicate that they employ a citizen hotline to report illicit discharges and other water quality problems (Brown et al., 2004), which sharply increases the number of illicit discharge problems observed.

Stormwater Education

Like IDDE, stormwater education is one of the six minimum management measures that MS4 communities must address in their stormwater NPDES permits. Stormwater education involves municipal efforts to make sure individuals understand how their daily actions can positively or negatively influence water quality and work to change specific behaviors linked to specific pollutants of concern (Schueler, 2001c). Targeted behaviors include lawn fertilization, littering, car fluid recycling, car washing, pesticide use, septic system maintenance, and pet waste pickup. Communities may utilize a wide variety of messages to make the public aware of the behavior and more desirable alternatives through radio, television, newspaper ads, flyers, workshops, or door-to-door outreach. Several communities have performed before-and-after surveys to assess both the penetration rate for these campaigns and their ability to induce changes in actual behaviors. Significant changes in behaviors have been recorded (see Schueler,

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2002), although few studies are available to link specific stormwater quality improvements to the educational campaigns (but see Turner, 2005; CASQA, 2007).

Residential Stewardship

This SCM involves municipal programs to enhance residential stewardship to improve stormwater quality. Residents can undertake a wide range of activities and practices that can reduce the volume or quality of runoff produced on their property or in their neighborhood as a whole. This may include installing rain barrels or rain gardens, planting trees, xeriscaping, downspout disconnection, storm-drain marking, household hazardous waste pickups, and yard waste composting (CWP, 2005). This expands on stormwater education in that a municipality provides a convenient delivery service to enable residents to engage in positive watershed behavior. The effectiveness of residential stewardship is enhanced when carrots are provided to encourage the desired behavior, such as subsidies, recognition, discounts, and technical assistance (CWP, 2005). Consequently, communities need to develop a targeted program to educate residents and help them engage in the desired behavior.

SCM Performance Monitoring and Modeling

Stormwater is characterized by widely fluctuating flows. In addition, inflow pollutant concentrations vary over the course of a storm and can be a function of time since the last storm, watershed, size and intensity of rainfall, season, amount of imperviousness, pollutant of interest, and so forth. This variability of the inflow to SCMs along with the very nature of SCMs makes performance monitoring a complex task. Most SCMs are built to manage stormwater, not to enable flow and water quality monitoring. Furthermore, they are incorporated into the collection system and spread throughout developments. Measurement of multiple inflows, outflows, evapotranspiration, and infiltration are simply not feasible for most sites. Many factors, such as temperature and climate, play a role in how well SCMs function. Infiltration rates can vary by an order of magnitude as a function of temperature (Braga et al., 2007; Emerson and Traver, 2008), such that a reading in late summer might be twice that of a winter reading. Determining performance can be further complicated because, e.g., at the start of a storm a detention basin could still be partially full from a previous storm, and removal rates for wetlands are a function of the growing season, not to mention snowmelt events.

Monitoring of SCMs is usually performed for one of two purposes: functionality or more intensive performance monitoring. Monitoring of functionality is primarily to establish that the SCM is functioning as designed. Performance monitoring is focused on determining what level of performance is achieved by

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the SCM.

Functionality Monitoring

Functionality monitoring, in a broad sense, involves checking to see whether the SCM is functioning and screening it for potential problems. Both the federal and several state industrial and construction stormwater general permits have standard requirements for visual inspections following a major storm event. Visual observations of an SCM by themselves do not provide information on runoff reduction or pollutant removal, but rather only that the device is functioning as designed. Adding some grab samples for laboratory analysis can act as a screening tool to determine if a more complex analysis is required.

The first step of functionality monitoring for any SCM is to examine the physical condition of the device (piping, pervious surfaces, outlet structure, etc.). Visual inspection of sediments, eroded berms, clogged outlets, and other problems are good indications of the SCM's functionality (see Figure 5-50). For infiltration devices, visiting after a storm event will show whether or not the device is functioning. A simple staff gauge (Figure 5-51) or a stilling well in pervious pavement can be used to measure the amount of water-level change over several days to estimate infiltration rates. Minnesota suggests the use of fire equipment or hydrants to fill infiltration sites with a set volume of water to measure the rate of infiltration. For sites that are designed to capture a set volume, for example a green roof, a visit could be coordinated with a rainfall event of the appropriate size to determine whether there is overflow during the event. If so, then clearly further investigation is required.



FIGURE 5-50 Rusted outlet structure. SOURCE: Reprinted, with permission, from Emerson. Copyright by Clay Emerson.

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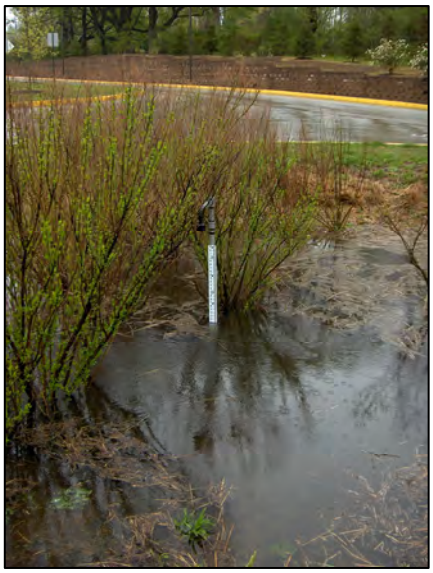

FIGURE 5-51 Staff gauge attached to ultrasonic sensor after a storm. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

For extended detention and stormwater wetlands, the depth of water during an event is an indicator of how well the SCM is functioning. Usually high-water marks are easy to determine due to debris or mud marks on the banks or the structures. If the size of the storm event is known, the depths can be compared to what was expected for the structure. Other indicators of problems would include erosion downstream of the SCM, algal blooms, invasive species, poor water clarity, and odor.

For water quality and manufactured devices, visual inspections after a storm event can determine whether the SCM is functioning properly. Standing water over a sand or other media filter 48 hours after a storm is a sign of problems. Odor and lack of flow clarity could be a sign of filter breakthrough or other problems. For manufactured devices, literature about the device should specify inspection and maintenance procedures.

Monitoring of nonstructural SCMs is almost exclusively limited to visual observation due to the difficulty in applying numerical value to their benefits. Visual inspection can identify eroded stream buffers, additional paved areas, or denuded conservation areas (see Figure 5-52).

Performance Monitoring

Performance monitoring is an extremely intensive effort to determine the performance of an SCM over either an individual storm event or over a series of

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FIGURE 5-52 Wooded conservation area stripped of trees. Note pile of sawdust. SOURCE: Robert Traver, Villanova University.

storms. It requires integration of flow and water quality data creating both a hydrograph and a polutograph for a storm event as shown in Figure 5-53. The creation of these graphs requires continuous monitoring of the hydrology of the site and multiple water quality samples of the SCM inflow and outflow, the vadose zone, and groundwater. Event mean concentrations can then be determined from these data. There should be clear criteria for the number and type of storms to be sampled and for the conditions preceding a storm. For example, for most SCMs it would be improper to sample a second storm event in series, as the inflow may be free of pollutants and the soil moisture filled, resulting in a poor or negative performance. (Extended detention basins are an exception because the outflow during a storm event may include inflows from previous events.) The size of the sampled storm is also important. If the water quality goal is focused on smaller events, the 100-year storm would not give a proper picture of the performance because the occurrence is so rare that it is not a water quality priority.

For runoff-volume-reduction SCMs, performance monitoring can be extremely difficult because these systems are spread over the project site. The monitoring program must consider multiple-size storms because these SCMs are designed to remove perhaps the first inch of runoff. Therefore, for storms of less than an inch, there is no surface water release, so the treatment is 100

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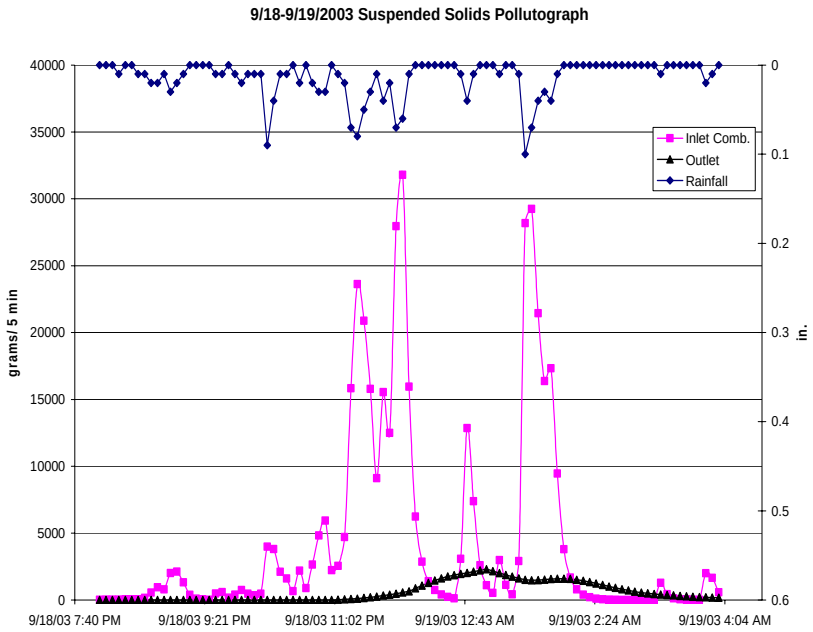

FIGURE 5-53 Example polutograph that displays inflow and outflow TSS during a storm event from the Villanova wetland stormwater SCM. SOURCE: Reprinted, with permission, Rea and Traver (2005). Copyright 2005 by the American Society of Civil Engineers.

percent effective for surface discharges. During larger events, a bioretention SCM or green roof may export pollutants. When viewed over the entire spectrum of storms, these devices are an outstanding success; however, this may not be evident during a hurricane.

Through the use of manufactured weirs (Figure 5-54), it is possible to develop flow-depth criteria based on hydraulic principles for surface flows entering or leaving the SCM. Where this is not practical, various manufacturers have Doppler velocity sensors that, combined with geometry and depth, provide a reasonable continuous record of flow. Measurement of depth within a device can be accomplished through use of pressure transducers, bubblers, float gauges, and ultrasonic sensors. Other common measures would include rainfall and temperature. One advantage of these data recording systems is that they can be connected to water quality probes and automated samplers to provide a flow-weighted sample of the event for subsequent laboratory analysis. Field calibration and monitoring of these systems is required.

Groundwater sampling for infiltration SCMs is a challenge. Although the rate of change in water depth can indicate volume moving into the soil mantle, it is difficult to establish whether this flow is evapotranspirated or ends up as baseflow or deep groundwater input. Sampling in the vadose zone can be established

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FIGURE 5-54 Weir flow used to measure flow rate. SOURCE: Robert Traver, Villanova University.

through the use of lysimeters that, through a vacuum, draw out water from the soil matrix. Soil moisture probes can give a rough estimation of the soil moisture content, and weighing lysimeters can establish evapotranspiration rates. Finally groundwater wells can be used to establish the effect of the SCM on the groundwater depth and quality during and after storm events.

Performance monitoring of extended detention SCMs is difficult because the inflows and outflows are variable and may extend over multiple days. Hydrologic monitoring can be accomplished using weirs (Figure 5-54), flow meters, and level detectors. The new generation of temperature, dissolved oxygen, and conductivity probes allows for automated monitoring. (It should be noted that in many cases the conductivity probes are observing chlorides, which are not generally removed by SCMs.) In many cases monitoring of the downstream stream-channel geomorphology and stream habitat may be more useful than performance monitoring when assessing the effect of the SCM.

The performance monitoring of treatment devices is straightforward and involves determining the pollutant mass inflows and outflows. Performance monitoring of manufactured SCMs has been established through several protocols. An example is TARP, used by multiple states (*http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/).* This requires the manufacturer to test their units according to a set protocol of lab or field experiments to set performance criteria. Several TARP member and other states have published revised

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protocols for their use. These and other similar criteria are evolving and the subject of considerable effort by industry organizations that include the American Society of Civil Engineers.

Finally, much needs to be done to determine the performance of nonstructural SCMs, for which little to no monitoring data are available (see Table 5-2). Currently most practitioners expand upon current hydrologic modeling techniques to simulate these techniques. For example, disconnection of impervious surfaces is often modeled by adding the runoff from the roof or parking area as distributed "rainfall" on the pervious area. Experiments and long-term monitoring are needed for these SCMs.

More information on SCM monitoring is available through the International Stormwater BMP Database (*http://www.bmpdatabase.org*).

Modeling of SCM performance

Modeling of SCMs is required to understand their individual performance and their effect on the overall watershed. The dispersed nature of their implementation, the wide variety of possible SCM types and goals, and the wide range of rainfall events they are designed for makes modeling of SCMs extremely challenging. For example, to model multiple SCMs on a single site may require simulation of many hydrologic and environmental processes for each SCM in series. Modeling these effects over large watersheds by simulating each SCM is not only impractical, but the noise in the modeling may make the simulation results suspect. Thus, it is critical to understand the model's purpose, limitations, and applicability.

As discussed in Chapter 4, one approach to simulating SCM performance is through mathematical representation of the unit processes. The large volumes of data needed for process-based models generally restrict their use to smaller-scale modeling. For flow this would start with the hydrograph entering the SCM and include infiltration, evapotranspiration, routing through the system, or whatever flow paths were applicable. The environmental processes that would need to be represented could include settling, adsorption, biological transformation, and soil physics. Currently there are no environmental process models that work across the range of SCMs. Rather, the state of art is to use general removal efficiencies from publications such as the International Stormwater BMP Database (http://www.bmpdatabase.org) and the Center for Watershed Protection's National Pollutant Removal Database (CWP, 2000b, 2007b). Unfortunately, this approach has many limitations. The percent removal used on a site and storm basis does not include storm intensity, period between the storms, land use, temperature, management practices, whether other SCMs are upstream, and so forth. It also should be noted that percent removals are a surface water statistic and do not address groundwater issues or include any biogeochemistry.

Mechanistic simulation of the hydrologic processes within an SCM is much advanced compared to environmental simulation, but from a modeling scale it is

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still evolving. Indeed, models such as the Prince George's County Decision Support System are greatly improved in that the hydrologic simulation of the SCM includes infiltration, but they still do not incorporate the more rigorous soil physics and groundwater interactions. Some models, such as the Stormwater Management Model (SWMM), have the capability to incorporate mechanistic descriptions of the hydrologic processes occurring inside an SCM.

At larger scales, simulation of SCMs is done primarily using lumped models that do not explicitly represent the unit processes but rather the overall effects. For example, the goal may be to model the removal of 2 cm of rainfall from every storm from bioinfiltration SCMs. Thus, all that would be needed is how many SCMs are present and their configuration and what their capabilities are within your watershed. What is critical for these models is to represent the interrelated processes correctly and to include seasonal effects. Again, the pollutant removal capability of the SCM is represented with removal efficiencies derived from publications.

Regardless of the scale of the model, or the extent to which it is mechanistic or not, nonstructural SCMs are a challenge. Limiting impervious surface or maintenance of forest cover have been modeled because they can be represented as the maintenance of certain land uses. However, aquatic buffers, disconnected impervious surfaces, stormwater education, municipal housekeeping, and most other nonstructural SCMs are problematic. Another challenge from a watershed perspective is determining what volume of pollutants comes from streambank erosion during elevated flows versus from nonpoint source pollution. Most hydrologic models do not include or represent in-stream processes.

In order to move forward with modeling of SCMs, it will be necessary to better understand the unit processes of the different SCMs, and how they differ for hydrology versus transformations. Research is needed to gather performance numbers for the nonstructural SCMs. Until such information is available, it will be virtually impossible to predict that an individual SCM can accomplish a certain level of treatment and thus prevent a nearby receiving water from violating its water quality standard.

DESIGNING SYSTEMS OF STORMWATER CONTROL MEASURES ON A WATERSHED SCALE

Most communities have traditionally relied on stormwater management approaches that result in the design and installation of SCMs on a site-by-site basis. This has created a large number of individual stormwater systems and SCMs that are widely distributed and have become a substantial part of the contemporary urban and suburban landscape. Typically, traditional stormwater infrastructure was designed on a subdivision basis to reduce peak storm flow rates to predevelopment levels for large flood events (> 10-year return period). The problem with the traditional approach is that (1) the majority of storms throughout the year are small and therefore pass through the detention facilities

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uncontrolled, (2) the criterion of reducing storm flow does not address the need for reducing total storm volume, and (3) the facilities are not designed to work as a system on a watershed scale. In many cases, the site-by-site approach has exacerbated downstream flooding and channel erosion problems as a watershed is gradually built out. For example, McCuen (1979) and Emerson et al. (2005) showed that an unplanned system of site-based SCMs can actually increase flooding on a watershed scale owing to the effect of many facilities discharging into a receiving waterbody in an uncoordinated fashion—causing the very flooding problem the individual basins were built to solve.

With the relatively recent recognition of unacceptable downstream impacts and the regulation of urban stormwater quality has come a rethinking of the design of traditional stormwater systems. It is becoming rapidly understood that stormwater management should occur on a watershed scale to prevent flow control problems from occurring or reducing the chances that they might become worse. In this context, the "watershed scale" refers to the small local watershed to which the individual site drains (i.e., a few square miles within a single municipality). Together, the developer, designer, plan reviewer, owners, and the municipality jointly install and operate a linked and shared system of distributed practices across multiple sites that achieve small watershed objectives. Many metropolitan areas around the country have institutions, such as the Southeast Wisconsin Regional Planning Commission and the Milwaukee Metropolitan Sewage District, that are doing stormwater master planning to reduce flooding, bank erosion, and water quality problems on a watershed scale.

Designing stormwater management on a watershed scale creates the opportunity to evaluate a system of SCMs and maximize overall effectiveness based on multiple criteria, such as the incremental costs to development beyond traditional stormwater infrastructure, the limitations imposed on land area required for site planning, the effectiveness at improving water quality or attenuating discharges, and aesthetics. Because the benefits that accrue with improved water quality are generally not realized by those entities required to implement SCMs, greater value must be created beyond the functional aspects of the facility if there is to be wide acceptance of SCMs as part of the urban landscape. Stormwater systems designed on a watershed basis are more likely to be seen as a multi-functional resource that can contribute to the overall quality of the urban environment. Potential even exists to make the stormwater system a primary component of the civic framework of the community—elements of the public realm that serve to enhance a community's quality of life like public spaces and parks. For example, in central Minneapolis, redevelopment of a 100-acre area called Heritage Park as a mixed-density residential neighborhood was organized around two parks linked by a parkway that served dual functions of recreation and stormwater management.

Key elements of the watershed approach to designing systems of SCMs are discussed in detail below. They include the following:

1. Forecasting the current and future development types.

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2. Forecasting the scale of current and future development.
3. Choosing among on-site, distributed SCMs and larger, consolidated SCMs.
4. Defining stressors of concern.
5. Determining goals for the receiving water.
6. Noting the physical constraints.
7. Developing SCM guidance and performance criteria for the local watershed.
8. Establishing a trading system.
9. Ensuring the safe performance of the drainage network, streams, and floodplains.
10. Establishing community objectives for the publically owned elements of stormwater infrastructure.
11. Establishing a maintenance plan.

Forecasting the Current and Future Development Types

Forecasting the type of current and future development within the local watershed will guide or shape how individual practices and SCMs are generally assembled at each individual site. The development types that are generally thought of include Greenfield development (small and large scales), redevelopment within established communities and on Brownfield sites, and retrofitting of existing urban areas. These development types range roughly from lower density to higher density impervious cover. Box 5-10 explains how the type of development can dictate stormwater management, discussing two main categories—*Greenfield* development and *redevelopment* of existing areas. The former refers to development that changes pristine or agricultural land to urban or suburban land uses, frequently low-density residential housing. Redevelopment refers to changing from an existing urban land use to another, usually of higher density, such as from single-family housing to multi-family housing. Finally, *retrofitting* as used in this report is not a development type but rather the upgrading of stormwater management within an existing land use to meet higher standards.

Table 5-7 shows which SCMs are best suited for Greenfield development (particularly low-density residential), redevelopment of urban areas, and intense industrial redevelopment. The last category is broken out because the suite of SCMs needed is substantially different than for urban redevelopment. Each type of development has a different footprint, impervious cover, open space, land cost, and existing stormwater infrastructure. Consequently, SCMs that are ideally suited for one type of development may be impractical or infeasible for another. One of the main points to be made is that there are more options during Greenfield development than during redevelopment because of existing infrastructure, limited land area, and higher costs in the latter case.

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BOX 5-10
Development Types and their Relationship to the Stormwater System

Development falls into two basic types. Greenfield development requires new infrastructure designed according to contemporary design standards for roads, utilities, and related infrastructure. Redevelopment refers to developed areas undergoing land-use change. In contrast to Greenfields, infrastructure in previously developed areas is often in poor condition, was not built to current design standards, and is inadequate for the new land uses proposed. The stormwater management scenarios common to these types of development are described below.

Greenfield Development

At the largest scale, Greenfield development refers to planned communities at the developing edge of metropolitan areas. Communities of this type often vary from several hundred acres to very large projects that encompassed tens of thousands of acres requiring buildout over decades. They often include the trunk or primary stormwater system as well as open stream and river corridors. The most progressive communities of this type incorporate a significant portion of the area to stormwater systems that exist as surface elements. Such stormwater system elements are typically at the subwatershed scale and provide for consolidated conveyance, detention, and water quality treatment. These elements of the infrastructure can be multi-functional in nature, providing for wildlife habitat, trail corridors, and open-space amenities.

Greenfield development can also occur on a small scale—neighborhoods or individual sites within newly developing areas that are served by the secondary public and tertiary stormwater systems. This smaller-scale, incremental expansion of existing urban patterns is a more typical way for cities to grow. A more limited range of SCMs are available on smaller projects of this type, including LID practices.

Redevelopment of Existing Areas

Redevelopment within established communities is typically at the scale of individual sites and occasionally the scale of a small district. The area is usually served by private, on-site systems that convey larger storm events into preexisting stormwater systems that were developed decades ago, either in historic city centers or in “first ring,” post-World War II suburbs adjacent to historic city centers. Redevelopment in these areas is typically much denser than the original use. The resulting increase in impervious area, and typically the inadequacy of existing stormwater infrastructure serving the site often results in significant development costs for on-site detention and water quality treatment. Elaborate vaults or related structures, or land area that could be utilized for development, must often be committed to on-site stormwater management to comply with current stormwater regulations.

Brownfields are redevelopments of industrial and often contaminated property at the scale of an individual site, neighborhood, or district. Secondary public systems and private stormwater systems on individual sites typically serve these areas. In many cases, especially in outdated industrial areas, little or no stormwater infrastructure exists, or it is so inadequate as to require replacement. Water quality treatment on contaminated sites may also be necessary. For these reasons, stormwater management in such developments presents special challenges. As an example, the most common methods of remediation of contaminated sites involve capping of contaminated soils or treatment of contaminants in situ, especially where removal of contaminated soils from a site is cost prohibitive. Given that contaminants are still often in place on redeveloped Brownfield sites and must not be disturbed, certain SCMs such as infiltration of stormwater into site soils, or excavation for stormwater piping and other utilities, present special challenges.

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TABLE 5-7 Applicability of Stormwater Control Measures by Type of Development

Stormwater Control Measure	Low-Density Greenfield Residential	Urban Redevelopment	Intense Industrial Redevelopment
Product Substitution	○	●	●
Watershed and Land-Use Planning	■	■	○
Conservation of Natural Areas	■	♦	○
Impervious Cover Minimization	■	♦	♦
Earthwork Minimization	■	♦	♦
Erosion and Sediment Control	■	■	■
Reforestation and Soil Conservation	■	●	●
Pollution Prevention SCMs	♦	●	■
Runoff Volume Reduction—Rainwater Harvesting	■	■	●
Runoff Reduction—Vegetated	■	○	●
Runoff Reduction—Subsurface	■	○	♦
Peak Reduction and Runoff Treatment	■	♦	○
Runoff Treatment	●	●	■
Aquatic Buffers and Managed Floodplains	●	♦	○
Stream Rehabilitation	○	♦	♦
Municipal Housekeeping	○	○	NA
IDDE	○	○	○
Stormwater Education	●	●	●
Residential Stewardship	■	●	NA

NOTE: ■, always; ●, often; ○, sometimes; ♦, rarely; NA, not applicable.

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Forecasting the Scale of Current and Future Development

The choice of what SCMs to use depends on the area that needs to be serviced. It turns out that some SCMs work best over a few acres, whereas others require several dozen acres or more; some are highly effective only for the smallest sites, while others work best at the stream corridor or subwatershed level. Table 5-1 includes a column that is related the scale at which individual SCMs can be applied ("where" column). The SCMs mainly applied at the site scale include runoff volume reduction—rainwater harvesting, runoff treatment like filtering, and pollution prevention SCMs for hotspots. As one goes up in scale, SCMs like runoff volume reduction—vegetated and subsurface, earthwork minimization, and erosion and sediment control take on more of a role. At the largest scales, watershed and land-use planning, conservation of natural areas, reforestation and soil conservation, peak flow reduction, buffers and managed floodplains, stream rehabilitation, municipal housekeeping, IDDE, stormwater education, and residential stewardship play a more important role. Some SCMs are useful at all scales, such as product substitution and impervious cover minimization.

Choosing Among On-Site, Distributed SCMs and Larger, Consolidated SCMs

There are distinct advantages and disadvantages to consider when choosing to use a system of larger, consolidated SCMs versus smaller-scale, on-site SCMs that go beyond their ability to achieve water quality or urban stream health. Smaller, on-site facilities that serve to meet the requirements for residential, commercial, and office developments tend to be privately owned. Typically, flows are directed to porous landscape detention areas or similar SCMs, such that volume and pollutants in stormwater are removed at or near their source. Quite often, these SCMs are relegated to the perimeter project, incorporated into detention ponds, or, at best, developed as landscape infiltration and parking islands and buffers. On-site infiltration of frequent storm events can also reduce the erosive impacts of stormwater volumes on downstream receiving waters. Maintenance is performed by the individual landowner, which is both an advantage because the responsibility and costs for cleanup of pollutants generated by individual properties are equitably distributed, and a disadvantage because ongoing maintenance incurs a significant expense on the part of individual property owners and enforcement of properties not in compliance with required maintenance is difficult. On the negative side, individual SCMs often require additional land, which increases development costs and can encourage sprawl. Monitoring of thousands of SCMs in perpetuity in a typical city creates a significant ongoing public expense, and special training and staffing may be required to maintain SCM effectiveness (especially for subgrade or in-building vaults used in ultra-urban environments). Finally, given that as much as 30 per-

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cent of the urban landscape is comprised of public streets and rights-of-way, there are limited opportunities to treat runoff from streets through individual on-site private SCMs. (Notable exceptions are subsurface runoff-volume-reduction SCMs like permeable pavement that require no additional land and promote full development density within a given land parcel because they use the soil areas below roads and the development site for infiltration.)

In contrast, publicly owned, consolidated SCMs are usually constructed as part of larger Greenfield and infill development projects in areas where there is little or no existing infrastructure. This type of facility—usually an infiltration basin, detention basin, wet/dry pond, or stormwater wetland—tends to be significantly larger, serving multiple individual properties. Ownership is usually by the municipality, but may be a privately managed, quasi-public special district. There must be adequate land available to accommodate the facility and a means of up-front financing to construct the facility. An equitable means of allocating costs for ongoing maintenance must also be identified. However, the advantage of these facilities is that consolidation requires less overall land area, and treatment of public streets and rights-of-way can be addressed. Monitoring and maintenance are typically the responsibility of one organization, allowing for effective ongoing operations to maintain the original function of the facility. If that entity is public, this ensures that the facility will be maintained in perpetuity, allowing for the potential to permanently reduce stormwater volumes and for reduction in the size of downstream stormwater infrastructure. Because consolidated facilities are typically larger than on-site SCMs, mechanized maintenance equipment allows for greater efficiency and lower costs. Finally, consolidated SCMs have great potential for multifunctional uses because wildlife habitat, recreational, and open-space amenities can be integrated to their design. Box 5-11 describes sites of various scales where either consolidated or distributed SCMs were chosen.

Defining Stressors of Concern

The primary pollutants or stressors of concern (and the primary source areas or stormwater hotspots within the watershed likely to produce them) should be carefully defined for the watershed. Although this community decision is made only infrequently, it is critical to ensuring that SCMs are designed to prevent or reduce the maximum load of the pollutants of greatest concern. This choice may be guided by regional water quality priorities (such as nutrient reduction in the Chesapeake Bay or Neuse River watersheds) or may be an outgrowth of the total maximum daily load process where there is known water quality impairment or a listed pollutant. The choice of a pollutant of concern is paramount, since individual SCMs have been shown to have highly variable capabilities to prevent or reduce specific pollutants (see WERF, 2006; ASCE, 2007; CWP, 2007b). In some cases, the capability of SCMs to reduce a specific pollutant may be uncertain or unknown.

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BOX 5-11
Examples of Communities Using Consolidated versus Distributed SCMs

Stapleton Airport New Community

This is a mixed-use, mixed-density New Urbanist community that has been under development for the past 15 years on the 4,500-acre former Stapleton Airport site in central Denver. As shown in Figures 5-55 and 5-56, the stormwater system emphasizes surface conveyance and treatment on individual sites, as well as in consolidated regional facilities.

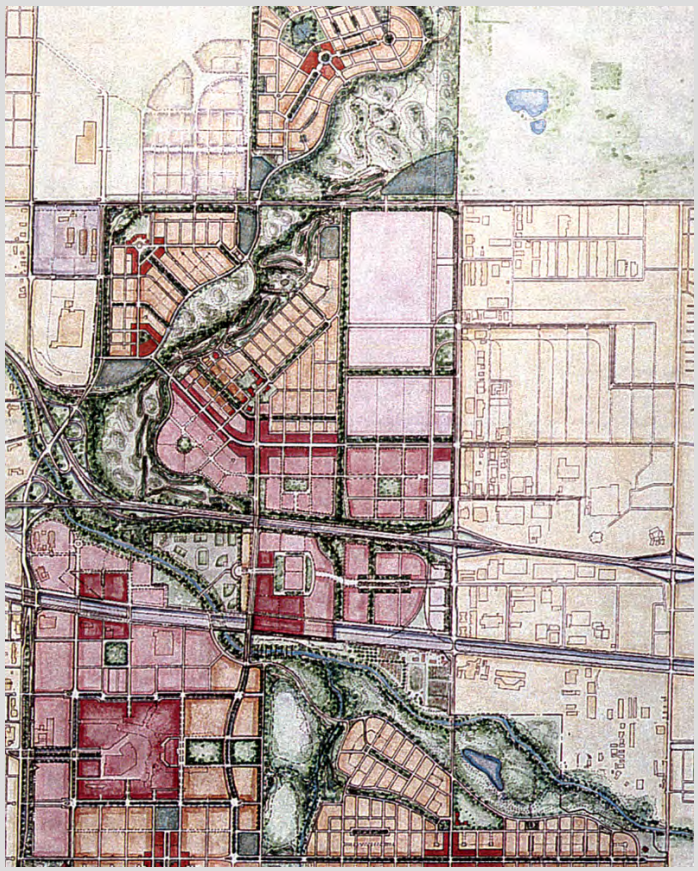

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FIGURE 5-55 The community plan, shown on the left, is organized around two day lighted creeks, formerly buried under airport runways, and a series of secondary conveyances which provide recreational open space within neighborhoods. The image above illustrates one of the multi-functional creek corridors. Consolidated stormwater treatment areas and surface conveyances define more traditional park recreation and play areas. SOURCE: Courtesy of the Stapleton Redevelopment Foundation.



FIGURE 5-56 A consolidated treatment area adjacent to one of several neighborhoods that have been constructed as part of the project's build-out. SOURCE: Courtesy of Wenk Associates.

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BOX 5-11 Continued

Heritage Park Neighborhood Redevelopment

A failed public housing project adjacent to downtown Minneapolis, Minnesota, has been replaced by a mixed-density residential neighborhood. Over 1,200 rental, affordable, and market-rate single- and multi-family housing units have been provided in the 100-acre project area. The neighborhood is organized around two neighborhood parks and a parkway that serve dual functions as neighborhood recreation space and as surface stormwater conveyance and a consolidated treatment system (see Figure 5-57). Water quality treatment is being provided for a combined area of over 660 acres that includes the 100-acre project area and over 500 acres of adjacent neighborhoods. Existing stormwater pipes have been routed through treatment areas with treatment levels ranging from 50 to 85 percent TSS removal, depending on the available land area.



FIGURE 5-57 View of a sediment trap and porous landscape detention area in the central parkway spine of Heritage Park. The sediment trap in the center left of the photo was designed for ease of maintenance access by city crews with standard city maintenance equipment. SOURCE: Courtesy of the SRF Consulting Group, Inc.

The High Point Neighborhood

This Seattle project is the largest example of the city's Natural Drainage Systems Project and it illustrates the incorporation of individual SCMs into street rights-of-way as well as a consolidated facility. The on-site, distributed SCMs in this 600-acre neighborhood are swales, permeable pavement, and disconnected downspouts. A large detention pond services the entire region that is much smaller than it would have been had the other SCMs not been built. Both types of SCMs are shown in Figure 5-58.

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FIGURE 5-58 Natural drainage system methods have been applied to a 34-block, 1,600-unit mixed-income housing redevelopment project called High Point. Shown on top, vegetated swales, porous concrete sidewalks, and frontyard rain gardens convey and treat stormwater on-site. Below is the detention pond for the development. SOURCE: top, William Wenk, Wenk Associates, and bottom, Laura Ehlers, National Research Council.

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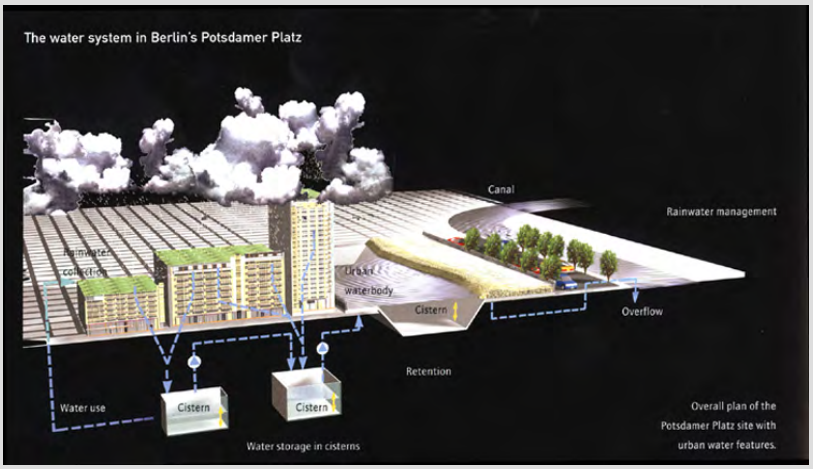
BOX 5-11 Continued

Pottsdammer Platz

This project, in the heart of Berlin, Germany, illustrates the potential for stormwater treatment in the densest urban environments by incorporating treatment into building systems and architectural pools that are the centerpiece of a series of urban plazas. As shown in Figure 5-59, on-site, individual SCMs are used to collect stormwater and use it for sanitary purposes.



FIGURE 5-59 As shown to the left and below, stormwater is collected and stored on-site in a series of vaults. Water is circulated through a series of biofiltration areas and used for toilets and other mechanical systems in the building complex. Large storms overflow into an adjacent canal. SOURCE: Reprinted, with permission, from Herbert Dreiseitl, Dieter Grau (2001). Copyright 2001 by Birkhäuser Publishing Ltd.



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Menomonee Valley Redevelopment, Wisconsin

The 140-acre redevelopment of abandoned railyards illustrates how a Brownfield site within an existing floodplain can be redeveloped using both on-site and consolidated treatment. As shown in Figure 5-60, consolidated treatment is incorporated into park areas which provide recreation for adjacent neighborhoods and serve as a centerpiece for a developing light industrial area that provides jobs to surrounding neighborhoods. Treatment on individual privately owned parcels is limited to the removal of larger sediments and debris only, making more land available for development. The volume of water that, by regulation, must be captured and treated on individual sites is conveyed through a conventional subsurface system for treatment in park areas.



FIGURE 5-60 Illustrations show consolidated treatment areas in proposed parks. The top image illustrates the fair weather condition, the center image the water quality capture volume, and the bottom image the 100-year storm event. Construction was completed in spring 2007. SOURCE: Courtesy of Wenk Associates.

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Determining Goals for the Receiving Waters

It is important to set biological and public health goals for the receiving water that are achievable given the ultimate impervious cover intended for the local watershed (see the Impervious Cover Model in Box 3-10). If the receiving water is too sensitive to meet these goals, one should consider adjustments to zoning and development codes to reduce the amount of impervious cover. The biological goals may involve a keystone species, such as salmon or trout, a desired state of biological integrity in a stream, or a maximum level of eutrophication in a lake. In other communities, stormwater goals may be driven by the need to protect a sole-source drinking water supply (e.g., New York watersheds) or to maintain water contact recreation at a beach, lake, or river. Once again, the watershed goals that are selected have a strong influence on the assembly of SCMs needed to meet them, since individual SCMs vary greatly in their ability to achieve different biological or public health outcomes.

Noting the Physical Constraints

The specific physical constraints of the watershed terrain and the development pattern will influence the selection and assembly of SCMs. The application of SCMs must be customized in every watershed to reflect its unique terrain, such as karst, high water tables, low or high slopes, freeze–thaw depth, soil types, and underlying geology. Each SCM has different restrictions or constraints associated with these terrain factors. Consequently, the SCM prescription changes as one moves from one physiographic region to another (e.g., the flat coastal plain, the rolling Piedmont, the ridge and valley, and mountainous headwaters).

Developing SCM Guidance and Performance Criteria for the Local Watershed

Based on the foregoing factors, the community should establish specific sizing, selection, and design requirements for SCMs. These SCM performance criteria may be established in a local, regional, or state stormwater design manual, or by reference in a local watershed plan. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how SCM guidance can be customized to protect specific types of receiving waters (e.g., high-quality lakes, trout streams, drinking water reservoirs, and impaired waters). In general, the watershed- or receiving water-based criteria are more specific and detailed than would be found in a regional or statewide stormwater manual. For example, the local stormwater guidance criteria may be more prescriptive with respect to runoff reduction and SCM sizing requirements, outline a preferred sequence for SCMs, and indicate where SCMs should (or should not) be located

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in the watershed. Like the identification of stressors or pollutants of concerns, this step is rarely taken under current paradigms of stormwater management.

Establishing a Trading System

A stormwater trading or offset system is critical to situations when on-site SCMs are not feasible or desirable in the watershed. Communities may choose to establish some kind of stormwater trading or mitigation system in the event that full compliance is not possible due to physical constraints or because it is more cost effective or equitable to achieve pollutant reduction elsewhere in the local watershed. The most common example is providing an offset fee based on the cost to remove an equivalent amount of pollutants (such as phosphorus in the Maryland Critical Area—MD DNR, 2003). This kind of trading can provide for greater cost equity between low-cost Greenfield sites and higher-cost ultra-urban sites.

Ensuring the Safe and Effective Performance of the Drainage Network, Streams, and Floodplains

The urban water system is not solely designed to manage the quality of runoff. It also must be capable of safely handling flooding from extreme storms to protect life and property. Consequently, communities need to ensure that their stormwater infrastructure can prevent increased flooding caused by development (and possibly exacerbated future climate change). In addition, many SCMs must be designed to safely pass extreme storms when they do occur. This usually requires a watershed approach to stormwater management to ensure that quality and quantity control are integrated together, with an emphasis on the connection and effective use of conveyance channels, streams, riparian buffers, and floodplains.

Establishing Community Objectives for the Publicly Owned Elements of Stormwater Infrastructure

The stormwater infrastructure in a community normally occupies a considerable surface area of the landscape once all the SCMs, drainage easements, buffers, and floodplains are added together. Consequently, communities may require that individual SCM elements are designed to achieve multiple objectives, such as landscaping, parks, recreation, greenways, trails, habitat, sustainability, and other community amenities (as discussed extensively above). In other cases, communities may want to ensure that SCMs do not cause safety or vector problems and that they look attractive. The best way to maximize community benefits is to provide clear guidance in local SCM criteria at the site

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level and to ensure that local watershed plans provide an overall context for their implementation.

Establishing an Inspection and Maintenance Plan

The long-term performance of any SCM is fundamentally linked to the frequency of inspections and maintenance. As a result, NPDES stormwater permit conditions for industrial, construction, and municipal permittees specify that pollution prevention, construction, and post-construction SCMs be adequately maintained. MS4 communities are also required under NPDES stormwater permits to track, inspect, and ensure the maintenance of the collective system of SCMs and stormwater infrastructure within their jurisdiction. In larger communities, this can involve hundreds or even thousands of individual SCMs located on either public or private property. In these situations, communities need to devise a workable model that will be used to operate, inspect, and maintain the stormwater infrastructure across their local watershed. Communities have the lead responsibility in their MS4 permits to assure that SCMs are maintained properly to ensure their continued function and performance over time. They can elect to assign the responsibility to the public sector, the private sector (e.g., property owners and homeowners association), or a hybrid of the two, but under their MS4 permits they have ultimate responsibility to ensure that SCM maintenance actually occurs. This entails assigning legal and financial responsibilities to the owners of each SCM element in the watershed, as well as maintaining a tracking and enforcement system to ensure compliance.

Summary

Taking all of the elements above into consideration, the emerging goal of stormwater management is to mimic, as much as possible, the hydrological and water quality processes of natural systems as rain travels from the roof to the stream through combined application of a series of practices throughout the entire development site and extending to the stream corridor. The series of SCMs incrementally reduces the volume of stormwater on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure required.

There is no single SCM prescription that can be applied to each kind of development; rather, a combination of interacting practices must be used for full and effective treatment. For a low-density residential Greenfield setting, a combination of SCMs that might be implemented is illustrated in Table 5-8. There are many successful examples of SCMs in this context and at different scales. By contrast, Tables 5-9 and 5-10 outline how the general “roof-to-stream” stormwater approach is adapted for intense industrial operations and urban redevelopment sites, respectively. As can be seen, these development situations require a differ combination of SCMs and practices to address the unique design

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TABLE 5-8 From the Roof to the Stream: SCMs in a Residential Greenfield

SCM	What it Is	What it Replaces	How it Works
Land-Use Planning	Early site assessment	Doing SWM design after site layout	Map and plan submitted at earliest stage of development review showing environmental, drainage, and soil features
Conservation of Natural Areas	Maximize forest canopy	Mass clearing	Preservation of priority forests and reforestation of turf areas to intercept rainfall
Earthwork Minimization	Conserve soils and contours	Mass grading and soil compaction	Construction practices to conserve soil structure and only disturb a small site footprint
Impervious Cover Minimization	Better site design	Large streets, lots and cul-de-sacs	Narrower streets, permeable driveways, clustering lots, and other actions to reduce site IC
Runoff Volume Reduction—Rainwater Harvesting	Utilize rooftop runoff	Direct connected roof leaders	A series of practices to capture, disconnect, store, infiltrate, or harvest rooftop runoff
Runoff Volume Reduction—Vegetated	Frontyard bioretention	Positive drainage from roof to road	Grading frontyard to treat roof, lawn, and driveway runoff using shallow bioretention
	Dry swales	Curb/gutter and storm drain pipes	Shallow, well-drained bioretention swales located in the street right-of-way
Peak Reduction and Runoff Treatment	Linear wetlands	Large detention ponds	Long, multi-cell, forested wetlands located in the stormwater conveyance system
Aquatic Buffers and Managed Floodplains	Stream buffer management	Unmanaged stream buffers	Active reforestation of buffers and restoration of degraded streams

Note: SCMs are applied in a series, although all of the above may not be needed at a given residential site. This “roof-to-stream” approach works best for low- to medium-density residential development.

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TABLE 5-9 From the Roof to the Outfall: SCMs in an Industrial Context

SCM Category	What it Is	What it Replaces	How it Works
Pollution Prevention	Drainage mapping	No map	Analysis of the locations and connections of the stormwater and wastewater infrastructure from the site
	Hotspot site Investigation	Visual inspection	Systematic assessment of runoff problems and pollution prevention opportunities at the site
	Rooftop management	Uncontrolled rooftop runoff	Use of alternative roof surfaces or coatings to reduce metal runoff, and disconnection of roof runoff for stormwater treatment
	Exterior maintenance practices	Routine plant maintenance	Special practices to reduce discharges during painting, powerwashing, cleaning, sealcoating and sandplasting
	Extending roofs for no exposure	Exposed hotspot operations	Extending covers over susceptible loading/unloading, fueling, outdoor storage, and waste management operations
	Vehicular pollution prevention	Uncontrolled vehicle operations	Pollution prevention practices applied to vehicle repair, washing, fueling, and parking operations
	Outdoor pollution prevention practices	Outdoor materials storage	Prevent rainwater from contact with potential pollutants by covering, secondary containment, or diversion from storm-drain system
	Waste management practices	Exposed dumpster or waste streams	Improved dumpster location, management, and treatment to prevent contact with rainwater or runoff
	Spill control plan and response	No plan	Develop and test response to spills to the storm-drain system, train employees, and have spill control kits available on-site
	Greenscaping	Routine landscape and turf maintenance	Reduce use of pesticides, fertilization, and irrigation in pervious areas, and conversion of turf to forest
	Employee stewardship	Lack of storm-water awareness	Regular ongoing training of employees on stormwater problems and pollution prevention practices
	Site housekeeping and stormwater maintenance	Dirty site and unmaintained infrastructure	Regular sweeping, storm-drain cleanouts, litter pickup, and maintenance of stormwater infrastructure
Runoff Treatment	Stormwater retrofitting	No stormwater treatment	Filtering retrofits to remove pollutants from most severe hotspot areas
IDDE	Outfall analysis	No monitoring	Monitoring of outfall quality to measure effectiveness

Note: While many SCMs are used at each individual industrial site, the exact combination depends on the specific configuration, operations, and footprint of each site.

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TABLE 5-10 From the Roof to the Street: SCMs in a Redevelopment Context

SCM Category	What it Is	What it Replaces	How it Works
Impervious Cover Minimization	Site design to prevent pollution	Conventional site design	Designing redevelopment footprint to restore natural area remnants, minimize needless impervious cover, and reduce hotspot potential
Runoff Volume Reduction—Rainwater Harvesting and Vegetated	Treatment on the roof	Traditional rooftops	Use of green rooftops to reduce runoff generated from roof surfaces
	Rooftop runoff treatment	Directly connected roof leaders	Use of rain tanks, cisterns, and rooftop disconnection to capture, store, and treat runoff
	Runoff treatment in landscaping	Traditional landscaping	Use of foundation planters and bioretention areas to treat runoff from parking lots and rooftops
Soil Conservation and Reforestation	Runoff reduction in pervious areas	Impervious or compacted soils	Reducing runoff from compacted soils through tilling and compost amendments, and in some cases, removal of unneeded impervious cover
	Increase urban tree canopy	Turf or landscaping	Providing adequate rooting volume to develop mature tree canopy to intercept rainfall
Runoff Reduction—Subsurface	Increase permeability of impervious cover	Hard asphalt or concrete	Use of permeable pavers, porous concrete, and similar products to decrease runoff generation from parking lots and other hard surfaces.
Runoff Reduction—Vegetated	Runoff treatment in the street	Sidewalks, curb and gutter, and storm drains	Use of expanded tree pits, dry swales and street bioretention cells to further treat runoff in the street or its right-of-way
Runoff Treatment	Underground treatment	Catch basins and storm-drain pipes	Use of underground sand filters and other practices to treat hotspot runoff quality at the site
Municipal Housekeeping	Street cleaning	Unswept streets	Targeted street cleaning on priority streets to remove trash and gross solids
Watershed Planning	Off-site stormwater treatment or mitigation	On-site waivers	Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met on-site

Note: SCMs are applied in a series, although all of the above may not be needed at a given redevelopment site.

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challenges of dense urban environments. The tables are meant to be illustrative of certain situations; other scenarios, such as commercial development, would likely require additional tables.

In summary, a watershed approach for organizing site-based stormwater decisions is generally superior to making site-based decisions in isolation. Communities that adopt the preceding watershed elements not only can maximize the performance of the entire system of SCMs to meet local watershed objectives, but also can maximize other urban functions, reduce total costs, and reduce future maintenance burdens.

COST, FINANCE OPTIONS, AND INCENTIVES

Municipal Stormwater Financing

To be financially sustainable, stormwater programs must develop a stable long-term funding source. The activities common to most municipal stormwater programs (such as education, development design review, inspection, and enforcement) are funded through general tax revenues, most commonly property taxes and sales taxes (NAFSMA, 2006), which is problematic for several reasons. First, stormwater management financed through general tax receipts does not link or attempt to link financial obligation with services received. The absence of such links can reduce the ability of a municipality to adequately plan and meet basic stormwater management obligations. Second, when funded through general tax revenues, stormwater programs must compete with other municipal programs and funding obligations. Finally, in programs funded by general tax revenue, responsibilities for stormwater management tend to be distributed into the work responsibilities of existing and multiple departments (e.g., public works, planning, etc.). One recent survey conducted in the Charles River watershed in Massachusetts found that three-quarters of local stormwater management programs did not have staff dedicated exclusively for stormwater management (Charles River Watershed Association, 2007).

Increasingly, many municipalities are establishing stormwater utilities to manage stormwater (Kaspersen, 2000). Most stormwater utilities are created as a separate organizational entity with a dedicated, self-sustaining source of funding. The typical stormwater utility generates the large majority of revenue through user fees (Florida Stormwater Association, 2003; Black and Veatch, 2005; NAFSMA, 2006). User fees are established and set so as to have a close nexus to the cost of providing the service and, thus, are most commonly based on the amount of impervious surface, frequently measured in terms of equivalent residential unit. For example, an average single-family residence may create 3,000 square feet of impervious surface (roof and driveway area). A per-unit charge is then assigned to this "equivalent runoff unit." To simplify program

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administration, utilities typically assign a flat rate for residential properties (customer class average) (NAFSMA, 2006). Nonresidential properties are then charged individually based on the total amount of impervious surface (square feet or equivalent runoff units) of the parcel. Fees are sometimes also based on gross area (total area of a parcel) or some combination of gross area and a development intensity measure (Duncan, 2004; NAFSMA, 2006).

Municipalities have the legal authority to create stormwater utilities in most states (Lehner et al., 1999). In addition to creating the utility, a municipality will generally establish the utility rate structure in a separate ordinance. Separating the ordinances allows the municipality flexibility to change the rate structure without revising the ordinance governing the entire utility (Lehner et al., 1999). While municipalities generally have the authority to collect fees, some states have legal restrictions on the ability of local governments to levy taxes (Lehner et al., 1999; NAFSMA, 2006). The legal distinction between a tax and a fee is the most common legal challenge to a stormwater utility. For example, stormwater fees have been subject to litigation in at least 17 states (NAFSMA, 2006). To avoid legal challenges, care must be taken to meet a number of legal tests that distinguish a fee for a specific service and a general tax.

Stormwater utilities typically bill monthly, and fees range widely. A recent survey of U.S. stormwater utilities reported that fees for residential households range from $1 to $14 per month, but a typical residential household rate is in the range of $3 to $6 (Black and Veatch, 2005). Despite the dedicated funding source, the majority of stormwater utilities responding to a recent survey (55 percent) indicated that current funding levels were either inadequate or just adequate to meet their most urgent needs (Black and Veatch, 2005).

Both municipal and state programs can finance administrative programming costs through stormwater permitting fees. Municipal stormwater programs can use separate fees to finance inspection activities. For instance, inspection fees can be charged to cover the costs of ensuring that SCMs are adequately planned, installed, or maintained (Debo and Reese, 2003). Stormwater management programs can also ensure adequate funding for installation and maintenance of SCMs by requiring responsible parties to post financial assurances. Performance bonds, letters of credit, and cash escrow are all examples of financial assurances that require up-front financial payments to ensure that longer-term actions or activities are successfully carried out. North Carolina's model stormwater ordinance recommends that the amount of a maintenance performance security (bond, cash escrow, etc.) be based on the present value of an annuity based on both inspection costs and operation and maintenance costs (Whisnant, 2007).

In addition to fees or taxes, exactions such as impact fees can also be used as a way to finance municipal stormwater infrastructure investments (Debo and Reese, 2003). An impact fee is a one-time charge levied on new development. The fee is based on the costs to finance the infrastructure needed to service the new development. The ability to levy impact fees varies between states. Municipalities that use impact fees are also required to show a close nexus between the size of the fee and the level of benefits provided by the fee; a failure to do so

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exposes local government to law suits (Keller, 2003). Compared to other funding sources, impact fees also exhibit greater variability in revenue flows because the amount of funds collected is dependent on development growth.

Bonds and grants can supplement the funding sources identified above. Bonds and loans tend to smooth payments over time for large up-front stormwater investments. For example, state and federal loan programs (state revolving funds) provide long-term, low-interest loans to local governments or capital investments (Keller, 2003). In addition, grant opportunities are sometimes available from state and federal sources to help pay for specific elements of local stormwater management programs.

Municipalities require funds to meet federal and state stormwater requirements. Understanding of the municipal costs incurred by implementing stormwater regulations under the Phase I and II stormwater rules, however, is incomplete (GAO, 2007). Of the six minimum measures of a municipal stormwater program (public education, public involvement, illicit discharge detection and elimination, construction site runoff control, post-construction stormwater management, and pollution prevention/good housekeeping—see Chapter 2), a recent study of six California municipalities found that pollution prevention activities (primarily street sweeping) accounted for over 60 percent of all municipal stormwater management costs in these communities (Currier et al., 2005). Annual per-household costs ranged from $18 to $46.

Stormwater Cost Review

Conceptually, the costs of providing SCMs are all opportunity costs (EPA, 2000). Opportunity costs are the value of alternatives (next best) given up by society to achieve a particular outcome. In the case of stormwater control, opportunity costs include direct costs necessary to control and treat runoff such as capital and construction costs and the present value of annual operation and maintenance costs. Initial installation costs should also include the value of foregone opportunities on the land used for stormwater control, typically measured as land acquisition (land price).

Costs also include public and private resources incurred in the administration of the stormwater management program. Private-sector costs might include time and administrative costs associated with permitting programs. Public costs include agency monitoring and enforcement costs.

Opportunity costs also include other values that might be given up as a consequence of stormwater management. For example, the creation of a wet pond in a residential area might be opposed because of perceived safety, aesthetic, or nuisance concerns (undesirable insect or animal species). In this case, the diminished satisfaction of nearby property owners is an opportunity cost associated with the wet pond. On the other hand, if SCMs are considered a neighborhood amenity (e.g., a constructed wetland in a park setting), opportunity costs may decrease. In addition, costs of a given practice may be reduced by reducing

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costs elsewhere. For example, increasing on-site infiltration rates can reduce off-site storage costs by reducing the volume and slowing the release of runoff.

In general the cost of SCMs is incompletely understood and significant gaps exist in the literature. More systematic research has been conducted on the cost of conventional stormwater SCMs (wet ponds, detention basins, etc.), with less research applied to more recent, smaller-scale, on-site infiltration practices. Cost research is challenging given that stormwater treatment exhibits considerable site-specific variation resulting from different soil, topography, climatic conditions, local economic conditions, and regulatory requirements (Lambe et al., 2005).

The literature on stormwater costs tend to be oriented around construction costs of particular types of SCMs (Wiegand et al., 1986; SWRPC, 1991; Brown and Schueler, 1997; Heaney et al., 2002; Sample et al., 2003; Wossink and Hunt, 2003; Caltrans, 2004; Narayanan and Pitt, 2006; DeWoody, 2007). In many of these studies, construction cost functions are estimated statistically based on a sample of recently installed SCMs and the observed total construction costs. Observed costs are then related statistically to characteristics that influence cost such as practice size. Other studies estimate costs by identifying the individual components of a construction project (pipes, excavation, materials, labor, etc.), estimating unit costs of each component, and then summing all project components. These studies generally find that construction costs decrease on a per-unit basis as the overall size (expressed in volume or drainage area) of the SCM increases (Lambe et al., 2005). These within-practice economies of scale are found across certain SCMs including wet ponds, detention ponds, and constructed wetlands. Several empirical studies, however, failed to find evidence of economies of scale for bioretention practices (Brown and Schueler, 1997; Wossink and Hunt, 2003).

Increasing attention has been paid to small-scale practices, including efforts to increase infiltration and retain water through such means as green roofs, permeable pavements, rain barrels, and rain gardens (under the label of LID). The costs of these practices are less well studied compared to the other stormwater practices identified above. In general, per-unit construction and design costs exceed larger-scale SCMs (Low Impact Development Center, 2007). Higher construction costs, however, may be offset to various degrees by reducing the investments in stormwater conveyance and storage infrastructure (i.e., less storage volume is needed) (CWP, 1998a, 2000a; Low Impact Development Center, 2007). Others have suggested that per-unit costs to reduce runoff may be less for these small-scale distributed practices because of higher infiltration rates and retention rates (MacMullan and Reich, 2007).

Compared to construction costs, less is known about the operation and maintenance costs of SCMs (Wossink and Hunt, 2003; Lambe et al., 2005; MacMullan and Reich, 2007). Most stormwater practices are not maintenance free and can create financial and long-term management obligations for responsible parties (Hager, 2003). Cost-estimation programs and procedures have been developed to estimate operation and maintenance costs as well as construction

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costs (SWRPC, 1991; Lambe et al., 2005; Narayanan and Pitt, 2006), but examination of observed maintenance costs is less common. Based on estimates from Wossink and Hunt (2003), the total present value of maintenance costs over 20 years can range from 15 to 70 percent of total capital construction costs for wet ponds and constructed wetlands and appear generally consistent with percentages reported in EPA (1999). Operation and maintenance costs were also reported to be a substantial percentage of construction costs of infiltration pits and bioretention areas in Southern California (DeWoody, 2007). Others estimate that over the life of many SCMs, maintenance costs may equal construction costs (CWP, 2000a). In general, maintenance costs tend to decrease as a percentage of total SCM cost as the total size of the SCM increases (Wossink and Hunt, 2003).

Very few quantifiable estimates are available for public and private regulatory compliance costs. Compliance costs could include both initial permitting costs (labor and time delays) of gaining regulatory approval for a particular stormwater design to post-construction compliance costs (administration, inspection monitoring, and enforcement). Compliance monitoring is a particular concern if a stormwater management program relies on widespread use of small-scale distributed on-site practices (Hager, 2003). Unlike larger-scale or regional stormwater facilities that might be located on public lands or on private lands with an active stormwater management plan, a multitude of smaller SCMs would increase monitoring and inspection times by increasing the number of SCMs. Furthermore, municipal governments may be reluctant to undertake enforcement actions against citizens with SCMs located on private land.

Land costs tend to be site specific and exhibit a great deal of spatial variation. Some types of SCMs, such as constructed wetlands, are more land intensive than others. In highly urban areas, land costs may be the single biggest cost outlay of land-intensive SCMs (Wossink and Hunt, 2003).

In general, cost analyses generally find that the cost to treat a given acreage or volume of water is less for regional SCMs than for smaller-scale SCMs (Brown and Schueler, 1997; EPA, 1999; Wossink and Hunt, 2003). For example, considering maintenance, capital construction, and land costs, recent estimates for North Carolina indicate that annual costs for wet ponds and constructed wetlands range between $100 and $3,000 per treated acre (typically less than $1,000). Per-acre annual costs for bioretention and sand filters typically ranged between $300 and $3,500, and between $4,500 and 8,500, respectively. However, if SCMs face space constraints, bioretention areas can become more cost effective. Furthermore, other classes of small, on-site practices, such as grass swales and filter strips, can sometimes be implemented for relatively low cost.

There are exceptions to the general conclusion that larger-scale stormwater practices tend to be less costly on a per-unit basis than more numerous and distributed on-site practices. For instance, in Sun Valley, California, a recent study indicates that installing small distributed practices (infiltration practices, porous pavement, rain gardens) was more cost effective than centralized approaches for

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a retrofit program (Cutter et al., 2008). In this particular setting, the difference tended to revolve around the high land costs in the urbanized setting. Small-scale practices can be placed on low-valued land or integrated into existing landscaping, reducing land costs. Centralized stormwater facilities require substantial purchases of high-priced urban properties. Similarly, small distributed practices (porous pavement, green roofs, rain gardens, and constructed wetlands) can also provide a more cost-effective approach to reducing combined sewer overflow (CSO) discharges in a highly urban setting than large structural CSO controls (storage tanks) (Montalto et al., 2007).

SCMs are now a part of most development processes and consequently will increase the cost of the development. Randolph et al. (2006) report on the cost of complying with stormwater and sediment and erosion control regulations for six developments in the Washington, D.C., metropolitan area. These costs include primarily stormwater facility construction and land costs. The findings from these case studies indicate that stormwater and erosion and sediment control comprised about 60 percent of all environmental-related compliance costs for the residential developments studied and added about $5,000 to the average price of a home. Nationwide, stormwater and erosion and sediment controls are estimated to add $1,500 to $9,000 to the cost of a new residential dwelling unit (Randolph et al., 2006).

As a means to control targeted chemical constituents, SCMs may be an expensive control option relative to other control alternatives. For example, nutrients from anthropocentric sources are an increasing water quality concern for many fresh and marine waters. Some states (e.g., Virginia, Maryland, and North Carolina) require stormwater programs to achieve specific nutrient (nitrogen or phosphorus) stormwater standards. The construction, maintenance, and land costs of reducing nitrogen discharge from residential developments using bioretention areas, wet ponds, constructed wetlands, or sand filters range from $60 to $2,500 per pound (Aultman, 2007). These control costs can be an order of magnitude higher than nitrogen control costs from point sources or agricultural nonpoint sources. The high per-pound removal costs are due in part to the relatively low mass load of nutrients carried in stormwater runoff. These estimates, however, assume that all costs are allocated exclusively to nitrogen removal. The high per-pound removal costs from the control of single pollutants highlight the importance of achieving ancillary and offsetting benefits associated with stormwater control (e.g., removal of other pollutants of concern, stream-channel protection from volume reduction, and enhancement of neighborhood amenities).

It should also be noted that installing SCMs in an existing built environment tends to be significantly more expensive than new construction. Construction costs for retrofitted extended detention ponds, wet ponds, and constructed wetlands were estimated to be two to seven times more costly than new SCMs (Schueler et al., 2007). Retrofit costs can be higher for a variety of reasons, including the need to upgrade existing infrastructure (culverts, drainage channels, etc.) to meet contemporary engineering and regulatory requirements. Retrofitting a single existing residential city block in Seattle with a new stormwater

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drainage system that included reduced street widths, biofiltration practices, and enhanced vegetation cost an estimated $850,000 (see Box 5-5; Seattle Public Utilities, 2007). Estimates suggested that the costs might have been even higher using more conventional stormwater piping/drainage systems (Chris May, personal communication, August 2007; EPA, 2007).

As discussed earlier in the chapter, stormwater runoff can be reduced and managed through better site design to reduce impervious cover. Low- to medium-density developments can reduce impervious cover through cluster development patterns that preserve open space and reduce lot sizes. Impervious surfaces and infiltration rates could be altered by any number of site-design characteristics such as reduction in street widths, reduction in the number of cul-de-sacs, and different setback requirements (CWP, 2000a). Finally, impervious surface per capita could be substantially reduced by increasing the population per dwelling unit.

Quantifying the cost of many of these design features is more challenging, and the literature is much less developed or conclusive than the literature on conventional SCM costs. Many design features described above (clustering, reduced setbacks, narrower streets, less curb and gutter) can significantly lower construction and infrastructure costs (CWP, 2001; EPA, 2007). Such features may reduce the capital cost of subdivision development by 10 to 33 percent (CWP, 2000a).

On the other hand, the evidence is unclear whether consumers are willing to pay for these design features. If consumers prefer features typically associated with conventional developments (large suburban lot, for example), then some aspects of alternative development designs/patterns could impose an opportunity cost on builders and buyers alike in the form of reduced housing value. For example, most statistical studies in the U.S. housing market find that consumers prefer homes with larger lots and are willing to pay premiums for homes located on cul-de-sacs, presumably for privacy and safety reasons (Dubin, 1998; Fina and Shabman, 1999; Song and Knapp, 2003). These effects, however, might be partly or completely offset by the higher value consumers might place on the proximity of open space to their homes (Palmquist, 1980; Cheshire and Sheppard, 1995; Qiu et al., 2006). Anecdotal evidence indicates that residents feel that Seattle's Street Edge Alternative program (the natural drainage system retrofit program that combines swales, bioretention and reduced impervious surfaces) increased their property values (City of Seattle, undated). Studies that have attempted to assess the net change in costs are limited, but some evidence suggests that the amenity values of lower-impact designs may match or outweigh the disamentities (Song and Knapp, 2003).

Incentives for Stormwater Management

The dominant policy approach to controlling effluent discharge under the Clean Water Act is through the application of technology-based effluent stan-

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dards or the requirements to install particular technologies or practices. Some note that this general policy approach may not provide the regulated community with (1) incentives to invest in pollution prevention activities beyond what is required in the standard or with (2) sufficient opportunities or flexibility to lower overall compliance costs (Parikh et al., 2005).

A loosely grouped set of policies, called here "incentive-based,"[1] aim to create financial incentives to manage effluent or volume discharge. Such policies tend to be classified into two groups: price- and quantity-based mechanisms (Stavins, 2000; Parikh et al., 2005). Price-based mechanisms are created when government creates a charge (tax, fee, etc.) or subsidy (payment) on an outcome that government wants to either discourage or encourage. Ideally, the price would be placed on a target outcome (effluents discharged, volume of water released, etc.) and not on the means to achieve that outcome end (such as a tax or subsidy to adopt specific technologies or practices).[2] Quantity-based policies require government to establish some binding limit or cap on an outcome (e.g., mass load of effluent, volume of runoff, etc.) for an identified group of dischargers, but then allow the regulated parties to "trade" responsibilities for meeting that limit or cap. The opportunity to trade creates the financial incentive. The trading concept is discussed in greater detail in Chapter 6, while this section focuses on price-based incentives.

Some stormwater utilities offer reductions in stormwater fees to landowners who voluntarily undertake activities to reduce runoff from their parcels (Doll and Lindsey, 1999; Keller, 2003). The reduction in tax obligations, called credits, can be interpreted as a financial subsidy or payment for implementing onsite runoff controls. Credit payments are typically made based on the volume of water detained. For example, as part of Portland, Oregon's Clean River Rewards program, residents and commercial property owners can reduce their stormwater utility fee by as much as 35 percent by reducing stormwater runoff from existing developed properties (Portland Bureau of Environmental Services, 2008a). Residential and commercial property owners are given a number of ways to reduce runoff to receive this financial benefit. In addition, Portland has a downspout disconnection program that aims to reduce discharge into CSOs in targeted areas in the city. Property owners may be reimbursed up to $53 per eligible downspout (Portland Bureau of Environmental Services, 2008b).

Alternatively, stormwater utilities could (where allowed) also use fee revenue to provide private incentives for stormwater control through a competitive

[1] These policies are sometimes called "market-based" policies, but that term will not be used here because many of the incentive-based policies discussed fail to contain features characteristic of a market system.

[2] The literature on what level to set the price (tax or subsidy) is vast, complex, and controversial. Parikh et al. (2005) seem to wander into this debate (perhaps unwittingly) by making a distinction between taxes based on some optimality rule (marginal damage costs equal to marginal control costs) and those based on some other sort of decision rule. Without getting into the specifics of this debate here, this discussion will simply assert more generally that price-based incentive policies structure taxes and subsidies to induce desirable behavioral change (rather than simply to raise revenue).

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bidding process. Such a bidding process ("reverse auction") would request proposals for stormwater reduction projects and fund projects that reduce volume at the least cost. Proposed investments that can meet the program objectives at the lowest per unit cost would receive payments. Such a program creates private incentives to search for low-cost stormwater investments by creating a price for runoff volume reduction. The bidding program could also be used to identify cost-effective stormwater investments in areas targeted for enhanced levels of restoration. A bidding program has been proposed as a way to lower overall costs of a stormwater program in Southern California (Cutter et al., 2008). Revenue to fund such a competitive bid program could come from a variety of sources including stormwater utility fees or fees paid into an in lieu fee program.

Finally, impact fees on new developments can be structured in a way to create incentives to reduce stormwater runoff volumes. Charges based on runoff volume (or a surrogate measure like impervious surface) can provide an incentive for developers to reduce the volume of new runoff created.

CHALLENGES TO IMPLEMENTATION OF WATERSHED-BASED MANAGEMENT AND STORMWATER CONTROL MEASURES

The implementation of SCMs has seen variable success. Environmental awareness, threats to potable water sources or to habitat for threatened and endangered species, problems with combined sewer overflows, and other environmental factors have caused cities such as Portland, Oregon; Seattle, Washington; Chicago, Illinois; and Austin, Texas to aggressively pursue widespread implementation of a broad range of SCMs. In contrast, other cities have been slow to implement recommended practices, for many reasons. This is particularly true for nonstructural SCMs, despite their popularity among planners and regulators for the past two decades. A host of real and perceived concerns about individual nonstructural SCMs are often raised regarding development costs, market acceptance, fire safety, emergency access, traffic and parking congestion, basement seepage, pedestrian safety, backyard flooding, nuisance conditions, maintenance, and winter snow removal operations. While most of these concerns are unfounded, they contribute to a culture of inertia when it comes to code change (CWP, 1998a, 2000a). As a result, some nonstructural SCMs are discouraged or even prohibited by local development codes. Very few communities make the consideration of nonstructural practices a required element of stormwater plan review, nor do they require that they be considered early in the site layout and design process when their effectiveness would be maximized. Finally, many engineers and planners feel they can fully comply with existing stormwater criteria without resorting to nonstructural SCMs.

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Cost Issues

There are numerous cost issues that have proven to be significant barriers to the use of innovative SCMs. Special construction techniques required for the proper design and function of SCMs, specially formulated manufactured soils, expensive subsurface vaults, and increased land area requirements as a result of increased stormwater storage requirements can significantly increase site development costs. For smaller projects in highly urbanized areas where land costs are high, there can be a disproportionately large expense to comply with stormwater regulations, causing developers to seek, and often receive, exemption from requirements.

Sediment removal and related maintenance activities required to ensure the proper ongoing functioning of SCMs are activities that are not a part of normal building maintenance. Data on maintenance costs of SCMs on privately owned facilities are limited, and management companies responsible for commercial and office building maintenance have yet to provide SCM maintenance as part of their services.

Additional costs are incurred when development review periods by public agencies get extended because of an increased level of design review required to evaluate the compliance of SCMs with city ordinances. Additional review increases development costs and extends the design process. Even with specialized training for city staff to evaluate SCM submittals, deviation from the most basic type of SCM design seems to require extended review and documentation.

Cost concerns are partly responsible for the markedly slow implementation of the stormwater program. The federal deadlines for permit coverage have long passed; in fact more than 14 years have lapsed for medium and large municipalities. A good part of the delay can be explained by the resistance of states and local governments to the unknown cost burden. Cities contend that the permit requirements are unreasonable, expensive, and unrealistic to achieve. Many local government officials view some permit provisions such as LID or better site design as intrusion into the land-use authority of local governments.

As discussed in Chapter 2, the U.S. Congress provided no start-up or upgrade financial assistance, unlike what it did for municipally owned and operated wastewater treatment plants after the promulgation of the NPDES permit program under the Clean Water Act in 1972. Local governments have been reluctant to tax residents or create stormwater utilities. States like California and Michigan even have laws that require voter approval in order for local governments to assess new fees. Thus, to implement the NPDES stormwater program, states have had to largely rely on stormwater permit fees collected to support a skeletal to modest staff for program oversight. In Denver, and presumably in other cities, there is no reduction in stormwater fees when impervious area is reduced because of construction of on-site SCMs. This amounts to a disincentive to do the “right thing.” Meanwhile, the overall federal budget for the NPDES program, including stormwater, has been declining.

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Long-Term Maintenance of Stormwater Control Measures

One of the weakest parts of most stormwater management programs is the lack of information about, and funding to support, the long-term maintenance of SCMs. If SCMs are not inspected and maintained on a regular basis, the stormwater management program is likely to fail. This also negatively impacts the design process—if there is no inspection program oand no accountability for maintenance, the designer has no incentive to build better, more maintenance-friendly SCMs. Finally, without an accurate assessment of the maintenance needs of an SCM, land owners and other responsible parties cannot anticipate their total costs over the lifetime of the device.

Almost all SCMs require active long-term maintenance in order to continue to provide volume and water quality benefits (Hoyt and Brown, 2005; Hunt and Lord, 2006b). Furthermore, a typical municipality may contain hundreds or thousands of individual SCMs within its jurisdiction. Thus, the long-term obligations for maintenance are considerable. For example, the annual maintenance cost of 100 medium-sized wet ponds (one-half acre to 2 acres) is estimated to be a quarter of a million dollars (Hunt and Lord, 2006c). Currently, the majority of municipal stormwater programs do not have adequate plans or resources in place for the long-term maintenance of SCMs (GAO, 2007).

A number of issues confront the long-term maintenance of SCMs. First, legal and financial responsibility for maintenance must be assigned. Historically stormwater ownership and responsibility have been poorly defined and implemented (Reese and Presler, 2005). If a party is an industrial facility that is required to obtain a permit, then responsibility for maintaining SCMs rests with the permittee. Other instances are more ambiguous. For residential developments, the responsibility for long-term maintenance could be assigned to the developer (e.g., establishing long-term financial accounts for maintenance), individual landowners, homeowners associations, or the municipality itself. Some cities, like Austin and Seattle, assume responsibility for long-term maintenance of SCMs in residential areas. Concerns over assigning responsibility to individual residential landowners or homeowners associations include insufficient technical and financial resources to conduct consistent maintenance and a lack of inspection to require maintenance. A recent survey of municipal stormwater programs found that less than one-third perform regular maintenance on stormwater detention ponds or water quality SCMs in general residential areas (Reese and Presler, 2005). To ensure that adequate maintenance will occur, municipalities can require performance securities (performance bonds, escrow accounts, letter of credit, etc.) that ensure adequate funds are available for maintenance and repair in the event of failure to maintain the SCM by the responsible party.

An effective maintenance program also requires a system to inventory and track SCMs, inspection/monitoring, and enforcement against noncompliance. The large number of SCMs to track and manage creates management challenges. Municipal stormwater programs must administer their regulatory programs, perform inspection and enforcement activities, and maintain SCMs in public

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lands/rights-of-way and sometimes in residential areas. Municipal programs often do not have adequate staff to ensure that these maintenance responsibilities are adequately carried out. The lack of adequate staff for inspection and an inadequate system for prioritizing inspections have been repeatedly pointed out (Duke and Beswick, 1997; Duke, 2007; GAO, 2007).

Tracking and monitoring costs may also create disincentives for municipalities to adopt smaller-scale SCMs. Residential-scale rain gardens, porous driveways, rain barrels, and grass swales all have the potential to increase the cost and complexity of compliance monitoring because of the multitude of small infiltration devices that are located on private property as opposed to having fewer SCMs located in public rights-of-way or public lands. Small-scale distributed SCMs located on private property raise concerns of municipal willingness to inspect and enforce against noncompliance. Indeed, some municipalities have banned innovative SCMs like pervious pavement because the municipalities have no means to ensure their maintenance and continued operation.

Finally, there is concern that there is inadequate funding to maintain the growing number of SCMs on the landscape. The long-term funding obligation for maintenance has been difficult to assess (GAO, 2007), partly because many stormwater programs frequently do not have adequate accounting practices to define capital value and depreciation, maintenance, operation, or management programs (Reese and Presler, 2005). The problem is compounded because the long-term maintenance cost associated with various types of SCMs is not well understood. Additional research and information are needed on the costs of maintaining the performance of SCMs as experienced in the field (rather than ex ante estimates based on design plans). Research into long-term maintenance costs should include not only routine operation and maintenance costs but also costs for inspection and enforcement and remediation costs associated with SCM performance failures. Such research is critical to understanding the long-term cost obligation that is being assumed by municipal stormwater programs that are responsible for managing a growing number of SCMs.

At the present time, the maintenance schedule for many of the proprietary and non-proprietary SCMs is poorly defined. It will vary with the type of drainage area and the activities that are occurring within it and with the efficiency of the SCM. (For example, the city of Austin, Texas, has determined that the average lifespan of their sand filters ranges from 5 to 15 years, but can be as little as one year if there is construction in the drainage area.) In order to establish a maintenance schedule, an assessment protocol needs to be adopted by municipalities. The protocol, which is specific to the type of SCM, could consist of the following: each year municipalities would be required to collect data from a subset of their SCMs on public and private property, and then over a period of years these data could be used to determine maintenance schedules, predict performance based on age and sediment loading, and identify failed systems. A measurement of the depth of deposited sediment might be the only test needed for settling devices, such as hydrodynamic devices and wet detention ponds. Two levels of analysis could be performed for infiltration devices—one based

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on simple visual observations and the other using an instrument to check infiltration rates. These assessment methods for infiltration devices have been tested at the University of Minnesota (Gulliver and Anderson, 2007). Without an assessment protocol for SCMs, the chances for poor maintenance and outright failure are greatly increased, it is difficult if not impossible to determine the actual performance of an SCM, and there will be insufficient data to reduce the uncertainty in future SCM design.

Lack of Design Guidance on Important SCMs and Lack of Training

Progress in implementing SCMs is often handicapped by the lack of local or national design guidance on important SCMs, and by the lack of training among the many players in the land development community (planners, designers, plan reviewers, public works staff, regulators, and contractors) on how to properly implement them on the ground. For example, design guidance is lacking or just emerging for many of the non-traditional SCMs, such as conservation of natural areas, earthwork minimization, product substitution, reforestation, soil restoration, impervious cover reduction, municipal housekeeping, stormwater education, and residential stewardship. Some LID techniques are better covered, such as the standards for pervious concrete from the American Concrete Institute and the National Ready Mixed Concrete Association. Design guidance for traditional SCMs such as erosion and sediment control may exist but is often incomplete, outdated, or lacking key implementation details to ensure proper on-the-ground implementation. In other cases, design guidance is available, but has not been disseminated to the full population of Phase II MS4 communities. For example, in an unpublished survey of state manuals used to develop national post-construction stormwater guidance, Hirschman and Kosco (2008) found that less than 25 percent provided sizing criteria, detailed engineering design specifications, or maintenance criteria. Nationwide guidance on SCM design and implementation may not be advisable or applicable to all physiographic, climatic, and ecoregions of the country. Rather, EPA and the states should encourage the development of regional design guidance that can be readily adapted and adopted by municipal and industrial permittees. Improvement of SCM design guidance should incorporate more direct consideration of the parameters of concern, how they move across the landscape, and the issues in receiving waters—a strategy both espoused in this report (page 351) and in recent publications on this topic (Strecker et al., 2005, 2007).

The second key issue relates to how to train and possibly certify the hundreds of thousands of individuals that are responsible for land development and stormwater infrastructure at the local and state level. New stormwater methods and practices cannot be effectively implemented until local planners, engineers, and landscape architects fully understand them and are confident on how to apply them to real-world sites. Currently, stormwater design is not a major com-

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ponent of the already crowded curriculum of undergraduate or graduate planning engineering or landscape architecture programs. Most stormwater professionals acquire their skills on the job. Given the rapid development of new stormwater technologies, there is a critical need for implementation of regional or statewide training programs to ensure that stormwater professionals are equipped with the latest knowledge and skills. The training programs should ultimately lead to formal certification for stormwater designers, inspectors, and plan reviewers.

Different Standards in Different Jurisdictions That Are Within the Same Watershed

Governmental and watershed boundaries rarely coincide, with the result that most watersheds are made up of many municipal bodies regulating stormwater management. Unfortunately in most cases there is no overarching stormwater regulatory structure that is based upon a watershed analysis. This can result in many unfortunate conflicts, where approval of a stormwater facility does not affect the community issuing the permit. It is often said that the most effective stormwater management for an area high in the watershed is to speed the water downstream, thus saving the upstream community but severely damaging the downstream rivers. While this may be an exaggeration, the problems downstream are less of a concern to the upper watershed communities, and downstream communities may not be able to solve their water issues without help from the upstream communities.

Often neighboring communities' plans or the methods or data used do not coincide. For example, often out-of-date rainfall distributions, methods, or standards are required in the code that do not apply to the newer focus on smaller storms and volume reduction. If methods that include Modified Rational or TR-55 are used, it is difficult if not impossible to show the benefits in peak flow reduction gained through volume reduction devices. Also, some municipalities may require curb and piping and not allow swales, impending the implementation of a cost-effective design. Finally, it is difficult to observe a measureable impact of SCMs when they are guided by a patchwork of regulations. One community may require removal of the first inch of runoff, and another may require the reduction of the 25-year, post-construction peak to the 10-year pre-construction level.

Water Rights that Conflict with Stormwater Management

In the West, water is considered real property, governed by state law and regional water compacts. Landowners in urban areas rarely own surface water rights and are typically prohibited from "beneficial use" of that water, which affects how SCMs are chosen. For example, current practices in Colorado typically allow stormwater to be infiltrated within a short period of time on-site

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without violation of water laws. However, storage of and/or pumping this water for broader distribution is considered to be a beneficial use and is therefore prohibited. Moreover, as discussed in Chapter 2, SCMs that manage stormwater by driving the water underground with a bored, drilled, or driven shaft or a hole dug deeper than its widest surface dimension are typically considered to be "injection wells," requiring a federal permit and regular monitoring under the Safe Drinking Water Act.

Some states prohibit infiltration because of concerns over long-term groundwater pollution. In California, which does not have a uniform policy for groundwater management and groundwater rights, authority over groundwater quality management falls to several regional and local agencies. For example, the Upper Los Angeles River Area (ULARA) has a court-appointed Watermaster to manage the complex appropriation of its groundwater to user cities and agencies. The ULARA has clashed with the City of Los Angeles regarding rights to all of the water that normally recharges the Los Angeles River via runoff from precipitation. In 2000, the ULARA Watermaster expressed a concern with certain permit provisions of the Los Angeles County MS4 Permit for New Development/ Redevelopment that promoted infiltration, stating that the MS4 permit interfered with the adjudicated right of the City of Los Angeles to manage groundwater.

Urban Development and Sprawl

The continued expansion of urban areas is inevitable given population increases worldwide and the transition from agricultural to industrial economies. Given that urbanization of almost any magnitude—even less than 10 percent impervious area—has been demonstrated to have an impact on in-stream water quality, a central question to be addressed is how water quality can be maintained as cities grow, without having negative impacts on social and economic systems. Ideally, SCMs would perform their water quality function, contribute to the livability of cities, and enhance their economic and social potentials.

Low-density, auto-oriented urban development, commonly known as sprawl, has been the predominant pattern of development in the United States, and increasingly worldwide, since World War II. It has been widely criticized for its inefficient use of land, its high use of natural resources, and its high energy costs—all of which are associated with the required auto-oriented travel. Additionally, ongoing economic costs related to the provision of widely dispersed services and social impacts of a breakdown in community life have been identified (Bruegmann, 2005). Sprawl and the impacts on in-stream water quality that result from urbanization have been an inevitable consequence of improved economic conditions. In the United States, sprawl constitutes the vast majority of development occurring today because a majority of the population is attracted to the benefits of a suburban lifestyle, government has subsidized roads and highways at the expense of public transit, and local zoning often limits de-

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velopment density.

There has been a great deal of innovation in city planning and design in the past decade that encourages greater density and a return to urban living. New types of zoning, New Urbanism, Smart Growth, and related innovations in urban planning and design have been developed in parallel with environmental regulations at local to national levels (see Chapter 2). They acknowledge the importance of protecting natural resources to maintain quality of life and have established water quality as an important consideration in city building.

It is not clear that current stormwater regulations can be effectively implemented over the broad range of development patterns that characterize contemporary cities or if they inadvertently favor one type of development over another. For example, on-site SMCs are often recommended as the preferred means of stormwater management, although they tend to encourage lower-density development patterns. And while they are easily implemented and regulated given the incremental, site-by-site development that is typical of most urban growth, monitoring and maintenance can be expensive and difficult for both the individual property owner and the regulating authority. In highly urbanized areas, they are often relegated to subsurface systems that are expensive and that, to be effective, require high levels of maintenance.

In newly developing areas, cluster development should be encouraged whenever possible, according to the Smart Growth principles of narrower streets, reduced setbacks, and related approaches to reduce the amount of impervious area required and land consumed. Furthermore, an interconnected series of on-site and consolidated SCMs can reduce subsurface stormwater piping requirements. Most planned communities have dedicated park and open-space areas that can constitute 25 percent or more of a development's total land area, making it feasible to easily accommodate consolidated SCMs (typically 8 to 10 percent of impervious area) within multi-functional open space and park lands. Cost efficiencies such as a 30 percent reduction in infrastructure costs (Duaney Plater-Zyberk & Company, 2006) can be realized through Smart Growth development techniques. Clustered housing surrounded by open space, laced with trails, has appreciated in value at a higher rate than conventionally designed subdivisions (Crompton, 2007).

In order to encourage infill or redevelopment over sprawl patterns of development, innovative zoning and other practices will be needed to prevent stormwater management from becoming onerous. For example, incentive zoning or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Innovations in governance and finance can also be used to incorporate consolidated SCMs into urban environments. For example, the City of Denver, in updating its Comprehensive Plan, designated certain underdeveloped corridors and districts in the city as "areas of change" where it hoped to encourage large-scale infill redevelopment. Given the scale of redevelopment, it would be feasible to establish special maintenance districts, allowing the development of consolidated SCMs that have multiple functions. To fund land purchase and facility design and construction, cash in lieu of pay-

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ments could be made.

Safety and Aesthetic Concerns

Vector-borne diseases, especially West Nile virus, are a concern when SCMs such as extended detention basins, constructed wetlands, and rain barrels are proposed. Furthermore, other SCMs that are poorly designed, improperly constructed, or inadequately maintained may retain water and provide an ideal breeding ground for mosquitoes, increasing the potential for disease transmission to humans and wildlife. Kwan et al. (2005) found that water-retaining SCMs increase the availability of breeding habitats for disease vectors and provide opportunistic species an extended breeding season. State Health Departments generally recommend that SCMs be designed to drain fully in 72 hours, which is the minimum time required for a mosquito to complete its life cycle under optimum conditions. In SCMs where there is permanent standing water, such as stormwater wetlands, there is the possibility of introducing biota that might prey on mosquitoes. Municipalities may have to consider the added cost of vector control and public health when implementing stormwater quality management programs.

With larger consolidated and regional extended detention facilities, concerns about the safety of children who may be attracted to such SCMs and ensuing liability must be considered. These SCMs need to be fenced off or otherwise designed appropriately to reduce the risk of drowning.

One aspect of stormwater management that is infrequently considered is the aesthetic appeal, or lack thereof, of SCMs. The visual qualities of SCMs are important because they are a growing part of the urban landscape setting. Although it can be assumed that landscapes that are carefully tended are often preferred over other types of landscapes, it depends substantially on one's point of view. For example, an engineer may consider a particular SCM that is functioning as expected to be beautiful in the sense that its engineering function has been realized, even though there is sediment buildup, algae, or other products of a properly functioning SCM visible. Similarly, a biologist or ecologist evaluating an ecologically healthy SCM in an urban context might find it to be beautiful because of its biological or ecological diversity, whereas another individual who evaluates the same SCM finds it to be "weedy." SCMs can be viewed as a means of restoring a degraded landscape to a state that might have existed before urban development. The desire to "return to nature" is a seductive idea that suggests naturalistic SCMs that may have very little to do with an original landscape, given the dramatic changes in hydrology that are inevitable with urban streams. Each of these widely varied views of SCMs may be appropriate depending on the context and the viewer.

A goal of stormwater management should be to make SCMs desirable and attractive to a broader audience, thereby increasing their potential for long-term effectiveness. For example, the Portland convention center rain gardens demon-

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strate how native and non-native wetland plantings can be carefully composed as a landscape composition and also provide for stormwater treatment. If context and aesthetics of a chosen SCM are poorly matched, there is a high probability that the SCM will be eliminated or its function compromised because of modifications that make its landscape qualities more appropriate for its context.

CONCLUSIONS AND RECOMMENDATIONS

SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. However, in very few cases has the performance of SCMs been mechanistically linked to the guaranteed sustainment at the watershed level of receiving water quality, in-stream habitat, or stream geomorphology. Many studies demonstrate that degradation in rivers is directly related to impervious surfaces in the contributing watershed, and it is clear that SCMs, particularly combinations of SMCs, can reduce the runoff volume, erosive flows, and pollutant loadings coming from such surfaces. However, none of these measures perfectly mimic natural conditions, such that the accumulation of these SCMs in a watershed may not protect the most sensitive beneficial aquatic life uses in a state. Furthermore, the implementation of SCMs at the watershed scale has been too inconsistent and too recent to observe an actual cause-and-effect relationship between SCMs and receiving waters. The following specific conclusions and recommendations about stormwater control measures are made.

Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds. SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.

Nonstructural SCMs such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.

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SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the "first flush" of contaminants. SCMs designed to remove this class of storms from surface runoff (runoff-volume-reduction SCMs—rainwater harvesting, vegetated, and subsurface) can also address larger watershed flooding issues.

Performance characteristics are starting to be established for most structural and some nonstructural SCMs, but additional research is needed on the relevant hydrologic and water quality processes within SCMs across different climates and soil conditions. Typical data such as long-term load reduction efficiencies and pollutant effluent concentrations can be found in the International Stormwater BMP Database. However, understanding the processes involved in each SCM is in its infancy, making modeling of these SCMs difficult. Seasonal differences, the time between storms, and other factors all affect pollutant loadings emanating from SCMs. Research is needed that moves away from the use of percent removal and toward better simulation of SCM performance. Hydrologic models of SCMs that incorporate soil physics (moisture, wetting fronts) and groundwater processes are only now becoming available. Research is particularly important for nonstructural SCMs, which in many cases are more effective, have longer life spans, and require less maintenance than structural SCMs. EPA should be a leader in SCM research, both directly by improving its internal modeling efforts and by funding state efforts to monitor and report back on the success of SCMs in the field.

Research is needed to determine the effectiveness of suites of SCMs at the watershed scale. In parallel with learning more about how to quantify the unit processes of both structural and nonstructural practices, research is needed to develop surrogates or guidelines for modeling SCMs in lumped watershed models. Design formulas and criteria for the most commonly used SCMs, such as wet ponds and grass swales, are based on extensive laboratory and/or field testing. There are limited data for other SCMs, such as bioretention and proprietary filters. Whereas it is important to continue to do rigorous evaluations of individual SCMs, there is also a role for more simple methods to gain an approximate idea about how SCMs are performing. The scale factor is a problem for watershed managers and modelers, and there is a need to provide guidance on how to simulate a watershed of SCMs, without modeling thousands of individual sites.

Improved guidance for the design and selection of SMCs is needed to improve their implementation. Progress in implementing SCMs is often

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handicapped by the lack of design guidance, particularly for many of the non-traditional SCMs. Existing design guidance is often incomplete, outdated, or lacking key details to ensure proper on-the-ground implementation. In other cases, SCM design guidance has not been disseminated to the full population of MS4 communities. Nationwide guidance on SCM design and implementation may not be advisable or applicable to all physiographic, climatic, and ecoregions of the country. Rather, EPA and the states should encourage the development of regional design guidance that can be readily adapted and adopted by municipal and industrial permittees. As our understanding of the relevant hydrologic, environmental, and biological processes increases, SCM design guidance should be improved to incorporate more direct consideration of the parameters of concern, how they move across the landscape, and the issues in receiving waters.

The retrofitting of urban areas presents both unique opportunities and challenges. Promoting growth in these areas is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, it is more complex than Greenfields development because of the need to upgrade existing infrastructure, the limited availability and affordability of land, and the complications caused by rezoning. These sites may be contaminated, requiring cleanup before redevelopment can occur. Both innovative zoning and development incentives, along with the selection of SCMs that work well in the urban setting, are needed to achieve fair and effective stormwater management in these areas. For example, incentive or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Publicly owned, consolidated SCMs should be strongly considered as there may be insufficient land to have small, on-site systems. The performance and maintenance of the former can be overseen more effectively by a local government entity. The types of SCMs that are used in consolidated facilities—particularly detention basins, wet/dry ponds, and stormwater wetlands—perform multiple functions, such as prevention of streambank erosion, flood control, and large-scale habitat provision.

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6
Innovative Stormwater Management and Regulatory Permitting

There are numerous innovative regulatory strategies that could be used to improve EPA's stormwater program. This chapter first outlines a substantial departure from the status quo, namely, basing all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries. Watershed-based permitting is not a new concept, but it has been attempted in only a few communities. Development of the new permitting paradigm is followed by more modest and easily implemented recommendations for improving the stormwater program, from a new plan for monitoring industrial sites to encouraging greater use of quantitative measures of the maximum extent practicable requirement. The recommendations in the latter half of the chapter do not preclude adoption of watershed-based permitting at some future date, and indeed they lay the groundwork in the near term for an eventual shift to watershed-based permitting.

WATERSHED PERMITTING FRAMEWORK FOR MANAGING STORMWATER

At its initial meeting in January 2007, the committee heard opinions that collectively pointed in a new direction for managing and regulating stormwater that would differ from the end-of-pipe approach traditionally applied by regulatory agencies under the National Pollutant Discharge Elimination System (NPDES) permits and be based instead on a watershed framework. Indeed, the U.S. Environmental Protection Agency (EPA) has already given substantial thought to watershed permitting and issued a Watershed-Based NPDES Permitting Policy Statement (EPA, 2003a) that defined watershed-based permitting as an approach that produces NPDES permits that are issued to point sources on a geographic or watershed basis. It went on to declare that, "The utility of this tool relies heavily on a detailed, integrated, and inclusive watershed planning process. Watershed planning includes monitoring and assessment activities that generate the data necessary for clear watershed goals to be established and permits to be designed to specifically address the goals."

In the statement, EPA listed a number of important benefits of watershed permitting:

- More environmentally effective results;
- Ability to emphasize measuring the effectiveness of targeted actions on improvements in water quality;

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- Greater opportunities for trading and other market-based approaches;
- Reduced cost of improving the quality of the nation's waters;
- More effective implementation of watershed plans, including total maximum daily loads (TMDLs); and
- Other ancillary benefits beyond those that have been achieved under the Clean Water Act (e.g., integrating CWA and Safe Drinking Water Act [SDWA] programs).

Subsequent to the policy statement, EPA published two guidance documents that lay out a general process for a designated state that wishes to set up any type of permit or permits under CWA auspices on a watershed basis (EPA, 2003b, 2007a). It also outlined a number of case studies illustrating various kinds of permits that contain some watershed-based elements. Box 6-1 describes in greater detail the more recent report (EPA, 2007a) and its 11 "options" for watershed-based permitting. Unfortunately, the EPA guidance is lacking in its description of what constitutes watershed-based permitting, who would be covered under such a permit, and how it would replace the current program for municipalities and industries discharging stormwater under an individual or general NPDES permit. Few examples are given, some of which are not even watershed-based, with most of the examples involving grouping municipal wastewater treatment works under a single permit with no reference to stormwater. Most of the 11 options are removed from the fundamental concept of watershed-based permitting. Finally, the guidance fails to elaborate on the policy statement goal to make water quality standards watershed-based. The committee concluded that, although the EPA documents lay some groundwork for watershed-based permitting—especially the ideas of integrated municipal permits, water quality trading, and monitoring consortia—the sum total of EPA's analysis does not define a framework for moving toward true watershed-based permitting. The guidance attends to few of the details associated with such a program and it has made no attempt to envision how such a system could be extended to the states and the municipal and industrial stormwater permittees. This chapter attempts to overcome these shortcomings by presenting a more comprehensive description of watershed-based permitting for stormwater dischargers.

The approach proposed in this chapter fits within the general framework outlined by EPA but goes much further. First, it is intended to replace the present structure, instead of being an adjunct to it, and to be uniformly applied nationwide. The proposal adopts the goal orientation of the policy statement and then extends it to root watershed management and permitting in comprehensive objectives representing the ability of waters to actually support designated beneficial uses. The proposal builds primarily around the integrated municipal permit concept in the policy statement and technical guidance. Like EPA's outline, the committee emphasizes measuring the effectiveness of actions in bringing improvements, but goes on from there to recommend a set of monitoring activi-

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BOX 6-1
EPA's Current Guidance on Watershed-Based Permitting

Rather than explicitly define watershed based permitting, the EPA's recent guidance (EPA, 2007a) groups a large number of activities as having elements of watershed-based permitting, and defines how each might be utilized by a community. They are

- NPDES permitting development on a watershed basis,
- Water quality trading,
- Wet weather integration,
- Indicator development for watershed-based stormwater management,
- TMDL development and implementation,
- Monitoring consortium,
- Permit synchronization,
- Statewide rotating basin planning,
- State-approved watershed management plan development,
- Section 319 planning, and
- Source water protection planning.

Taking these topics in order, the first option is generally similar to that in EPA (2003a,b), but with some more detail on possible permitting forms. "Coordinated individual permits" implies that individual permits would be made similar and set with respect to one another and to a holistic watershed goal. The nature of such permits is not fully described, and there are no examples given. An "integrated municipal permit," also presented in the earlier policy statement, would place the disparate individual NPDES permits in a municipality (e.g., wastewater plants, combined sewer overflows, municipal separate storm sewer systems [MS4s]) under one permit. However, such a permit is not necessarily watershed-based. Finally, the "multi-source permit" could go in numerous directions, none of which are described in detail. In one concept, all current individual permittees who discharge a common pollutant into a watershed would come under one new individual permit that regulates that pollutant, while keeping the existing individual permits intact for other purposes. The Neuse River Consortium is given as an example. Alternatively, a multi-source permit could cover all dischargers of a particular type now falling under one individual permit that regulates all of their pollutants (no examples are given). In yet another application, this permit could be a general permit, and it would be identical to the existing general permits, except that it would be organized along watershed boundaries. As above, it could be refined on the basis of pollutant or discharger type.

The other ten options are more distant from the fundamental concept of watershed-based permitting. The water quality trading description is minimal, though it does mention a new EPA document that gives guidance to permittees for trading. Wet weather integration, the third topic, can mean any number of things, from creating a single permit to cover all discharges of pollutants during wet weather in a municipality, as described above for "coordinated individual permits," to just having all the managers of the systems get together and strategize. Although a stated goal is to reduce the amount of water in the sewer system after a storm, this integration is not particularly well defined in the document, nor is it well differentiated from other activities that would normally occur under an MS4 permit.

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BOX 6-1 Continued

Indicator development for watershed-based stormwater management refers to identifying indicators that are better than one or a few pollutants at characterizing the degree of impairment wrought by stormwater. Stormwater runoff volume is one indicator being developed by Vermont, and percent impervious surface is another. As discussed in Chapter 2, some states have long used biological indicators that integrate the effects of many pollutants as well as physical stresses such as elevated flow velocities. Indicators can be used as TMDL targets or as goals in NPDES permits. Identifying and adopting indicators is, essentially, a prerequisite to implementing some of the other options listed above.

Regarding the next topic on the list, the option of TMDL development is obvious, since the TMDL program is by definition watershed based. If it can be made the highest priority, and if stormwater is a contributor, then the implementation plan can be an excellent way to combat stormwater pollution on a watershed basis. Reducing the contribution of the pollutant from a stormwater source can involve water quality trading, better enforcement of existing permits, or creating new watershed-based permits. Hence, again, there is considerable overlap with the previously discussed options.

Developing a monitoring consortium is an option that works when sufficient data are not available to do much else. The concept mainly refers to monitoring of ambient waters. The activity is shared among partners (e.g., all wastewater plants in a region), with the goal of collecting and analyzing enough data to improve management decisions on a watershed basis, instead of for a single plant.

The following topic, permit synchronization, refers to having all permits within a watershed expire and be renewed simultaneously. This approach could be helpful for streamlining administrative, monitoring, and management tasks associated with maintaining the permits. Some states have operated in this way, whereas others have decided not to. It is one way to coordinate permits in cases where other types of watershed-based permitting would not work. Similarly, the statewide rotating basin approach, used by many states, relies on a five-year cycle. The state is divided into major watersheds, and each watershed is in a different stage of the cycle every year. It is a way to distribute the workload such that there is never a year when, for example, every watershed would require monitoring. Since it is a statewide program, how it relates to a watershed-based permitting situation is not at all clear.

ties designed to support active adaptive management to achieve objectives, aswell as to assess compliance. Credit trading, indicator development, the rotating basin approach, and monitoring should be part of management and permitting programs within watersheds, and ideas are advanced to develop these and other elements.

In addition to building on the work of EPA, the proposed approach tackles many of the impediments to effective watershed management identified in the National Research Council (NRC) treatise on watershed management (NRC, 1999). That report noted that watershed approaches are easiest to implement at the local level; thus, the approach developed in this chapter is a bottom-up process in which programmatic responsibility lies mainly with municipalities. Because the natural boundaries of watersheds rarely coincide with political jurisdictions, watersheds as geographic areas are less useful for political, institutional, and funding purposes, such that initiatives and organizations directed at watershed management should be flexible. The proposed approach recognizes this reality and makes numerous suggestions for pilot testing, funding, and institutional arrangements that will facilitate success. Finally, NRC (1999) notes the

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With regard to the next topic, there has been a great deal of watershed planning around the nation and tremendous variety in form and comprehensiveness. Plans generally contain some information on the state of the watershed, goals for the watershed, and activities to meet those goals. Development of such plans in areas that do not have them could facilitate watershed-based permitting by providing much needed information about conditions, sources of pollutants, and methods to reduce pollution. According to EPA, a watershed plan may or may not indicate the need for watershed-based permitting.

The Section 319 Program refers to voluntary efforts to reduce pollution from nonpoint sources. The program in and of itself is not relevant to NPDES permits, since it deals strictly with activities that are not regulated. However, these activities could be traded with more traditional stormwater practices as part of a watershed-based effort to reduce overall pollution reaching waterbodies. Many watershed plans must consider guidance for the 319 program in order to get funding for their management activities.

If the watershed in question contains a drinking water source (either surface water or groundwater), then a good source water protection plan can have a significant impact on NPDES permitting in a watershed. Information collected during the assessment phase of source water protection could be used to help inform watershed-based permitting. Also, NPDES permits could be rewritten taking into account the proximity of discharges to source water intakes.

Following its coverage of the 11 options, EPA (2007a) gives a hypothetical example of picking six of the options to develop permitting for a watershed. It discusses how the options might be prioritized, but in a very qualitative manner, according to considerations such as availability of funding and personnel, stakeholder desires, environmental impacts, and sequencing of events. Chapter 1 of the report ends with a list of performance goals that might apply to the 11 options.

Chapter 2 further explains the multi-source watershed-based permit, discussing, for example, who would be covered by it, who would administer it, and how credit trading fits in. The chapter has a lot of practical, although quite intuitive, information about how to write such a permit. Much of the decision making is left to the permit writer. There are discussions of effluent limitations, monitoring requirements, reporting and record keeping, special conditions, and public notice. Chapter 3 follows by presenting case studies, although fewer than appeared in 2003 and not all truly watershed based.

need to "develop practical procedures for considering risk and uncertainty in real world decision-making in order to advance watershed management." The proposed revised monitoring system presented later in this chapter is designed to provide information in the face of ongoing uncertainty, i.e., adaptive management in a permitting context.

Watershed Management and Permitting Issues

There are many implications of redirecting the stormwater management and regulatory system from a site-by-site, SCM-by-SCM approach to an emphasis on attainment of beneficial uses throughout a watershed. Most fundamentally, the program's focus would shift to a primary concentration on broad goals in terms of, for example, achieving a targeted condition in a biological indicator associated with aquatic ecosystem beneficial uses or no net increase in elevated

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flow duration. Application of site-specific stormwater control measures (SCMs) would no longer constitute presumptive evidence of permit compliance, as is often the case in permits now, although it would still be an essential means to meeting goals. Achieving those goals, however, would form the compliance criteria.

In recognition of the demonstrated negative effects of watershed hydrologic modification on the attainment of beneficial uses, the proposal steps beyond the generally prevailing practice by embracing water quantity as a concern along with water quality. The inclusion of hydrology is consistent with the CWA on several grounds. First, elevated runoff peak flow rates and volumes increase erosive shear stress on stream beds and banks and directly contribute particulate pollutants to the flow (such as suspended and settleable solids, as well as nutrients and other contaminants bound to the soil material). Conversely, reduced dry-weather flows often occur in urban streams as a result of lost groundwater recharge and tend to concentrate pollutants and, hence, worsen their biological effects. Moreover, pollutant mass loading is the product of concentration and flow volume, and thus increased wet-weather surface runoff directly augments the cumulative burden on receiving waters. Finally, regulatory precedent for incorporating hydrology exists, as demonstrated by Vermont's stormwater program (LaFlamme, 2007).

At this time, stormwater management and regulation are divorced from the management and regulation of municipal and industrial wastewater. A true watershed-based approach would incorporate the full range of municipal and industrial sources, including (1) public streets and highways; (2) municipal stormwater drainage systems; (3) municipal separate and combined wastewater collection, conveyance, and treatment systems; (4) industrial stormwater and process wastewater discharges; (5) private residential and commercial property; and (6) construction sites. These many sources represent an array of uncoordinated permits under the current system and a strong challenge to developing a watershed-based approach. As pointed out in Chapter 2, multi-source considerations are an implicit facet of TMDL assessments, wherein states must consider both point and nonpoint sources. EPA (2003b) identified, among other possible permit types, an Integrated Municipal NPDES Permit, which would bundle all requirements for a municipality (e.g., stormwater, combined sewer overflows, biosolids, pretreatment) into a single permit. The Tualatin River watershed in Oregon has faced this challenge, at least in part, through an innovative watershed permit that combines both wastewater treatment and stormwater, brings in management of agricultural contributions to thermal pollution, and allows for pollutant trading among sources (see Box 6-2). It appears that the various participating parties did not use their energies in trying to allocate blame but instead determined the most effective and efficient ways of improving conditions. For example, the municipal permittees willingly offered incentives to agricultural landowners to plant riparian shade trees as an alternative to more expensive means of reducing stream temperatures under their direct control. Indeed, with agriculture not being regulated by the Clean Water Act, watershed permitting

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BOX 6-2
Watershed-Based Permitting in Oregon

Clean Water Services is a wastewater and stormwater utility that covers a special service district of 12 cities and unincorporated areas in urban Washington County, Oregon. It was originally chartered in the 1970s as the Unified Sewerage Agency to consolidate the management of 26 "package" wastewater treatment facilities. Its responsibilities expanded to stormwater management in the early 1990s and it now serves nearly 500,000 customers. There are four wastewater treatment plants (WWTPs) in the district, with a dry weather capacity of 71 million gallons per day (MGD). During low-flow months, the discharge from these plants can account for 50 percent of the water in the Tualatin River. The district also own rights to one-quarter of the stored water in Hagg Lake. The land use in the watershed is about one-third urban, one-third agriculture, and one-third forest.

In 2001, the region was faced with TMDLs on the Tualatin River or its tributaries for total phosphorus, ammonia, temperature, bacteria, and dissolved oxygen. By 2002, the area was also dealing with four expired NPDES permits and one expired MS4 permit (all of which had been administratively extended), approval of a second TMDL, and an Endangered Species Act (ESA) listing. The region decided that it wanted to try to integrate all of these programs using a watershed-based regulatory framework. This would include a TMDL implementation mechanism, an ESA response plan, and integrated water resources management (meaning that water quantity, water quality, and habitat considerations would be made at the same time). Prior to integration, water quality was covered by the TMDL and NPDES programs, but these programs did not cover water quantity and habitat issues. The ESA listing addressed the habitat issues, but it was done totally independently of the TMDLs and NPDES permits.

Thus, the region applied for an integrated municipal NPDES permit that bundles all NPDES permit requirements for a municipality into a single permit, including publicly owned treatment works (POTWs), pretreatment, stormwater, sanitary sewer overflows, and biosolids. Initially, it encompassed the four WWTP permits, the one MS4 permit, and the industrial and construction stormwater permits. The hope was that this would streamline multiple permits and capture administrative and programmatic efficiencies; provide a mechanism for implementing more cost-effective technologies and management practices including water quality credit trading; integrate watershed management across federal statutes such as the CWA, SDWA, and ESA; and encourage early and meaningful collaboration and cooperation among key stakeholders.

This case study was successful because a single entity—Clean Water Services—was already in charge of what would have otherwise been a group of individual permittees. Furthermore, all the NPDES permits had expired and the TMDL had just been issued, providing a window of opportunity. The state regulatory agency was very willing, and EPA provided a $75,000 grant. Finally, there was a robust water quality database and modeling performed for the area because of the previous TMDL work. The watershed-based permit, the first in the nation, was issued February 26, 2004. Among its unique elements are an intergovernmental agreement companion document signed by the Oregon Department of Environmental Quality (DEQ), water quality credit trading, and consolidation of reporting requirements. The water quality trading is one of the most interesting elements, and several variations have been attempted. Biological oxygen demand (BOD) and NH_3 have been traded both intra-facility and inter-facility.

The temperature TMDL on the Tualatin River is a particularly interesting example of trading because it helped to bring agriculture into the process, where it would otherwise not have been involved. Along the length of the river, there are portions that exceed the temperature standard. A TMDL allocation was calculated that would lower temperatures by the

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BOX 6-2 Continued

same amount everywhere, such that there would be no point along the river that would be in exceedance. Options for reducing temperature include reducing the influent wastewater temperature (which is hard to do), reducing the total WWTP discharge to the Tualatin River (which is not practical), mechanically cooling or refrigerating WWTP discharge (which would require more energy), or trading the heat load via flow augmentation and increased shading (which is what was attempted).

Clean Water Services choose to utilize a market-based, watershed approach to meet the Tualatin temperature TMDL. It was market-based because it had financial incentives for certain groups to participate, it was cost-effective, and it provided ancillary ecosystem services. It was a watershed-based approach because it capitalized on the total assimilative capacity of the basin. What was done was to (1) provide cooling and in-stream flow augmentation by releasing water from Hagg Lake Reservoir, and (2) trade riparian stream surface shading improvement credits. They also reused WWTP effluent in lieu of irrigation withdrawals. For the riparian shading, they developed an "enhanced" CREP program to increase the financial incentives to rural landowners (with Clean Water Services paying the difference over existing federal and state programs). Clean Water Services also made incentive payments to the Soil and Water Conservation District to hire people to act as agents of Clean Water Services. Oregon DEQ's Shadalator model was used to quantify thermal credits for riparian planting projects, which required that information be collected at 100-foot increments along the stream on elevation, aspect, wetted width, Nordfjord-Sogn Detachment Zone, channel incision, and plant type and planting corridor width. To summarize, over the five-year term of the permit, Clean Water Services will release 30 cfs/d of stored water from Hagg Lake each July and August and shade roughly 35 miles of tributary riparian area (they have already planted 34 miles of riparian buffer). This plan involved an element of risk taking, since the actions of unregulated parties (such as farmers) have suddenly become the responsibility of Clean Water Services.

and initiatives of this type represent the best, and perhaps only, mechanism for ameliorating negative effects of agricultural runoff that, left unattended, would undo gains in managing urban runoff. The Neuse River case study, discussed later in this chapter, is another example of bringing agricultural contributions to aquatic degradation under control, along with urban sources, through a watershed-based approach.

Significant disadvantages of the current system of separate permits for municipal, construction, and industrial activities are (1) the permits attack the problem on a piecemeal basis, (2) they are hard to coordinate because they expire at different times, (3) they are not designed to allow for long-term operation of SCMs, and (4) they do not cover all discharges. A solution to these problems would be to integrate all discharge permitting under municipal authority, as is proposed here. The lead permittee and co-permittees would bear ultimate responsibility for meeting watershed goals and would regulate all public and private discharges within their jurisdictions to attain them. Municipalities are the natural focus for this role because they are the center of land-use decisions throughout the nation.

Municipalities must be provided with substantially greater resources than they have now to take on this increased responsibility. Beyond funding, regula-

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tory responsibilities must be realigned to some degree. The norm now is for states to administer industrial permits directly and generally attend to all aspects of permit management. However, states, more often than not, are unable because of resource limitations to give permittees much attention in the form of inspection and feedback to ensure compliance. At the same time, some states, explicitly or implicitly, expect municipal permittees to set up programs to meet water quality standards in the waters to which all land uses under their jurisdictions discharge.[1] It only makes sense in this situation to have designated states (or EPA for the others) specify criteria for industrial and construction permits but revise regulations to empower and support municipal co-permittees in compliance-related activities. This paradigm is not unprecedented in environmental permitting, as under the Clean Air Act, states develop state implementation plans for implementation by local entities. For this new arrangement to work, states would have to be comfortable that municipalities could handle the responsibility and be able to exercise the added authority granted. The committee's opinion is that municipalities generally do have the capability, working together as co-permittees with a large-jurisdiction lead permittee and with guidance and support from states.

It bears noting at the outset that the proposed new program would not reduce the present system's reliance on general permits. Whereas a general permit now can be issued to a group of municipalities having differing circumstances, under the new system a permit could just as well be formulated in the same way for a group of varying watersheds. General industrial and construction permits would be just as prevalent too.

Toward Watershed-Based Permitting

Watershed-based permitting is taken in this report to mean regulated allowance of discharges of water and wastes borne by those discharges to waters of the United States, with due consideration of (1) the implications of those discharges for preservation or improvement of prevailing ecological conditions in the watershed's aquatic systems, (2) cooperation among political jurisdictions sharing a watershed, and (3) coordinated regulation and management of all discharges having the potential to modify the hydrology and water quality of the watershed's receiving waters.

[1] For example, the second Draft Ventura County [California] Municipal Separate Storm Sewer System Permit states (under Findings D. Permit Coverage), "Provisions of this Order apply to the urbanized areas of the municipalities, areas undergoing urbanization and areas which the Regional Water Board Executive Officer determines are discharging storm water that causes or contributes to a violation of a water quality standard … ." The permit further states (under Part 2—Receiving Water Limitations), "1. Discharges from the MS4 that cause or contribute to a violation of water quality standards are prohibited. … 3. … This Order shall be implemented to achieve compliance with receiving water limitations. If exceedence(s) of water quality objectives or water quality standards persist … the Permittee shall assure compliance with discharge prohibitions and receiving water limitations … ."

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Determining Watershed Scale for Permitting

A fundamental question that must be answered at the outset of any move to watershed permitting is, What is a watershed? Hydrologically, a watershed is the rain catchment area draining to a point of interest. Hence, the question comes down to, Where should the point of interest be located to define watersheds for permitting purposes? If placed close to the initial sources of surface runoff (e.g., on each first-order stream just above its confluence with another first-order stream), attention would be very specifically directed. However, there would be little flexibility to devise solutions for the greatest good. For example, trading of the commodities runoff quantity and quality would be very restricted. If on the other hand the point of interest is placed far downstream, thus defining a very large watershed, a welter of issues, and probably also of involved jurisdictions, would overly confuse the management and regulatory task.

The U.S. Geological Survey (USGS) delineates watersheds in the United States using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloging units. These hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). USGS identifies each hydrologic unit by a unique hydrologic unit code (HUC) consisting of 2 to 16 digits based on the four levels of classification in the hydrologic unit system. Watersheds thus delineated are typically of the order a few square kilometers in area. This system is now being linked to the National Hydrography Dataset (NHD) and the National Land Cover Dataset to produce NHDPlus, an integrated suite of application-ready geospatial datasets.

The USGS system provides a starting point. Ultimately, though, what constitutes a watershed will best be answered with reference to specific biogeophysical conditions and problems and by personnel at relatively close hand (i.e., state or regional oversight agency staff). A general guideline might be the catchment area of a waterbody influenced by a set of similar subwatersheds. Similar subbasins would presumably be amenable to similar solutions and trading off reduced efforts in some places for compensating additional efforts elsewhere, as well as to analysis and monitoring on a representative basis, instead of exhaustively throughout. Often, a watershed defined in this way would flow into another watershed and influence it. Thus, there would have to be coordination among managers and regulators of interacting watersheds. It would be common for several watersheds ranging from relatively small to large in scale to be nested. Each would have its management team, and a committee drawn from those teams should be formed to coordinate goals and actions.

A prerequisite to moving toward watershed permitting, then, is for states or regions within states to delineate watersheds. California took this step early in the NPDES stormwater permitting process and offers a model in this respect, as well as in encompassing all jurisdictions coordinated by a lead permittee. First, the state organized its California EPA regional water boards on a watershed ba-

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sis. Furthermore, since 1992 it has been common in California to establish one jurisdiction as the lead permittee (e.g., Los Angeles County in the Los Angeles region, Orange County in the Santa Ana Region, and San Diego County in the San Diego Region) and all of the politically separate cities as co-permittees. The lead permittee has typically been the jurisdiction most widely distributed geographically in the region and large enough to develop compliance mechanisms and coordinate their implementation among all participants. Box 6-3 describes the approach taken to delineating management units within the Chesapeake Bay watershed, which comprises parts of Pennsylvania, Maryland, Virginia, and the District of Columbia. The case study illustrates well the approach advocated here of focusing on the outcome in the receiving water and considering all aspects of land and water resources management that determine that outcome.

Steps Toward Watershed-Based Permitting

Once a watershed is defined, a further question arises regarding how much and what part of its territory to cover formally under permit conditions. Under the present system substantial development occurring outside Phase I or Phase II municipal jurisdictions is escaping coverage. Failing to control relatively high levels of development both outside a permitted jurisdiction and upstream of more lightly developed areas within a permitted area is particularly contrary to the watershed approach. Areas having a more urban than rural character are already essentially treated as urban in water supply and sewer planning, and the same should occur in the area of stormwater management. Accordingly, the permit should extend to any area in the watershed, even if outside Phase I or II jurisdictions, zoned or otherwise projected for development at an urban scale (e.g., more than one dwelling per acre). States do have authority under the CWA to designate any area for Phase II coverage based on projected growth or the presence of impact sources. They should be required to do so for nationwide uniformity and best protection of water resources.

It is essential to clarify that watershed-based permitting as formulated in this chapter differs sharply from what has been termed watershed (or basin) planning. According to EPA, watershed planning "identifies broad goals and objectives, describes environmental problems, outlines specific alternatives for restoration and protection, and documents where, how, and by whom these action alternatives will be evaluated, selected, and implemented" (*http://www.epa.gov/watertrain/planning/planning7.htm*). Drawing up such a plan is a time-consuming process, which has often become an end in itself, instead of a means to an end. Completing a full watershed plan, as usually construed, should not be a prerequisite to watershed-based permitting. Rather, the anticipated process would spring much more from comprehensive, advanced scientific and technical analysis of the water resources to be managed and their contributing catchment areas than from a planning framework.

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BOX 6-3
Watershed Delineation for the Chesapeake Bay

The "Tributary Strategy Team" approach of the Chesapeake Bay Watershed provides a specific example of a watershed-scale approach to implementation of water quality control measures. Some background on this longstanding program is first provided, before turning to how watersheds were delineated. In 1983, the states of Virginia, Maryland, and Pennsylvania; the District of Columbia; and EPA signed an agreement to form the Chesapeake Bay Program with a goal to restore and protect the bay, which was suffering from nutrient overenrichment, severely reduced submerged aquatic vegetation, and contamination by toxics. In 1987 the program established a target of a 40 percent reduction in the amount of nutrients entering the Bay by 2000. In 1992 the bay program partners agreed to continue the 40 percent reduction goal beyond 2000 by allocating nutrient reduction targets to the bay's tributaries. In Chesapeake 2000, the most recent version of the Chesapeake Bay agreement, the nutrient reduction goals were reaffirmed, and an additional goal of sediment reduction was established. New York, Delaware, and West Virginia, locations of the bay's headwaters, also became involved in nutrient and sediment reduction. Cap load allocations for nutrients (nitrogen and phosphorus) and sediment to be reached by 2010 were agreed upon by the states. The states began developing 36 voluntary watershed-based tributary strategies to meet the state cap load allocations covering the entire 64,000-square-mile Chesapeake Bay watershed.

Watershed-based tributary strategies are developed in cooperation with local watershed stakeholders. For rural areas, where stakeholders include farmers, nutrient strategies include promotion of management practices such as maintaining cover crops on recently harvested cropland to reduce soil erosion, reduction in nitrogen applications, conservation tillage, and establishment of riparian buffers. For urban-area stakeholders such as homeowners and municipalities, tributary strategies include practices such as enhanced nutrient removal at WWTPs, low-impact development (LID) practices, erosion and sediment control practices, and septic system upgrades.

The first cut at delineating the watershed, which was based on hydrography and topography, defined the eight major areas draining to the Chesapeake Bay: six major basins (Susquehanna, Potomac, York, James, Rappahannock, and Patuxent) plus smaller areas not draining to a major river on the Eastern and Western Shores of the bay in Maryland. These subdivisions are disparate with respect to size (the Susquehanna can engulf almost the entire other seven), but direct drainage to the bay was the criterion at this level.

The next cut was made at state borders. For example, the Susquehanna traverses three states and was subdivided at the New York–Pennsylvania and Pennsylvania–Maryland political boundaries. Further cuts were subsequently made within some states. The criteria for these cuts varied from state to state, but generally involved a combination of smaller political jurisdictions (e.g., county, township), subwatershed basin borders, and other local considerations, such as local interest and investment (e.g., watershed associations).

The resulting delineations are highly variable in size but apparently satisfactory to the local parties who decided on the areas. They represent individual "tributary strategy areas" but are also nested within the larger eight designations and involve interjurisdictional and interstate coordination where a subbasin is divided by a political boundary. Although the example of the Chesapeake Bay is at a very large scale, the principles of watershed delineation it illuminates apply at all scales.

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Effective watershed-based permitting as outlined in this report is composed of:

- Centralizing responsibility and authority for implementation with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees;
- Adopting a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses within the watershed's component waterbodies;
- Assessing waterbodies that are not providing designated beneficial uses in order to set goals aimed at recovering these uses;
- Defining careful, complete, and clear specific objectives to be achieved through management and permitting;
- Comprehensive impact source analysis as a foundation for targeting solutions;
- Determining the most effective ways to isolate, to the extent possible, receiving waterbodies from exposure to those impact sources;
- Developing and appropriately allocating funding sources to enable the lead permittee and partners to implement effectively;
- Developing a monitoring program composed of direct measures to assess compliance and progress toward achieving objectives and diagnosing reasons for the ability or failure to meet objectives, in support of active adaptive management; and
- Developing a market system of trading credits as a tool available to municipal co-permittees to achieve watershed objectives, even if solutions cannot be uniformly applied.

The system proposed herein is a significant departure from the road traveled in the 20 years since CWA amendments began to bring stormwater under direct regulation. This reorganization is necessary because of the failure of the present system to achieve widespread and relatively uniform compliance (see Chapter 2) and, ultimately, to protect the nation's water resources from degradation by municipal, industrial, and construction runoff. The workload associated with adopting this approach will be considerable and will take some time to complete. The structure of the new program should be fully in place within five years, which is considered to be a reasonable period to complete the work. It could be fully implemented throughout the nation within ten years. However, interim measures toward its fulfillment should occur sooner, within one to two years. Such measures should be applied to each land-use and impact-source category (i.e., existing residential and commercial development, existing industry, new development, redevelopment, construction sites). For example, measures such as an effective impervious area limit or a requirement to maintain predevelopment recharge to the subsurface zone could make early progress in man-

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aging new development, and lead toward the ultimate, objective-based management and permitting strategy for that category. Advanced source control performance standards would be appropriate interim measures for existing development.

One innovative approach to watershed-based management that can ease the burden of the proposed new system is the rotating basin approach. As described by EPA (2007a), this option entails delineating state watershed boundaries and grouping the watersheds into basin management units, usually by the state water pollution control agency. Next, states implement a watershed management process on a rotating schedule, which is usually composed of five activities: (1) data collection and monitoring, (2) assessment, (3) strategy development, (4) basin plan review, and (5) implementation. Over time, different waterbodies are intensively studied as part of the rotation. Data collected can be used to support a number of different reporting and planning requirements, including a finding of attainment of water quality standards, a determination of impairment, or possible delisting if the waterbody is found not to be impaired. Florida offers a good example of the rotating basin approach. The Florida Department of Environmental Protection has defined five levels of intensity, or phases, each taking about one year to complete, and it has divided the state into 30 areas based on HUCs. At any one time six areas are in each phase before rotating to a subsequent phase. This division of effort would help alleviate the burden of moving to a new system of watershed-based permitting by programming the work over a period of years. It could certainly be organized on a priority basis, in which the watersheds of greatest interest for whatever reason (e.g., having the highest resource values, being most subject to new impacts) would get attention first.

An Objective-Based Framework

The proposed framework for watershed-based management and regulation of stormwater relies on broad goals to retain and recover aquatic resource beneficial uses, backed by specific objectives (e.g., water quality criteria) that must be achieved if the goals are to be fulfilled. Meeting the objectives and overarching goals is intended to become the basis for determining permit compliance, instead of the current reliance on implementation of SCMs as presumptive evidence of compliance.

The broad goals of retaining and recovering beneficial uses are entirely consistent with the antidegradation clause of the CWA. Antidegradation means that the current level of water quality shall be maintained and protected, unless waters exceed levels necessary for maintaining their beneficial uses *and* the state finds that allowing lower water quality is necessary to accommodate important economic or social development. In accordance with the antidegradation clause, a major pillar of the proposed concept is the goal of preventing degradation from the existing state of biological health, whatever it may be, to a lower state. Thus, fully and nearly pristine watersheds are to remain so and, at a minimum,

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partially or highly impaired ones are to suffer no further impairment. Beyond this minimum, impaired waters should be assessed to determine if feasible actions can be taken to recover lost designated beneficial uses or at least improve degraded uses.

As discussed in Chapter 2, beneficial uses relate to the social and ecological services offered, or intended to be offered, by waterbodies. For example, California has 20 categories of beneficial uses embracing water supply for various domestic, agricultural, and industrial purposes; provision of public recreation; and support of aquatic life and terrestrial wildlife (CalEPA, Central Coast Regional Water Board Basin Plan). That beneficial uses are usually assigned at the state level by waterbody classes or specific waterbodies would not change under the proposed permitting program revision. Most waters have several beneficial uses encompassing some water supply and ecological functions and, perhaps, some form of recreation. Unlike most current stormwater programs where attainment of beneficial uses is only implicit, these goals would become explicit in the altered system and officially promulgated by the authority operating the permit program (a designated state, in most cases, or EPA). The permitting authority would then partner with municipal permittees to determine the conditions that must be brought to bear to attain beneficial uses, set objectives or criteria to establish those conditions, and follow through with the tasks to accomplish objectives.

The proposed framework's reliance on achieving objectives that reflect the cumulative aquatic resource effects of contributing watershed conditions suggests the following related concepts:

- In whatever manner watershed boundaries are set, the full extent of the watershed from headwaters onward should be considered in defining objectives. This is important even where watershed scale and boundaries are based on local and/or regional hydrogeomorphic circumstances and their associated management and regulatory needs. Watersheds can and often will be defined and nested at different scales (e.g., streams tributary to a lake, a river flowing into an estuary or marine bay).

- The scale of objectives must be consistent with the scale and recognized beneficial uses of the watershed(s) in question; for example, sustaining salmonid fish spawning could be the basis for a stream objective, while retaining an oligotrophic state could be the essential objective for a lake to which the stream is tributary.

- Whenever beneficial uses pertain to living organisms (aquatic life or humans), representing the vast majority of all cases, objectives should be largely in biological terms. That is not to say that supplementary objectives cannot be stated otherwise (e.g., in terms of flow characteristics, chemical water quality constituents, or habitat attributes), but the ultimate direct thrust of the program

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should be toward the biota.

- Objectives must be carefully chosen to represent attributes of importance from a resource standpoint, limited in number for feasibility of tracking achievement, and defined in a way that achievement can be measured. For example, nitrogen is generally the nutrient limiting algal growth in saline systems and in excess it stimulates growth that can reduce dissolve oxygen, killing fish and other aerobic organisms. In this case the most productive objectives would probably target reduction of nitrogen concentration and mass flux and maintenance of dissolved oxygen. For waterbodies designated for contact recreation, fecal coliform indicators (although not directly pathogenic when waterborne) have proven to be an effective means of assessing condition and should continue to form the basis for objectives to protect contact recreation until research produces superior measures. If drinking water supply is a designated beneficial use of a lake, it will better serve that function in a lower than a higher state of eutrophication, which can be managed, according to a long limnological research record, by restricting water column chlorophyll *a* as an objective. Where the beneficial use is fish protection and propagation, biological criteria might include (1) maintenance of a specific population size of a resident fish species when that species' population can be assayed conveniently; (2) maintenance of a numerical index (e.g., benthic index of biotic integrity) when a fish species of ultimate interest cannot be assessed so conveniently but is known or reasonably hypothesized to be associated with the index; or (3) a related parameter, such as eelgrass beds, which are important fish nursery areas in estuarine waters, such that areal coverage by these beds would be an appropriate objective to track over time. An intermittent waterbody could have biological criteria related to, for example, fish migration or amphibian reproduction.

- The achievement of objectives, or lack thereof, is the basis for follow-up and prescription of remedies in an active adaptive management mode; that is, falling short of objectives would trigger a search for reasons throughout the watershed, followed by identification of actions necessary and sufficient to remedy the shortfall, assessment of their ability to reach objectives, and the cost of doing so. In the course of this assessment it may be concluded that the objective itself is faulty and should be restated, replaced, or discarded.

Basing the watershed framework principally on biological objectives grows out of the CWA's fundamental charge to protect the biological (as well as physical and chemical) integrity of the nation's waters. The tie between specific physical and chemical conditions and the sustenance of aquatic biological communities is not well established through an extensive, well-verified body of research. Moreover, living organisms consuming or living in water are subject to a vast multitude of simultaneous physical and chemical agents having the potential to harm them individually and interactively. There are no realistic prospects

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for research to determine the levels of these numerous agents that must be maintained to support beneficial uses. Therefore, their integrative effects must be determined using measures of biological populations or communities of interest.

By and large, state water quality standards as now promulgated would not serve the proposed objective-based system well. They are usually not phrased in biological terms or with respect to hydrologic variables now known to have instrumental negative effects on aquatic organisms, but instead mostly as concentrations of selected chemical elements or compounds. However, there is no prohibition of biological or hydrologic standards in the law. The recommended emphasis is consistent with and informed by the tiered aquatic life uses system applied by some states and illustrated for Ohio in Box 2-1. The use of such systems must expand greatly to support the recommended framework. An opportunity to do so exists through the triennial review already required for each state's water quality standards.

Certain special considerations affect the development and use of objectives as the device to carry forward watershed-based stormwater management and regulation. First, other elements of the CWA beyond the stormwater program and other laws may very well be involved in a watershed (see Chapter 2). Municipal and industrial wastewater discharges will often be contributors along with stormwater. Aquatic organisms may be listed as threatened or endangered under the federal ESA or state authority. Both objectives and the management and regulatory program designed to achieve objectives should reflect any such circumstances.

Instituting the proposed permitting program will require converting the TMDL program to one more suitable for its purposes and structure. The TMDL program is watershed based and hence offers some precedent and experience applicable to the new system. However, for the most part, it has operated only on waters declared to be impaired for specific pollutants, and it relies on management of specific physical and chemical water quality variables. Furthermore, in its current mode it takes no account of potential future impact sources. The TMDL program should be replaced with one adapted to the objective-based framework proposed here. This new program should apply to all waters assigned objectives, "impaired" or not, and formulate limits in whatever terms are best to achieve objectives. Hence, although the program would expand in coverage area, the efficient tailoring of objectives directly to beneficial uses could compensate for the expansion by targeting fewer variables. Finally, the new program should look to the future as well as the present by encompassing the anticipated impacts of prospective landscape changes.

The nature of a program to replace TMDLs can be glimpsed from a few attempts to move in the anticipated direction even under the existing structure. For example, Connecticut collected data directly linking impervious cover to poor stream health in Eagleville Brook (Connecticut Department of Environmental Protection, 2007). The stream's TMDL was developed using watershed impervious cover as a surrogate parameter for a mix of pollutants conveyed by stormwater. The intention is to reduce effective imperviousness by disconnect-

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ing impervious areas, installing unspecified SCMs, minimizing additional disturbance, and enhancing in-stream and riparian habitat. Flow was used as a surrogate for stormwater pollution in the Potash Brook, Vermont TMDL (Vermont DEC, 2006). In this waterbody, the impairment was based on biological indices that were then related to a hydrologic condition believed to be necessary to achieve the Vermont criteria for aquatic life. The TMDL will be implemented via the use of runoff-volume-reduction SCMs throughout the watershed.

Impact Sources

The CWA provides for regulating, as specific land-use types, only designated industrial categories, with construction sites disturbing one acre or more considered to be one of those categories. Otherwise, it gives authority to regulate municipal jurisdictions operating separate storm sewer systems. Generally speaking, these jurisdictions encompass, in addition to the industrial categories, the full range of urban land-use types, such as single- and multiple-family residential, various kinds and scales of commercial activity, institutional, and parks and other open space. All of these land uses and the activities conducted on them are, to one degree or another, sources of the agents that physically and chemically modify aquatic systems to the detriment of their biological health. Hence, most of the impact sources to which these aquatic systems are subject are not directly regulated under CWA authority as are industrial sources, but instead are indirectly regulated through the municipal program. Also, as already discussed, the situation is further complicated by the presence of municipal and industrial wastewater sources along with landscape sources contributing flow and pollutants to receiving waters via stormwater discharges.

The watershed-based framework envisioned here relies on municipalities led by a principal permittee. Thus, a fundamental task that municipal permittees charged with operating under a watershed-based permit must do is to find industries and construction sites in the watershed that have not filed for permit coverage and bring them under regulation. Furthermore, municipal co-permittees, with leadership by a watershed lead permittee, must classify industries and construction sites within their borders according to risk and accordingly prioritize them for inspection and monitoring (methods for doing this are discussed later in the chapter). Municipal permittees must have better tools than they have had in the past to assess the various impact sources and formulate strategies to manage them that have a reasonably high probability of fulfilling objectives. The present state of practice and research findings offers some directions for choosing or more completely developing these tools. However, by no means are all the necessary elements available, and substantial new basic and applied research must be performed.

From the literature come several possibilities to improve source analysis in the complex urban environment. Some examples of apparent promise, drawn from Clark et al. (2006) include the following:

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- Nirel and Revaclier (1999) used the ratio of dissolved rubidium (Rb) to strontium (Sr) to identify and quantify the impact of sewage effluents on river quality in Switzerland. Rubidium was present in larger quantities than strontium in feces and urine, making the ratio of these two elements an effective tracer that does not vary with river flow for a given water quality condition. Using the ratio alone produced the same conclusions regarding impact as measuring a host of physicochemical water quality variables. The researchers estimated that the Rb:Sr ratio must be lower than 0.007 if biological diversity is to be maintained, which could be the basis of an objective to manage river water quality. Although this case pertains to municipal wastewater and the technique works best in waters with a naturally low Rb:Sr ratio (e.g., calcareous regions), it success points out a potential avenue of research to simplify stormwater management on the basis of quantitative objectives related to biological integrity.

- Cosgrove (2002) described the approach used in New Jersey to characterize the relative contribution of point and nonpoint sources of pollutants in the Raritan River Basin. Twenty-one surface water sampling locations within the watershed were monitored four to five times per year from 1991 to 1997. These data were evaluated by comparing the median concentration at each sampling location with land-use statistics. Cumulative probability curves were also developed for each pollutant to demonstrate the probability that the concentration at a given location would be below a certain level (e.g., a stream standard). These probability curves were useful in determining the risk that a given location would violate a particular standard. The concentration data, coupled with continuous flow monitoring records, were utilized to determine the total load for each constituent. Regression analysis was used to develop a relationship between the total in-stream loads and flow. Such an analysis provided an indication of municipal or industrial discharge versus diffuse-source-dominated locations. Pollutant loads could then be converted to yield (load per unit area) to normalize the results for comparison from one station to another. The "screening level" methodology uses only existing data and, not requiring advanced modeling techniques, can be used to understand where to focus more rigorous modeling techniques.

- Maimone (2002) presented the overall approach that was used to screen and evaluate potential pollutant sources within the Schuylkill River watershed as part of the Schuylkill River Source Water Assessment Partnership. The partnership performed source water assessments of 42 public water supply intakes for the Pennsylvania Department of Environmental Protection. The watershed encompasses over 1,900 square miles with more than 3,000 potential point sources of contamination. In addition, runoff from diverse land uses such as urban and agriculture had to be characterized using the Stormwater Management Model. For all 42 surface water intakes, potential point sources were identified using existing databases. The list was first passed through a series of Geographic In-

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formation System-based "screening" sieves to limit the sources to only those considered to be high priority (including proximity and travel time from source to intake). Ten categories were identified that cover the range of the most important contaminants that might be found within the watershed, and a representative or surrogate chemical was identified whose properties were used to stand in for the category. Beyond the geographic screening, a more sophisticated screening was needed to limit the number of sites, using a decision support computer software program called EVAMIX. The greatest benefit of EVAMIX, compared to other software, is that it allows mixed criteria evaluation, qualitative and quantitative, to be considered concurrently. EVAMIX produced source rankings representing an organized and consistent use of both the objective data and the subjective priorities of decision makers.

- Hetling et al. (2003) investigated the effect of water quality management efforts on wastewater discharges to the Hudson River (from Troy, New York to the New York City Harbor) from 1900 to 2000. The paper demonstrated a methodology for estimating historic loadings where data are not available. Under these circumstances, estimated historic sewered and treated populations and per capita values were used to calculate wastewater flow and loadings for 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen, and total phosphorus. The analysis showed that dispersed landscape sources have become the most significant contributors of the first two contaminants to the river, while municipal wastewater plants remain the largest sources of nutrients. The methodology presented in this paper could be used by co-permittees to estimate present-day sources of various types and contribute to moving toward a comprehensive permit incorporating multiple sources.

- Zeng and Rasmussen (2005) used multivariate statistics to characterize water quality in a lake and its tributaries. Tributary water was composed of three components. Factor analysis demonstrated that stormwater runoff was the predominant cause of elevation of a group of water quality variables in a factor including TSS, the measurement of which is a convenient surrogate for all variables in the factor. Similarly, municipal and industrial discharges could be characterized by total dissolved solids, and groundwater by alkalinity plus soluble reactive phosphorus. These sources can thus be distinguished through measurement of just four common water quality variables. Reducing the number of analytes reduces laboratory costs and allows resources to be freed up for other purposes. Cluster analyses performed on the data indicated that further savings could be realized by sampling just one among several stations in a cluster and sampling at just one point in time over a period of relatively stable water quality (e.g., a relatively dry period).

A key research need associated with applying the proposed framework is assessment of these and other mechanisms for sorting out the contributions of

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the variety of impact sources in the urban environment. Leading this effort would be a natural role for EPA.

Impact Reduction Strategies

The philosophical basis for impact reduction under a modified permitting system centered on a lead municipal permittee and associated co-permittees is to avoid, as far as possible, exposing receiving waters to impact sources or to otherwise minimize that exposure. The concept embraces both water quantity and quality impact sources and specifically raises the former category to the same level of scrutiny as traditionally applied to water quality sources. Furthermore, the endpoints upon which success and compliance would be judged are directly related to achievement of beneficial uses. This approach to impact reduction, where the direct focus is on reducing the loss of aquatic ecosystem functioning supportive of beneficial uses, fundamentally contrasts with the currently prevailing system. What are primary concerns in the existing system (e.g., discharge concentrations of certain chemical and physical substances, technological strategies from a menu of practices) are still prospectively important, but only as a means toward realizing functional objectives, not as endpoints themselves. To be sure, attaining beneficial uses will require wise choices among tools to decrease discharges and contaminant emissions. However, the ultimate proof will always be in biological outcomes.

As made clear in Chapters 3 and 4, linkages among myriad stressing agents, impact receptors, and specific mitigating abilities of technological fixes are poorly understood and not easily understandable. The proposed new paradigm acknowledges that the linkages are not established among the voluminous elements in an exceptionally complex system ranging from impact sources, through environmental transport and fate mechanisms, to ecosystem health. However, it is intuitively and theoretically clear that minimizing the generation of impacts in the first place and slowing their progression into aquatic environments can break the chain of landscape alteration that leads to increased runoff and pollutant production, modifies aquatic habitat, and ultimately causes deterioration of the biological community. Landscapes can be managed in a preventive, integrated fashion that deals with the many undifferentiated agents of impact and avoids, or at least reduces, the damage. Although the application of these theories may not automatically and quickly stem biological losses, the powerful mechanism of adaptive management, if correctly applied, can be used to make course corrections toward meeting the defined objectives.

An earlier National Research Council (NRC) committee examined the scientific basis of EPA's TMDL program and recommended "adaptive implementation" (AI) to water quality standards (NRC, 2001a). That committee drew AI directly from the concept of adaptive management for decision making under uncertainty, introduced by Holling and Chambers (1973) and Holling (1978) and described it as an iterative process in which TMDL objectives and the imple-

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mentation plans to meet those objectives are regularly reassessed during the ongoing implementation of controls. Shabman et al. (2007) and Freedman et al. (2008) subsequently extended and refined the applicability of AI for promoting water quality improvement both within and outside of the TMDL program. In that broader context, AI fits well with the framework put forward here. Indeed, the proposed revised monitoring system presented later in this chapter is designed to provide information to support adaptive management in a permitting context.

The Stages of Urbanization and Their Effects on Strategy

In waterbodies that are not in attainment of designated uses, it is likely that the physical stresses and pollutants responsible for the loss of beneficial uses will have to be decreased, especially as human occupancy of watersheds increases. Reducing stresses, in turn, entails mitigative management actions at every life stage of urban development: (1) during construction when disturbing soils and introducing other contaminants associated with building; (2) after new developments on Greenfields are established and through all the years of their existence; (3) when any already developed property is redeveloped; and (4) through retrofitting static existing development. Most management heretofore has concentrated on the first two of those life stages.

The proposed approach recognizes three broad stages of urban development requiring different strategies: new development, redevelopment, and existing development. *New development* means building on land either never before covered with human structures or in prior agricultural or silvicultural use relatively lightly developed with structures and pavements (i.e., Greenfields development). *Redevelopment* refers to fully or partially rebuilding on a site already in urban land use; there are significant opportunities for bringing protective measures to these areas where none previously existed. The term *existing development* means built urban land not changing through redevelopment; retrofitting these areas will require that permittees operate creatively.

What is meant by redevelopment requires some elaboration. Regulations already in force typically provide some threshold above which stormwater management requirements are specified for the redeveloped site. For example, the third Draft Ventura County Municipal Separate Storm Sewer System Permit defines “significant redevelopment” as land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site. The permit goes on to state that where redevelopment results in an alteration to more than 50 percent of the impervious surfaces of a previously existing development, and the existing development was not subject to postdevelopment stormwater quality control requirements, the entire site becomes subject to application of the same controls required for new development. Where the alteration affects 50 percent or less of the impervious surfaces, only the modified portion is subject to these controls.

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All urban areas are redeveloped at some rate, generally slowly (e.g., roughly one or at most a few percent *per annum*) but still providing an opportunity to ameliorate aquatic resource problems over time. Extending stormwater requirements to redeveloping property also gradually "levels the playing field" with new developments subject to the requirements. As pointed out in Chapter 2, some jurisdictions offer exemptions from stormwater management requirements to stimulate desired economic activities or realize social benefits. Such exemptions should be considered very carefully with respect to firm criteria designed to weigh the relative socioeconomic and environmental benefits, to prevent abuses, to gauge just how instrumental the exemption is to gaining the socioeconomic benefits, and to compensate through a trading mechanism as necessary to achieve set aquatic resource objectives.

It is important to mention that not only residential and commercial properties are redeveloped, but also streets and highways are periodically rebuilt. Highways have been documented to have stormwater runoff higher than other urban land uses in the concentrations and mass loadings of solids, metals, and some forms of nutrients (Burton and Pitt, 2002; Pitt et al., 2004; Shaver et al., 2007). Redevelopment of transportation corridors must be taken as an opportunity to install SCMs effective in reducing these pollutants.

Opportunities to apply SCMs are obviously greatest at the new development stage, somewhat less but still present in redevelopment, but most limited when land use is not changing (i.e., existing development). Still, it is extremely important to utilize all readily available opportunities and develop others in static urban areas, because compromised beneficial uses are a function of the development in place, not what has yet to occur. Often, possibly even most of the time, to meet watershed objectives it will be necessary to retrofit a substantial amount of the existing development with SCMs. To further progress in this overlooked but crucial area, the Center for Watershed Protection issued a practical Urban Stormwater Retrofit Practices manual (Schueler et al., 2007).

Practices for Impact Reduction

As described in Chapter 5, in the past 15 to 20 years stormwater management has passed through several stages. First, it was thought that the key to success was to match postdevelopment with predevelopment peak flow rates, while also reducing a few common pollutants (usually TSS) by a set percentage. Finding this to require large ponds but still not forestalling impacts, stormwater managers next deduced that runoff volumes and high discharge durations would also have to decrease. Almost simultaneously, although not necessarily in concert, the idea of LID arose to offer a way to achieve actual avoidance or at least minimization of discharge quantity and pollutant increases reaching far above predevelopment levels. For purposes of this discussion, the SCMs associated with LID along with others are named Aquatic Resources Conservation Design (ARCD). First, this term signifies that the principles and many of the methods

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apply not only to building on previously undeveloped sites, but also to redeveloping and retrofitting existing development. Second, incorporating aquatic resources conservation in the title is a direct reminder of the central reason for improving stormwater regulation and management. ARCD goes beyond LID to encompass many of the SCMs discussed in Chapter 5, in particular those that decrease surface runoff peak flow rates, volumes, and elevated flow durations caused by urbanization, and those that avoid or at least minimize the introduction of pollutants to any surface runoff produced. This concentration reduction, together with runoff volume decrease, cuts the cumulative mass loadings (mass per unit time) of pollutants entering receiving waters over time. The SCM categories from Table 5-1 that qualify as ARCD include:

- Product Substitution,
- Watershed and Land-Use Planning,
- Conservation of Natural Areas,
- Impervious Cover Minimization,
- Earthwork Minimization,
- Reforestation and Soil Conservation,
- Runoff Volume Reduction—Rainwater Harvesting, Vegetated, and Subsurface,
- Aquatic Buffers and Managed Floodplains, and
- Illicit Discharge Detection and Elimination.

The menu of ARCD practices begins with conserving, as much as possible, existing trees, other vegetation, and soils, as well as natural drainage features (e.g., depressions, dispersed sheet flows, swales). Clustering development to affect less land is a fundamental practice advancing this goal. Conserving natural features would further entail performing construction in such a way that vegetation and soils are not needlessly disturbed and soils are not compacted by heavy equipment. Using less of polluting materials, isolating contaminating materials and activities from contacting rainfall or runoff, and reducing the introduction of irrigation and other non-stormwater flows into storm drain systems are essential. Many ARCD practices fall into the category of minimizing impervious areas through decreasing building footprints and restricting the widths of streets and other pavements to the minimums necessary. Water can be harvested from impervious surfaces, especially roofs, and put to use for irrigation and gray water system supply. Harvesting is feasible at the small scale using rain barrels and at larger scales using larger collection cisterns and piping systems. Relatively low traffic areas can be constructed with permeable surfaces such as porous asphalt, open-graded Portland cement concrete, coarse granular materials, concrete or plastic unit pavers, or plastic grid systems. Another important category of ARCD practices involves draining runoff from roofs and pavements onto pervious areas, where all or much can infiltrate or evaporate in many situations.

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If these practices are used, but excess runoff still discharges from a site, ARCD offers an array of techniques to reduce the quantity through infiltration and evapotranspiration and improve the quality of any remaining runoff. These practices include (1) bioretention cells, which provide short-term ponded and soil storage until all or much of the water goes into the deeper soil or the atmosphere; (2) swales, in which water flows at some depth and velocity; (3) filter strips, broad surfaces receiving sheet flows; (4) infiltration trenches, where temporary storage is in below-ground gravel or rock media; and (5) vegetated ("green") roofs, which offer energy as well stormwater management benefits. Natural soils sometimes do not provide sufficient short-term storage and hydraulic conductivity for effective surface runoff reduction because of their composition but, unless they are very coarse sands or fine clays, can usually be amended with organic compost to serve well.

ARCD practices should be selected and applied as close to sources as possible to stem runoff and pollutant production near the point of potential generation. However, these practices must also work well together and, in many cases, must be supplemented with strategies operating farther downstream. For example, the City of Seattle, in its "natural drainage system" retrofit initiative, built serial bioretention cells flanking relatively flat streets that subsequently drain to "cascades" of vegetated stepped pools created by weirs, along more sloping streets. The upstream components are highly effective in attenuating most or even all runoff. Flowing at higher velocities, the cascades do not perform at such a high level, although under favorable conditions they can still infiltrate or evapotranspire the majority of the incoming runoff (Horner et al., 2001, 2002, 2004; Chapman, 2006; Horner and Chapman, 2007). Their role is to reduce runoff from sources not served by bioretention systems as well as capture pollutants through mechanisms mediated by the vegetation and soils. The success of Seattle's natural drainage systems demonstrates that well-designed SCMs can mimic natural landscapes hydrologically, and thereby avoid raising discharge quantities above predevelopment levels.

In some situations ARCD practices will not be feasible, at least not entirely, and the SCMs conventionally used now and in the recent past (e.g., retention/detention basins, biofiltration without soil enhancement, and sand filters) should be integrated into the overall system to realize the highest management potential.

The proposed watershed-based program emphasizing ARCD practices would convey significant benefits beyond greatly improved stormwater management. ARCD techniques overall would advance water conservation, and infiltrative practices would increase recharge of the groundwater resource. ARCD practices can be made attractive and thereby improve neighborhood aesthetics and property values. Retention of more natural vegetation would both save wildlife habitat and provide recreational opportunities. Municipalities could use the program in their general urban improvement initiatives, giving incentives to property owners to contribute to goals in that area while also complying with their stormwater permit.

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Municipal Permittee Roles in Implementing Strategies

Municipal permittees sharing a watershed will have key roles in promoting ARCD under the proposed new system. First, the lead permittee and its partners would be called upon to perform detailed scientifically and technically based watershed analysis as the program's foundation. The City of San Diego (2007) offers a model by which permittees could operate with its Strategic Plan for Watershed Activity Implementation. The plan consists of:

- Activity location prioritization—locations prioritized for action based on pollutant loading potential;
- Implementation strategy and activity prioritization—tiered approach identifying activities directed at meeting watershed goals over a five-year period;
- Potential watershed activities—general list of activities required and potentially required to meet goals as guidance for planning and budgeting;
- Watershed activity maps—specified locations for activities; and
- Framework for assessment monitoring—a plan for development of the monitoring and reporting program.

Municipal permittees would be required under general state regulations to make ARCD techniques top priorities for implementation in approving new developments and redevelopments, to be used unless they are formally and convincingly demonstrated to be infeasible. In that situation permit approval would still require full water quantity and quality management using conventional practices. Beyond regulation, municipalities would be called upon to give private property owners attractive incentives to select ARCD methods and support to implement them. Furthermore, they should supplement on-site ARCD installations with municipally created, more centralized facilities in subwatersheds.

Other municipal roles in the proposed program revolve around the prominence of soil infiltration as a mechanism in ARCD. Successful use of infiltration requires achieving soil hydraulic conductivity sufficient to drain the runoff collector quickly enough to provide capacity for subsequent storms and avoid nuisance conditions, while not so rapid that contaminants would reach groundwater. One important task for municipal co-permittees will be defining watershed soils and hydrogeological conditions to permit proper siting and design of infiltrative facilities. A great deal of soils information already exists in any community but must be assembled and interpreted to assist stormwater managers. U.S. Department of Agriculture soil surveys, while a start, are often insufficiently site-specific to characterize the subsurface accurately at a point on the landscape. More localized data available to municipalities come from years of recorded well logs, soil borings, and percolation test results. Municipalities should tap these records to define, to their best ability, soil types, hydraulic conductivities, and seasonal groundwater positions. Although abundant and valu-

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able, these data are unlikely to be sufficient to define subsurface attributes across a watershed. Thus, municipalities should collect additional data (soil borings, soils analyses, and percolation tests) to obtain a good level of assurance of the prospects for infiltrative ARCD.

Part of the task for municipalities will be overcoming opposition to infiltration if it is unjustified. Some opponents discourage infiltration based on coarse soil survey data that may not apply at all at a locality, or they fail to take into account that the well-established ARCD practice of soil amendment, generally with organic compost, can improve the characteristics of somewhat marginal soils sufficiently to function well during infiltration. While such amendment cannot increase hydraulic conductivity sufficiently in restrictive clay soils, the technique has proven to effectuate substantial infiltration and attendant reduction in runoff volumes and peak flow rates in Seattle's natural drainage systems, discussed above. These systems lie on variable soils, including formations categorized by the Natural Resources Conservation Service (2007) as being in hydrologic group C. This group generally has somewhat restricted saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters (20 inches) of between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). Furthermore, additional runoff reduction often occurs through evapotranspiration, which is enhanced by the vegetation in ARCD systems.

Another objection sometimes raised to infiltrating stormwater is its perceived potential to compromise groundwater quality. Whether or not that potential is very great depends upon a number of variables: rate of infiltration, ability of the soil type to extract and retain contaminants, distance of travel to groundwater, and any contaminated layers through which the water passes. It is unlikely that urban stormwater, with its prevailing pollutant concentrations, will threaten groundwater if it travels at a moderate rate, through soils of medium or fine textures without contaminant deposits, to groundwater at least several meters below the surface. To ensure that groundwater is not compromised when surface water is routed through infiltrative practices, municipalities must establish where appropriate conditions do and do not exist and spot infiltration opportunities accordingly. Records of past waste disposal, leaks, and spills must be consulted to clean up or stay away from contaminated zones. There are alternatives even if documented soils or groundwater limitations rule out infiltrative practices. Much can be accomplished to reduce the quantities of contaminated urban runoff discharged to receiving waters through impervious surface reduction, water harvesting, and green roofs.

One additional problem to infiltrating stormwater runoff exists in some relatively dry areas and must be countered by municipalities. Overirrigation of lawns and landscape plantings has already increased infiltration well over the predevelopment amount and raised groundwater tables, sometimes to problematic levels. This unnecessary use of irrigation not only wastes potable water, often scarce in such areas, but reduces capacity to infiltrate stormwater without further water table rise. Municipalities should set up effective programs to con-

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serve water and simultaneously increase stormwater infiltration capacity.

A final element of an integrated management and permitting program under municipal control is use of capacity in the sanitary sewer and municipal wastewater treatment systems to treat some stormwater. This initiative must be pursued very carefully. One reason for care is that municipal treatment works have historically been overburdened with stormwater flows in combined sewers and have not yet broken free of that burden through sewer separation programs. A second reason is that municipal sewage treatment plants are generally designed to remove particulates and decompose organic wastes and not to capture the array of pollutants in stormwater, many dissolved or associated with the finest and most difficult to capture particles. Toxic contaminants can damage microbes and upset biological treatment plants. Nonetheless, capacity exists in many WWTPs to treat stormwater. The delivery of pollutants the plant was not designed to handle can be managed by pretreatment requirements, applied to industrial stormwater dischargers particularly. Dry weather flows, consisting mostly of excess irrigation runoff, can be diverted to treatment plants to prevent at least some of the nutrient and pesticide contamination that otherwise would flow to receiving waters. Additional capacity to treat stormwater can be gained by repairing defective municipal wastewater pipes that allow groundwater entry.

Special Considerations for Construction and Industrial Land Uses

All of the principles discussed above apply to industrial and construction sites as well: minimize the quantity of surface runoff and pollutants generated in the first place, or act to minimize what is exported off the site. Unfortunately, construction site stormwater now is managed all too often using sediment barriers (e.g., silt fences and gravel bags) and sedimentation ponds, none of which are very effective in preventing sediment transport. Much better procedures would involve improved construction site planning and management, backed up by effective erosion controls, preventing soil loss in the first place, which might be thought of as ARCD for the construction phase of development. Just as ARCD for the finished site would seek to avoid discharge volume and pollutant mass loading increase above predevelopment levels, the goal of improved construction would be to avoid or severely limit the release of eroded sediments and other pollutants from the construction site. Chapter 5 discusses construction-phase stormwater management in more detail.

Other industrial sites are faced with some additional challenges. First, industrial sites usually have less landscaping potentially available for land-based treatments. Their discharges are often more contaminated and carry greater risk to groundwater. On the other hand, industrial operations are amenable to a variety of source control options that can completely break the contact between pollutants and rainfall and runoff. Moving operations indoors or roofing outdoor material handling and processing areas can transform a high-risk situation to a

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no-risk one. It is recommended that industrial permits strongly emphasize source control (e.g., pollution prevention) as the first priority and the remaining ARCD measures as secondary options (as outlined in Table 5-9). Together these measures would attempt to avoid, or minimize to the extent possible, any discharge of stormwater that has contacted industrial sources.

It is likely that the remaining discharges that emanate from an industrial site will often require treatment and, if relatively highly contaminated, very efficient treatment to meet watershed objectives. Some industrial stormwater runoff carries pollutant concentrations that are orders of magnitude higher than now prevailing water quality standards. In these cases meeting watershed objectives may require providing active treatment, which refers to applying specifically engineered physicochemical mechanisms to reduce pollutant concentrations to reliably low levels (as opposed to the passive forms of treatment usually given stormwater, such as ponds, biofiltration, and sand filters). Examples now in the early stages of application to stormwater include chemical coagulation and precipitation, ion exchange, electrocoagulation, and filtration enhanced in various ways. These practices are undeniably more expensive than source controls and other ARCD options and traditional passive treatments. If they must be used at all, it is to the advantage of all parties that costs be lowered by decreasing contaminated waste stream throughput rates to the absolute minimum.

Administrative and Funding Arrangements

A number of practical, logistical considerations pertain to converting to the permitting and regulatory system discussed above. These considerations include:

- What design and performance standards should be placed on the management systems?
- What administrative vehicles offer the best prospects for success?
- What funding arrangements are necessary to support the revised permitting and management system?

Design and Performance Standards

It has already been asserted under the discussion of objectives above that ultimate performance standards should be based on results in the aquatic systems under protection. The report further advocates promulgating these standards primarily in terms of biological health (for protection of human health, aquatic life, or both), supplemented by measures of conditions well known to influence biological health quite directly, such as hydrologic variables. It was further proposed that active adaptive management be applied in relation to the degree of

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achievement of water resource objectives. However, it would not be wise to standardize entirely on this level and leave all questions of the means to the end to individual permittees. Certain design-level standards would also be appropriate. An example is provided by the recently issued draft municipal permit for Ventura County, California. In that permit, application of low-impact methods to new development and redevelopment is specified to hold the effective impervious area to 5 percent of the total contributing catchment. While technical experts may disagree on the precise number, the point is that adopting such a standard gives a straightforward design requirement on an evidentiary basis. Results in the receiving waters would still be tracked and used in active adaptive management if necessary, but effective application of the design standard would provide some level of initial assurance that the aquatic health standards can be met.

Forging Institutional Partnerships

At the heart of the proposal for a new system of regulating discharges to the nation's waters is issuing permits to groups of municipalities in a watershed operating as co-permittees under a lead permittee. Furthermore, the proposal envisions these municipal permittees assuming responsibility for and implementing the permits for all public and private dischargers in their jurisdictions. These admittedly sweeping changes in the way waters have been managed almost everywhere in the nation raise serious issues of acquiescence to the new arrangements, compatibility, and devising a sufficient and stable funding base. This section draws from the small number of examples where arrangements like those proposed here have been attempted.

The Los Angeles County Municipal Storm Water Permit offers a case study in how to aggregate municipalities in a co-permittee system while still allowing prospective members latitude should they perceive their own interests to deviate, even considering the advantages of group action. The permit, first issued in 1990, presently covers five watersheds and 86 municipal permittees. During the process of reissuing the 1996 permit, the City of Long Beach challenged the provisions of the Los Angeles County MS4 permit. The city was given the option of applying for its own individual permit, which it did. Long Beach was issued its own individual MS4 permit in 1999 with provisions similar to the Los Angeles County MS4 permit. As another example, a small coastal municipality (Hermosa Beach) covered by the Los Angeles County Municipal Storm Water Permit investigated the possibility of withdrawing from the county permit in 2000 to be reclassified as a Phase II municipality. Just as with Long Beach, Hermosa Beach was given the option of applying for an individual permit as a Phase I MS4, but in the end Hermosa Beach elected to remain within the areawide permit. Although this report strongly encourages cooperative participation of municipalities as co-permittees, it does not mandate it. Rather, the flexibility illustrated above should be retained in the proposed new permitting pro-

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gram. What matters for compliance with the CWA is that a municipality manage discharges in a manner at least equivalent to other permittees in the watershed.

Stephenson and Shabman (2005) gave thought to the dilemma of entities who may not naturally work well together being asked to cooperatively solve a problem that all have had a share in creating. They argued that new organizational forms that consolidate multiple regulated entities under a single organizational umbrella could be used to coordinate and manage jointly the collective obligations of a group of regulated parties at lower costs to members. Private and public regulated entities alike could benefit from participation in these new organizations. Such cooperative organizations could offer participating parties financial incentives and decision-making flexibility through credit trading programs.

Two larger-scale compliance associations exist in the Neuse and Tar-Pamlico river basins in North Carolina (Stephenson and Shabman, 2005). In both programs the state was concerned about nutrient enrichment of estuary waters and imposed an aggregate cap on industrial and municipal wastewater dischargers equivalent to a 30 percent reduction in nitrogen loads. In both programs, the state granted individual point source dischargers a choice: (1) accept new requirements to control nitrogen through individual NPDES permits or (2) form and join a discharger association. The rigidities associated with individual NPDES permits provided enough incentive for most point source dischargers to opt for the second choice. Compliance associations were then created and issued permits.

The Neuse River rules cover nonpoint agricultural sources as well as point discharges. Counties are responsible for reducing nutrient loads, and farmers must either join county associations that apply different strategies or individually contribute to meeting objectives by setting aside 50- to 100-foot buffers along all streams.

North Carolina requires compliance associations to meet a single mass load cap. In the Tar-Pamlico case, the legal requirement to meet the cap was established by an enforceable contractual agreement signed by the association and the state. In the Neuse program, a single "group compliance permit" was issued to the association. Both legal mechanisms established financial penalties for the two associations if aggregate discharges of the group exceed the association cap. A key advantage of the association is similar to that of a formal effluent trading program—granting dischargers flexibility to decide how best to meet the aggregate load cap. To date, the associations have managed to keep nitrogen loads considerably below their respective caps. Compliance costs have also fallen below original projections. Further, there is some evidence that the association concept is producing incentives for strong cooperative behavior that did not exist prior to implementation.

The case studies presented here illustrate ways in which both public and private entities subject to regulation can exercise options for operating autonomously should they not wish to incorporate with a group, while still contributing

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to the achievement of watershed objectives. The case studies suggest that most dischargers conclude in the end that group membership offers considerable advantages.

Funding Considerations

The existing stormwater permit program is characterized, in most of the nation, by municipal Phase I and now Phase II permittees operating mostly alone. In contrast the new system envisions coalitions of permittees that share a watershed operating in concert, under the coordination and leadership of a principal permittee. The present structure tends to bring about duplication in effort and staff, whereas cooperation should stimulate efficiencies that could defray at least part or even much of the extra local costs associated with new responsibilities for municipal permittees.

As explored in the preceding section, municipalities may not necessarily wish to join in co-permittee arrangements; and mechanisms are proposed to allow them to operate individually, as long as watershed objectives are met. However, the state could encourage participation through financial inducements, for example, by estimating the resources needed to meet the requirements of each watershed permit and pointing out to permittees how shared resources can save each contributor money. The state should also set preferences and better terms for grants in the favor of municipalities who join together.

To the questions of administrative vehicles and funding arrangements, stormwater utilities are the preferred mechanism, and regulations should support creating stormwater utilities. It should be added that, with watershed-based permitting as proposed here, utilities should also be regionalized on a watershed basis. A utility draws funds from the entities served in direct relation to the cost of providing the services, here management of the quantity and quality of stormwater discharged to natural waterbodies. These funds must be dedicated to that purpose and that purpose only, and cannot be redirected to general agency coffers or for any unrelated use.

Not only are more funds from more reliable sources needed, but monies should be redirected in ways differing from their allocation under the current system. It was proposed earlier that a lead municipal permittee, working with other municipal co-permittees, be given responsibility for coordinating permitting and management of municipal, industrial, and construction stormwater permits, and even permits involving other sources, such as industrial process and municipal wastewaters. Those entities would hence be doing work now devolving to individual private developers and industrial plants and other public authorities. They would need to attract the revenue from those other bodies in proportion to the added work taken on. A utility structure would provide a well-tested means of carrying out this reallocation.

Stormwater utility fees are generally assessed according to a simple formula, such as a flat rate for all single-unit dwellings and in proportion to imper-

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vious area for commercial property. Some municipalities have investigated charging more directly according to the estimated quantity and quality of stormwater discharged into the public drainage system. Municipal permittees may choose to formulate such a system, but the development process itself is not a trivial task and, being based on general (and usually quite simple) hydrologic and water quality models, can generate considerable arguments from rate payers. Going through this process is probably not necessary or even advisable for most municipal permittees, who will have many new functions should the proposed system be adopted. Instead, they should concentrate on implementing a fee structure based on a simple formula like the one above and then capture additional revenues for special functions that they will take over from industrial and construction permittees.

As discussed previously, in the proposed program municipal co-permittees, with leadership by a watershed lead permittee, will be asked to classify industries and construction sites within their borders according to risk and accordingly prioritize them for inspection and monitoring. It is proposed in the section on Measures of Achievement, below, that inspection include reviewing and approving industrial and construction site stormwater pollution prevention plans (SWPPPs). While many municipalities now inspect construction sites for stormwater compliance and some inspect industries, this work will increase significantly in the new system, and SWPPP review and approval will be a completely new element. Moreover, municipalities would perform some industrial monitoring now conducted by the industries themselves and may monitor high-risk construction sites. These special functions would require different institutional arrangements and substantial new revenue that could not be fairly charged to all rate payers. There are several possible sources for these funds. One way would be to increase industrial and construction permit fees and direct large proportions to municipalities to support inspection and monitoring. The permitting authority (designated state or EPA) would still hold ultimate authority, and municipalities could refer industrial and construction permittees found during inspection to be out of compliance to the permitting authority for enforcement. Another means would be to form consortia of industries of similar type and assess fees directly applicable to inspection and monitoring. For example, scrapyards under the jurisdiction of the California EPA Los Angeles Regional Water Board formed a monitoring consortium under which sample collection by a qualified contractor rotates among the members, with funding by all. While the members operate this system, it could be adapted to operation by municipal co-permittees.

A second-level funding concern is, once revenues are generated, how should they be put to use? It is very important that funds largely be devoted directly to the tasks at hand regarding the achievement of objectives instead of into excessive administrative and bureaucratic structure. These tasks are scientific and technical and are highly oriented toward what is actually going on in the drainage systems and their receiving waters. Thus, the majority of funds should be directed to making scientific and technical judgments based on obser-

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vations and monitoring results obtained in the field (see the discussion below).

Measures of Achievement

Critique of the Current Monitoring System

No area exemplifies the differences between the present and proposed new stormwater permitting and monitoring systems more than the measures used to gauge achievement. The current monitoring system is characterized by scattered and uncoordinated measurements of discharges from Phase I MS4s and some industries, and some visual observations of construction sites. The system proposed to take its place would emphasize monitoring of receiving water biological conditions as a data source for prescribing management adaptations to meet specified biological objectives. The discussion here first critiques the prevailing system to construct part of the rationale for changing it. It then proceeds to outline a recommended monitoring structure to replace it.

To expand very briefly on the point that the present system is scattered and uncoordinated, monitoring under all three stormwater permits is according to minimum requirements not founded in any particular objective or question. It therefore produces data that cannot be applied to any question that may be of importance to guide management programs, and it is entirely unrelated to the effects being produced in the receiving waters. Phase I municipal permit holders are generally required to monitor some storms at some discharges for no stated purposes but to report periodically to the permitting agency (Phase II municipalities have no monitoring requirements, although they may represent the major or even only impact sources in a given watershed). The usual model for industries across the nation is to collect a few discharge grab samples a year and send the results to the permitting authority, plus occasionally to make observations for obvious signs of pollution (e.g., oil sheen, odor). Construction site monitoring is less standardized and often involves no water quality monitoring at all. Again, no permittee under any of the three programs is obligated according to national standards to check the effects of its discharges on receiving waters. Since the individual effects of any discharger are often not distinguishable from any other, the scattershot system would usually not be able to discern responsibility for negative effects in the receiving water ecosystem.

Input to the committee conveyed the strong sense that monitoring as it is being done is nearly useless, burdensome, and producing data that are not being utilized. For example, the City of Philadelphia conducts substantial amounts of wet weather monitoring, which is very expensive, but it can barely monitor for TSS in many of its heavily impacted streams (Crockett, 2007). The resources to monitor for the more exotic pollutants do not exist. Smaller municipal permittees without the resources and sophistication of a big-city program have difficulty performing even the most basic monitoring. City water managers believe

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that the traditional stormwater program places too much emphasis on monitoring of individual chemicals rather than looking at ecological results (Crockett, 2007).

Industry representatives have also described several problems they see in industrial stormwater monitoring as it is performed now (Bromberg, 2007; Longsworth, 2007; Smith, 2007). One concerns the high degree of variability, from the methods used to what is actually measured (Stenstrom and Lee, 2005; Lee et al., 2007). Opponents have been quite critical of the benchmarks to which industrial monitoring data are compared, believing that the benchmarks have no basis in direct measurements associating stormwater with impacts. Some have suggested replacing monitoring with an annual stormwater documentation report to the permitting authority. It seems that industry personnel disrespect the current monitoring framework for some good reasons and feel it conveys a burden for little purpose. There was some implication that industry would be receptive to measures offering more meaningful information in place of poorly conceived monitoring requirements (Bromberg, 2007; Longsworth, 2007; Smith, 2007).

Proposed Revised Monitoring System

A structure in several tiers is proposed as a monitoring system to serve the watershed-based permitting and management framework.

Progress Evaluation Tier. This tier would represent the ultimate basis for judgment on whether the objectives adopted for the watershed are being met. Because these objectives would mainly be expressed in terms related to direct support of beneficial uses, so too would monitoring in the Progress Evaluation Tier principally emphasize direct measurements of ecological health. The preferred model for this evaluation would be the paired watershed approach, which is based on the classic method of scientific experimentation and was developed for water resource management investigations by EPA (Clausen and Spooner, 1993). Ideally, conditions in the waterbody under evaluation would be compared to conditions in the same waterbody before imposition of a permit and management scheme (before versus after comparison), as well as to conditions in a similar waterbody not subject to human-induced changes (affected system versus reference system comparison). At least one of these comparisons must be made if both cannot. If the objectives involve improving conditions, and not just avoiding more degradation, the reference should represent that state to which the objective points.

This function has traditionally been the province of the permitting authority (i.e., the designated state or EPA). In the new program, the function is assigned to municipal permittees, guided by the lead permittee, to conduct or contract, but with a substantial contribution by the permitting authority in the form of material support and guidance. The primary vehicle envisioned to perform the pro-

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gress assessment is a well-qualified monitoring consortium serving the watershed, and perhaps other watersheds in the vicinity. Case studies below present examples of successful joint ventures in monitoring that can serve as models. The proposal is based on the belief that monitoring should be more manageable and effective at the watershed compared to the state level and, furthermore, that utilizing a consortium approach should make it feasible for a coalition of municipal co-permittee partners to commission monitoring.

Findings of objective shortfall would trigger development of active adaptive management strategies. Generally, an assessment should be conducted to determine what additional measures should be put in place in regulating new development and redevelopment, as well as increasing coverage of existing developments with retrofits.

Diagnostic Tier. The second tier would be designed to provide the municipal permittees with the necessary information to formulate active adaptive management strategies, and they would be responsible for this second tier as well as the first. The Diagnostic Tier would be composed of assessment of information from the Compliance Reporting Tier, plus some specific field monitoring to determine the main reasons for ability or failure to meet objectives. Some highly directed monitoring of receiving water conditions could determine the need to improve management of water quantity, water quality, or both. A tool like the Vermont flow-duration curves is an example of a potentially useful device for diagnostic purposes. To allow the use of such a tool, it is important that continuous flow recorders be installed on key streams in the watershed. The techniques described in the Impact Sources section above, once they are further developed, would also be useful in Diagnostic Tier monitoring.

An important dimension of this tier would be prioritized inspection and monitoring of potentially high-risk industrial and construction sites. In addition, data submitted by the industrial and construction permittees according to the Compliance Reporting Tier would assist in targeting dischargers to bring about the necessary improvements in water quantity and/or quality management.

Compliance Reporting Tier. It is proposed that the first step in compliance reporting be submission of SWPPPs by all construction and industrial permittees (plus municipal corporation yards as an industrial-like activity) to the jurisdictional municipal permittee for review and approval. It is further proposed that the industrial permittees and municipal corporation yards be relieved of sample collection, *if* they develop SWPPPs making maximum possible use of ARCD practices, supplemented by active treatment as necessary, and the municipal permittee approves the SWPPP. Construction sites would be given a similar sampling dispensation if they develop an approved SWPPP along the lines of Box 5-3.

Otherwise, the permittees would be required to perform scientifically valid sampling and analysis and report results to the watershed co-permittees. This more comprehensive and meaningful monitoring would increase the burden al-

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ready felt by permittees and create a strong incentive to apply excellent SCMs. This burden could be relieved to a degree through participation with other similar dischargers in the watershed in a monitoring coalition. As an example, in North Carolina coalitions of wastewater dischargers are working with the state Division of Water Quality (DWQ) to create and manage coalition-led watershed monitoring programs that operate in conjunction with DWQ's ambient chemistry and biological programs (Atkins et al., 2007). Lee et al. (2007), after an assessment of industrial stormwater and other monitoring data, concluded that selecting a subset of permittees from each monitored category would yield better results at lower overall cost compared to monitoring at every location. This strategy would permit the use of more advanced sampling techniques, such as flow-weighted composite samplers instead of grab sampling, to estimate representative loads from each category with improved accuracy and reduced variability.

All permittees would still make observations of the SCMs and discharges and keep records. The final proposed step in compliance reporting is an annual report covering observations, SCM operation and maintenance, SWPPP modifications, and monitoring results (if any), to be sworn as to correctness, notarized, and submitted to the lead municipal permittee. The Massachusetts Environmental Results Program (April and Greiner, 2000) offers a possible model for compliance reporting and verification. This program uses annual self-certification to shift the compliance assurance burden onto facilities. Senior-level company officials certify annually that they are, and will continue to be, in compliance with all applicable air, water, and hazardous waste management performance standards. The state regulatory agency reviews the certifications, conducts both random and targeted inspections, and performs enforcement when necessary.

Research Tier. The final tier would be outside the permit system and exist to develop broad mechanistic understanding of stormwater impacts and SCM functioning important to assist permittees in reaching their objectives. EPA and state agencies designated to operate the permit system would have charge of this tier. These agencies would develop projects and contract with universities and other qualified research organizations on a competitive basis to carry out the research.

Instructive Case Studies for the Proposed Revised Monitoring System

Many municipalities, even large ones, would be challenged and burdened by taking on comprehensive watershed monitoring. The Southern California Coastal Water Research Project Authority (SCCWRP, http://www.sccwrp.org) offers an excellent model of how co-permittees in a watershed or an even broader area could organize to diffuse these challenges and burdens. SCCWRP

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is a joint-powers agency, one that is formed when several government bodies have a common mission that can be better addressed by pooling resources and knowledge. In SCCWRP's case, the common mission is to gather the necessary scientific information so that member agencies can effectively and cost-efficiently protect the Southern California marine environment. Key goals adopted by SCCWRP are defining the mechanisms by which aquatic biota are potentially affected by anthropogenic inputs and fostering communication among scientists and managers. Comprised of a multidisciplinary staff, SCCWRP encompasses units specializing in analytical chemistry, benthic ecology, fish biology, watershed conditions, toxicology, and emerging research.

SCCWRP's current mission stems from the results of a 1990 NRC review of marine environmental monitoring programs in the Southern California Bight (NRC, 1990). It was determined that although $17 million was being spent annually on marine monitoring, it was not possible to provide an integrated assessment of the status of the Southern California coastal marine environment. Most monitoring was associated with NPDES permit requirements and directed toward addressing questions about site-specific discharge sources. As a result, most monitoring in the bight was restricted to an area covering less than 5 percent of the bight's overall watershed, making it difficult to draw conclusions about the system as a whole. The limited spatial extent of monitoring was also found to limit the quality of local-scale assessments, since the boundaries of most monitoring programs did not match the spatial and temporal boundaries of the important physical and biological processes in the bight.

NRC (1990) further found that there was a lack of coordination among existing programs, with substantial differences in the parameters measured among programs, preventing integration of data. Even when the same parameters were examined, they were often measured with different methodologies or with different (or unknown) levels of quality assurance. Moreover, the NRC found that even when the same parameters were measured in the same way, substantial differences in data storage systems among monitoring programs limited access to the data for more comprehensive assessment. To avoid repetition of these shortcomings, the SCCWRP example should be given very thorough consideration as a template for the Progress Evaluation, Diagnostic, and Research Tiers in the proposed revised monitoring program.

The San Gabriel River Regional Monitoring Program (SGRRMP, *http://www.lasgrwc.org/SGRRMP.html*) is a watershed-scale counterpart to the larger-scale regional monitoring efforts in Southern California. The SGRRMP incorporates local and site-specific issues within a broader watershed-scale perspective. The program exists to improve overall monitoring cost effectiveness, reduce redundancies within and between existing monitoring programs, target monitoring efforts to contaminants of concern, and adjust monitoring locations and sampling frequencies to better respond to management priorities in the San Gabriel River watershed. Five core questions provide the structure for the regional program:

- What is the environmental health of streams in the overall watershed?

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- Are the conditions at areas of unique importance getting better or worse?
- Are receiving waters near discharges meeting water quality objectives?
- Are local fish safe to eat?
- Is body-contact recreation safe?

The workgroup convened to establish the program recommended monitoring designs to answer the core questions effectively and efficiently. The resulting program is a multilevel monitoring framework that combines probabilistic and targeted sampling for water quality, toxicity, and bioassessment and habitat condition.

The City of Austin, Texas, has more than 20 years of stormwater monitoring experience and offers additional guidance on designing and implementing watershed monitoring programs (City of Austin, 2006). Austin performs detailed periodic synoptic sampling in the watersheds it manages to track trends in stormwater quantity and quality. The city uses the results to evaluate the impacts of land development on stormwater quantity and pollution, establishing statistical relationships between measures of these conditions and the amount of impervious cover. Trend assessment over time leads to recommended changes to the City of Austin Environmental Criteria Manual as needed.

Creating Flexibility and Incentives Within a Watershed Approach

A watershed-based permitting approach to stormwater management focuses attention on watershed objectives and endpoints. To be able to achieve these goals, observable performance measures beyond the success of an individual SCM need to be identified that are consistent and necessary to meet designated uses. These might include watershed-level numeric limits on the amount of a particular pollutant allowed to enter a waterbody (e.g., pounds of phosphorus) or various measures of allowable volume of discharge. A watershed focus shifts attention away from specific SCM performance and site-specific technological requirements to achieving a larger watershed goal. As a consequence, there is considerable management flexibility in deciding how these goals will be achieved. Indeed, this flexibility was cited by the NRC (1999) as a prerequisite to successful watershed management.

One way of exercising this flexibility is to create an "incentive-based" or "market-based" approach to choose how watershed goals are met. It is recognized throughout the environmental management field that entities subject to regulation do not necessarily have equal opportunities and qualifications to comply sufficiently to sustain resources. To compensate for this, the market-based approach allows individual discretion to select how effluent (or runoff volume) will be controlled (choice of technology, processes, or practices) and where they will be controlled (on site or off site). That is, any discharger legiti-

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mately unable to meet discharge quantity and quality allocations would be able to finance offsets elsewhere to achieve the watershed goals. An important element and challenge is to couple this decision-making flexibility with personal (typically financial) incentives so that people willingly make choices supportive of the watershed objectives. Broadly stated, the idea is to create financial reasons and decision-making opportunities to lower compliance costs and create or implement new effluent/volume control options (Shabman and Stephenson, 2007).

Because incentive-based policies require a shift in emphasis from technologies and practices to outcomes (e.g., volume or quantity of effluents), the municipal manager would not be responsible for deciding what SCM will be implemented in specific areas or hand picking specific practices to promote. Rather the stormwater program manager's responsibilities shift to establishing watershed goals, developing metrics to measure outcomes and performance, and performing necessary inspection and enforcement activities.

Effluent trading, sometimes called "water-quality trading," is one type of incentive-based policy. In an ideal form, effluent trading requires government to establish a binding aggregate limit or cap on an outcome (e.g., mass load of effluent, volume of runoff) for an identified group of dischargers. The cap or aggregate allowable discharge is set to support and achieve a socially determined environmental goal. Because it is fixed, the cap provides the public assurances that environmental objectives will be achieved in the face of a growing and changing economy. The total allowable discharge is then divided into discrete and transferable units, called allowances, and either distributed or auctioned to existing dischargers. All dischargers must own sufficient allowances to cover their discharges. For instance, any new or expanding source must first purchase allowances (and hence effluent or volume reductions) from another source before legally discharging. The requirement to hold allowances on the condition to discharge and the positive allowance price creates financial incentives for pollution prevention. Dischargers holding allowances rather than reducing discharge face forgone revenues that could have been achieved from the sale of allowances. Conversely, expanding dischargers have incentives to invest in pollution prevention in order to avoid the cost of purchasing additional allowances.

In the context of the revised permit system advocated here, achievement of objectives (generally of a biological nature) will require some combination of strategies such as no net increases in hydrologic parameters (e.g., peak flow rates, durations, volumes), water pollutants, forest cover loss, and effective impervious area. If one entity is unable to contribute adequately to meeting its share of compliance, then it must obtain the necessary credit by buying it from another similar entity that is able to contribute more than its designated share. Ideally, all sources of a waterbody's problems, not only stormwater, would come under the trading system.

Implementing the market system requires development of a resource-based currency, a nontrivial exercise but one for which models are available in other

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fields, especially air emissions. For example, emission trading has been a critical element of the nation's strategy to limit sulfur dioxide and nitrogen oxide emissions (Ellerman et al., 2000). Carbon trading is a cornerstone policy in the European Union effort to limit greenhouse gas emissions. The EPA promotes the use of trading to help achieve the goals of the CWA and has issued several policy statements and recently published guidance on how trading programs can be grafted within existing NPDES permitting programs (EPA, 2003a, 2007b).

However, compared to the air program, experience and success with trading in the water program have been limited (Shabman et al., 2002). Furthermore, programs labeled trading have been implemented in a multitude of ways in the nation's water quality program (Woodward et al., 2002; Stephenson et al., 2005; Shabman and Stephenson, 2007). In many instances, trading programs are case-specific and isolated "trades" that do not fundamentally change the choice and incentives facing dischargers in a conventional permitting system. The extent to which trading policies can be effectively employed on a watershed scale is limited not only by the physical differences between air and water mediums, but also by the unique legal structure of the CWA (Stephenson et al., 1999). For example, the CWA is oriented around imposing technology-based performance requirements on specific subset of discharge sources. Individual NPDES permits require sources to achieve these agency-identified levels of performance and may specify how performance is achieved. The statute also places limits and disincentives on the degree to which permit agencies can deviate from these limits (e.g., "antibacksliding").

Thus, the focus of the NPDES permitting system has been on individual source control and technologies, unlike the air program, which has a stronger statutory orientation around achieving broader air quality goals (ambient air quality standards). The orientation of the NPDES program limits the flexibility and incentives for regulated parties that might make market-oriented trading possible. It turns out that some of the more successful applications of trading in the water program have occurred because of permitting innovations that effectively avoid some of these rigidities (see discussion of North Carolina point source control program on the Neuse River, above).

Trading programs of various types have been proposed or suggested for stormwater (Thurston et al., 2003; Parikh et al., 2006). Although conceptual models of a comprehensive trading program based on the total volume of allowable water to be discharged have been proposed, no working examples have yet to be implemented. More limited versions of trading programs, however, have been developed. These programs provide compliance flexibility for new sources of stormwater runoff. In some locations, new developments face a requirement to provide a specific level of volume or effluent control from the parcel to be developed. The regulated entity is typically obligated to meet this requirement with the applications of on-site SCMs. Trading programs create opportunities for regulated entities to meet their regulatory requirement off site (off the parcel to be developed), called here an offset. In some trading programs, the off-site controls can be accomplished by the creation of an in lieu fee program. Such

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programs typically occur for dischargers that are not required to hold or obtain individual NPDES permits.

In lieu fee programs offer some opportunity for regulated parties to make a financial payment (fee) to a local government entity in lieu of implementing on-site controls. The fees are collected and used to implement stormwater controls in other areas of the watershed. Controlling runoff at a regional level rather than through the construction of many small on-site controls may be more cost-effective given the economies of scale associated with some SCMs (see Chapter 5 pages 362–363). The option for off-site controls also allows the stormwater program to direct investments in stormwater control to specifically targeted areas of the watershed.

Examples of in lieu fee programs include Santa Monica, California, the Neuse River Basin in North Carolina, and Williamsburg, Virginia. Santa Monica's program requires new and redevelopment projects to treat a specific volume of runoff. The program first requires the regulated entity to take all feasible steps to meet the requirement through the implementation of on-site infiltration practices. If the regulated party can demonstrate why it is economically and physically infeasible to install any type of infiltration or treatment SCM, the regulated party can pay a fee based on the volume of water that needs to be controlled (the total mitigation volume is the volume that would have been attenuated via an SCM). The fee set by Santa Monica is $18/gallon of total required mitigation volume. The $18 reflects the cost of constructing an SCM and maintaining it over 40 years (DeWoody, 2007). Presumably these fees are used to construct infiltration measures elsewhere.

The Neuse River Program requires all new land development to meet a nitrogen export standard of 3.6 pounds per acre per year (North Carolina Division of Water Quality, 1999). The water quality goal for the Neuse basin is to reduce mass nitrogen loads by 30 percent in order to improve water quality in the estuary. The export standard was set to achieve a 30 percent reduction from the average nitrogen load from lands prior to development. Developers have the option to meet this export standard either through the application of on-site SCMs or by paying a fee into a state-administered Riparian Buffer Restoration Fund (see 15A North Carolina Administrative Code 02B .0240), which would be used to reduce nitrogen loads elsewhere in the basin. Developer discretion, however, is not unlimited. Under no circumstances may developers discharge more than an estimated 6.0 pounds per acre per year from a residential site.

The Williamsburg program has an in lieu fee program for total phosphorus loads created by new development (Frie et al., 1996; Stephenson et al., 1998). For every new development, the increase in total phosphorus load from stormwater runoff from impervious surfaces is estimated. Developers have the choice to meet the phosphorus load reduction requirement through the application of on-site controls or by paying a fee to the city. The fee is set at $5,000/lb of phosphorus, with the fees earmarked to the construction of regional stormwater facilities or for the preservation of open space within the city. The presence of a fee option could also provide incentives for developers to implement source

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reduction practices.

The above programs differ in some important ways. For example, the Santa Monica program requires regulated entities to undergo a "sequencing" process that places regulatory preference on on-site controls before being able to use the fee option. The Williamsburg program allows regulated entities the option to select between constructing on-site controls and paying the fee without a regulatory preference for on-site controls. Sequencing rules tend to limit control options and thus the cost-effectiveness of these types of programs.

In lieu fee programs are distinguished from other offset programs in that it is the responsibility of the local government (or more generally, any designated fee service provider such as a nongovernmental organization) to provide the off-site SCMs. In lieu fee programs, common in the U.S. wetlands program, face a number of implementation and design challenges (Shabman and Scodari, 2004). For example, enforcement sometimes becomes a concern because the local stormwater management agency responsible for constructing and maintaining the SCMs is also responsible for monitoring and enforcement. These dual responsibilities create potential conflicts of interest; if an off-site mitigation project fails, there maybe no apparent overseeing agency to enforce corrective actions. The lack of transparency in accounting to determine whether the offset projects provide enough compensation is also sometimes a challenge. Finally, the ability to fully offset the volume of effluent discharge from a new development is contingent on collecting enough revenue from the fee to pay for the construction and maintenance of offsite SCMs. The delay between impacts and compensation and lack of full public cost accounting complicate the challenges of setting an appropriate fee.

Ensuring that in lieu fee programs provide the necessary mitigation could be accomplished in a number of ways. For example, an oversight agency may be designated to establish tracking and reporting requirements and monitor in lieu fee program performance. Or, the potential conflicts of interest inherent in the lieu fee program design could be avoided by separating the provision of the off-site mitigation service from the monitoring and enforcement. It is possible to imagine that the private sector, rather than an in lieu fee administrator, could provide off-site stormwater reduction services to those subject to the stormwater control requirements. In this case, the private sector would provide stormwater detention/retention services above and beyond what is required by law. These private service providers would receive stormwater runoff credits for these investments ("above baseline") that could be sold to developers who might wish to meet their control obligations in ways other than on-site controls. In essence, the role of searching, designing, and constructing offsite SCMs would be transferred to the private-sector stormwater credit providers. The local stormwater managers, however, would retain full authority to monitor, verify, and enforce to ensure that these offsets are successfully implemented.

The flexibility provided by in lieu fee and trading programs requires that pollutant loads or runoff volume created at one site be reduced at another site. Thus, a design issue confronting these types of programs is the consideration of

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the spatial extent in which offsetting activities can occur. The extent of the spatial range of offsetting activities in turn will depend partly on the nature and type of service being offset. For example, in the Neuse example nitrogen is a regional, basinwide concern with minimal localized effects. In such cases, the offsetting activities might be allowed basinwide (after adjusting for nitrogen attenuation through the basin). In other situations where localized concerns maybe a greater concern (say from localized flooding), the flexibility offered by such programs may be more limited. However, such spatial flexibility might also be a way to implement and achieve watershed planning objectives. For example, development may be encouraged in high-impact areas, and offsetting fees could be used to protect and enhance water quality objectives in other areas.

This last point deserves further explanation. Although this chapter advocates that biological conditions in waterbodies should be maintained or improved, there are many urban areas where local waterbodies cannot achieve the same designated uses as less developed areas. If a goal-setting entity chose to do so, beneficial uses for waters in these areas could be set at levels that acknowledge this highly altered condition, such that these streams would not be expected to achieve the same biological condition as streams outside the urban core (see Chapter 5 pages 364-366). This might be done to encourage development in high impact areas; San Jose, CA, provides an example (see Chapter 2). In that city's stormwater program, in urban areas where on-site control is either technically impossible (due to soil or space constraints) or prohibitively costly, the developers can meet the post-construction treatment standard by providing volume control either through participation in a regional stormwater project or by providing equivalent projects off site (e.g., stream restoration).

It is also possible to design a stormwater offset program that allows the different functions of stormwater management to be separated to achieve watershed objectives. For example, management of peak flow serves mostly to prevent localized flooding while more stringent volume control maybe required to protect stream channels and aquatic life. Control of peak flow might be required on site or within a narrow geographic region. In areas targeted for development, however, the volume control needed for channel protection might be transferred off site and into areas where watershed planning has identified the need for higher levels of stream channel protection or enhancement (more stringent water quality standards). A similar watershed approach based on functional assessment was recommended for wetland compensation (NRC, 2001b).

Regulatory and Legal Implications of Proposed Watershed-Based Permitting Framework for Managing Stormwater

EPA, the states, and municipal permittees would all have tasks to perform to transform the framework set forth in this report to a fully developed and functioning program. These efforts would be rewarded with a program that is rooted

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in science, transparent in its aims, fairer for all than the current program, and better for the aquatic environment. This section of the report outlines the tasks necessary to carry the proposal forward to full development.

EPA should seek significant congressional funding to support the states and municipalities in undertaking this new program, in the nature of the support distributed to upgrade municipal WWTPs after the 1972 passage of the Federal Water Pollution Control Act. Beyond financial support, EPA's tasks emphasize broad policy formulation, regulatory modifications and adaptations necessary to initiate the new program, and guidance to the states and permittees. The principal adaptation needed in the regulatory arena involves converting the current TMDL program to a form suitable for the new system. Guidance would be needed in a number of crucial areas, and it is EPA's natural role to develop it.

States (or EPA for states without delegated authority) would have broad responsibilities to translate policies and federal regulations into their own regulatory and management systems. A key task in this regard would be to recast water quality standards into objectives most directly supporting sustenance and improvement of beneficial uses. States already have considerable background for performing this task through their present definitions of beneficial uses, the Section 303(d) process for assessing waterbody compliance with water quality standards, and the triennial review of those standards. However, the added prominence of biological aspects of beneficial uses and associated objectives will require additional analysis. Other prominent state tasks will involve defining the watersheds subject to permits, forming bodies of co-permittees associated with the watersheds, and appointing the lead permittee. Many other state tasks entail cooperative work with the permittees to support and assist them in funding and conducting their activities.

Many aspects of the municipal permittees' roles in implementing strategies were explored above in a section titled accordingly. That section especially focused on activities to advance the use of ARCD methods. More broadly, the permittees will be coordinators of all permits pertaining to the watershed's aquatic resources, collectively pointed toward meeting objectives that the permittees adopt under state oversight. Other categories of tasks assigned to the municipalities under the proposed system include monitoring, in the contexts of both inspections and sampling performed through a consortium, and enforcement actions and program adaptations to promote progress toward achieving objectives. Box 6-4 provides a listing of anticipated tasks for the municipal permittees as well as the states and EPA.

A Pilot Program as a Stepping Stone

The shift of responsibility for stormwater regulation to municipalities under the watershed-based approach may lead to some surprises in implementation and enforcement. Primarily because of this, EPA is well advised to institute a pilot

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BOX 6-4
Government Agencies Roles during the Operation of a Watershed-Based Permitting System

EPA

1. Petition Congress for significant funding support for states and municipal permittees, and develop a program of fairly distributing funds based on environmental and financial needs at the watershed level.
2. Initiate regulatory modifications and clarifications necessary to establish the system.
3. Set policies for watershed permitting based on this report's recommendations.
4. Adapt TMDL program for use in the new program.
5. Produce guidance to assist the states and municipal permittees in the areas of:
   a. Developing a rotating basin approach;
   b. Developing an integrated municipal NPDES permit incorporating the full range of sources;
   c. Developing stormwater utilities and other funding mechanisms;
   d. Using impact source analysis (e.g., using reasonable potential analysis and new research results, industrial and construction site risk assessment);
   e. Using ARCD techniques for new development, redevelopment, and retrofitting;
   f. Developing monitoring consortia;
   g. Developing a credit trading system;
   h. Developing an active adaptive management program

Designated States (or EPA otherwise)

1. Define watersheds for which permits will be issued and set up a rotating basin approach to govern watershed analysis in support of subsequent steps.
2. Formulate and formally adopt goals relative to avoiding any further loss or degradation of designated beneficial uses in each watershed's component waterbodies and recovering lost beneficial uses.
3. Use the results of the existing Section 303(d) process and supplementary work to assess the extent of designated beneficial use achievement in each watershed and set goals for protection and recovery.
4. Match municipal permittees to watersheds and designate a lead permittee for each watershed.
5. Estimate resource needs to fulfill permit requirements in each watershed.
6. Develop a grant program, drawing on EPA and state funds, to support municipal permittees, with incentives for joining co-permittee associations.
7. Identify areas outside the jurisdictions of permitted municipalities that should be brought into the program because of projected development or the existence of problem sources that would compromise the protection and recovery of beneficial uses.
8. Use the triennial review process to modify water quality standards to the objective basis, emphasizing biological outcomes recommended in this report.
9. Revise the TMDL program in accord with the needs of the new program.
10. Set requirements for credit trading systems.
11. Set up an integrated municipal NPDES permit incorporating the full range of sources.
12. Work with municipal permittees to establish specific objectives as the basis for progress assessment.
13. Work with municipalities to develop adaptive management programs responding to progress assessment results.

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14. Write municipal permits incorporating the above elements.
15. Write industrial and construction general or individual permits incorporating the recommendations in this report.
16. Allocate a substantial portion of industrial and construction permit fees to municipal permittees to oversee those sectors.
17. Set requirements for municipalities and private properties to opt out of the defined program without compromising the achievement of objectives.
18. Provide consultation, support, and guidance (adapted from EPA materials or originally produced) to municipal permittees in the areas of:
    a. Developing stormwater utilities and other funding mechanisms;
    b. Using impact source analysis (e.g., industrial and construction site risk assessment);
    c. Using ARCD techniques for new development, redevelopment, and retrofitting;
    d. Developing monitoring consortia;
    e. Developing a credit trading system
19. Perform enforcement actions on non-complying dischargers referred by municipal permittees.
20. Assess performance of municipal permittees and specify corrections, rewards, and penalties accordingly.

Municipal Co-permittees (led by Lead Permittee)

1. Adopt specific objectives as the basis for program progress assessment.
2. Convert ordinances and regulations as needed to implement the modified program.
3. Supplement and reorganize staffing to emphasize progress and compliance assessment as the principal functions of the program.
4. Perform or contract detailed scientifically and technically based watershed analysis as a foundation for permit compliance.
5. Assemble existing data on soils and hydrogeologic properties and supplement with additional data collection as necessary to assess infiltration prospects across the municipality.
6. Create incentives for private property owners to maximize the use of ARCD methods in new development and redevelopment.
7. Build subwatershed-scale, publicly owned ARCD works to supplement on-site management measures and as retrofits.
8. Develop capacity for stormwater management in municipal WWTPs by reducing groundwater inflows to sanitary sewer lines.
9. In areas experiencing excessive infiltration and groundwater table rise resulting from non-stormwater flows, develop capacity for stormwater management through infiltration by formulating water conservation programs.
10. Identify industries and construction sites that are required to apply for permits but have not done so and compel their filing.
11. Establish or enhance existing programs to inspect and oversee industries and construction sites; report non-complying dischargers to the state for enforcement actions.
12. Set up or join a monitoring consortium structured to implement the progress evaluation and diagnostic tiers of the proposed monitoring program.
13. Annually report monitoring results to the permitting authority; submit a comprehensive progress assessment triennially.

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program that provides some experience in municipality-based stormwater regulation before instituting a nationwide program. This pilot program will also allow EPA to work through more predictable impediments to this watershed-based approach. The most obvious impediment arises from the inevitable limits of an urban municipality's responsibility within a larger watershed: substantial growth and accompanying stormwater loading may occur on the outside periphery of a municipality's designated boundaries. If an urban authority lacks legal authority over this future growth, and if this growth contributes significantly to water quality degradation, then a considerable share of the urban stormwater problem could remain poorly addressed. A pilot program should help identify the extent of this jurisdictional slippage and help identify ways to overcome it. Second, it is possible that some municipalities will balk at the added responsibility involved with the watershed-based approach, even with adequate funding. Unless the objective performance standards are rigid, the monitoring requirements substantial, and the rewards for compliance compelling for municipalities that meet the standards, it is quite possible that noncompliance or bare minimal compliance will be the norm. A pilot program provides a less politically charged atmosphere to experiment with the benefits of watershed-based regulation at the local level and to generate local government support for the approach. Finally, because the watershed-based approach necessitates legislative amendments to the CWA, instituting a pilot program in the interim—both to improve the design of a watershed-based program as well as to generate enthusiasm for it—seems a sensible course.

The pilot program should target those local governments that are most eager to redress water quality degradation in their watersheds, but feel stymied by what they perceive as inadequate legal authority and flexibility to make the necessary improvements. Willing municipalities or regional governments would thus opt-in to the program. The pilot program entices these more progressive municipalities to participate by allowing them to serve as the lead authority and providing them with much greater flexibility to determine how to meet their performance-based water quality goals with fewer legal constraints.

Under the pilot program, a municipal government or similar legal authority would apply to EPA or a delegated state to be designated as the lead agency for that portion of the watershed within its legal jurisdiction. In the application itself the municipality would establish—using modeling and ambient data—how it plans at a general level to maintain or exceed its water quality goals (objective performance standards). These goals must be at or above the state water quality goals, or if they are different (i.e., use biological criteria when the state adopts chemical criteria), the municipality must demonstrate how its performance standards will attain the equivalent of the state water quality goals at the downstream edge of the municipality's border. The municipality would also be required to provide assurance of sufficient infrastructure and funding to allow it to develop a water quality plan, implement that plan, issue permits, and enforce the requirements within its boundaries. Finally, municipal plans, once finalized, would need to meet minimum federal procedural requirements. For example,

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the plans must be transparent and provide opportunities for public comment; they must be enforceable; and they must establish monitoring programs that will track whether they in fact meet the objective performance standards. If a municipality fails to meet any of its performance standards by the requisite deadline, the state and EPA would have the option of revoking the municipality's program, and reinstituting federal requirements. Ideally, federal guidance would also be available to municipalities to provide direction on how they might institute a watershed-based plan within their boundaries, while still reserving considerable flexibility to allow them to develop creative and progressive stormwater solutions. For example, municipalities would be encouraged to form stormwater utilities that are financed from point and even nonpoint sources that assist them in establishing rigorous permitting and enforcement of their water quality plan.

Municipalities that voluntarily take on this role as lead authority will be rewarded with few legal constraints on how they meet their performance-based objectives. NPDES permits for major sources will still be required and must meet federal minima (technology-based controls) to avoid possible hot spots surrounding large dischargers, and states would remain listed as the lead permittee for these permits, but the lead municipality or other regional government would be able to propose new, more stringent limits that are presumptively favored in revised NPDES permits. Stormwater permits would also be mandatory, but their substantive requirements would be left wholly within the discretion of the lead municipality. Finally, states and municipalities would *not* be required to comply with all of the federal regulations governing TMDLs (they would make a basic load calculation for pollutants contributing to degraded conditions, 33 U.S.C. § 1313(d), but would not be required to do more). Instead, the watershed-based program would be considered the functional equivalent of TMDLs for at least the municipality's portion of the watershed since the program ensures that water quality objectives are met. Municipalities could even be allowed to set interim goals over a period of a decade or more so that TMDLs need not be achieved in a single permit cycle.

Other than federal minimum standards for major NPDES sources, municipalities would have primary if not exclusive authority to decide what types of sources (including nonpoint) require permits, whether certain land uses might be taxed for stormwater management fees, and whether and how to create trading programs among the contributors to water quality impairments within their watershed. Municipalities would also have legal authority to petition EPA to restrict upstream sources that contribute significantly to water quality degradation in ways that make it difficult for them to reach their goals. Upstream governments or sources could be subject to more rigorous federal or state TMDLs and could be vulnerable to tort and related claims from downstream municipalities.

This added flexibility and authority for municipalities to control water quality problems within their legal jurisdiction—coupled with objective performance standards—should lead to more creative approaches to stormwater management that create significant benefits to the municipality (i.e., more green-space buffers along waterways for recreation) and stronger planning and taxation of new de-

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velopments that otherwise might be uncontrolled. Municipal green space, parks, and a variety of other public goods that both reduce stormwater and enhance the public enjoyment of the surface waters could result from allowing a municipality the freedom to determine how best to regulate sources within its local boundaries. For example, rather than automatically allowing federally approved SCMs that have little aesthetic or recreational qualities, alternative approaches to SCMs that retain their effectiveness but provide other qualities (particularly qualities that draw the public outdoors for recreation or relaxation) are more likely to be encouraged or even required by a municipality that serves as lead over implementation of its water quality program.

Although a national watershed-based approach to stormwater regulation is likely to require legislative amendments, the pilot program may not necessitate additional legislative authorization. It is possible that through regulation, EPA may be able to develop "in lieu of" or "functional equivalent" requirements that allow a rigorous watershed plan to substitute for the bare federal requirements governing stormwater regulation, general permits, and TMDL planning laid out in the CWA. This type of intricate legal analysis, however, is beyond the scope of this document.

Final Thoughts

The watershed-based stormwater permitting program outlined above is ultimately essential if the nation is to be successful in arresting aquatic resource depletion stemming from sources dispersed across the landscape. EPA is called upon to adopt the framework now and set in motion a process to move it toward implementation over the next five to, at most, ten years. This chapter deals with some but not the entire realm of political, legal, regulatory, and logistical issues raised by converting to a fundamentally different system of management and permitting. Ideas are contributed regarding piloting and transitioning toward the new program, altering institutional arrangements to accommodate it, and incentives for effective participation. For watershed-based permitting to take hold, specific actions will have to be undertaken by EPA, state permitting authorities, and municipal permittees during the adoption and transition process.

The proposed program could be implemented by EPA in a number of ways, ranging from making it mandatory without any exception in all states and jurisdictions to leaving it entirely voluntary. The committee recommends neither extreme and believes the best course would be: (1) pilot test and refine the program as described in the report section titled "A Pilot Program as a Stepping Stone;" (2) make the refined program the default to be followed by all designated states (and EPA in others) and all municipal, industrial, and construction permittees, unless a state permitting authority convincingly demonstrates to EPA's satisfaction than an alternative approach will accomplish the program's overall goal of retaining and recovering aquatic resource beneficial uses; (3) develop very significant incentives for states and permittees to participate; and

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(4) require objective demonstration by any state opting for an alternative that it is broadly achieving the goal to at least the same extent as states within the program, with appropriate sanctions for noncompliance.

ENHANCEMENT OF EXISTING PERMITTING BASIS

The current federal stormwater regulatory framework has been in place since 1990, and the point source NPDES program under which it is being implemented has existed since 1972. The U.S. Congress deliberately acted in 1987 to amend the federal CWA with the goal of addressing stormwater pollution because it had been identified as a leading cause of surface water impairments, and regulations were inadequate to address it effectively. The total rethinking of the current framework of regulating stormwater pollution described above may require changes in statute and take a long time to implement. Thus, in addition to the longer-term approach that integrates a watershed-wide planning and permitting strategy into the program, several near-term solutions are also offered, with the objective of improving the current regulatory implementation and which at most might require changes in regulation.

Problems Complying with Both Municipal and General Industrial Permits

The NPDES permitting authority issues (1) separate individual permits or general permits to impose discharge requirements on small, medium, and large MS4s; (2) general permits that require construction activity operators who discharge stormwater to waters of the United States, including those who discharge via MS4s, to implement SCMs; and (3) general permits for operators of stormwater discharges associated with industrial activity who discharge to waters of the United States, including those who discharge via MS4s, to implement SCMs. The MS4 operators in turn are also required under the terms of their MS4 permits to require industries and construction site operators who discharge stormwater via the MS4 to implement controls to reduce pollutants in stormwater discharges to the maximum extent practicable, including those covered under the permitting authority's NPDES general permits. This dual-coverage scheme appears intended to recognize the separation of governmental authorities. Unfortunately, in practice it is duplicative, inefficient, and ineffective in controlling stormwater pollution that enters the MS4 from diffuse and dispersed sources. Particularly in the area of monitoring of water quality, the dual approach seems to have resulted in a lack of prioritization of high-risk industrial sources and the purposeless collection of industrial stormwater monitoring data or the poor use of it to strategically reduce the discharge of stormwater pollutants to the MS4.

The preference of EPA to use general NPDES permits to alleviate the administrative burden associated with permitting more than a 100,000 point

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sources discharging stormwater is understandable. It would have been prudent to have some form of prioritization to select some subset of the whole as high-risk or have a strategy for identifying a subset for individual NPDES permits to better achieve the objective of ensuring compliance with water quality standards on the basis of potential risk. As discussed in Chapter 2, there are no federal guidelines for prioritization (determining what industries are high-risk for stormwater discharges), and the state permitting authorities have largely not prioritized because of the overwhelming burden of administering a very expansive stormwater permitting program.

In the existing permitting scheme, the MS4 operator cannot be faulted for having a reasonable expectation that the permitting authority's general NPDES permits that regulate industrial activities and construction that discharge to the MS4 would require, at a minimum, a sufficient level of identification and implementation of SCMs to facilitate the MS4 operator's compliance with the MS4 permit. However, such controls are not identified by the NPDES permitting authority and rather are left to the choice of the industrial facility and construction site operators. Furthermore, the NPDES permitting authority imposes weak to no discharge sampling requirements on industrial facility and construction activity operators, which greatly impairs the MS4's ability to determine and control the worst regulated stormwater discharges to the MS4. Similarly, the NPDES permitting authority's general permit for construction activity encourages construction facility operators to consider post-construction stormwater controls, but it does not require them, even though the MS4 permit's programmatic measures mandate new development planning and post-construction controls as essential elements of the MS4 program. The lack of integration among stormwater permits and the absence of objective measures of compliance that are quantifiable is a glaring shortcoming in current stormwater permits and renders them difficult to enforce for water quality protection.

The California EPA State Water Board asked an expert panel to evaluate the extent of implementation success of the stormwater program in California and the feasibility of numeric effluent limits in stormwater permits. In its report (CA SWB, 2006), the panel concluded that the flexible approach of allowing a permittee to self-select SCMs for the purpose of controlling stormwater pollution was largely ineffective. The reasons stated were: (1) the SCMs were selected without proper consideration of design, performance, hydraulics, and function; (2) the MS4 permittees were not accountable for the performance of the SCMs; (3) the industrial and construction permittees were not responsible for the performance of the SCMs; and (4) the SCMs were seldom maintained properly except for aesthetic purposes. In other words, the flexibility provided by self-determination, self-evaluation, and self-reporting did not assure that SCMs were being implemented to effectively reduce stormwater pollutants to the MEP. Rather, the flexibility resulted in a lack of coordination of purpose and accountability between the MS4 permittees who owned or operate the MS4 and the industry and construction permittees who discharge to the MS4. Although typically enforcement by the permitting authority would have restored the integrity

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of the stormwater program, that remedy is likely to be ineffective here because the choice of SCMs is left too much to discretion and there are no quantifiable performance or design criteria for water quality purposes.

Integration and Dissemination of Authority

This section offers a near-term alternative solution to the problem cited above that utilizes the existing framework of the NPDES stormwater program. The strategy builds on the authority of MS4s over industry and construction sites to implement an integrated permitting scheme to reduce stormwater pollution into the waters of the United States. Unlike the first section of this chapter, it does not take a watershed approach to protecting water quality, even though the municipal stormwater programs may be more cost-effective if implemented on a watershed scale. It also addresses a significant shortcoming of the current scheme, that is, failure to recognize the enormous staff resources that it would take at the federal and state level for successful implementation in the absence of the leadership of local governments. Further, federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel under the principles of democratic governance, such as in the United States, to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees, who are local governments working for the public good, to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality—an approach here called "integration."

The central concept of integration is to give the MS4s controlling jurisdiction and responsibility over discharges from construction and industry to the MS4 in addition to their responsibility to implement the programmatic minimum measures identified in regulation. This approach would be similar to the current NPDES permitting scheme for publicly owned WWTPs, where a WWTP operator controls the quality of wastewater inputs (industrial waste streams) to make sure that the total output will not exceed water quality standards (see Box 6-5 on the National Pretreatment Program). The WWTP operators establish additional criteria such as local limits, require discharge monitoring of industrial wastes, and conduct inspections to make sure industrial discharges implement adequate wastewater treatment technologies, so that treated effluent from the wastewater treatment can comply with water quality standards to protect receiving waters. The same could be done for stormwater, except here the WWTP is replaced by the MS4, and the other inputs in this case are all industrial and construction discharges of stormwater into the MS4. The criteria by which the outputs of the industries are judged could be either water quality- or technology-based criteria. This arrangement puts the burden on the MS4 to identify high-risk industries because the MS4 is now responsible for the overall output (which could be, for example, the concentration of pollutants in stormwater monitored during

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BOX 6-5
National Pretreatment Program

EPA's NPDES Permitting Program requires that all point source discharges to waters of the United States (i.e., "direct discharges") must be permitted. To address "indirect discharges" from industries to Publicly Owned Treatment Works (POTWs), EPA, through CWA authorities, established the National Pretreatment Program as a component of the NPDES Permitting Program. The National Pretreatment Program requires industrial and commercial dischargers to treat or control pollutants in their wastewater prior to discharge to POTWs.

In 1986, more than one-third of all toxic pollutants entered the nation's waters from POTWs through industrial discharges to public sewers. Certain industrial discharges, such as slug loads, can interfere with the operation of POTWs, leading to the discharge of untreated or inadequately treated wastewater into rivers, lakes, etc. Some pollutants are not compatible with biological wastewater treatment at POTWs and may pass through the treatment plant untreated. This "pass through" of pollutants impacts the surrounding environment, occasionally causing fish kills or other detrimental alterations of the receiving waters. Even when POTWs have the capability to remove toxic pollutants from wastewater, these toxics can end up in the POTW's sewage sludge, which in many places is land-applied to food crops, parks, or golf courses as fertilizer or soil conditioner.

The National Pretreatment Program is unique in that the general pretreatment regulations require all large POTWs (i.e., those designed to treat flows of more than 5 MGD) and smaller POTWs with significant industrial discharges to establish local pretreatment programs. These local programs must enforce all national pretreatment standards (effluent limitations) and requirements, in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW. More than 1,500 POTWs have developed and are implementing local pretreatment programs designed to control discharges from approximately 30,000 significant industrial users.

EPA has supported the pretreatment program through development of more than 30 manuals that provide guidance to EPA, states, POTWs, and industry on various pretreatment program requirements and policy determinations. Through this guidance, the pretreatment program has maintained national consistency in interpretation of the regulations.

The general pretreatment regulations establish responsibilities of federal, state, and local government, industry, and the public to implement pretreatment standards to control pollutants that pass through or interfere with POTW treatment processes or that may contaminate sewage sludge. The general pretreatment regulations apply to all non-domestic sources that introduce pollutants into a POTW. These sources of "indirect discharge" are more commonly referred to as industrial users (IUs). Since IUs can be as simple as an unmanned coin-operated car wash to as complex as an automobile manufacturing plant or a synthetic organic chemical producer, EPA developed four criteria that define a significant industrial user (SIU). Many of the general pretreatment regulations apply to SIUs as opposed to IUs, based on the fact that control of SIUs should provide adequate protection of the POTW.

Unlike other environmental programs that rely on federal or state governments to implement and enforce specific requirements, the Pretreatment Program places the majority of the responsibility on local municipalities**.** Specifically, Section 403.8(a) of the general pretreatment regulations states that any POTW (or combination of treatment plants operated by the same authority) with a total design flow greater than 5 million MGD and smaller POTWs with SIUs must establish a local pretreatment program. As of early 1998, 1,578 POTWs were required to have local programs. Although this represents only about 15 percent of the total treatment plants nationwide, these POTWs account for more than 80 percent (i.e., approximately 30 billion gallons a day) of the national wastewater flow.

Consistent with Section 403.8(f), POTW pretreatment programs must contain the six minimum elements described below (EPA, 1999):

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1. Legal Authority

The POTW must operate pursuant to legal authority enforceable in federal, state, or local courts, which authorizes or enables the POTW to apply and enforce any pretreatment regulations developed pursuant to the CWA. At a minimum, the legal authority must enable the POTW to:

i. deny or condition discharges to the POTW,
ii. require compliance with pretreatment standards and requirements,
iii. control IU discharges through permits, orders, or similar means,
iv. require IU compliance schedules when necessary to meet applicable pretreatment standards and/or requirements and the submission of reports to demonstrate compliance,
v. inspect and monitor IUs,
vi. obtain remedies for IU noncompliance, and
vii. comply with confidentiality requirements.

2. Procedures

The POTW must develop and implement procedures to ensure compliance with pretreatment requirements, including:

i. identify and locate IUs subject to the pretreatment program,
ii. identify the character and volume of pollutants contributed by such users,
iii. notify users of applicable pretreatment standards and requirements,
iv. receive and analyze reports from IUs,
v. sample and analyze IU discharges and evaluate the need for IU slug control plans,
vi. investigate instances of noncompliance, and
vii. comply with public participation requirements.

3. Funding

The POTW must have sufficient resources and qualified personnel to carry out the authorities and procedures specified in its approved pretreatment programs.

4. Local Limits

The POTW must develop local limits or document why those limits are not necessary.

5. Enforcement Response Plan (ERP)

The POTW must develop and implement an ERP that contains detailed procedures indicating how the POTW will investigate and respond to instances of IU noncompliance.

6. List of SIUs

The POTW must prepare, update, and submit to the approval authority a list of all significant industrial users (SIUs).

In addition to the six specific elements, pretreatment program submissions must include:

- A statement from the city solicitor (or the like) declaring the POTW has adequate authority to carry out program requirements;
- Copies of statutes, ordinances, regulations, agreements, or other authorities the POTW relies upon to administer the pretreatment program, including a statement reflecting the endorsement or approval of the bodies responsible for supervising and/or funding the program;

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BOX 6-5 Continued

- A brief description and organizational chart of the organization administering the program; and
- A description of funding levels and manpower available to implement the program.

The objectives of the National Pretreatment Program are achieved by applying and enforcing three types of discharge standards: (1) prohibited discharge standards, (2) categorical standards, and (3) local limits.

Prohibited Discharge Standards

All IUs, whether or not subject to any other national, state, or local pretreatment requirements, are subject to the general and specific prohibitions identified in 40 C.F.R. §§403.5(a) and (b), respectively. General prohibitions forbid the discharge of any pollutant(s) to a POTW that cause pass-through or interference. These prohibited discharge standards are intended to provide general protection for POTWs. Examples of these include prohibitions on discharges of pollutants that can create fire or explosion hazards, cause corrosive structural damage, obstruct flow within the POTW, and interfere with the POTW's biological treatment activity. However, their lack of specific pollutant limitations creates the need for additional controls, namely categorical pretreatment standards and local limits.

Categorical Standards

Categorical pretreatment standards (i.e., categorical standards) are national, uniform, technology-based standards that apply to discharges to POTWs from specific industrial categories (i.e., indirect dischargers) and limit the discharge of specific pollutants. Categorical pretreatment standards for both existing and new sources are promulgated by EPA pursuant to Section 307(b) and (c) of the CWA. Limitations developed for indirect discharges are designed to prevent the discharge of pollutants that could pass through, interfere with, or otherwise be incompatible with POTW operations. The categorical pretreatment standards can be concentration based or mass based. For example, the pretreatment standard for the electrical and electronic component manufacturing industry (40 C.F.R. Part 469, Subparts A-D) are concentration-based daily maximum and monthly average limits that vary by subpart and pollutant parameter.

Local Limits

Prohibited discharge standards are designed to protect against pass-through and interference generally. Categorical pretreatment standards, on the other hand, are designed to ensure that IUs implement technology-based controls to limit the discharge of pollutants. Local limits, however, address the specific needs and concerns of a POTW and its receiving waters**.** Federal regulations at 40 CFR §§403.8(f)(4) and 122.21(j)(4) require control authorities to evaluate the need for local limits and, if necessary, implement and enforce specific limits as part of pretreatment program activities. Local limits are developed for pollutants (e.g., metals, cyanide, BOD_5, TSS, oil and grease, organics) that may cause interference, pass-through, sludge contamination, and/or worker health and safety problems if discharged in excess of the receiving POTW treatment plant's capabilities and/or receiving water quality standards.

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events). If put in this position, municipalities will make intelligent choices and adopt effective strategies to identify which industries and sources to focus upon. Each of these issues is discussed in greater detail below.

Determination of High-Risk Dischargers

At present, the federal stormwater regulations do not specifically identify which sources would be considered high risk given the common pollutants in MS4 stormwater discharges. With the exception of the category of municipal landfills and hazardous waste treatment, storage, and disposal facilities, it does not even state that the other nine categories of industry singled out in the regulations for permitting under the multi-sector industrial stormwater general permit (MSGP) are really high risk. The devolution of this responsibility to the municipality is sensible because the municipality, as the land-use authority, already conducts development review and issues industrial conditional-use permits. The permitting authority would still be responsible for inspecting high-risk state, federal, and other facilities over which the MS4 permittee has no jurisdiction. In addition, the permitting authority would inspect municipal facilities such as airports, ports, landfills, and waste storage facilities to avoid the situation of self-inspection. Methods for ranking industries according to risk are discussed in a subsequent section.

It is likely that some of the designated high-risk facilities would be better regulated by individual stormwater NPDES permits. In particular, good candidates for individual NPDES permits include international ports, airports, and multiphase construction land developments, which are similar (in the potential risk they pose to water quality) to traditional major wastewater facilities such as petroleum refineries and large POTWs.

SCM Design Parameters, Numerical SCM Performance Criteria, and Monitoring

For the integration approach to work, the permitting authority and the MS4 permittee must better delineate SCM design parameters, numerical performance criteria, and default SCMs based on best available technology or water quality standards for the discharge of industrial and construction stormwater. Both the ASCE International Storm Water Database (which is now called the WERF International Storm Water Database because it is maintained by the Water Environment Research Foundation) and the National Stormwater Quality Database (NSQD), which were developed with EPA funding, are comprehensive datasets that can be used to develop numeric technology-based effluent criteria or limits for industrial and construction stormwater discharges. The MS4 can then determine the compliance of industry and construction activity with its requirements by using either some numeric criteria or a suite of SCMs that have been

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presumptively determined as capable of achieving the performance criteria. The EPA MSGP includes a general list of sector-specific SCMs, but these presently have no performance criteria associated with them. It is important that the EPA continue to support both the WERF and the NSQD databases as the repositories of SCM performance and MS4 monitoring data, so that MS4s can use them to establish local limits and update the performance criteria periodically to fully effectuate the iterative approach to ensuring that MS4 discharges eventually will meet water quality standards.

The proposed integration scheme will also facilitate the MS4 permittee's implementation of a purpose-oriented stormwater monitoring program directed toward identifying problematic industrial or construction stormwater discharges or high-risk industrial facility sectors. The current benchmark monitoring conducted by MSGP facilities would be eliminated. Instead, MSGP facilities would have the option of performing scientifically valid stormwater discharge sampling to demonstrate their compliance with performance criteria or to participate in an MS4-led monitoring program by paying in lieu fees to support the cost of the purpose-oriented MS4 monitoring program. The net effect of this alternative is to pool the resources to come up with an optimal sampling strategy to replace what is now a stormwater monitoring strategy that is haphazard and not useful.

MS4 Responsibilities

Under integration, the MS4 permittee would be primarily responsible for the quality of stormwater discharges that exit the MS4 to the waters of the United States. The MS4 permittee would not be responsible for stormwater discharges from federal and state facilities or for facilities that have been issued an individual NPDES permit for stormwater discharges. The MS4 permittee would be responsible for implementing the six minimum program measures, assisting in the oversight and inspection of facilities covered under the MSGP and the construction general permit (CGP), and implementing a strategic water quality monitoring program to identify and control pollutant discharges from high-risk sites. The permitting authority would share any fees collected under the MSGP and CGP with the MS4, and facilities covered by them would have the option to opt-out of self-monitoring and contribute equivalent funds to an MS4-led monitoring program. Similarly, the permitting authority would be expected to support research and special studies that address issues of regional or national significance through partnerships with the MS4 permittees.

Some MS4s may balk at taking on more responsibility for the control of stormwater pollution, as required for integration to succeed. However, there are already several case examples that exist. The State of Oregon requires facilities that discharge industrial stormwater to file a Notice of Intent (NOI) for coverage under the MSGP with both the state and the local MS4 (Campbell, 2007). The state has an agreement with the local MS4s for the inspection of the facilities covered under the MSGP and the sharing of NOI fees. The State of Tennessee

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has a statewide pilot program to partner with local MS4s for the inspection of construction sites that are covered under the CGP.

Analogy to the WWTP Pretreatment Program

It is certainly true that the MS4s are a more challenging point source to regulate for the discharge of pollutants than WWTPs. WWTPs have fewer outfalls discharging to waters of the United States than MS4s, and inputs into them are through discrete rather than diffuse sources as in the case of MS4s. It is thus expected to be more difficult to identify problem stormwater sources and to hold them accountable for discharges in excess of standards. This problem is not insurmountable, however. Watershed and land-use hydrologic models can be developed and refined by strategic sampling of pollutant sources for use by MS4 permittees and regulatory agencies. If EPA and state permitting authorities establish measurable outcomes as expected endpoints of progress, MS4 permittees will make intelligent choices about which measures to implement in order to meet these endpoints. In large part, the lack of progress nationally towards controlling pollutants in stormwater discharges from the MS4s has been due to the absence of national SCM design standards, MS4 discharge performance criteria, and stormwater effluent guidelines. Presently, the MS4 permittees as owners and operators of the MS4 affirmatively approve connections to the conveyance system for rainfall runoff. Historically the issuance of the MS4 connection permit has been based on the sizing of the pipes for the conveyance of flood waters. There are few barriers to including water quality considerations in reauthorizing these connections and adding new ones.

Note that EPA did initially consider using the WWTP pretreatment approach for stormwater discharges by requiring MS4 permittees to be primarily responsible for discharges of stormwater associated with industrial activity through the MS4 (53 Fed. Reg. 49428; December 7, 1988). However, EPA deviated from this approach in issuing its Final Storm Water Rule (55 Fed. Reg. 48006; November 16, 1990). In the absence of regulations that specifically confer authority on MS4 permittees to establish local limits for stormwater discharges to the MS4 from industry and businesses, the EPA should promulgate specific SCMs and performance guidelines with rigorous requirements for self-monitoring and compliance in order to support the integrated framework for controlling stormwater pollution from MS4s.

Potential Legal Barriers

A revised stormwater program that requires MS4s to play a more significant role in enforcement and oversight and that provides greater specificity in permit requirements is not only contemplated, but arguably demanded by Congress in the CWA. Specifically, Congress directs that MS4 permits be conditioned on

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the requirement that the MS4s "shall require controls to reduce the discharge of pollutants to the maximum extent practicable" 42 U.S.C. § 1342(p)(3)(B)(iii). EPA has already conditioned Phase I MS4 permits on the requirement that the municipality establish that it has the legal authority to inspect discharges into the system and take regulatory and enforcement action against excessive or violating sources [40 C.F.R. § 122.26(d)(2)(i)]. Nevertheless, to ensure that MS4s play an even more active role, EPA should include several additional requirements in its implementing regulations. In addition to promulgating more detailed and specific SCM requirements as discussed above, EPA should also require that the Phase I MS4s establish that they possess sufficient funding and staff to effectuate their responsibilities [see, e.g., 40 C.F.R. § 403.8(f)(2) and (3) requiring this showing for the POTW program]. Like the POTW program, states should also be authorized as MS4 permittees when the local governments are unable or unwilling to carry out their mandatory stormwater permit responsibilities [see, e.g., 40 C.F.R. § 403.10(e) providing this authority for the POTW program].

Industrial Program

The industrial stormwater permit program presently incorporates a menu of SCMs that are to be selected by the facility operator, a rudimentary monitoring program that includes visual observations, some water quality sampling for selected parameters for certain types of industries subject to numerical effluent limitations (see Table 2-6) or a set of pollutant-level benchmarks that are to be used as a measure to appropriately revise the SWPPP (see Table 2-5), and annual reporting. Neither SCM performance criteria nor the characteristics of a design storm for water quality purposes have been established. Given the broad discretion that facility operators enjoy as a result, it has been difficult to gauge compliance with the MSGP and initiate enforcement for non-compliance even though industrial stormwater discharges are required to meet effluent limitations (technology- or water quality-based) that reflect water quality standards (Duke and Beswick, 1997; Duke and Augustenborg, 2006; Wagner, 2006). Several ideas to address some of the shortcomings in the implementation of the permitting program for industrial stormwater discharges are offered as *additions* to the concept of MS4 regulatory integration discussed previously. They would substantively improve the current industrial stormwater permitting program even if the integration recommendations were not acted upon.

Criteria for a Water Quality Design Storm and Subsequent SCM Selection

To improve the quality of stormwater discharges from industry, provide for better accountability, and advance the objectives of the CWA, it is important

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first to identify the criteria for a water quality design storm as opposed to one for flood control design, where the objective is to protect human life and real property. It is important that the permitting authority designate the basis for the determination of the water quality design storm, and explicitly state that it would form the criteria for evaluation of compliance with technology-based standards or water quality-based standards. This is essential because the engineering design decisions that determine how much stormwater is to be treated to remove toxic pollutants that pose a risk to human health or aquatic life is more a policy matter than a scientific one (Schiff et al., 2007). While modeling exercises using continuous simulation methods in theory could be performed for every project or subwatershed or region to support planning decisions on how much stormwater needs to be treated for optimum water quality benefits, such a detailed analysis will be too cumbersome and cost-prohibitive for routine planning and implementation purposes. Thus it is recommended that the EPA establish guidelines for the selection of water quality design storms for controlling pollution from MS4 and industrial stormwater discharges. This would not be a new practice for EPA because the agency has previously established design storms for certain industrial sectors when promulgating effluent guidelines (Table 2-6). Conceivably, unlike the technology limiting design storms that are set on rainfall recurrence intervals, the design storm to protect surface water quality and beneficial uses could be different for different eco-regions of the United States.

The water quality design storm, which may be expressed as total rainfall depth, runoff volume, or rainfall intensity, incorporates the concept that extreme rainfall events are rare, and that a few times each year the runoff volume or flow rate from a storm will exceed the design volume or rate capacity of an SCM. Therefore, for the purpose of best available technology and cost-effectiveness, industrial facility operators should not be held accountable for pollutant removal from storms beyond the size for which an SCM is designed.

For MS4 operators, the concept of designing MS4s for both flood control conveyance (capital flood design) and for water quality protection (water quality design) involves a fundamental shift. Whereas flood control engineers design conveyance systems with return frequencies of two years (streets), ten years (detention basins), 50 years, and 100 years (channels), the water quality design storm event is for a return frequency of six months to a year. The water quality design implicitly focuses on treating the first flush of runoff, which contains the highest load and concentration of pollutants and which occurs in the first half to one inch of runoff. In contrast, flood control designs are built to convey tens of inches of runoff.

In addition to issuing the guidelines to support the setting of stormwater criteria for water quality design, it is important that the EPA establish SCM performance criteria based on best technologies and identify the “presumptive technologies” that have been demonstrated to achieve the performance criteria. The water quality design storm and the best available technologies with their associated criteria can then form a basis for technology-based effluent limitations to be included in industrial stormwater permits. If the facility operator elects the iden-

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tified presumptive technology, then compliance monitoring requirements can be scaled down to a minimum to ensure that the treatment systems are being properly maintained. On the other hand, if the operator elects to go with a suite of alternative SCMs, then the monitoring requirements sufficient to demonstrate that the suite of alternative SCMs are in fact achieving the effluent quality of the selected technology can be prescribed. In such a scheme, visual monitoring will serve to ensure that the treatment systems are being properly maintained, and compliance can be reported using the same procedures as required presently for the industrial wastewater permits.

How to Identify a High-Risk Industry

Both the watershed-based permitting approach described previously in this chapter and the integration approach call for municipal permittees, as part of their responsibilities, to identify high-risk industrial stormwater dischargers. This involves identifying the potential sources of concern, evaluating the extent of their potential impacts, and then prioritizing them for attention—a classic risk assessment. Municipalities would generally not be able to give equal and full attention to all sources, nor should they. Unfortunately, what constitutes high risk or any level of risk for industries covered by NPDES stormwater permits has not been defined by EPA, although the states have developed various interpretations (see Appendix C).

Two methodologies for identifying industrial and commercial facilities that are considered high-risk for discharging pollutants in stormwater are presented below. Box 6-6 describes the "intensity of industrial activity" method devised for the City of Jacksonville (Duke, 2007). This method uses telephone queries and a point scale system to visually score each facility based on the intensity of the industrial activities exposed to stormwater, and groups the results into categories A, B, C, or D in increasing order of intensity (Cross and Duke, 2008). The categories are designed to distinguish high-risk facilities from low-risk facilities, and not to make fine distinctions among facilities with similar characteristics. This typology is sufficient to distinguish facilities with little or no potential for discharging pollutants associated with stormwater from facilities that might discharge those pollutants. More than half of the facilities that were subject to Florida's MSGP were determined to be low-risk (Cross and Duke, 2008).

Box 6-7 outlines an empirical methodology used by the County of Los Angeles to rank the risk of industrial facilities for stormwater pollution on the basis of pollution potential P. The pollution potential P was computed as a product of the number of on-site sources, percent imperviousness, pollutant toxicity, degree of exposure, and the number of facilities (Los Angeles County, 2001). Based on this ranking scheme, five top high-risk industries were selected: (1) automobile dismantlers, (2) automobile repair, (3) metal fabrication, (4) motor freight, and (5) automobile dealers. Stormwater discharges from six facilities in each category were characterized over a two-year period, and the effectiveness of SCMs

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BOX 6-6
Risk Assessment for Industrial Dischargers of Stormwater

The City of Jacksonville has had very good success in determining what industries pose the highest stormwater risks by starting with businesses having the Standard Industrial Classification (SIC) codes designated for permit coverage but using multiple lists of potential sources and cross checking them to target inspections and other interventions where they will have the best effect. Other clues to sources of interest include other environmental permits (e.g., wastewater NPDES permits, permits for discharge to sanitary sewer), tax records, records of fire code inspections, building permit filings, planning agency proceedings, contacts with business associations, marketing information put out by companies, Resource Conservation and Recovery Act hazardous waste reports, and telephone and field surveys.

Duke (2007) proposed a 0- to 8-point scoring scheme (shown below) to rate the intensity of industrial activities exposed to stormwater. The system is based on the relative amount of exposure to precipitation and runoff by industrial materials, processes, wastes, and vehicles. Once municipalities gather the data and then classify their industries accordingly, they would have a very useful tool to program inspections and monitoring emphasizing the industries most risking their success in achieving established objectives. A similar system could and should be developed for construction sites.

0 points
- Small bulk waste, e.g., covered dumpster: area <100 m^2
- Hazardous waste: containers not exposed to precipitation

1 point
- Outdoor vehicle use: 1-2 vehicles, outdoors occasionally/never, not used in precipitation
- Vehicle washing outdoors, 1-2 vehicles, rarely or occasionally done

2 points
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors occasionally/never, used in precipitation
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors every day, not used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors occasionally/never, not used in precipitation
- Vehicle maintenance or re-fueling, 1-2 vehicles, rarely or occasionally done, outside
- Vehicle washing outdoors, 1-2 vehicles, regularly done
- Vehicles washing outdoors, 3 vehicles, rarely or occasionally done

4 points
- Storage of materials or products: area < 100m^2 and/or < five 55-gallon drums
- Fixed outdoor equipment: 1-2 small or large item(s)
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors every day, used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors occasionally/never, used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors every day, not used in precipitation
- Uncovered shipping/receiving area: 1-2 docks
- Vehicle maintenance or re-fueling outdoors, 1-2 vehicles, regularly done
- Vehicle maintenance or re-fueling outdoors, vehicles, rarely or occasionally done
- Plant yard, rail lines, access roads: 1,000 ft^2
- Small process equipment, e.g., compressors, generators: exposed to precipitation

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BOX 6-6 Continued

6 points
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors every day, used in precipitation
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors occasionally, used in precipitation
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors every day, not used in precipitation
- Vehicle maintenance or re-fueling outdoors, 3 vehicles, regularly done
- Plant yard, rail lines, access roads: 1,000 ft^2

8 points
- Storage of materials or products: area 100^2 and/or five 55-gallon drums
- Boneyard of scrap, disused equipment, similar
- Hazardous waste: containers exposed to precipitation
- Fixed outdoor equipment: small or 2 large items
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors every day, used in precipitation
- Uncovered shipping/receiving area: 3 docks
- Plant yard, rail lines, access roads: 5,000 ft^2
- Manufacturing activities, e.g., cutting, painting, coating materials: exposed to precipitation

SOURCE: Duke (2007).

was assessed at a subset of them. However, the monitoring was minimal, and so much of the prioritization was based on best professional judgment about pollutant discharges.

Industrial Stormwater Discharge Monitoring

Monitoring data from Phase I MS4s have been compiled in the NSQD for several years, making possible a number of important findings about the quality of municipal stormwater (see Chapter 3). Although industry that occurs within MS4s is technically included in the NSQD, the data are lumped together and not sector specific. There is no comparable, reliable source of data specifically on industrial discharges, even though EPA requires benchmark monitoring for MSGP industrial permittees. The intent was that industrial facility operators would use benchmark exceedances as action levels to improve SCMs, but this self-directed approach has been largely a failure. Many industrial facilities reported repeated exceedances of benchmark values without action, and others have failed to report any monitoring data at all. In addition, the representativeness of single grab samples taken to characterize the discharge and less-than-rigorous sample collection and quality assurance procedures have resulted in monitoring data that are not very useful. One of the only analyses of benchmark monitoring data ever done evaluated California's program between 1992 and 2001 (see Box 4-2; Stenstrom and Lee, 2005; Lee et al., 2007). The study showed no relationship between facility type and stormwater discharge quality. The cited reasons for the poor relationship included variability in sampling parameters, sampling time, and sampling strategy—that is, poor data.

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BOX 6-7
Los Angeles County Critical Facilities Monitoring Data

One of the few sources of data on industrial stormwater discharges comes from the County of Los Angeles. A stepwise process was used to identify the highest-risk industrial/commercial facilities, which were then monitored to measure the quality of their stormwater discharges and to evaluate the effectiveness of SCMs. The initial list of candidate facilities was identified from their relative numbers and the extent of their outdoor activities. This list was then refined using an empirical equation for pollutant potential P:

$$P = Q \times R \times T \times E \times N$$

where

Loading (*Q*) is the number of sources at a site and the likelihood of release;
Imperviousness (*R*) of a site is the percent of paved area;
Pollutant toxicity (*T*) denotes the number of toxic pollutants and the inherent toxicity of the mix;
An exposure factor (*E*) signifies if activities are exposed to rainfall; and
The Number (*N*) represents the total number of sites in the county.

Each variable was assigned a qualitative number from 1 to 10, with 10 representing the worst condition.

Based on this equation, five top "critical source" industries were determined: (1) automobile dismantlers; (2) automobile repair; (3) metal fabrication; (4) motor freight; and (5) automobile dealers. Six facilities from each of these categories were monitored during five storms a year for two years. The stormwater discharge samples were analyzed for general conventional pollutants, heavy metals, bacteria, and semi-volatile organic compounds. Half of the facilities were then fitted with SCMs, which were monitored to evaluate their effectiveness.

The highest median values were observed for total zinc (approx. 450 µg/L), dissolved zinc (approx. 360 µg/L), total copper (approx. 240 µg/L), and dissolved copper (approx. 110 µg/L) in stormwater discharges from fabricated metal sites. However, levels for total and dissolved zinc did not appear to be significantly different among the industry types. SCMs in the form of good housekeeping and spill containment measures were installed at half of the sites. For total and dissolved zinc, the median concentration lowered or stayed nearly the same with the implementation of SCMs at the auto dismantling, auto repair, and fabricated metals industries (i.e., in none of the circumstances was the difference significant). For total and dissolved copper, however, where the fabricated metal industry had displayed the highest median concentrations, levels were significantly reduced with the implementation of SCMs. The auto dismantling and auto repair businesses showed no significant differences in copper after the implementation of SCMs.

SOURCE: Los Angeles County (2001).

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In the past, it has been proposed to EPA that it fund a project that would systematically collect the benchmark monitoring data across the nation, as has been done for MS4s, but these suggestions have been rejected. To get better data from specific industrial sectors, it is recommended that a small subset of industrial users and sectors be selected for composite sampling in a program directed by the MS4. Alternatively, making a trained team responsible for monitoring of small-business industrial dischargers would reduce, if not eliminate, current problems with quality assurance.

Monitoring of industrial stormwater discharges could be streamlined by considering the adoption of a Reasonable Potential Analysis (RPA), which is already part of the existing practice in developing limits for NPDES wastewater permits (EPA, 1991). The RPA is a procedure that uses statistical distribution assumptions in association with a limited number of wastewater discharge quality measurements to determine the likelihood that a receiving water quality standard would be violated, which assists the permitting authority in determining what permit limitations should be set to protect receiving water quality. The effluent data from any treatment system may be described using standard descriptive statistics such as the mean concentration and the coefficient of variation. Using a statistical distribution such as the lognormal, an entire distribution of values can be projected from limited data; limits on pollutant concentrations in discharge can then be set at a specified probability of occurrence so that the receiving water is protected. An RPA for stormwater pollutants may be particularly relevant in developing performance criteria for SCMs for facilities discharging stormwater within the integrated framework of MS4 permitting. Also, MS4 permittees could use the method to reduce the number of pollutants that high-risk industries would be required to monitor in order to demonstrate to the municipality that they are not the source of pollutants in MS4 discharges that are impairing surface waters.

Construction Program

The recommendations for stormwater discharges associated with construction activity are very similar to those offered for stormwater discharges associated with industrial activity. The integration with the MS4 program is less of a challenge because municipalities have always had primacy on land development planning and construction activity. Most municipalities have had requirements for soil erosion and sediment control plans on construction sites that precede the federal stormwater regulations. EPA regulations already allow permitting authorities to approve Phase I and Phase II MS4 permittee oversight of CGP construction sites under the qualifying local program provision (40 C.F.R. 122.44(s)) (Grumbles, 2006). The weakness in the implementation of this provision currently is the absence of rigorous SCM performance criteria guidelines for MS4s permittees to meet in order to be deemed as qualifying.

The construction stormwater general permit program requires the develop-

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ment and implementation of an SWPPP. The SWPPP, which must be prepared before construction begins, focuses on two major requirements: (1) describing the site adequately and identifying the sources of pollution to stormwater discharges associated with construction activity on site and (2) identifying and implementing appropriate measures to reduce pollutants in stormwater discharges to ensure compliance with the terms and conditions of this permit. The SWPPP must describe the sequence of major stormwater control activities and the kinds of SCMs that will be in place, and it must identify interim and permanent stabilization practices, including a schedule of their implementation. There is an expectation that the construction site operator will use good site planning, preserve mature vegetation, and properly stage major earth-disturbing activities to avoid sediment loss and prevent erosion. Post-construction stormwater controls need to be considered, but are not required. Construction site operators are required to visually inspect the construction site weekly and perform a walk through before predicted storm events. No annual reports are required, but records must be kept for a period of three years after permit coverage has been terminated. There are no SCM performance criteria, other than a suggestion that most SCMs should be able to achieve 80 percent TSS removal. As with industry, it is difficult to gauge compliance with the CGP except when inadequate SCMs result in a massive discharge of sediment from a construction site.

The pollutant parameters that are of concern in stormwater discharges from construction activity are TSS, settleable solids, turbidity, and nutrients from erosion; pH from concrete and stucco; and a wide range of metallic and organic pollutants from construction materials, processes, wastes, and vehicles and other motorized equipment. The permitting authority, in addition to guidelines for the water quality design storm, must establish SCM performance criteria for stormwater discharges associated with construction activity. The construction site operator should be given the option of implementing SCMs that are the presumptive technology, or equivalent SCMs that can achieve the performance criteria. For example, the recommended SCMs in Box 5-3 could serve as the presumptive construction SCMs on a typical construction site that is less than 50 acres in size. If the operator elects to go with a suite of alternative SCMs, then adequate monitoring must be performed to demonstrate that the alternative SCMs are in fact achieving the performance criteria. In addition, the CGP presently does not mandate or require that post-construction SCMs be integrated with the MS4 permittee requirements under its New Development/Redevelopment Program requirements. The proper planning for and implementation of SCMs that will help mitigate stormwater pollution from planned future use of the site will be critical to protecting water quality. Thus the post-construction requirements of the CGP should be strengthened and better integrated with the new development/redevelopment requirements of the MS4 permits.

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Municipal Program

Several key enhancements to the MS4 permitting program are needed to ensure that resources are targeted to achieve the greatest on-the-ground implementation of SCMs to make incremental progress in meeting water quality standards. Six specific issues are discussed below; their implementation will require greater collaboration and flexibility among regulators and permitted parties. These recommendations are suggested for communities that are not ready for the integrated watershed approach proposed in the prior section, and represent a bridge toward building internal capacity to implement them.

Numeric Expression of "Maximum Extent Practicable"

The ambiguity of the term "maximum extent practicable" (MEP) has been a major impediment to achieving meaningful water quality results in the MS4 program. The EPA should develop numerical expressions of MEP in the next round of permit renewals that can be measured and tracked. A national numeric benchmark should be avoided; states should focus on regional benchmarks that are tied to their water quality problems. Four examples of methods to define MEP in a numeric manner are provided below: the first three are applied at a regional or state level, whereas the last (impervious cover-based TMDLs) offers more flexibility to be applied at individual sites.

Establish Municipal Action Levels. This approach relies on the use of a national database of stormwater runoff quality to establish reasonable expectations for outfall monitoring in highly developed watersheds. The NSQD (Pitt et al., 2004) allows users to statistically establish action levels based on regional or national event mean concentrations developed for pollutants of concern. The action level would be set to define unacceptable levels of stormwater quality (e.g., two standard deviations from the median statistic, for simplicity). Municipalities would then routinely monitor runoff quality from major outfalls. Where an MS4 outfall to surface waters consistently exceeds the action level, municipalities would need to demonstrate that they have been implementing the stormwater program measures to reduce the discharge of pollutants to the maximum extent practicable. The MS4 permittees can demonstrate the rigor of their efforts by documenting the level of implementation through measures of program effectiveness, failure of which will lead to an inference of noncompliance and potential enforcement by the permitting authority.

Site-Based Runoff and/or Pollutant Load Limits. This approach is primarily used for watersheds that are experiencing rapid development; it establishes numeric targets or performance standards for pollutant or runoff reduction that must be met on individual development sites. The numeric targets may involve specific pollutant load limits or runoff reduction volumes. For example,

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Virginia DCR (2007) and Hirschman et al. (2008) established a statewide computational method to ensure that SCMs are sized, designed, and sequenced to comply with specific nutrient-based load and runoff reduction limits. The nutrient load limits of 0.28 lb/acre/yr for total phosphorus and 2.68 lb/acre/yr for total nitrogen were computed using the Chesapeake Bay Model for Virginia tributaries to the bay. The design process also requires the computation of runoff reduction volumes achieved to promote the use of nonstructural SCMs. The basic concept is that new development on non-urban land must not exceed the average annual nutrient load and runoff volume for non-urban land using effective SCMs in the watershed. This blended site-based runoff and load limit approach has been advocated by the Office of Inspector General (2007) and Schueler (2008a) and is under active consideration by several other Chesapeake Bay states.

Wenger et al. (2008) reports on a no-net-hydrologic-increase strategy to protect endangered fish species in the northern Georgia Piedmont that sets specific on-site runoff reduction requirements for a range of land uses and design storm events. A similar approach has been incorporated into the recently enacted Energy Independence and Security Act of 2007 that contains provisions that require that the "sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

The challenge of defining MEP as a runoff reduction or pollutant load limit is that considerable scientific and engineering analysis is needed to establish the performance standards, evaluate SCM capability to meet them, and devise a workable computational approach that links them together at both the site and watershed levels. In addition, care must be taken to define an appropriate baseline to represent predevelopment conditions that does not unduly penalize redevelopment projects or make it impossible to comply with limits at new development sites after maximum effort to apply multiple SCMs is made.

Turbidity Limits for Construction Sites. Numeric enforcement criteria can be used to define what constitutes an egregious water quality violation at construction sites and provide a technical criterion to measure the effectiveness of erosion and sediment control practices. Currently, most states and localities do not specify either numeric enforcement criteria or a monitoring requirement within their CGP (see the survey data contained in Appendix C).

A maximum turbidity limit would establish definitive criteria as to what constitutes a direct sediment control violation and trigger an assessment for remediation and prevention actions. For example, local erosion and sediment control ordinances could establish a numeric turbidity limit of 75 Nephelometric Turbidity Units (NTU) as an instantaneous maximum for rainfall events less than an inch (or a 25 NTU monthly average) and would prohibit visible sedi-

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ment in water discharged from upland construction sites. While the exact turbidity limit would need to be derived on a regional basis to reflect geology, soils, and receiving water sensitivity, research conducted in the Puget Sound of Washington indicates that turbidity limits in the 25 to 75 NTU can be consistently achieved at most highway construction sites using current erosion and sediment control technology that is properly maintained (Horner et al., 1990). If turbidity limits are exceeded, a detailed assessment of site conditions and follow-up remediation actions would be required. If turbidity limits continue to be exceeded, penalties and enforcement actions would be imposed. Enforcement of turbidity limits could be performed either by state, local, or third party erosion and sediment control inspectors, or—under appropriate protocols, training, and documentation—by citizens or watershed groups.

Impervious Cover Limits and IC-based TMDLs. MS4s that discharge into TMDL watersheds also require more quantitative expression of how MEP will be defined to reduce pollutant loads to meet water quality standards. Maine, Vermont, and Connecticut have recently issued TMDLs that are based on impervious cover rather than individual pollutants of concern (Bellucci, 2007). In such a TMDL, impervious cover is used as a surrogate for increased runoff and pollutant loads as a way to simplify the urban TMDL implementation process. Impervious cover-based TMDLs have been issued for small subwatersheds that have biological stream impairments associated with stormwater runoff but no specific pollutant listed as causing the impairment (in most cases, these subwatersheds are classified as impacted according to the Impervious Cover Model [ICM]—see Box 3-10). A specific subwatershed threshold is set for effective impervious cover, which means impervious cover reductions are required through removal of impervious cover, greater stormwater treatment for new development, offsets through stormwater retrofits, or other means.

Traditional pollutant-based TMDLs would continue to be appropriate for "non-supporting" and "urban drainage" subwatersheds, although they could be modified to focus compliance monitoring on priority urban source areas or subwatersheds that produce the greatest pollutant loads. Although EPA (2002) indicates that this analysis does not extend to demonstrating that changes will occur in receiving waters, it does outline a rigorous process for evaluating pollutant discharges and SCM performance. More recent EPA guidance (2007c) recommends that MS4s conduct a four-step analysis, which is distilled to its essence below:

Step 1: Estimate loads for pollutant of concern for the watershed.

Step 2: Provide a specific list of SCMs that will be applied in the listed watershed.

Step 3: Estimate the pollutant removal capability of the individual SCMs applied.

Step 4: Compute aggregate watershed pollutant reduction achieved by the MS4.

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Although this is not a particularly new interpretation of addressing stormwater loads in watersheds listed as impaired and/or having written TMDLs, it is exceptionally uncommon for individual MS4s to document the link between their stormwater discharges and water quality standard exceedances, as modified by the system of SCMs that they used to reduce these pollutants. As of 2007, EPA could only document 17 TMDLs that addressed stormwater discharges using this sequential analysis. EPA and states need to provide more specific guidance for MS4s to comply with TMDLs in their permit applications and annual reports.

Focus MS4 Permit Implementation at the Subwatershed Level

Chapter 5 noted the importance of the watershed context for making better local stormwater decisions. This context can be formally incorporated into local MS4 permits by focusing implementation on a subwatershed basis, using the ICM, as described in Box 3-10 and outlined in Table 6-1. When urban streams are classified by the ICM, this basic subwatershed planning process can be used to establish realistic water quality and biodiversity goals for individual classes of subwatersheds, as shown in Table 6-2. As can be seen, goals for water and habitat quality become less stringent as impervious cover increases within the subwatershed. This subwatershed approach provides stormwater managers with more specific, measurable, and attainable implementation strategies than the one-size-fits-all approach that is still enshrined in current wet-weather management regulations.

Some examples of how to customize stormwater strategies for different subwatersheds are described in Table 6-3. This approach enables MS4s to utilize the full range of watershed planning, engineering, economic, and regulatory tools that can manage the intensity, location, and impact of impervious cover on receiving waters. In addition, the application of multiple tools in a given subwatershed class helps provide the maximum level of protection or restoration for an individual subwatershed when impervious cover is forecast to increase due to future growth and development. The conceptual management approach shown in Table 6-3 is meant to show how urban stream classification can be used to guide stormwater decisions on a subwatershed basis. The first column of the table lists some key stormwater management issues that lend themselves to a subwatershed approach and are explained in greater detail below.

Linkage with Local Land-Use Planning and Zoning. Given the critical relation between land use and the generation of stormwater, communities should ensure that their planning tools (e.g., comprehensive plans, zoning, and watershed planning) are appropriately aligned with the intended management classification for each subwatershed. For example, it is reasonable to encourage redevelopment, infill, and other forms of development intensification within non-

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TABLE 6-1 Components of Subwatershed-Based Stormwater Management

1. Define interim water quality and stormwater goals (i.e., pollutants of concern, biodiversity targets) and the primary stormwater source areas and hotspots that cause them.
2. Delineate subwatersheds within community boundaries.
3. Measure current and future impervious cover within individual subwatersheds.
4. Establish the initial subwatershed management classification using the ICM.
5. Undertake field monitoring to confirm or modify individual subwatershed classifications.
6. Develop specific stormwater strategies within each subwatershed classification that will guide or shape how individual practices and SCMs are generally assembled at each individual site.
7. Undertakes restoration investigations to verify restoration potential in priority subwatersheds.
8. Agree on the specific implementation measures that will be completed within the permit cycle. Evaluate the extent to which each of the six minimum management practices can be applied in each subwatershed to meet municipal objectives.
9. Agree on the maintenance model that will be used to operate or maintain the stormwater infrastructure, assign legal and financial responsibilities to the owners of each element of the system, and develop a tracking and enforcement system to ensure compliance.
10. Define the trading or offset system that will be used to achieve objectives elsewhere in the local watershed objectives in the event that full compliance cannot be achieved due to physical constraints (e.g., indexed fee-in-lieu to finance municipal retrofits).
11. Establish sentinel monitoring stations in subwatersheds to measure progress towards goals.
12. Revise subwatershed management plans in the subsequent NPDES permitting cycle based on monitoring data.

supporting or urban drainage subwatersheds, whereas down-zoning, site-based IC caps, and other density-limiting planning measures are best applied to sensitive subwatersheds.

Stormwater Treatment and Runoff Reduction MEP. Subwatershed classification allows managers to define achievable numerical benchmarks to define treatment in terms of the maximum extent practicable. Thus, a greater level of treatment is required for less-developed subwatersheds and a reduced level of treatment is applied for more intensely developed subwatersheds. This is most frequently expressed in terms of a rainfall depth associated with a given design storm. Designers are required to treat and/or reduce runoff for all storm events up to the designated storm event. This flexibility recognizes the greater difficulty and cost involved in providing the same level of treatment in an in-

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TABLE 6-2 Expectations for Different Urban Subwatershed Classes

Lightly Impacted Subwatersheds (1 to 5% IC)	• Consistently attain scores for specific indicators for hydrology, biodiversity, and geomorphology that are comparable to streams whose entire subwatersheds are fully protected in a natural state (e.g., national parks). Should provide for healthy reproduction of trout, salmon, or other keystone fish species.
Moderately Impacted Subwatersheds (6 to 10% IC)	• Consistently attain scores for specific stream indicators that are comparable to the highest 10 percent of streams in a population of rural watersheds in order to maintain or restore ecological structure, function, and diversity of the streams. The "good to excellent" indicator scores for this category of subwatersheds will be the benchmark against which the relative quality of more developed subwatersheds will be measured.
Heavily Impacted Subwatersheds (11 to 25% IC)	• Consistently attain good stream quality indicator scores to ensure enough stream function to adequately protect downstream receiving waters from degradation. • Function is defined in terms of flood storage, in-stream nutrient processing, biological corridors, stable stream channels, and other factors.
Non-Supporting Subwatersheds (26 to 60% IC)	• Consistently attain "fair to good" stream quality indicator scores. • Meet bacteria standards during dry weather and trash limits during wet weather. • Maintain existing stream corridor to allow for safe passage of fish and floodwaters.
Urban Drainage Subwatersheds (61 to 100% IC)	• Maintain "good" water quality conditions in downstream receiving waters. • Consistently attain "fair" water quality scores during wet weather and "good" water scores during dry weather. • Provide clean "plumbing" in upland land uses such that discharges of sewage and toxics do not occur.

Note: the objectives presume some portion of the subwatershed has already been developed, thereby limiting attainment of objectives. If a subwatershed is not yet developed, managers should shift expectations up one category (e.g., urban drainage should behave like non-supporting). Also, the specific ranges of IC that define each management category should always be derived from local or regional monitoring data. Note that the ranges in IC shown to define a subwatershed management category are illustrative and will vary regionally.

tensely developed subwatershed, as well as the fact that less treatment is needed to maintain stream condition in a highly urban subwatershed.

The other key element of defining MEP is to specify how much of the treatment volume must be achieved through runoff reduction. The runoff reduction volume has emerged as the primary performance benchmark to maintain predevelopment runoff conditions at a site after it is developed. In its simplest terms, this means achieving the same predevelopment runoff coefficient for each storm up to a defined storm event through a combination of canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration, or evapotranspiration (Schueler, 2008b). Once again, the physical feasibility and need to provide treatment through runoff reduction becomes progressively harder as subwatershed impervious cover increases.

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TABLE 6-3 Examples of Customizing Stormwater Strategies on a Subwatershed Basis

Stormwater Management Issue	Lightly Impacted Subwatershed (1 to 5% IC)	Moderately Impacted Subwatershed (6 to 10% IC)	Impacted (IC 11 to 25%)	Non-Supporting (IC 26 to 60%)	Urban Drainage (61% + IC)
Linkage with Local Land-Use Planning and Zoning	Utilize extensive land conservation and acquisition to preserve natural land cover	Implement site-based or watershed-based IC caps and maximize conservation of natural areas	Reduce the IC created for each zoning category by changing local codes and ordinances	Encourage redevelopment, development intensification and mass transit to decrease per-capita IC utilization in the urban landscape. Develop watershed restoration plans to maintain or enhance existing aquatic resources.	
Site-based Stormwater Reduction and Treatment Limits	Allow no net increase in runoff volume, velocity and duration up to the five-year design storm	Treat runoff from two-year design storm, using SCMs to achieve 100% runoff reduction		Treat runoff from the one-year design storm, using SCMs to achieve at least 75% runoff reduction	
Site-Based IC Fees	None	Establish Excess IC fee for projects that exceed IC for zoning category		Allow IC mitigation fee	
Subwatershed Trading	Receiving Area for Conservation Easements	Receiving Area for Restoration Projects and/or Retrofit		Receiving or Sending Area for Retrofit	Sending Area for Restoration Projects
Stormwater Monitoring Approach	Measure in-stream metrics of biotic integrity		Track subwatershed IC and measure SCM performance	Check outfalls and measure SCM performance	Check stormwater quality against municipal actions levels at outfalls
TMDL Approach	Protect using antidegradation provisions of the CWA	Use IC-based TMDLs that use flow or IC as a surrogate for traditional pollutants		Use pollutant TMDLs to identify problem subwatersheds	Use pollutant TMDLs to identify priority source areas
Dry Weather Water Quality	Perform in-stream grab sampling of water quality at sentinel stations	Check for failing septic systems	Screen outfalls for illicit discharges	Perform dry weather sampling in streams and outfall screening	Perform dry weather sampling in receiving waters
Addressing Existing Development	Protect or conserve natural areas, enhance riparian cover, assess road crossings, and ensure farm, forest, and pasture best practices are used		Perform stream repairs, riparian reforestation, and residential stewardship	Perform storage retrofits and stream repairs	Use pollution source controls and municipal housekeeping

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Site-Based IC Fees. Several economic strategies can be used to promote equity and efficiency when it comes to managing stormwater in different kinds of subwatersheds. In lower-density subwatersheds, an excess impervious cover fee can be charged to individual sites that exceed a maximum threshold for impervious cover for their zoning category. Similarly, an impervious cover mitigation fee can be levied at individual development sites in more intensely developed subwatersheds when on-site compliance is not possible or it is more cost-effective to provide an equivalent amount of treatment elsewhere in the watershed. The type of fee and the frequency that is used is expected to be closely related to the subwatershed classification.

Subwatershed Trading. The degree of impervious cover in a subwatershed also has a strong influence on the feasibility, cost, and appropriateness of restoration projects. Consequently, any revenues collected from various site IC fees can be traded among subwatersheds to arrive at the least-cost, effective solutions. In general, the most intensely developed subwatersheds are sending areas and the more lightly developed subwatersheds are used as receiving areas for such projects.

Stormwater Monitoring Approach. Subwatershed classification can also be used to define the type and objectives for stormwater monitoring to track compliance over time. For example, in sensitive subwatersheds, it may be advisable to routinely measure in-stream metrics of biological integrity to ensure stream quality is being maintained or enhanced. As impervious cover increases, stormwater managers may want to shift toward tracking of subwatershed impervious cover and actual performance monitoring of select SCMs to establish their effectiveness (e.g., impacted subwatersheds). At even higher levels of impervious cover, streams are transformed into urban drainage, and monitoring becomes more focused on identifying individual stormwater outfalls with the worst quality during storm conditions.

TMDL Approach. Subwatershed classification may also serve as a useful tool to decide how to apply TMDLs to impaired waters, or how to ensure that healthy waters are not degraded by future land development. For example, most lightly developed subwatersheds will seldom be subject to a TMDL, or if so, urban stormwater is often only a minor component in the final waste load allocation. Antidegradation provisions of the CWA are often the best means to protect the quality of these healthy waters before they are degraded by future land development. By contrast, impaired watersheds appear to be the best candidates to apply impervious cover-based TMDLs, as described earlier in this section. As subwatershed impervious cover increases, more traditional pollutant-based TMDLs are warranted, with a focus on problem subwatersheds for non-supporting streams and priority source areas for urban drainage.

Dry Weather Water Quality. The type, severity, and sources of illicit dis-

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charges often differ among different subwatershed classifications, which can have a strong influence on the kind of dry weather detective work needed to isolate them. For example, in lightly developed subwatersheds, failing septic systems are often the most illicit discharges, which prompts assessments at the lot or ditch level. The storm-drain network and potential discharge source areas becomes progressively more complex as subwatershed impervious cover increases. Consequently, illicit-discharge assessments shift toward outfall screening, catchment analysis, and individual source analysis.

Addressing Existing Development. The need for, type of, and feasibility for restoration efforts shift as subwatershed impervious cover increases. In general, lightly developed watersheds have the greatest land area available for retrofits and restoration projects in the stream corridor. Consequently, unique restoration strategies are developed for different subwatershed classifications (Schueler, 2004).

Require More Quantitative Evaluation of MS4 Programs

The next round of permit renewals should contain explicit conditions to define and measure outcomes from the six minimum management measures that constitute a Phase II MS4 program. Measurable program evaluation is critical to develop, implement, and adapt effective local stormwater programs, and has been consistently requested in permits and application guidance. To date, however, only a small fraction of MS4 communities have provided measurable outcomes with regard to aggregate pollutant reduction achieved by their municipal stormwater programs.

CASQA (2007) defines a six-level pyramid to assess program effectiveness, beginning with documenting activities, raising awareness, changing behaviors, reducing loads from sources, improving runoff quality, and ultimately leading to protection of receiving water quality (see Figure 6-1).

At the current time, most MS4s are struggling simply to organize or document their program activities (i.e., the first level), and few have moved up the pyramid to provide a quantitative link between program activities and water quality improvements. The framework and methods to evaluate program effectiveness for each of the six minimum management measures has been outlined by CASQA (2007). Regulators are encouraged to work with permitted municipalities to define increasingly more specific quantitative measures of program performance in each succeeding permit cycle.

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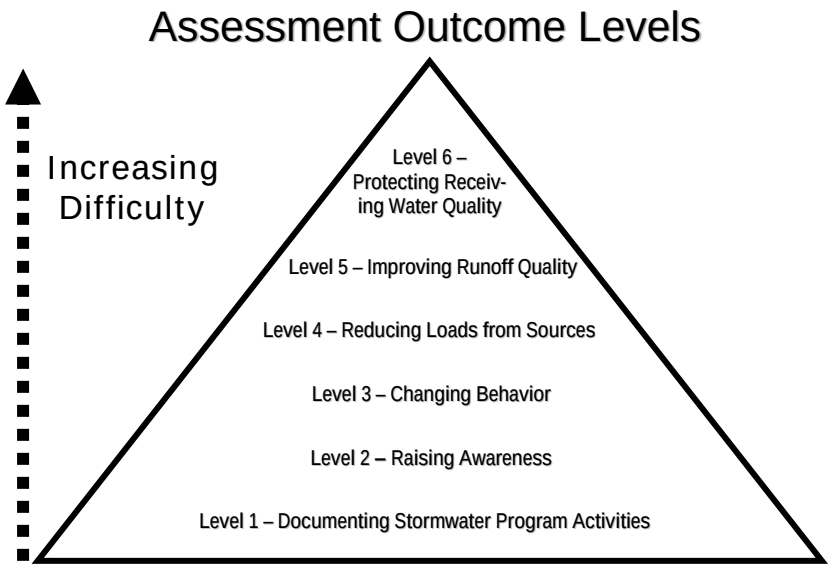

FIGURE 6-1 Pyramid of Assessment Outcome Levels for an MS4. SOURCE: CASQA (2007).

Shift Monitoring Requirements to Measure the Performance of Stormwater Control Measures

The lack of monitoring requirements in the Phase II stormwater program makes it virtually impossible to measure or track actual pollutant load or runoff volume reductions achieved. While the existing Phase I outfall monitoring requirements have improved our understanding of urban stormwater runoff quality, they are also insufficient to link program effort to receiving water quality. It is recommended that both Phase I and II MS4s shift to a more collaborative monitoring effort to link management efforts to receiving water quality, as described below:

- If a review of past Phase 1 MS4s stormwater outfall monitoring indicates no violations of the Municipal Action Limits, then their current outfall monitoring efforts can be replaced by pooled annual financial contributions to a regional stormwater monitoring collaborative or authority to conduct basic research on the performance and longevity of range of SCMs employed in the community.

- If some subwatersheds exceed Municipal Action Levels, outfall monitoring should be continued at these locations, as well as additional source area sampling in the problem subwatershed to define the sources of the stormwater

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pollutant of concern.

- Phase II MS4s should be encouraged to make incremental financial contributions to a state or regional stormwater monitoring research collaborative to conduct basic research on SCM performance and longevity. Although the committee knows of no examples where this has been accomplished, this pooling of financial resources by multiple MS4s should produce more useful scientific data to support municipal programs than could be produced by individual MS4s alone. Phase II communities that do not participate in the research collaborative would be required to perform their own outfall and/or SCM performance monitoring, at the discretion of the state or federal permitting authority.

- All MS4s should be required to indicate in their annual reports and permit renewal applications how they incorporated research findings into their existing stormwater programs, ordinances, and design manuals.

CONCLUSIONS AND RECOMMENDATIONS

The watershed-based permitting program outlined in the first part of this chapter is ultimately essential if the nation is to be successful in arresting aquatic resource depletion stemming from sources dispersed across the landscape. Smaller-scale changes to the EPA stormwater program are also possible. These include integration of industrial and construction permittees into municipal permits ("integration"), as well as a number of individual changes to the current industrial, construction, and municipal programs.

Improvements to the stormwater permitting program can be made in a tiered manner. Thus, individual recommendations specific to advancing one part of the municipal, industrial, or construction stormwater programs could be implemented immediately and with limited additional funds. "Integration" will need additional funding to provide incentives and to establish partnerships between municipal permittees and their associated industries. Finally, the watershed-based permitting approach will likely take up to ten years to implement. The following conclusions and recommendations about these options are made:

The greatest improvement to the EPA's Stormwater Program would be to convert the current piecemeal system into a watershed-based permitting system. The proposed system would encompass coordinated regulation and management of all discharges (wastewater, stormwater, and other diffuse sources), existing and anticipated from future growth, having the potential to modify the hydrology and water quality of the watershed's receiving waters.

The committee proposes centralizing responsibility and authority for implementation of watershed-based permits with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees,

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with enhanced authority and funding commensurate with increased responsibility. Permitting authorities would adopt a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses in the watershed's component waterbodies and additional goals in some cases aimed at recovering lost beneficial uses. The framework envisions the permitting authorities and municipal co-permittees working cooperatively to define careful, complete, and clear specific objectives aimed at meeting goals.

Permittees, with support from the permitting authority, would then move to comprehensive scientific and technically based watershed analysis as a foundation for targeting solutions. The most effective solutions are expected to lie in isolating, to the extent possible, receiving waterbodies from exposure to those impact sources. In particular, low-impact design methods, termed Aquatic Resources Conservation Design in this report, should be employed to the full extent feasible and backed by conventional SCMs when necessary. This report also outlines a monitoring program structured to assess progress toward meeting objectives and the overlying goals, diagnosing reasons for any lack of progress, and determining compliance by dischargers. The new concept further includes market-based trading of credits among dischargers to achieve overall compliance in the most efficient manner and adaptive management to program additional actions if monitoring demonstrates failure to achieve objectives.

Integration of the three permitting types, such that construction and industrial sites come under the jurisdiction of their associated municipalities, would greatly improve many deficient aspects of the stormwater program. Federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality. The National Pretreatment Program, EPA's successful treatment program for municipal and industrial wastewater sources, could serve as a model for integration.

Short of adopting watershed-based permitting or integration, a variety of other smaller-scale changes to the EPA stormwater program could be made now, as outlined below.

EPA should issue guidance for MS4, MSGP, and CGP permittees on what constitutes a design storm for water quality purposes. Precipitation events occur across a spectrum from small, more frequent storms to larger and more extreme storms, with the latter being a more typical focus of guidance manuals to date. Permittees need guidance from regional EPA offices on what water quality considerations to design SCMs for beyond issues such as safety of human life and property. In creating the guidance there should be a good faith

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effort to integrate water quality requirements with existing stormwater quantity requirements.

EPA should issue guidance for MS4 permittees on methods to identify high-risk industrial facilities for program prioritization such as inspections. Two visual methods for establishing rankings that have been field tested are provided in the chapter. Some of these high-risk industrial facilities and construction sites may be better covered by individual NPDES stormwater permits rather than the MSGP or the CGP, and if so would fall directly under the permitting authority and not be part of MS4 integration.

EPA should support the compilation and collection of quality *industrial* stormwater effluent data and SCM effluent quality data in a national database. This database can then serve as a source for the agency to develop technology-based effluent guidelines for stormwater discharges from industrial sectors and high-risk facilities.

EPA should develop numerical expressions to represent the MS4 standard of Maximum Extent Practicable. This could involve establishing municipal action levels based on expected outfall pollutant concentrations from the National Stormwater Quality Database, developing site-based runoff and pollutant load limits, and setting turbidity limits for construction sites. Such numerical expressions would create improved accountability, bring about consistency, and result in implementation actions that will lead to measurable reductions in stormwater pollutants in MS4 discharges.

Communities should use an urban stream classification system, such as a regionally adapted version of the Impervious Cover Model, to establish realistic water quality and biodiversity goals for individual classes of subwatersheds. The goals for water and habitat quality should become less stringent as impervious cover increases within the subwatershed. This should not become an excuse to work less diligently to improve the most degraded waterways—only to recognize that equivalent, or even greater, efforts to improve water quality conditions will achieve progressively less ambitious results in more highly urbanized watersheds. This approach would provide stormwater managers with more specific, measurable, and attainable implementation strategies than the one-size-fits-all approach that is promoted in current wet weather management regulations.

Better monitoring of MS4s to determine outcomes is needed. Only a small fraction of MS4 communities have provided measurable outcomes with regard to aggregate flow and pollutant reduction achieved by their municipal stormwater programs. A framework and methods to evaluate program effectiveness for each of the six minimum management measures have been outlined by CASQA (2007) and should be adopted. In addition, the lack of monitoring

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requirements in the Phase II stormwater program makes it virtually impossible to measure or track actual pollutant load or runoff volume reductions achieved. It is recommended that both Phase I and II MS4s shift to a more collaborative monitoring paradigm to link management efforts to receiving water quality.

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Watershed-based permitting will require additional resources and regulatory program support. Such an approach shifts more attention to ambient outcomes as well as expanded permitting coverage. Additional resources for program implementation could come from shifting existing programmatic resources. For example, some state permitting resources may be shifted away from existing point source programs toward stormwater permitting. Strategic planning and prioritization could shift the distribution of federal and state grant and loan programs to encourage and support more watershed-based stormwater permitting programs. However, securing new levels of public funds will likely be required. All levels of government must recognize that additional resources may be required from citizens and businesses (in the form of taxes, fees, etc.) in order to operate a more comprehensive and effective stormwater permitting program.

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Appendixes

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Appendix A
Acronyms

BAC	best attainable conditions
BAT	best available technology
BCG	Biological Condition Gradient
BCT	best control technology
BOD	biochemical oxygen demand
CAFO	concentrated animal feeding operation
CBWM	Chesapeake Bay Watershed Model
CCI	Census of Construction Industries
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGP	Construction General Permit
CN	Curve Number
COD	chemical oxygen demand
COV	coefficient of variability
CWA	Clean Water Act
DHSVM	Distributed Hydrology, Soil, and Vegetation Model
EIA	effective impervious area
EMC	event mean concentration
ERP	Enforcement Response Plan
ETV	Environmental Technology Verification Program
EWH	exceptional warmwater habitat
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GIS	Geographic Information System
GWLF	General Watershed Loading Function
HRU	Hydrologic Response Unit
HSPF	Hydrologic Simulation Program–Fortran
HUC	hydrologic unit code
ICM	Impervious Cover Model
KCRTS	King County Runoff Time Series
LDC	least disturbed conditions
LEED	Leadership in Energy and Environmental Design
LID	low-impact development
MDC	minimally disturbed conditions
MEP	maximum extent practicable
MGD	million gallons per day
MSGP	multi-sector industrial stormwater general permit
MTBE	methyl tert-butyl ether
NCSI	Normalized Channel Stabilization Index
NOI	Notice of Intent

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NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NRI	National Resource Inventory
NSQD	National Stormwater Quality Database
NTU	Nephelometric Turbidity Unit
NURP	National Urban Runoff Program
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
POTW	publicly owned treatment works
PUD	planned unit development
RCRA	Resource Conservation and Recovery Act
RPA	Reasonable Potential Analysis
SBUH	Santa Barbara Unit Hydrograph
SCCWRP	Southern California Coastal Water Research Project Authority
SCM	stormwater control measure
SIC	Standard Industrial Classification
SLAMM	Source Loading and Management Model
SMDR	Soil Moisture Distributed and Routing
SWAT	Soil and Water Assessment Tool
SWMM	Stormwater Management Model
SWPPP	stormwater pollution prevention plan
TALU	tiered aquatic life use
TARP	Technology Acceptance and Reciprocity Partnership
TIA	total impervious area
TKN	total Kjedahl nitrogen
TMDL	total maximum daily load
TND	traditional neighborhood development
TOD	transit-oriented development
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UAA	Use Attainability Analysis
UDC	unified development code
ULARA	Upper Los Angeles River Area
USLE	Universal Soil Loss Equation
WERF	Water Environment Research Foundation
WQA	Water Quality Act
WQS	water quality standard
WWH	warmwater habitat
WWHM	Western Washington Hydrologic Model
WWTP	wastewater treatment plant

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Appendix B
Glossary

Antidegradation: Policies which ensure protection of water quality from a particular waterbody where the water quality exceeds levels necessary to protect fish and wildlife propagation and recreation on and in the water. This also includes special protection of waters designated as outstanding natural resource waters. Antidegradation plans are adopted by each state to minimize adverse effects on water.

Best Management Practice (BMP): Physical, structural, and/or managerial practices that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. The term is synonymous with Stormwater Control Measure (SCM).

Biofiltration: The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff flows over and through vegetated areas.

Bioinfiltration: A particular SCM that is like bioretention but has more infiltration, and thus would be categorized as an infiltration process.

Bioretention: A stormwater management practice that utilizes shallow storage, landscaping, and soils to control and treat urban stormwater runoff by collecting it in shallow depressions before filtering through a fabricated planting soil media. This SCM is often categorized under “filtration” although it has additional functions.

Buffer: The zone contiguous with a sensitive area that is required for the continued maintenance, function, and structural stability of the sensitive area. The critical functions of a riparian buffer (those associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, overflow during high-water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries over time due to hydrologic or climatic effects. The critical functions of terrestrial buffers include protection of slope stability, attenuation of surface water flows from stormwater runoff and precipitation, and erosion control.

> **Stream buffers** are zones of variable width that are located along both sides of a stream and are designed to provide a protective natural area along a stream corridor.

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Combined Sewer Overflow (CSO): A discharge of untreated wastewater from a combined sewer system at a point prior to the headworks of a publicly owned treatment works. CSOs generally occur during wet weather (rainfall or snowmelt). During periods of wet weather, these systems become overloaded, bypass treatment works, and discharge directly to receiving waters.

Combined Sewer System: A wastewater collection system that conveys sanitary wastewaters (domestic, commercial, and industrial wastewaters) and stormwater through a single pipe to a publicly owned treatment works for treatment prior to discharge to surface waters.

Constructed Wetland: A wetland that is created on a site that previously was not a wetland. This wetland is designed specifically to remove pollutants from stormwater runoff.

Created Wetland: A wetland that is created on a site that previously was not a wetland. This wetland is created to replace wetlands that were unavoidably destroyed during design and construction of a project. This wetland cannot be used for treatment of stormwater runoff.

Detention: The temporary storage of stormwater runoff in an SCM with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Detention Facility/Structure: An above- or below-ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater, and the facility is designed to not create a permanent pool of water.

Drainage: Refers to the collection, conveyance, containment, and/or discharge of surface and stormwater runoff.

Drainage Area: That area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge line.

Drainage Basin: A geographic and hydrologic subunit of a watershed.

Dry Pond: A facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels. Synonymous with detention basin, it is intended to be dry between storms.

Effluent Limitation: Any restriction imposed by the EPA director on quantities, discharge rates, and concentrations of pollutants that are discharged from

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point sources into waters of the United States, the waters of the contiguous zone, or the ocean.

Effluent Limitation Guidelines: A regulation published by the EPA Administrator under Section 304(b) of the Clean Water Act that establishes national technology-based effluent requirements for a specific industrial category.

Exfiltration: The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration SCM into the soil.

Extended Detention: A stormwater design feature that provides for the gradual release of a volume of water in order to increase settling of pollutants and protect downstream channels from frequent storm events. When combined with a pond, the settling time is increased by 24 hours.

Filter Strip: A strip of permanent vegetation above ponds, diversions, and other structures to retard the flow of runoff, causing deposition of transported material and thereby reducing sedimentation. As an SCM, it refers to riparian buffers, which run adjacent to waterbodies and intercept overland flow and shallow subsurface flow (both of which are usually sheet flow rather than a distinct influent pipe). The term is borrowed from the agricultural world.

Flood Frequency: The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the n-year flood as being the flood that will, over a long period, be equaled or exceeded on the average once every n years.

Frequency of Storm (Design Storm Frequency): The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows which occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

General Permit: A single permit issued to a large number of dischargers of pollutants in stormwater. General permits are issued by the permitting authority, and interested parties then submit a Notice of Intent (NOI) to be covered. The permit must identify the area of coverage, the sources covered, and the process for obtaining coverage. Once the permit is issued, a permittee may submit an NOI and receive coverage within a very short time frame.

Grab Sample: A sample which is taken from a stream on a one-time basis without consideration of the flow rate of the stream and without consideration of time.

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Hotspot: An area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydrograph: A graph of runoff rate, inflow rate, or discharge rate, past a specific point as a function of time.

Hydroperiod: A seasonal occurrence of flooding and/or soil saturation; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph: A graph of measured precipitation depth (or intensity) at a precipitation gauge as a function of time.

Impervious Surface or Impervious Cover: A hard surface area which either prevents or retards the entry of water into the soil. Common impervious surfaces include roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled surfaces.

Infiltration: The downward movement of water from the surface to the subsoil.

Infiltration Facility: A drainage facility designed to use the hydrologic process of runoff soaking into the ground, commonly referred to as percolation, to dispose of stormwater.

Infiltration Pond: A facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

Level Spreader: A temporary SCM used to spread stormwater runoff uniformly over the ground surface as sheet flow. The purpose of level spreaders is to prevent concentrated, erosive flows from occurring. Levels spreaders will commonly be used at the upstream end of wider biofilters to ensure sheet flow into the biofilter.

Municipal Separate Storm Sewer System: A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned by a state, city, town, or other public body that is designed or used for collecting or conveying stormwater, which is not a combined sewer and which is not part of a publicly owned treatment works.

National Pollutant Discharge Elimination System: A provision of the Clean Water Act that prohibits the discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or, where delegated, a

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tribal government on an Indian reservation. The permit applies to point sources of pollutants to ensure that their pollutant discharges do not exceed specified effluent standards. The effluent standards in most permits are based on the best available pollution technology or the equivalent.

Nonpoint Source: Diffuse pollution source, but with a regulatory connotation; a source without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater. Some common nonpoint sources are agriculture, forestry, mining, dams, channels, land disposal, and saltwater intrusion.

Nonstructural SCM: Stormwater control measure that uses natural measures to reduce pollution levels, does not require extensive construction efforts, and/or promotes pollutant reduction by eliminating the pollutant source.

Peak Discharge Rate: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Point Source: Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fixture, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged.

Pollutant: A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment. Dredged soil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended), heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water (EPA, 2008).

Polutograph: A graph of pollutant loading rate (mass per unit time) as a function of time.

Predevelopment Conditions: Those conditions that existed at a site just prior to the development in question, which are not necessarily pristine conditions.

Pretreatment: The removal of material such as gross solids, grot, grease, and scum from flows prior to physical, biological, and chemical treatment processes to improve treatability. The reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a publicly owned treatment works [40 C.F.R. § 403.3(q)]. Pretreatment may include screening, grit removal, stormwater, and oil separators. With re-

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spect to stormwater, it refers to techniques employed in stormwater SCMs to help trap coarse materials and other pollutants before they enter the SCM.

Recharge: The flow of groundwater from the infiltration of stormwater runoff.

Recharge Volume: The portion of the water quality volume used to maintain groundwater recharge rates at development sites.

Retention: The process of collecting and holding stormwater runoff with no surface outflow. Also, the amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

Retention/Detention Facility: A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold stormwater runoff for a short period of time and then release it to the stormwater management system.

Runoff: The term is often used in two senses. For a given precipitation event, direct *storm runoff* refers to the rainfall (minus losses) that is shed by the landscape to a receiving waterbody. In an area of 100 percent imperviousness, the runoff equals the rainfall. Over greater time and space scales, *surface water runoff* refers to streamflow passing through the outlet of a watershed, including base flow from groundwater that has entered the stream channel.

Soil Stabilization: The use of measures such as rock lining, vegetation, or other engineering structure to prevent the movement of soil when loads are applied to the soil.

Source Control: A type of SCM that is intended to prevent pollutants from entering stormwater. A few examples of source control are erosion control practices, maintenance of stormwater facilities, constructing roofs over storage and working areas, and directing wash water and similar discharges to the sanitary sewer or a dead end sump.

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility. According to 40 C.F.R. § 122.26(b)(13), this includes stormwater runoff, snow melt runoff, and surface runoff and drainage.

Stormwater Control Measure (SCM): Physical, structural, and/or managerial measures that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. Also, a permit condition used in place

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of or in conjunction with effluent limitations to prevent or control the discharge of pollutants. This may include a schedule of activities, prohibition of practices, maintenance procedures, or other management practices. SCMs may include, but are not limited to, treatment requirements; operating procedures; practices to control plant site runoff, spillage, leaks, sludge, or waste disposal; or drainage from raw material storage.

Stormwater Drainage System: Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat, or filter stormwater.

Stormwater Facility: A constructed component of a stormwater drainage system, designed or constructed to perform a particular function or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention basins, retention basins, constructed wetlands, infiltration devices, catch basins, oil/water separators, sediment basins, and modular pavement.

Structural SCMs: Devices which are constructed to provide temporary storage and treatment of stormwater runoff.

Swale: A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths of less than one foot.

> **Biofilter (**same as a **Biofiltration Swale):** A sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to SCMs designed for that purpose.
>
> **Dry Swale**: An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media. It has an underdrain.
>
> **Wet Swale:** An open drainage channel or depression, explicitly designed to retain water or intercept groundwater for water quality treatment.

Technology-Based Effluent Limit: A permit limit for a pollutant that is based on the capability of a treatment method to reduce the pollutant to a certain concentration.

Time of Concentration: The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

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Total Maximum Daily Load (TMDL): The amount, or load, of a specific pollutant that a waterbody can assimilate and still meet the water quality standard for its designated use. For impaired waters the TMDL reduces the overall load by allocating the load among current pollutant loads (from point and nonpoint sources), background or natural loads, a margin of safety, and sometimes an allocation for future growth.

Volumetric Runoff Coefficient (R_v): The value that is applied to a given rainfall volume to yield a corresponding runoff volume based on the percent impervious cover in a drainage basin.

Water Quality-Based Effluent Limit (WQBEL): A value determined by selecting the most stringent of the effluent limits calculated using all applicable water quality criteria (e.g., aquatic life, human health, and wildlife) for a specific point source to a specific receiving water for a given pollutant.

Water Quality SCM: An SCM specifically designed for pollutant removal.

Water Quantity SCM: An SCM specifically designed to reduce the peak rate of stormwater runoff.

Water Quality Volume (W_{qv}): The volume needed to capture and treat 90 percent of the average annual stormwater runoff volume equal to 1 inch times the volumetric runoff coefficient (R_v) times the site area.

Wetlands: Those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. This includes wetlands created, restored, or enhanced as part of a mitigation procedure. This does not include constructed wetlands or the following surface waters of the state intentionally constructed from sites that are not wetlands: irrigation and drainage ditches, grass-lined swales, canals, agricultural detention facilities, farm ponds, and landscape amenities.

Wet Pond: A facility that treats stormwater for water quality by utilizing a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration. Synonymous with a retention basin.

SOURCES: Most of the definitions are from EPA (2003), "BMP Design Considerations," 600/R-03/103, or EPA (2008), "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," EPA 841-B-08-002.

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Appendix C
Summary of Responses from State Stormwater Coordinators

On February 21, 2007, on behalf of the committee, Jenny Molloy of EPA's Office of Wastewater Management sent the following questions to a group of state stormwater program managers and received six responses (found in Tables C-1 and C-2).

1. For industrial and/or construction: do you have information on non-filers, i.e., folks who should have submitted NOIs, but did not? If so, how old are these data, and how do they compare to overall numbers of those with permit coverage? How did you find and/or estimate the number of non-filers?

2. Also for industrial and/or construction: do you have information on compliance rates? Yes, this is a really broad question, but something along the lines of: based on inspections (or monitoring data, or whatever metric you use), have you made any determinations on numbers of facilities out of compliance, or alternatively, in compliance? If so, define what you mean by compliance (paper violations, SWPPP/BMP inadequacies, water quality standards violations, etc.).

TABLE C-1 Nonfilers

State	Information on Industrial Non-Filers	Estimate Percent Non-Filers as of Total	Basis of Estimate	Period of Estimate	Comment
CA	Yes	50 percent of heavy industry statewide 69 percent Of industry within City of Los Angeles	Study—CA Water Board, 1999; Duke and Shaver, 1999. Study—Swamikannu et al., 2001	1995–1998 1998–2000	
MN	No				Study in progress
OH	No				Plan outreach to business
OR	No				Do not compile data
VT	Yes	88–90 percent of industry	Mass mailing	2006	No response from 2,400 of 3,000 mailings
WI	No				

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TABLE C-2 Compliance

State	Information on Compliance Rates	Estimate of Covered Facilities Non-Compliant	Basis of Estimate	Period of Estimate	Comment
CA	Yes (Construction)	40 percent deficient in paperwork; 30 percent with inadequate E&S controls	MS4 construction audit in Los Angeles and Ventura counties, and large CGP construction sites	2002, 2004, and 2005	Prioritized large CGP sites for inspection
	Yes (Industrial)	60 percent poor housekeeping practices; 40 percent incomplete SWPPPs	Transportation sector, plastics manufacturing inspections in Los Angeles County	2005 and 2007	
NH	No				Inspect in response to complaints
OH	No				Inspect construction sites as a priority
OR	No				Do not compile data
VT	No				Plan to inspect for compliance
WV	Yes (Industrial)	66 percent failed to submit report	Monitoring report submittal tracking	2007	Mailed deficiency notices
WI	Yes (Construction)	38 percent with minor and 43 percent with major violations	A subsample of 1 percent of CGP sites	2007	Perform inspections annually; no central database tracking

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In September 2007, the NRC Committee on Reducing Stormwater Discharge Contributions to Water Pollution sent the following survey to 50 state stormwater program managers. Responses were received from 18 states, including at least one from every EPA region. The blank survey is shown below, and Tables C-3 through C-9 contain the states' responses.

The NRC committee members will greatly appreciate receiving the following information from State Stormwater Coordinators. Please complete both sides of this form and return to Xavier Swamikannu, CalEPA, Los Angeles Regional Water Board, xswamikannu@waterboards.ca.gov or Fax: (213) 576-6625.

State:
Name of information provider:

Please summarize your State's Stormwater Permit Program

	Municipal Permit	Industrial General Permit	Construction General Permit
What are the monitoring requirements?			
How is compliance demonstrated (monitoring or other activity)?			
To whom is the SWPPP submitted?			
Can an MS4 perform an inspection of an industry within its boundary?			
What industries are considered "high-risk"?			
Do BMP manuals exist for implementation guidance?			
No. of dedicated staff or FTEs			

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Does your State Storm Water BMP Manual contain the following, and what are they?

WQ sizing criteria	
Recharge criteria	
Channel protection criteria	
Overbank flood criteria	
Extreme flows	
Acceptable BMP list	
Detailed engineering specs for BMPs	
Soil and erosion control requirements (unless this is left to the local government)	

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TABLE C-3 Monitoring Requirements

State	Municipal	Industrial	Construction
Alabama	Monitoring requirements are specific to the Phase I MS4. MS4 Phase II permit does not require monitoring.	Monitoring is specific to the General Permit type and associated discharge. Alabama has 18 NPDES Industrial Stormwater General Permits. http://www.adem.state.al.us/genpermits.htm	Monitoring is required under specific conditions, but in general compliance with the permit does not require monitoring. ADEM Admin. Code Chapter 335-6-12 is attached.
California	Monitoring requirements are specific to the Phase 1 MS4 permits. MS4 Phase II permit monitoring is discretionary.	2 wet weather sampling events per year – 4 basic parameters and other pollutants known to be on site. Quarterly visual monitoring.	Visual monitoring before, during, and after rain events. Analytical monitoring for discharges to sediment-impaired waterbodies.
Connecticut	Sample six outfalls once a year. Twelve chemical parameters.	Sample all outfalls once a year. Ten chemical parameters plus aquatic toxicity.	None, yet. Soon to modify permit to sample for turbidity.
Georgia	Dry weather outfall screening.	Standard monitoring from the EPA MSGP. Additional monitoring for the pollutant of concern for industries that may be causing or contributing to stream impairment.	Monitoring is required for a qualifying rain event (0.5 inch) once after clearing and grubbing, and once after mass grading.
Hawaii	Visual and water chemistry sampling.	Visual and water chemistry sampling.	Visual
Maine	None	No benchmark monitoring, only effluent limitations. Additional monitoring upon request based on discharges, complaints, audits, or inspections	None
Minnesota	The Phase I MS4 permits for Minneapolis and St. Paul require monitoring. MS4 Phase II permit does not require monitoring.	The current state MSGP does not have monitoring requirements. The proposed next term draft permit would require at least 4 stormwater monitoring events per year.	The current state CGP does not require monitoring. The proposed next term draft permit is not expected to include monitoring.

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TABLE C-3 Continued

State	Municipal	Industrial	Construction
Nebraska	Stormwater monitoring required on different use sites. BMP monitoring.	None. Monitoring can be required by the director through permit.	None. Monitoring can be required by the director through permit.
Nevada	Required for storm events that produce runoff.	None	None
New York	Ad hoc	Similar to monitoring in the EPA MSGP.	None. Self-inspection.
Ohio	Phase I MS4 permits require some chemical and biological monitoring. Phase II MS4 permit does not require mandatory monitoring, although recommended as part of IDDE program.	Similar to monitoring in the EPA MSGP, except annually. No priority chemical monitoring required.	For the state CGP, no chemical monitoring. For special watershed CGPs associated with TMDLs, TSS monitoring required.
Oklahoma	Phase 1 MS4s permits require dry weather monitoring, floatables monitoring, and watershed characterization monitoring, including biological assessments.	Quarterly visual monitoring and annual analytical monitoring.	None
Oregon	Monitoring requirements are specific to the Phase I MS4. The Phase II MS4 permit does not require monitoring, though some permittees do monitor on their own accord. The average frequency is 2-4 times a year.	Industrial facilities required to sample their stormwater discharge 4 times per year. Also required to conduct visual monitoring of their discharge on a monthly basis when discharge is present. Mining sites in addition are subject to the same requirements as in the state CGP since sediment is the main pollutant of concern.	None. However, permittees discharging stormwater to waters listed specifically for turbidity/sedimentation on the most recent 303(d) list or that have a TMDL for turbidity/sedimentation have the option of either monitoring for turbidity or implementing additional BMPs.

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State	Municipal	Industrial	Construction
Vermont	None other than the development of an IDDE program and follow-up until elimination occurs	Benchmark monitoring for individual sectors, quarterly for the first year. Visual inspection 4 times per year. Effluent limitations (if applicable) once per year.	None at present. Turbidity monitoring for moderate-risk projects included in draft CGP.
Virginia	Monitoring requirements are specific to the Phase I MS4 permit. The Phase II MS4 permit does not require monitoring.	Benchmark and effluent limitation (the same as EPA's 2000 MSGP), except we only require one sample per year for benchmark samples.	None
Washington	Monitoring requirements are specific to the Phase I MS4, *Outfall conveyance system monitoring*. Selected outfalls for representative land uses are monitored intensively for a wide range of chemical constituents including toxicity. *BMP effectiveness monitoring*. Selected stormwater BMPs are monitored to determine performance and how effective the designs are. The Phase II MS4 permit does not require monitoring, except as required under the IDDE program or for a TMDL.	Industry required to sample for turbidity, pH, zinc, and petroleum oil and grease. If exceeds zinc benchmark, then also need to monitor for total copper, total lead, and hardness. There are additional monitoring requirements for different industry categories. For discharges to impaired 303(d) waters monitor required for the pollutants for which the waterbody is impaired.	All state CGP sites are required to do weekly monitoring for turbidity and pH. If benchmark exceeded, specific actions/responses are triggered. For sites which discharge to waters impaired by phosphorous, turbidity, fine sediments, or high pH, monitoring required for these parameters additionally.
West Virginia	NA	Benchmark monitoring. Sector specific.	None
Wyoming	None	Benchmark monitoring for timber, metal mining, concrete and gypsum, junkyards and recycling. Effluent limitation monitoring for coal piles, concrete manufacture, and asphalt emulsion.	None

NOTE: NA, not answered

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TABLE C-4 How is Compliance Demonstrated?

State	Municipal	Industrial	Construction
Alabama	MS4 Phase I – monitoring and BMPs MS4 Phase II – BMPs	Monitoring reporting and BMP implementation	Inspections. Monitoring; SWPPP implementation during inspection; aerial reconnaissance
California	Annual and monitoring reporting. MS4 audits and inspections.	Annual and monitoring reporting. Inspections.	Annual certifications. Inspections
Connecticut	Annual and monitoring reporting.	Annual and monitoring reporting. Inspections.	Inspections. SWPPP review and implementation for large projects.
Georgia	Annual and monitoring reporting.	Annual and monitoring reporting.	Reporting.
Hawaii	Annual and Monitoring reporting. Inspections.	Annual and monitoring reporting. Inspections.	Inspections. Reporting.
Maine	Annual reporting and municipal audits.	Inspections and audits, at least two per 5-year permit term.	NA
Minnesota		Annual reporting and inspections.	
Nebraska	MS4 audits and annual reporting.	Inspections and SWPPP implementation.	Inspections and SWPPP implementation—complaint only.
Nevada	Annual reporting, MS4 audits, inspections.	Annual reporting, inspections	Inspections.
New York	Annual reporting and MS4 audits.	Annual and monitoring reporting. Inspections.	Inspections and SWPPP implementation.
Ohio	Annual reporting.	SWPPP implementation.	SWPPP implementation.
Oklahoma	Annual reporting. MS4 audits and compliance schedules.	Annual and monitoring reporting. Inspections.	SWPPP implementation and inspections based on complaints received.

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State	Municipal	Industrial	Construction
Oregon	Annual and monitoring reporting.	Annual and monitoring reporting. Action Plan approval.	Inspections and SWPPP implementation.
Vermont	Annual reporting and MS4 audits.	Monitoring reporting.	Inspections, recordkeeping.
Virginia	Registration statement BMP implementation.	Monitoring reporting and inspections.	Inspections. SWPPP and E&S plan implementation.
Washington	Implementation of prescriptive stormwater management program.	Monitoring reporting and inspections.	Inspections and monitoring reporting.
West Virginia	NA	SWPPP implementation and monitoring reporting.	Inspections. SWPPP implementation.
Wyoming	Periodic MS4 audits.	Inspections, monitoring reporting.	Inspections.

NOTE: NA, not answered.

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TABLE C-5 To Whom Is the SWPPP Submitted?

State	Municipal	Industrial	Construction
Alabama	MS4 Phase I – Storm Water Management Program (SWMP) sent to state. Should be available for review at the time of inspection. (SWPPP information should also be provided to the department.) MS4 Phase 2 – SWMP submitted with the Notice of Intent (NOI).	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection. SWPPP required to be submitted under certain circumstance during registration and re-registration.
California	MS4 Phase 1 – SWMP incorporated as prescriptive requirements in the permit. MS4 Phase 2 – SWMP submitted to state with NOI	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.
Connecticut	NA	The SWPPP is submitted to the state only if requested.	The SWPPP is submitted to the state only if requested.
Georgia	The SWMP is submitted to the state.	The SWPPP is submitted to the state only if requested. Otherwise it is kept on-site.	The E&S Control Plan equivalent to the SWPPP is submitted to the Local Issuing Authority. It is also submitted to the state if the project disturbs more than 50 ac, or if there is no LIA.
Hawaii	NA	The SWMP is submitted to the state.	The SWMP is submitted to the state.
Maine	NA	The SWPPP is submitted to the state only if requested.	The E&S Control Plan equivalent to the SWPPP is submitted to the state for review.

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State	Municipal	Industrial	Construction
Minnesota	Phase 1 MS4 - The SWMP is submitted to the state for review and public notice.	The SWPPP is not required to be submitted to the state.	The SWPPP must be must be submitted to the state for review for projects disturbing 50 acres or more, and has a discharge point within 2,000 feet of an impaired or special water listed in the state CGP. A SWPPP must also be submitted for projects proposing to use alternative method(s) for the permanent stormwater management system.
Nebraska	NA	The SWPPP is submitted to the state only if requested.	The SWPPP is submitted to the MS4 permittee and to the state when requested.
Nevada	NA	No submittal to state. The SWPPP must be kept on site.	No submittal to state. The SWPPP must be kept on site.
New York	NA	Some SWPPPs submitted to state (very few).	About 1/6 SWPPPs submitted to state.
Ohio	NA	The SWPPP is submitted to the MS4 permittee and to the state when requested.	The SWPPP is submitted to the state.
Oregon	NA	The SWPPP is submitted to the state on first application and when renewing coverage under the state MSGP.	The SWPPP is submitted to the state on first application and when renewing coverage under the state CGP. Projects that are greater than 5 acres are subject to public notice and comment.

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TABLE C-5 Continued

State	Municipal	Industrial	Construction
Vermont	NA	A copy of the SWPPP is submitted to the state, and the original kept on site.	The E&S Control Plan is submitted to the state. Low-risk projects have a standard assigned E&S Control Plan – "Low Risk Handbook".
Virginia	NA	No submittal to the state. The SWPPP must be kept on-site.	No submittal to the state. The SWPPP must be kept on-site.
Washington	NA	The SWPPP is submitted to the state upon first application only. Otherwise, the SWPPP must be kept on site and must be made available to the state, the MS4 permittee, or the public upon request.	The SWPPP is not submitted to the state. The SWPPP must be kept on site and must be made available to the state, the MS4 permittee or the public upon request.
West Virginia	NA	The SWPPP is submitted to the state upon first application only.	The SWPPP is submitted to the state.
Wyoming	NA	The SWPPP is submitted to the state for facilities >50 ac. Class 1 waters not eligible for coverage under the state MSGP.	The SWPPP is submitted to the state for projects >100 ac or on Class 1 waters.

NOTE: NA, not applicable.

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TABLE C-6 Can an MS4 Inspect Industries Within Its Boundary?

Alabama	Yes, if adequate legal authority exists.
California	Yes. Local agencies inspection to ensure compliance with local stormwater or municipal ordinance.
Connecticut	Yes. Nothing specific. State MSGP requires industries to comply with the stormwater management program of the MS4 in which they are located.
Georgia	Yes
Hawaii	Yes
Maine	Yes
Minnesota	Yes. Capability to do this varies with the MS4.
Nebraska	Yes. Phase 1 MS4s only.
Nevada	Yes
New York	Yes. MS4s can inspect for illicit discharge detection and elimination. Industries can be inspected under local authority, but local inspections are infrequently conducted.
Ohio	Yes. Phase I MS4s can check for MSGP coverage and that a SWPPP exists in conjunction with pretreatment inspections.
Oklahoma	Yes
Oregon	Yes, under various authorities. Pretreatment, industrial stormwater, construction stormwater, etc.
Vermont	Yes. The MS4 can request an inspection but can be denied access.
Virginia	No. No state statute for private property access to inspect for stormwater management. Some do use Fire Marshall's authority through the fire code.
Washington	Yes
West Virginia	NA
Wyoming	Yes. If the MS4 has authority.

NOTE: NA, not answered.

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TABLE C-7 What Industries Are Considered High Risk?

Alabama	Metal foundries.
California	None specified in the state MSGP. Some MS4 permits may specify high-risk industries. Construction activity discharging to sediment-impaired waterbodies are identified as high risk in the state CGP.
Connecticut	None specified in the state MSGP.
Georgia	None specified in the state MSGP. Facilities that may be causing or contributing to stream impairment are high risk.
Hawaii	None specified in the state MSGP
Maine	Auto salvage, scrap metal recycling, boatyards and marinas, concrete and asphalt, batch plants, vehicle maintenance facilities.
Minnesota	None specified in the state MSGP. Heavy industries are considered higher risk.
Nebraska	Ethanol, scrap metal recycling.
Nevada	Waste oil recyclers, auto salvage, aggregate mines, cement plants.
New York	Auto salvage, scrap recycling.
Ohio	None specified in the state MSGP. Individual stormwater permits required for some airports, landfills, sand and gravel operations, and bulk terminals.
Oklahoma	None specified in the state MSGP.
Oregon	None specified in the state MSGP.
Vermont	None specified in the state MSGP. Gravel pits, salvage yards, scrap recycling facilities are considered high risk.
Virginia	None specified in the state MSGP.
Washington	MS4 permit identifies a list of industries and land uses that the permittee must inspect (See Permit appendix 8).
West Virginia	None specified in the state MSGP. Mills and auto salvage yards are considered high risk.
Wyoming	None specified in the state MSGP. Case by case based on proximity to high class waters and industry type.

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TABLE C-8 Do State BMP Manuals Exist for Implementation Guidance?

State	Municipal	Industrial	Construction
Alabama	No. Use EPA materials.	No. Use EPA Materials.	Yes. State E&S Manual. http://swcc.state.al.us/erosion_handbook.htm
California	Yes. CASQA and Caltrans manuals. Not officially adopted.	Yes. CASQA and Caltrans manuals. Not officially adopted	Yes. CASQA and Caltrans manuals. Not officially adopted.
Connecticut	No	No. An SWPPP guidance document is available online.	Yes. E&S Guidelines (2002) and CT Stormwater Quality Manual (2004).
Hawaii	No. Use EPA materials.	No. Use EPA materials.	No. Use EPA materials.
Georgia	Yes. Georgia Stormwater Management Manual.	No. Use EPA materials.	Yes. Manual for Erosion and Sediment Control in Georgia.
Maine	Yes	Yes	Yes
Minnesota	Yes. The Minnesota Stormwater Manual at: http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html Stormwater BMPs – Protecting Water Quality in Urban Areas at: http://www.pca.state.mn.us/water/pubs/sw-bmpmanual.html	No. Plan to develop one.	Yes. Fact sheets and guidance at: http://www.pca.state.mn.us/water/stormwater/stormwater-ms4.html#bmp
Nebraska	No	No	No
Nevada	Yes	Yes	Yes
New York	Yes	Yes. A few state materials.	Yes

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TABLE C-8 Continued

State	Municipal	Industrial	Construction
Ohio	No. Use EPA materials.	No. Use EPA materials.	Yes. http://www.dnr.state.oh.us/water/rainwater/default/tabid/9186/Default.aspx
Oklahoma	No. Use EPA materials.	No. Use EPA materials.	No. Use EPA materials.
Oregon	No	No. Have BMP technical assistance guidance documents.	Yes. Use of Oregon BMP manual is optional.
Vermont	Yes	No	Yes. Standards for designers, a field guide for contractors (2006), and the Low Risk Handbook.
Virginia	Yes. E&S control and stormwater handbooks.	No	Yes. E&S control and stormwater handbooks.
Washington	Yes. Stormwater Management Manual for Western Washington (2005) and Stormwater Management Manual for Eastern Washington (2004)	Yes. http://www.ecy.wa.gov/programs/wq/stormwater/manual.html	Yes. http://www.ecy.wa.gov/programs/wq/stormwater/eastern_manual/index.html
West Virginia	No	No	Yes
Wyoming	No	No. Refer to manuals from other states.	No. Refer to manuals from other states.

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TABLE C-9 Full-Time Staff Dedicated to the Stormwater Program

State	Municipal	Industrial	Construction	Total Statewide
Alabama	1.5	7	25–30	33.5–38.5
California				89
Connecticut				5
Georgia	4.5	2.5	46	53
Hawaii	0.5	1	2	3.5
Maine	0.7	2.5	NA	
Minnesota		4.3	14	36
Nebraska				3
Nevada	1	1.5	3	5.5
New York	7	1	11	19
Ohio				18
Oklahoma				7
Oregon	1	4–5 (shared with construction)	4–5 (shared with industrial)	5–6
Vermont	0.5	2	5	7.5
Virginia	3	8 (shared with other programs)	10	13
Washington	10	17	16	43
West Virginia	NA	1	5	
Wyoming				4

NOTE: NA, not answered.

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Appendix D
Biographical Information for the Committee on Reducing Stormwater Discharge Contributions to Water Pollution

Claire Welty, *Chair*, is the Director of the Center for Urban Environmental Research and Education and Professor of Civil and Environmental Engineering at University of Maryland, Baltimore County (UMBC). Dr. Welty's work has primarily focused on transport processes in aquifers; her current research interest is in watershed-scale urban hydrology, particularly in urban groundwater. Prior to her appointment at UMBC, Dr. Welty was a faculty member at Drexel University for 15 years, where she taught hydrology and also served as Associate Director of the School of Environmental Science, Engineering, and Policy. Dr. Welty is the chair of the National Research Council's (NRC's) Water Science and Technology Board and has previously served on three NRC study committees. She is the Chair-Elect of the Consortium of Universities for the Advancement of Hydrologic Science Inc. Dr. Welty received a B.A. in environmental sciences from the University of Virginia, an M.S. in environmental engineering from the George Washington University, and a Ph.D. in civil and environmental engineering from the Massachusetts Institute of Technology.

Roger T. Bannerman has been an environmental specialist for the Wisconsin Department of Natural Resources for over 30 years. For most of that time he has directed research projects investigating urban runoff. Topics addressed by his studies over the years include the quality of urban streams, identification of problem pollutants in stormwater, toxicity of stormwater pollutants, effectiveness of different stormwater control practices, sources of stormwater pollutants, selection of cost-effective control practices, and benefits of low-impact development. He has applied these results to management plans developed for most urban areas in Wisconsin. This includes the calibration of the urban runoff model called the Source Loading and Management Model. The results of his research projects have been used to develop Wisconsin's new administrative rules that regulate stormwater management. Mr. Bannerman received his B.S. in chemistry from Humboldt State College and an M.S. from the University of Wisconsin in water chemistry.

Derek B. Booth has joint positions as Senior Geologist at Stillwater Sciences, Inc., and Adjunct Professor at the University of Washington where he is senior editor of the international journal *Quaternary Research* and holds faculty appointments in Civil Engineering and Earth & Space Sciences. Prior to this, he was director of the Center for Urban Water Resources Management (and its suc-

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cessor, the Center for Water and Watershed Studies) at the university. He maintains active research into the causes of stream-channel degradation, the effectiveness of stormwater mitigation strategies, and the physical effects of urban development on aquatic systems, with over a dozen publications and a wide range of national and international invited presentations on the topic. Dr. Booth received a B.A. in literature from Hampshire College, a B.A. in geology from the University of California at Berkeley, an M.S. in geology from Stanford University, and a Ph.D. in geological sciences from the University of Washington.

Richard R. Horner is a professor in the Department of Civil and Environment Engineering at the University of Washington, with adjunct appointments in Landscape Architecture and in the College of Forest Resources' Center for Urban Horticulture. He received his Ph.D. from the University of Washington's Department of Civil and Environmental Engineering and previous engineering degrees from the University of Pennsylvania. Dr. Horner splits his time between university research and private practice. In both cases his work concerns how human occupancy of and activities on the landscape affect natural waters, and how negative effects can be reduced. He has been involved in two extended research projects concerning the ecological response of freshwater resources to urban conditions and the urbanization process. The first studied the effect of human activities on freshwater wetlands of the Puget Sound lowlands and led to a comprehensive set of management guidelines to reduce negative effects. A ten-year study involved the analogous investigation of human effects on Puget Sounds' salmon spawning and rearing streams. In addition, he has broad experience in all aspects of stormwater management, having helped design many stormwater programs in Washington, California, and British Columbia. He previously served on the NRC's Committee on the Comparative Costs of Rock Salt and Calcium Magnesium Acetate for Highway Deicing.

Charles R. O'Melia (NAE) is the Abel Wolman Professor of Environmental Engineering and Chair of the Geography and Environmental Engineering Department at the Johns Hopkins University, where he has served on the faculty for over 25 years. Dr. O'Melia's research areas include aquatic chemistry, environmental colloid chemistry, water and wastewater treatment, modeling of natural surface and subsurface waters, and the behavior of colloidal particles. He has served on the advisory board and review committees for the environmental engineering departments of multiple universities. He has served in a range of advising roles to professional societies including the American Water Works Association and Research Foundation, the Water Pollution Control Federation, the American Chemical Society, and the International Water Supply Association. He has served on several NRC committees, including chairing the Steering Committee, Symposium on Science and Regulation, and the Committee on Watershed Management for New York City. He was also a member of the

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NRC Water Science and Technology Board and the Board on Environmental Studies and Toxicology. Dr. O'Melia earned a Ph.D. in Sanitary Engineering from the University of Michigan. In 1989, Dr. O'Melia was elected to the National Academy of Engineering for significant contributions to the theories of coagulation, flocculation, and filtration leading to improved water-treatment practices throughout the world.

Robert E. Pitt is the Cudworth Professor of Urban Water Systems in the Department of Civil, Construction, and Environmental Engineering at the University of Alabama (UA). He is also Director of the UA interdisciplinary Environmental Institute. Dr. Pitt's research concerns the effects, sources, and control of urban runoff, which has resulted in numerous development management plans, stormwater ordinances, and design manuals. Dr. Pitt has also developed and tested procedures to recognize and reduce inappropriate discharges of wastewaters to separate storm drainages. He has investigated the sources and control of stormwater toxicants and examined stormwater effects on groundwater. He has also carried out a number of receiving water impact studies associated with stormwater. These studies have included a variety of field monitoring activities, including water and sediment quality, fish and benthos taxonomic composition, and laboratory toxicity tests. His current research includes developing a nationwide database of national stormwater permit information and conducting comprehensive evaluations of these data. Dr. Pitt received a B.S. in engineering science from Humboldt State University, an M.S. in civil engineering from San Jose State University, and a Ph.D. in civil and environmental engineering from the University of Wisconsin.

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Urban Stormwater Management in the United States
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A Review of Low Impact Development Policies: Removing Institutional Barriers to Adoption

Commissioned and Sponsored by:
California State Water Resources Control Board Stormwater Program
And
The Water Board Academy

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December 2007



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EXECUTIVE SUMMARY

Managing stormwater runoff has historically presented technical challenges because of its diffuse and episodic nature, the range of pollutants requiring treatment, and the volume of runoff resulting from changes in land cover. Complicating the technical challenges is a regulatory environment that has been based on presumptive minimum treatment standards and has not effectively promoted innovative treatment approaches. Recent research and pilot applications have demonstrated efficient approaches to control and treat stormwater runoff and have removed many of the technical barriers. However, regulatory and institutional barriers still exist and can prevent application of effective control programs.

This analysis reviewed the State of California's primary mechanisms of regulating stormwater runoff and considered how low impact development (LID) approaches could be used for compliance purposes. A review of the country's more progressive regulatory approaches is also included to illustrate requirements or incentives for LID or other innovative treatment programs. California has already made steps toward a regulatory system that encourages better treatment performance and the application of LID; the State Water Resources Control Board's recent emphasis on limiting hydromodification impacts (changes in a site's runoff and transport characteristics) from development will create the framework for broader adoption of LID. In addition, the Porter-Cologne Act (commonly referred to as the California Water Code) allows the Water Boards broad discretion to implement innovative natural resource protection programs because it allows the regulation of any activity or factor that affects water quality and is not narrowly focused on end-of-pipe treatment.[1]

INTRODUCTION

When the Clean Water Act (CWA) was amended in 1987, a federal mandate to manage and control stormwater was established.[2] The past 20 years have witnessed significant shifts in the science and regulatory environment of municipal and post-construction runoff control. The recent movement to address stormwater on a watershed basis by limiting hydromodification and the volume of discharges is a departure from the convention of peak flow limitation and flood control. Advances in understanding the relationship between hydromodification and stream health and the science to preserve or restore water quality have greatly outpaced the changes in the regulatory environment and institutional structures that influence stormwater programs, neither of which having ever fully matured to achieve water quality or environmental goals.

With the technical approach coming into focus, the regulatory system needed to foster and propel these new strategies has not yet been developed. The intent of regulatory compliance is not necessarily meeting resource objectives. Regulations often set a minimum benchmark of environmental effort and often are not or cannot be designed to fully achieve water quality objectives. Maximum extent practicable or water quality standards along with other programs and efforts are used to augment regulations to achieve the full desired environmental outcome. Designing regulations and integrating them with other programs to achieve desired outcomes and benefits is critical to improving stormwater management.

[1] California Water Code sections 13000, 13050(i), 13140, 13142, 13241.
[2] 40 CFR 122.26

Several states, including California, have begun to evaluate the regulatory changes that are required and the impacts that they will have on the success of their programs. This effort is one step in that process. This paper will focus on municipal and post-construction runoff and review the regulatory and institutional structure that influences stormwater control in California. It will also evaluate new programs and efforts aimed at improving stormwater management. Lastly it will evaluate policy and program options that could further advance the implementation of comprehensive water programs.

BACKGROUND

The diversity of climatic and geographic conditions within California has influenced the structure of the State's water agencies. The State Water Resources Control Board (SWRCB), created in 1967, has water allocation and water quality protection responsibilities. Nine Regional Water Quality Control Boards (RWQCBs), established along major watershed boundaries, have development and enforcement responsibilities of water quality objectives and implementation plans. The U.S. Environmental Protection Agency (EPA) has authorized the State to administer the National Pollutant Discharge Elimination System (NPDES) program, which uses statewide and regional programs to fulfill the mandated requirements. Municipal NPDES permits are issued by the Regional Boards.

The Porter-Cologne Water Quality Control Act, passed in 1969 and predating the CWA, is the main statute that governs water quality control in the state. Porter-Cologne subjects any activity or factor that affects water quality to regulation and covers point and non-point sources. By looking comprehensively at influences on water quality, not only are pollutant discharges subject to regulation, but also parameters such as flow or riparian or land use changes that can impose physical or temperature impacts.[3] Porter-Cologne applies to all waters of the state including wetlands and groundwater. It also establishes the tenant that waste discharges to state waters are a privilege and not a right.[4,5]

Through Porter-Cologne the SWRCB and RWQCBs are provided:[6]

1. Planning authority to designate beneficial uses of State waters, establish water quality objectives, and develop implementation programs to meet water quality objectives and designated uses.
2. Permitting authority.
3. Enforcement authority to ensure permit compliance.

---

[3] J. M. Gerstein, et al., *State and Federal Approach to Control of Nonpoint Sources of Pollution*, University of California Cooperative Extension, August 2005.
[4] State Water Resources Control Board, *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, May 20, 2004.
[5] When the 1987 amendments to the CWA designated municipal stormwater runoff as a point source, regulation of stormwater came under the provisions of the National Pollutant Discharge Elimination System (NPDES) program. California, like other states, has a defined institutional and regulatory separation between municipal stormwater and other non-point sources that are influenced by Porter-Cologne.
[6] State Water Resources Control Board, *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, May 20, 2004.

With this authority, the SWRCB is responsible for setting statewide policy and regulations, in addition to developing statewide water quality control plans. Based on the SWRCB policies, the nine RWQCBs develop individual water quality control plans, referred to as Basin Plans. Once developed, the basin plans must be approved by the SWRCB, the Office of Chief Council, and the U.S. EPA.[7] The coordinated efforts between the State and Regional Boards constitute the primary mechanism through which the State addresses point and nonpoint source pollution and implements its control program. The SWRCB also has the authority to adopt statewide water quality control plans, like the California Ocean Plan, the Plan for California's Nonpoint Source Pollution Control Program, and the California Thermal Plan. The Ocean Plan contains a prohibition of any discharge of waste (e.g., stormwater) to waters designated as Areas of Special Biological Significance (ASBS).

In addition to the framework above, a number of other regulatory agents and programs (e.g., the California Water Boards and CWA 401 Certification, the California Coastal Commission and the Coastal Zone Act Reauthorization Amendments) also directly impact stormwater discharges in the state. Although not discussed in detail, the requirements of these programs work in concert with the stormwater program and can lead to more stringent pollutant discharge limitations in runoff.

NPDES Permits

Construction General Permit

The SWRCB last issued statewide general NPDES stormwater permits for designated construction activities in 1999 (SWRCB Order 99-08-DWQ). This permit contains minimum requirements to control post-construction runoff. Page 79 of SWRCB Order 99-08-DWQ states:

> *10. Post-Construction Storm Water Management*
>
> *The SWPPP shall include descriptions of the BMPs to reduce pollutants in storm water discharges after all construction phases have been completed at the site (Post-Construction BMPs). Post-Construction BMPs include the minimization of land disturbance, the minimization of impervious surfaces, treatment of storm water runoff using infiltration, detention/retention, biofilter BMPs, use of efficient irrigation systems, ensuring that interior drains are not connected to a storm sewer system, and appropriately designed and constructed energy dissipation devices. These must be consistent with all local post-construction storm water management requirements, policies, and guidelines. The discharger must consider site-specific and seasonal conditions when designing the control practices. Operation and maintenance of control practices after construction is completed shall be addressed, including short-and long-term funding sources and the responsible party.*

[7] State Water Resources Control Board, *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, May 20, 2004.

While this language describes LID techniques, there is no level of compliance specified. The standard for the Construction General Permit is Best Available Technology economically achievable/ Best Conventional pollutant control Technology (BAT/BCT).[8] However, since it is not easy to apply a technology standard to the practice of minimizing land disturbance, this permit language is difficult to enforce. Municipal permits have the standard of Maximum Extent Practicable (MEP) which lends itself more naturally to specifying and enforcing a level of compliance for low impact development.

In March 2007 the SWRCB released a preliminary draft NPDES stormwater permit for construction activities as part of the Reissuance process of SWRCB Order 99-08-DWQ. This preliminary draft permit contains much more specific requirements for post-construction stormwater runoff. If approved, the new permit would establish statewide post-construction runoff standards. This would significantly alter the existing framework that relies on the municipalities to address post-construction runoff and leaves the unincorporated areas of the State largely unaddressed. The draft permit requires mitigating hydromodification by maintaining pre-development hydrologic characteristics on a site.[9]

Municipal Phase I Permits

The Regional Boards are currently using their authority to issue municipal separate storm sewer system (MS4) permits to address post-construction runoff.[10] Each Regional Board issues individual MS4 NPDES stormwater permits to their qualifying or designated Phase I permittees. At a minimum these require the MS4 permittees to develop and implement plans such as Standard Urban Storm Water Mitigation Plans (SUSMPs) that address new development and redevelopment projects that disturb more than one acre.[11,12] For example, the SUSMPs in the Los Angeles Water Board jurisdiction establish which types of development will be required to implement stormwater controls and the control, pollutant removal, site design, and maintenance requirements. The Los Angeles County SUSMP stipulates the following runoff requirement:[13]

> *Post-development peak stormwater runoff discharge rates shall not exceed the estimated pre-development rate for developments where the increased peak stormwater discharge rate will result in increased potential for downstream erosion.*

This language, which is typical for many municipal stormwater permits in California and the country, establishes the regulated physical stormwater parameter as the *rate* of discharge. This definition is typically based on one or more single peak storm events rather than continual flow information from runoff events. The SUSMP regulatory construct is in line with the historical

[8] State Water Resources Control Board, National Pollutant Discharge Elimination System General Permit for Storm Water Discharges Associated with Construction Activity, Water Quality Order 99-08-DWQ, p.1.
[9] State Water Resources Control Board, Draft National Pollutant Discharge Elimination General System General Permit Number CAR000002, Waste Discharge Requirements For Discharges Of Storm Water Runoff Associated With Construction Activity, March 2007.
[10] Personal communication, Eric Berntsen, State Water Resources Control Board, April 2007.
[11] Memo from the SWRCB Office of Chief Counsel on SWRCB Order WQ 2000-11: SUSMP, Craig M. Wilson, December 26, 2000.
[12] Los Angeles County Urban Runoff and Stormwater NPDES Permit, Standard Urban Stormwater Mitigation Plan, March 2000.
[13] Ibid.

thinking about stormwater impacts that postulated that the velocity of stormwater was the main factor impacting receiving stream quality and channel impacts. This primary requirement along with site design and treatment requirements form the range of requirements necessary to be satisfied for new development and redevelopment.

Municipal Phase II Permit

The SWRCB adopted a statewide General Phase II MS4 Permit in April, 2003 (SWRCB Order No. 2003-0005-DWQ). The permit contains similar post-construction language to Phase I permits.

The Central Coast Water Board requires municipalities, via the General Phase II MS4 Permit, to minimize negative impacts on aquatic ecosystems and degradation of water quality to the maximum extent practicable by incorporating LID methodology into new and redevelopment ordinances and design standards, unless permittees can demonstrate that conventional BMPs are equally effective, or that conventional BMPs would result in a substantial cost savings while still adequately protecting water quality and reducing discharge volume. In order to justify using conventional BMPs based on cost, permittees must show that the cost of low impact development would be prohibitive because the "cost would exceed any benefit to be derived." (State Water Resources Control Board Order No. WQ 2000-11). The Central Coast Water Board has determined that conventional site layouts, construction methods, and stormwater conveyance systems with "end-of-pipe" basins and treatment systems that do not address the changes in volume and rates of storm water runoff and urban pollutants (including thermal pollution) do not meet MEP standards.[14]

HYDROMODIFICATION

Changes in land cover are the cause of hydromodification: changes in a site's runoff and transport characteristics. Impervious surfaces, compacted soils, deforestation, and topographic modifications alter the distribution and flow of water across a site. Infiltration, interception, and evapotranspiration are diminished and a greater percentage of precipitation is converted to overland flow. These changes impact the water balance on site, less water infiltrates and is available for groundwater recharge or shallow subsurface flows that constitute the base flows of receiving streams. In addition, the increased volume of overland flow imparts physical impacts on receiving streams and transports pollutants that have collected on impervious surfaces.[15]

The effects of hydromodification can be demonstrated on a hydrograph, a representation of a site's stormwater discharge with respect to time. The hydrograph in Figure 1 shows development's impact on a site's runoff. Individual points on the curve represent the rate of stormwater discharge at a given time. The graph shows that development and corresponding changes in land cover result in greater discharge rates, greater volume, and a shorter time to reach the maximum discharge rate (referred to as time of concentration, T_c). In a natural or pre-

[14] Central Coast Water Board Low Impact Development web page, How LID is currently required: http://www.waterboards.ca.gov/centralcoast/stormwater/low%20impact%20devel/lid_index.htm (accessed November 2007).

[15] U.S. EPA, *Protecting Water Quality from Urban Runoff*, Nonpoint Source Control Branch, EPA-841-F-03-003, February 2003.

development condition the initial rainfall is absorbed by the soil and vegetation. Once these are saturated, or the initial losses are satisfied, runoff occurs. In the post-development condition there is generally a much shorter time before runoff begins because of connectivity of impervious and developed areas and the loss of vegetative cover.

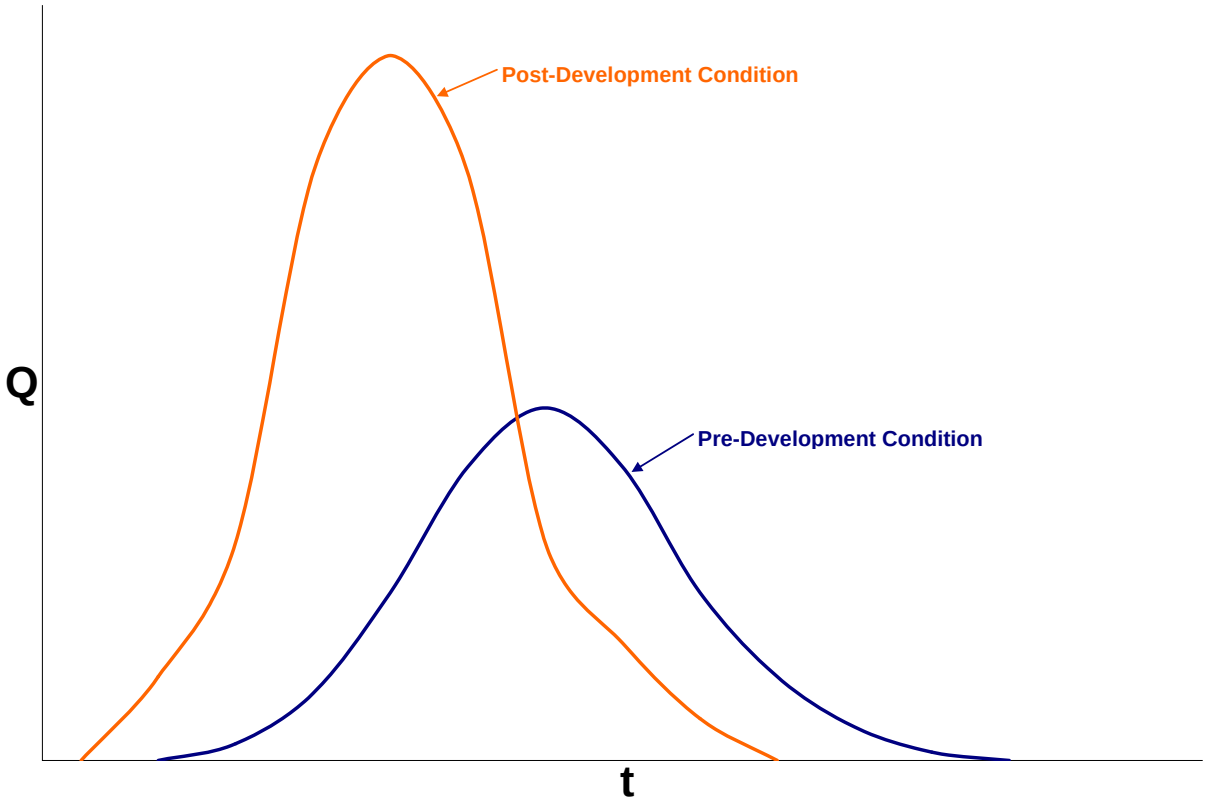


Figure 1. Hydrographs showing development's impact on runoff.
(Q = volumetric flow rate; t = time)

The area under the hydrographs represents the total volume of stormwater discharged. Along with the increased rate of discharge is an increased volume of discharge after development. The first analyses of these hydrograph impacts produced the consensus that the maximum rate of discharge was the critical parameter for protecting the integrity of receiving streams. The result of this concept was a regulatory structure, like those witnessed in many SUSMPs, that establishes requirements for the peak rate of discharge. Figure 2 shows how the post-development hydrograph responds to this type of regulatory structure.

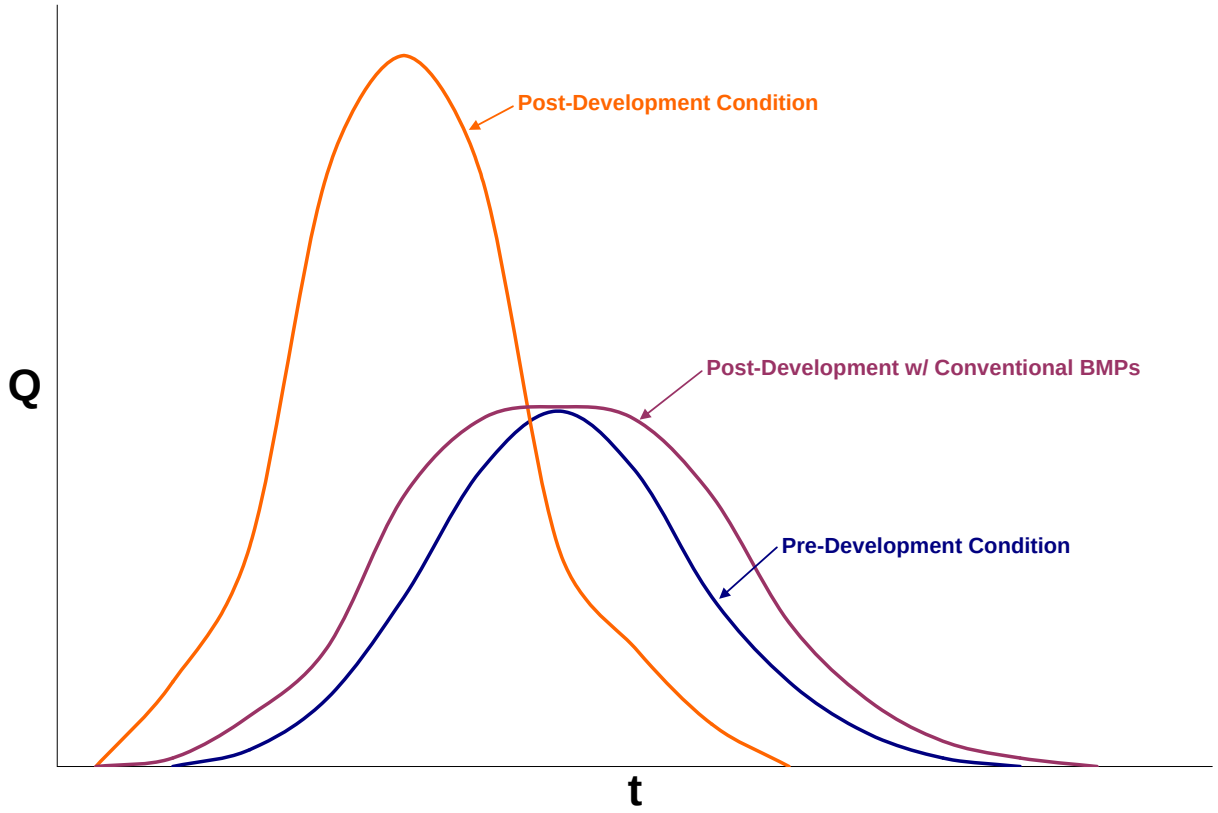


Figure 2. Post-development hydrograph response to conventional BMPs.
(Q = volumetric flow rate; t = time)

As Figure 2 illustrates, although the post-construction rate of stormwater discharge is equivalent to the pre-construction rate, it is sustained for a longer period of time and the total volume and energy of stormwater discharged, when compared to pre-development, is greater. This hydrograph response illustrates one reason why stormwater control efforts have been largely unsuccessful. Even when peak discharge rates are matched, the increased volume of stormwater delivers more energy and an increased amount of pollutants to the receiving stream when compared to pre-developed conditions. This result demonstrates the inefficiencies of the prevailing regulatory system and helps to predict that this type of framework will be unlikely to ultimately achieve water quality goals.

A regulatory system that attempts to address this deficiency and reduce the increase in the volume of stormwater discharge will propose a standard that stipulates that the rate of post-construction discharge will be equal not only to the pre-development peak rate, but also as every point-in-time along the hydrograph. This approach, a version of which is presented in the draft Construction stormwater NPDES permit, results in the hydrograph response represented in Figure 3.

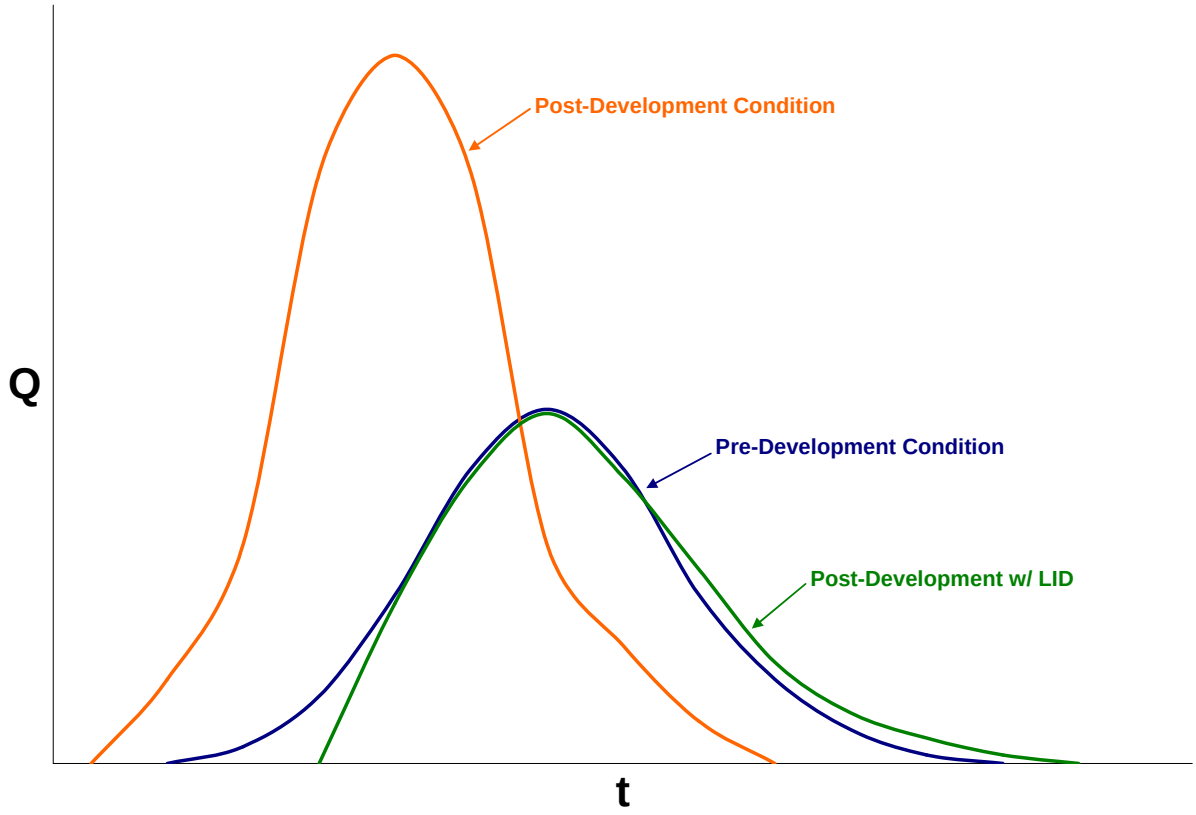


Figure 3. Post-development hydrograph response to LID controls.
(Q = volumetric flow rate; t = time)

Low Impact Development's Influence on Hydromodification

Traditionally, a wastewater collection and treatment system approach has been applied to stormwater management. End-of-pipe treatment and control technologies have been the predominate methods of stormwater control. However, this system of control essentially concedes the inevitability of hydromodification; that the only control options are those that deal with the consequences of development without addressing the root causes of the problem. To be fair, many stormwater management plans and manuals address site design, source control, and pollution prevention strategies. Mostly though, these are presented as "add-on" options that may be done above the standard end-of-pipe controls. The regulatory mandates still largely preserve the centralized collection and treatment system of control.

Over the past decade, LID has emerged as an alternative management approach. Rather than centralized, end-of-pipe controls, LID relies on an integrated system of decentralized, small-scale control measures. These measures range from site design practices to technology driven LID BMPs. The underlying principle of LID is that undeveloped land does not present a stormwater runoff or pollution problem. The evolved natural hydrology of any given site manages water in the most efficient manner. This most often translates to high rates of infiltration, vegetative interception, and evapotranspiration.

LID attempts to offset the inevitable consequences of development and changes in land cover by preserving or mimicking natural hydrology. It is a source control option that minimizes stormwater pollution by recognizing that the greatest efficiencies are gained by minimizing stormwater generation. This is a process that begins with functional conservation of watershed resources, reducing impacts of development, and then using innovative management practices to meet the stormwater objective; it is not the use of the management practices alone. Site preservation practices coupled with small-scale BMPs that rely on the environmental services of vegetation and soils or systems that mimic these services comprise the control approach of LID. These practices, taken in aggregate, limit the observed hydromodification on a developed site and present a more comprehensive and beneficial control approach.

Needing to be addressed, however, is the lag in broad LID implementation. Even though it has been demonstrated as an attractive strategy, its application is limited and has not yet been fully integrated. Several barriers have generally slowed and hampered greater LID adoption. Bureaucratic inertia involving the entrenchment of prevailing conventional practices, institutional structures, and regulatory shortfalls are the prime barriers preventing a broad shift in stormwater management philosophy. Of these, regulatory structure is the most critical barrier. If regulations are crafted appropriately and call for proper environmental performance, a significant catalyst for overcoming the other barriers will be created and facilitate further institutional changes.

To appropriately implement LID it is important to assess its role in water quality protection. LID is one part of a toolkit that can be used to better manage natural resources and limit the pollution delivered to waterways. It is not independent of watershed planning and to gain optimal benefits LID needs to be integrated with appropriate land use programs. LID by itself will not deliver the water quality outcomes desired; it does provide enhanced stormwater treatment and mitigate excess volume and flow rates. However, if not integrated in a comprehensive fashion, LID techniques can end up as a series of uncoordinated innovative BMPs that have limited water quality benefit.

The potential of LID is maximized when it is used in conjunction with other conservation and planning approaches. Programs like Smart Growth are the first step of the process. Before LID is used, decisions about where and how to develop within the watershed need to be evaluated to limit water quality impacts. Once these decisions are made, LID can then be used to mitigate the impacts of the development. Coordinating and integrating LID with Smart Growth and other innovative land use approaches will limit conversions in land cover, preserve natural watershed areas, and maximize the management of stormwater runoff. In urbanized areas, LID can be coordinated with green building and redevelopment efforts and it can be used to augment infrastructure projects by enhancing capacity. Retrofitting LID in urban locations provides opportunity to provide multiple environmental, social, and infrastructure benefits.

REGULATORY CLIMATE

Stormwater presents a significant challenge for establishing efficient and effective regulations. Its episodic and dynamic nature is the polar opposite of the largely predictable and constant nature of municipal and industrial wastewater discharges that have been such a large focus of the regulatory and permit efforts of the past decades. Incorporating stormwater into these programs

has been an institutional and technological challenge.[16] The resulting approach to stormwater control has been an adoption and reliance on minimum control measures that are implemented to demonstrate compliance with stormwater management plans. Discharge flow limitations and water quality criteria are often required and influence the selection of control measures. Even with the best efforts of these programs, water quality and use designations of waters nationwide are still well short of their intended goals.

The prevailing problem is that the current construct of many stormwater regulations do not require the use of the best available technologies and do not address hydromodification. This regulatory shortfall has hampered innovative applications of new technologies and an institutional shift in the practice of stormwater management. In California and other locations around the country, innovative practices are being adopted with increasing frequency. In certain instances innovation and implementation are outpacing regulatory programs and driving the revision of regulations; in others, innovative regulations have been adopted to establish environmental performance criteria that provide a significant incentive to adopt new control strategies. In either case, the resulting regulatory and incentive structures are informative for new program development.

A critical differentiation in regulatory application exists and will be presented in the examples in the following section. Minimizing and mitigating hydromodification is a critical performance criterion for Greenfield development. Undisturbed, Greenfield sites still possess natural hydrologic characteristics and attributes that can be used to inform appropriate control and mitigation strategies. Development or redevelopment of previously developed urban areas will require surrogate performance criteria. The natural hydrology of these areas has largely been lost due to the impacts of decades or centuries of urbanization. Linking performance criteria to hydrology in these areas is not as practical as Greenfield sites, but other approaches are used to approximate the desired outcomes of limited runoff volumes and pollutant loads.

POLICIES AND PROGRAMS

The following examples demonstrate how various jurisdictions have crafted their regulations to mitigate hydromodification or an increase in the volume of stormwater discharge.

- **401 Certifications**

  Section 401 of the CWA grants each state the right to ensure that the State's interests are protected concerning any federally permitted activity occurring in or adjacent to Waters of the State. In California, the Regional Water Quality Control Boards (Regional Boards) are the agency mandated to ensure protection of the State's waters. If a proposed project requires a U.S. Army Corps of Engineers CWA Section 404 permit, or involves dredge or fill activities that may result in a discharge to U.S. surface waters and/or "Waters of the State" the project proponent is required to obtain a Clean Water Act (CWA) Section 401 Water

[16] The NPDES program is not the only available avenue for regulating stormwater discharges. Other federal, state, and local water policies or programs offer significant opportunity for the development of comprehensive stormwater programs. In some cases, these provisions have influenced stormwater management, but municipal stormwater control is still largely driven by the NPDES program.

Quality Certification and/or Waste Discharge Requirements (Dredge/Fill Projects) from the Regional Board, verifying that the project activities will comply with state water quality standards.[17]

Section 401 gives the Regional Boards the authority to consider the impacts of the entire project and require mitigation for volume, velocity, and pollutant load of the discharge from new outfalls to surface waters. Some Regional Boards that have large areas not covered by Phase I or II Municipal permits, require low impact development and hydromodification mitigation consistent with municipal post-construction design standards.

- **404 Compliance**

Section 404 of the CWA regulates fill and disturbance of wetlands and waters of the United States. The US Corps of Engineers, Norfolk District, (which has permit review responsibilities) encourages 404 compliance with the use of LID principles. Projects applying for a permit are required to demonstrate that they have avoided and minimized impacts to jurisdictional areas to the maximum extent practicable. For unavoidable impacts, projects may be required to provide compensatory wetland mitigation. The Norfolk District office considers LID practices as partial mitigation, provided that there is no project-specific loss of wetland acreage.

This allowance is intended to minimize impacts that the Corps has witnessed to wetlands and streams that are associated with conventional stormwater management facilities. Therefore, the Corps allows consideration of LID BMPs (e.g., swales, bioretention facilities) as viable alternatives to in-channel or in-wetland stormwater basins. The initiative's goal is to reduce the number and size of conventional stormwater facilities impacting wetlands or waters of the U.S. In addition, the emphasis on LID design and BMPs is intended to ensure that the post-development and pre-development hydrographs are similar to reduce wetland impacts and maintain pre-development groundwater recharge.

- **Preliminary Draft California NPDES Construction General Permit for Stormwater Discharges**

The preliminary draft revised General Permit, released for comment in March 2007, included for the first time post-construction stormwater control performance standards.[18] Previously post-construction language was difficult to enforce as the standard of BAT/BCT was not easily applied to low impact development practices. If accepted, the draft permit will establish consistent state-wide post-construction standards that can be enhanced or augmented by the Regional Boards. The permit stipulates several performance standards for new development and redevelopment as identified below.

[17] North Coast Water Board, 401 Certification web page: http://www.waterboards.ca.gov/northcoast/programs/wqwetcert.html, (accessed November 2007).
[18] State Water Resources Control Board, National Pollutant Discharge Elimination System (NPDES) General Permit for Storm Water Discharges - Associated Construction and Land Disturbance Activities, March 2, 2007.

1. *The discharger shall, through the use of non-structural and structural measures, ensure that the post-development runoff volume approximates the pre-project runoff volume for areas covered with impervious surfaces...*
2. *For projects whose disturbed project area exceeds two acres, the discharger shall preserve the post-construction drainage divides for all drainage areas serving a first order stream or larger and ensure that post-project time of concentration is equal or greater than pre-project time of concentration.*
3. *For projects whose disturbed project area exceeds 50 acres, the discharger shall preserve pre-construction drainage patterns by distributing their non-structural and structural controls within all drainage areas serving first order streams or larger and ensuring that post-project time of concentration is equal to or greater than pre-project time of concentration.*

The regulatory approach of the draft permit is one of volume and time of concentration control. Pre-development site hydrology must be evaluated and guides post-construction performance objectives. The pre-development water balance must be approximated so that there is no increase in the volume of runoff that leaves the site. In addition, while the regulation expressly permits the use of both non-structural and structural controls, it is likely that achieving the hydrologic objectives of the standard will require a significant reliance on LID techniques.

- **Santa Clara Valley Hydromodification Management Plan**

The RWQCB, San Francisco Bay Region, requires stormwater programs to develop and implement hydromodification management plans (HMPs). The Santa Clara Valley Urban Runoff Pollution Prevention Program was the first permit to include the new HMP requirements.[19] The Program's hydromodification control standard requires that those who discharge stormwater manage increases in peak runoff flow and increased runoff volume where the increased volume or flow can cause erosion or siltation problems. The implemented HMP limits post-construction runoff to pre-construction rates and/or durations.[20]

Performance criteria to demonstrate compliance with the hydromodification control standard are also presented in the permit. The first of which is that the project shall use stormwater controls to maintain pre-construction stream erosion potential.[21] The second requires that post-construction stormwater discharge rates and flow durations be equivalent to pre-construction values for flows from 10% of the 2-year peak flow up to the full 10-year peak flow.[22]

[19] Santa Clara Valley Urban Runoff Pollution Prevention Program, Hydromodification Management Plan – Final Report, April 21, 2005.
[20] Ibid.
[21] Erosion potential is a measure of how a site's runoff hydraulically impacts a receiving stream. Greater volumes of stormwater released at greater rates and for longer durations impart greater physical impacts on receiving streams.
[22] Santa Clara Valley Urban Runoff Pollution Prevention Program, Hydromodification Management Plan – Final Report, April 21, 2005.

Santa Clara's HMP is an interesting case because the language differs greatly from conventional stormwater control regulations. By requiring quantification of the erosion potential of a site, the HMP directly addresses both the rate and volume of discharge. This requirement, coupled with flow duration criteria for small storms up to the 10-year storm, will require sites to maintain the pre-development hydrograph for a large percentage of storm events post construction.

This regulatory construct is efficient for several reasons. A great majority of stormwater regulations contain requirements for peak control only. As discussed in the background of this report, controlling only that single parameter is not sufficient to adequately protect receiving stream water quality because increased stormwater volumes and extended durations contribute larger mass loads of pollutants and impart greater physical impacts. By establishing discharge performance criteria for the volume, rate, and duration, these standards are more protective and demonstrate the full complement of factors that require control to limit the physical impacts of stormwater discharges.

Also important is the range of storms for which the duration of discharge must be controlled. Stormwater regulations routinely pick two design storms (often the two and 10 year events) for which peak flow rate requirements are established. The consequence of this is that no control is provided for the most frequently occurring small storms that are less than the two year event. Research shows that post-construction discharges from these small, frequent storms have much greater physical impacts than originally thought. Along this same line is the ability to effectively manage dry flows which can constitute a significant portion of runoff and pollutant transport in many areas of California. The duration control criterion recognizes the impacts of these small storms and established performance criteria designed to mitigate these effects.

- **San Diego County Phase I MS4 Permit**

In January 2007, the San Diego Regional Water Quality Control Board reissued the Phase I Municipal Stormwater Permit for San Diego County.[23] The permit has specific requirements for the implementation of low impact development BMPs and a Hydromodification Management Plan. Not only does the permit specify that LID is required to meet MEP for retail gas outlets and heavy industry meeting certain criteria, but also the permit requires all new and redevelopment projects to implement LID BMPs where feasible.

Priority Development Projects, a subset of development projects with a particular potential threat to water quality, as specified in the permit, are required to implement LID in the following ways:

[23] California Regional Water Quality Control Board, San Diego Region, Order No. R9-2007-0001, NPDES NO. CAS0108758, Water Discharge Requirements for Discharges of Urban Runoff from the Municipal Separate Storm Sewer Systems Draining the Watersheds of the County of San Diego, the Incorporated Cities of San Diego County, the San Diego Unified Port District, and the San Diego County Regional Airport Authority.

1. Draining a portion of the site's impervious areas into pervious areas prior to discharge to the MS4.[24]
2. Properly designing and constructing the pervious areas to effectively receive and infiltrate or treat runoff from impervious areas.
3. Constructing a portion of walkways, trails, overflow parking lots, alleys, or other low-traffic areas with permeable surfaces.

Another set of LID BMP requirements apply to Priority Development Projects where feasible:

1. Conserve natural areas, including existing trees, other vegetation, and soils.
2. Construct streets, sidewalks, or parking lot aisles to the minimum widths necessary, provided that public safety and a walkable environment for pedestrians are not compromised.
3. Minimize the impervious footprint of the project.
4. Minimize soil compaction.
5. Minimize disturbances to natural drainages (e.g., natural swales, topographic depressions).

Permittees are then given the responsibility of defining the applicability and feasibility of LID BMPs. They are required to establish minimum standards to maximize the use of LID practices and principles as a means of reducing stormwater runoff. This includes siting, design, and maintenance criteria for each LID BMP to ensure that they are constructed correctly and are effective at pollutant removal and/or runoff control. Additionally, prior to occupancy of a Priority Development Project, the LID BMPs must be inspected to verify compliance with specifications. Education concerning how to implement LID BMPs into the local regulatory programs and methods of minimizing impacts to receiving waters as a result of development is required for municipal personnel and development planning staff.

The permit's hydromodification requirements also apply to all Priority Development Projects. Each permittee must develop and apply criteria for priority projects so that runoff discharge rates, durations, and velocities are controlled to maintain or reduce downstream erosion conditions and protect stream habitat.

The Hydromodification Management Plan (HMP) must include:

1. A stability standard for channel segments which receive urban runoff discharges.
2. A range of runoff flows for which post-project runoff flow rates and durations shall not exceed pre-project runoff flow rates and durations.
3. Hydrologic control measures so that post-project runoff flow rates and durations do not exceed pre-project runoff flow rates and durations, and do not result in channel conditions which do not meet the channel standard.

[24] "Portion" corresponds with the total capacity of the project's pervious areas to infiltrate or treat runoff, taking into consideration the pervious areas' soil conditions, slope, and other pertinent factors.

4. Other performance criteria (numeric or otherwise) as necessary to prevent urban runoff from increasing erosion of channel beds and banks, silt pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force.
5. A review of pertinent literature.
6. A protocol to evaluate potential hydrograph change impacts to downstream watercourses.
7. A description of how the HMP requirements will be incorporated into the local approval processes.
8. The identified range of runoff flows to be controlled expressed in terms of peak flow rates of rainfall events.
9. Criteria for selection and design of management practices and measures to control flow rates and durations and address potential hydromodification impacts.
10. Technical information supporting standards and criteria proposed.
11. A description of inspections and maintenance to be conducted for management practices and measures to control flow rates and durations and address potential hydromodification impacts.
12. A description of pre- and post-project monitoring and other program evaluations to be conducted to assess the effectiveness of implementation of the HMP.
13. Mechanisms for addressing cumulative impacts within a watershed on channel morphology.
14. Information on evaluation of channel form and condition, including slope, discharge, vegetation, underlying geology.

Until the HMP is completed, the permit requires that interim criteria for projects disturbing 50 acres or more be established and implemented. The interim hydromodification criteria must contain a range of runoff flow rates for which Priority Development Project post-project runoff flow rates and durations shall not exceed pre-project runoff flow rates and durations.

While the San Diego Permit requirements have not been in effect long enough to draw conclusions about its implementation success, the concepts of:

- Including both LID and hydromodification requirements to address both on-site and receiving water concerns;
- Requiring the permittees to clearly define BMP feasibility in an effort to ensure maximum implementation;
- Including an education component for municipal staff to aid program implementation and consistency;
- Requiring inspection of management measures to ensure proper construction and long-term effectiveness; and
- Including interim requirements to implement until the more detailed plans have been approved.

The permit language and concepts are robust and specifically delineate LID and performance criteria requirements that are likely to lead to enhanced water quality protection and improvement.

- **Ventura County Draft Phase I MS4 Permit**

The August 2007 draft of the Ventura County Municipal Stormwater Permit also includes LID and hydromodification requirements.[25] The New Development and Redevelopment Criteria specify that all new and redevelopment shall integrate low impact development principles into project design. Permittees have 365 days to develop an LID technical guidance document for planners and developers that includes objectives and specifications for the integration of LID strategies, including:

1. Site assessment;
2. Site planning and layout;
3. Vegetative protection, re-vegetation, and maintenance;
4. Techniques to minimize land disturbance;
5. Techniques to implement LID measures at various scales;
6. Integrated water resources management practices;
7. LID design and flow modeling guidance;
8. Hydrologic analysis; and
9. LID credits.

In addition, the permit requires an LID training program for builders, design professionals, regulators, resource agencies, and stakeholders that addresses the integration of LID at various scales.

The permit's hydromodification control criteria require all new and redevelopment projects to implement control measures that prevent down stream erosion by maintaining the project's pre-development stormwater runoff flow rates and durations. The permit requires that the Erosion Potential (E_p) in streams be maintained at a value of 1, unless an alternative value is shown to be protective. The permit specifies a preference for LID strategies.

The Southern California Storm Water Monitoring Coalition is currently developing a regional methodology to eliminate adverse impacts from urbanization. The objectives for the Hydromodification Control Study (HCS) are:

1. Establishment of a stream classification for Southern California streams.
2. Development of a deterministic or predictive relationship between changes in watershed impervious cover and stream-bed/stream bank enlargement.
3. Development of a numeric model to predict stream bed/stream bank enlargement and evaluate the effectiveness of mitigation strategies.

Until the HCS is completed, permittees are required to implement the following interim hydromodification criteria:

[25] California Regional Water Quality Control Board, Los Angeles Region, Waste Discharge Requirements for Storm Water (Wet Weather) and Non-Storm Water (Dry Weather) Discharges from the Municipal Separate Storm Sewer Systems within the Ventura County Watershed Protection District, County of Ventura and the Incorporated Cities therein, August 28, 2007.

1. Projects disturbing land area of less than fifty acres must implement hydromodification controls such that the 2-year 24-hour storm event post-development hydrograph peak flow and volume will match within one percent of the 2-year 24-hour storm event pre-development peak flow and volume hydrograph.
2. Projects disturbing land areas of fifty acres or greater shall develop and implement a Hydromodification Analysis Study that demonstrates that post-development conditions are not expected to alter the duration of sediment transporting flows in receiving waters. The HAS must demonstrate that the selected hydromodification control BMPs will maintain an E_p value of 1 unless an alternative value can be shown to be protective.

Once the HCS is completed, permittees must develop Hydromodification Control Plans (HCPs) that are watershed specific and identify:

1. Stream classifications;
2. Flow rate and duration control methods;
3. Sub-watershed mitigation strategies; and
4. Stream restoration measures which will maintain the stream and tributary E_p at 1 unless an alternative value can be shown to be protective.

In addition, the HCP must contain the following elements:

1. Hydromodification management standards;
2. Natural drainage areas and hydromodification management control areas;
3. New development and redevelopment projects subject to the HCP;
4. Description of authorized hydromodification management control BMPs;
5. Hydromodification management control BMP design criteria;
6. For flow duration control methods, the range of flows to control for, and goodness of fit criteria;
7. Allowable low critical flow, Q_c, which initiates sediment transport;
8. Description of the approved hydromodification model;
9. Any alternate hydromodification management model and design;
10. Stream restoration measures design criteria;
11. Monitoring and effectiveness assessment; and
12. Record keeping.

The permit requires that verification of maintenance provisions be provided for the hydromodification controls for all new and redevelopment projects and that LID and hydromodification measures be inspected to ensure proper installation prior to the issuance of occupancy certificates. The permit also specifies that the permittee implement a tracking system, and an inspection and enforcement program for new and redevelopment post-construction stormwater BMPs.

While this permit is still in draft form and has not yet been adopted, it has a broad scope of requirements. The permit requires:

- An LID Technical Guidance document;
- An LID training program;
- A Hydromodification Control Plan;
- Interim hydromodification criteria;
- Verification of maintenance provisions for hydromodification controls;
- A tracking, inspection, and enforcement program for post-construction stormwater BMPs; and
- Inspection of LID and hydromodification measures prior to the issuance of occupancy certificates.

This permit does not allow for a feasibility assessment for its LID requirements. It requires that all new and redevelopment projects integrate LID principles into project design and that the permittee develop a LID Technical Guidance document that includes the specifications for the integration of LID strategies.

- **New Jersey Stormwater Management Rules**

New Jersey's new stormwater requirements adopted in 2004 contain specific criteria for infiltration and the rate and volume of discharge.[26] The state establishes groundwater recharge requirements with the following performance standards.

1. *…that the site and its stormwater management measures maintain 100 percent of the average pre-construction groundwater recharge volume for the site; OR*
2. *…that the increase of stormwater runoff volume from pre-construction to post-construction for the two-year storm is infiltrated.*

The recharge provisions contain exemptions for the defined "urban redevelopment area," hot spots, and industrial stormwater exposed to source material.[27] These provisions are complemented by runoff quantity requirements.

1. *…that post-construction runoff hydrographs for the two, 10, and 100-year storm events do not exceed, at any point in time, the pre-construction runoff hydrographs for the same storm events; OR*
2. *…that there is no increase, as compared to the pre-construction condition, in the peak runoff rates of stormwater leaving the site for the two, 10, and 100-year storm events and that the increased volume or change in timing of stormwater runoff will not increase flood damage…; OR*
3. *…that the post-construction peak runoff rates for the two, 10, and 100-year storm events are 50, 75, and 80 percent, respectively, of the pre-construction peak runoff rates…*

In addition to the hydrologic performance standards, water quality standards requiring 80% total suspended solids (TSS) removal for the water quality design storm of 1.25 inches in two hours is also required. The New Jersey standards took important steps forward with their primary hydrologic requirements. Maintaining groundwater recharge rates or infiltrating the

[26] "Stormwater Management Rule," *New Jersey Register*, N.J.A.C., Vol. 7, No. 8 (February 2, 2004).
[27] Ibid.

post-construction volume increase for the two year storm addresses one of the significant impacts of development – lost infiltration and groundwater recharge. Establishing these requirements will help to maintain pre-development water balance on the site.

Most importantly the primary runoff volume language requiring the post-construction hydrograph to match the pre-development hydrograph at each and every point does not allow an increase in the volume of stormwater discharged. This is not only an environmentally protective standard, but it would necessarily encourage wide adoption of non-structural controls and LID.

- **Portland Stormwater Requirements**

Portland's stormwater requirements are a good example of urban standards. Hydrology is not as much of a driving factor with urbanized areas as natural hydrology has been greatly altered and is likely not replicable in many instances because of factors such as existing utilities, density, soil compaction, fill materials, and existing historical contamination. Portland also has a combined sewer system and has a great interest in reducing stormwater inflow into the system.

The city's code requires on-site stormwater management for new development and redevelopment, and encourages the use of green infrastructure techniques to meet this objective.[28] In addition, new city-owned buildings are required to have a green roof covering 70% of the roof area. As an incentive for other buildings, a zoning bonus that allows additional square footage is available for those that install a green roof. The city will also allow up to a 35% discount in the stormwater utility for properties with on-site stormwater management.[29] This provides an incentive for existing properties to retrofit with on-site controls.

These are some of the most progressive urban stormwater standards in the country. They establish defined performance criteria based upon retention of stormwater and are a departure from many urban models whose aim is to provide water quality treatment for the first-flush of stormwater. Existing urban areas are often confronted by infrastructure capacity and maintenance concerns in addition to water quality requirements. Limiting the volume of stormwater discharged is a critical factor in addressing these issues. By also encouraging the use of green infrastructure, Portland is adopting a policy that will yield multiple environmental benefits in additional to providing stormwater retention.

- **Seattle Green Factor**

Adopted in January 2007, the Green Factor is an alternative approach for urban stormwater control. The Green Factor is a landscaping requirement in neighborhood business districts that stipulates that 30% of a site must be vegetated. This system encourages multiple layers of visible plantings and plantings in the public rights-of-way adjacent to the properties. The

[28] Portland City Code Chapter 17.38, Policy Framework, Appeals, and Update Process.
[29] C. Kloss and C. Calarusse, *Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows*, Natural Resources Defense Council, June 2006.

system is flexible and weights different landscaping practices according to their effectiveness. The square footage of each practice is multiplied by its green factor and then aggregated with the score of each additional practice to satisfy the requirements. For example, asphalt and concrete have a green factor of 0, permeable pavements 0.6, and green roofs 0.7. Bonuses are also provided for utilizing rain water harvesting and low water-use plants.[30]

This regulatory construct is interesting because it is not stormwater specific, nor does it contain specific discharge performance requirements. However, because of the practices selected for green factors and the benefits gained by adding vegetation and other green infrastructure practices, this policy will beneficially impact the volume of stormwater runoff. It is similar to the Green Area Ratio program in Berlin, Germany that has been a catalyst for encouraging green roof installation and the preservation or creation of other green spaces. The downside to this approach is that stormwater benefit may not be as great as stormwater specific performance requirements because of the flexibility in selecting green options. However, this is a progressive, multi-benefit/multi-pollutant policy approach.

This approach also provides an opportunity to assess appropriate amounts of vegetative cover in urban areas and the benefits gained from a comprehensive greening program. Analysis of this program can determine the environmental benefits with respect to the urban aesthetics desired. In addition, this type of system lends itself to a trading scheme where vegetative cover percentages can be increased in one area to offset a lack elsewhere or to provide enhanced performance in a critical or sensitive area.

- **Washington D.C. Anacostia Redevelopment Standards**

The area along the Anacostia River in Washington, DC (hereafter, the District) is slated for major redevelopment in the coming years. The Anacostia is one of the most polluted rivers in the country with a significant amount of this pollution contributed by stormwater runoff and combined sewer overflows. The District realized that the redevelopment presented an opportunity to revitalize a historically neglected portion of the city and established social, economic, and environmental benchmarks for the development area.

A comprehensive set of environmental standards was developed that included provisions for: (1) integrated environmental design; (2) stormwater; (3) green building; and (4) site planning and preservation. Like Portland's standards, natural hydrology is not as much a consideration as stormwater volume retention to limit discharges from the MS4 system and combined sewer overflows. The stormwater standards adopted serve as another example of an innovative urban application.

The stormwater control requirements stipulate on-site retention of the first inch of rainfall for new development and redevelopment and water quality treatment for up to the two-year storm volume along with a stated preference for vegetated controls. Where it is not technically feasible for on-site retention of stormwater, an off-set provision allows developers to provide off-site mitigation for 1½ times the volume that could not be provided

[30] Seattle Municipal Code, SMC 23.47A, Council Bill Number: 115746, Ordinance Number: 122311.

for the developed area or to pay into a dedicated stormwater fund for twice the cost of an equivalent volume reduction.[31] The off-set provision was modeled after other environmental off-set provisions and intended to provide an incentive to maximize on-site treatment.

These standards are considered some of the most progressive in the country. The driving focus was to significantly decrease stormwater inflow into the collection system and provide enhanced water quality treatment for any discharge while also supporting a green building and sustainability focus within the city. The stormwater standards were used as a platform to provide not only advanced stormwater control, but also encourage the integration of green space throughout an urban redevelopment to gain the associated social, economic, and multi-media environmental benefits.

- **Maryland Stormwater Act of 2007**

The Maryland Stormwater Act was passed by the General Assembly in April 2007 and signed into law by the Governor. The new act stipulates that Environmental Site Design (ESD) using LID practices is the preferred stormwater control method in the State and must be utilized as the first control option for new development projects.[32] Only after the developer or designer can demonstrate that they have used ESD to the maximum extent practicable are they permitted to use conventional stormwater controls.

This is more of a command-and-control regulatory construct mandating the use of a particular stormwater control system. However, because of the expansive list of LID BMPs and techniques, there is a great deal of flexibility built into the regulation. It also provides alternative options when site constraints may limit ESD's ability to achieve the stormwater management requirements. A significant benefit of this new policy is the understood preference for a new stormwater control regime based on LID principles that signals a departure from the standard methods of stormwater control.

An additional benefit of the new legislation is that it moves the State program to a more performance based system of stormwater management. Moving away from minimum treatment standards for selecting end-of-pipe BMPs and towards a system of integrated site design principles begins to allow the regulatory system to address overall site performance and function.

[31] Anacostia Waterfront Corporation, *Final Environmental Standards*, June 1, 2007.
[32] *Maryland Stormwater Management Act of 2007,* Senate Bill 784 / House Bill 786, (available at http://mlis.state.md.us/2007RS/billfile/sb0784.htm).

CONCLUSIONS AND RECOMMENDATIONS

The State of California has a well developed institutional framework that can aid the development of a comprehensive LID program. Many steps already taken by the State have established the necessary performance criteria needed for broader LID adoption. The draft general Construction permit establishes volume limitations for post-construction runoff rather than the traditional approach of limiting flow rate. Preserving pre-construction runoff volumes will require the use of site design approaches and LID that will limit stormwater generation and maximize natural hydrologic processes for treatment.

In addition, the San Francisco Region's requirement for hydromodification plans places the emphasis on in-stream impacts of stormwater runoff and the need to develop programs that effectively manage the increased volume and flow that contribute to these impacts. The critical link in both of these approaches is that they require stormwater volume to be limited. Establishing a performance criterion for volume will more than likely require LID or other similar approaches that limit the conversion of precipitation to runoff.

Importantly, the institutional structure within the State can function to efficiently promote the adoption of innovative control approaches. The coordinated efforts of the State Board establishing broad policy approaches and the Regional Boards setting additional requirements within their watersheds when needed allows for alternative and evolving regulatory approaches, as highlighted by the examples above. Critical to this is the authority granted by the Porter-Cologne Act to regulate any activity or factor that impacts water quality. This stipulation gives the State broad authority to assess the cause of stormwater runoff and pollution and develop strategies to mitigate the originating cause. This condition exceeds that of many states that are limited by choice or statute to manage stormwater as a waste product while giving limited attention to the upstream factors that affect runoff. The planning and permitting authority that exists in the State and Regional Boards allows for the development of comprehensive control requirements that maximize vegetation, natural systems, and LID.

Important to the successful application of LID, is evaluating how it will be used for new development and redevelopment or urban retrofit. The pre-draft of the Reissuance of the Statewide construction general permit and the hydromodification management plans apply to new development and redevelopment and assess pre-development hydrologic conditions. Matching pre-development hydrologic conditions is a fair method in Greenfield development and redevelopment situations where determinations of pre-development conditions can be made and will help to decrease the pollution impact of new development across the state.

However, existing development exerts a tremendous pollution impact largely due to the resulting, developed landscape and its associated runoff characteristics. Addressing it by matching pre-development hydrology may not always be possible because many urban areas lack land for stormwater control and natural hydrology has been altered so significantly. In these instances, the urban stormwater regulations in Portland and Washington, D.C. that require volume retention can serve as appropriate models. These regulations do not focus on the natural function of a site, but rather attempt to limit runoff as a means of pollution prevention and enhancing infrastructure capacity. The desired outcome is the same as the hydromodification

approaches, but the assessment and control requirements are structured differently to account for urban conditions.

The important concept across all of these approaches is that the regulations established a performance requirement to limit the volume of stormwater discharges. The fact that volume is the critical regulatory requirement instead of maximum flow rate leads to greater adoption of LID and vegetated systems. The City of Salinas and the Central Coast Regional Water Quality Control Board found that ordinances that only encourage LID adoption had little voluntary implementation, but ordinances that require LID have resulted in more widespread implementation.[33]

Regulations can address new development or redevelopment but LID retrofits are also a critical need on existing development to mitigate existing stormwater pollution. Appropriately structured incentive programs can encourage LID adoption outside of a regulatory structure and reduce stormwater volume. Portland uses the potential for a discount from its stormwater utility fee to create an incentive for existing properties to retrofit to on-site stormwater controls. The recurring financial benefits that can be gained from a one-time capital investment and limited maintenance requirements can entice owners to adopt on-site practices that otherwise may not have.

Utility fees or other dedicated funding can serve multiple purposes. Portland's utility fee funds its program and provides an incentive for volume reductions. The off-set fee that is permissible in the Anacostia portion of Washington creates a revenue stream that the city can use for installations within right-of-ways or city owned property. To be effective for both purposes, a fee must be structured and valued to provide sufficient programmatic funding and allow for a fee discount sufficient to create an incentive. Washington's preference is for on-site controls, so the required off-set fee is based upon twice the cost to manage the volume of stormwater to encourage the maximization of on-site options.

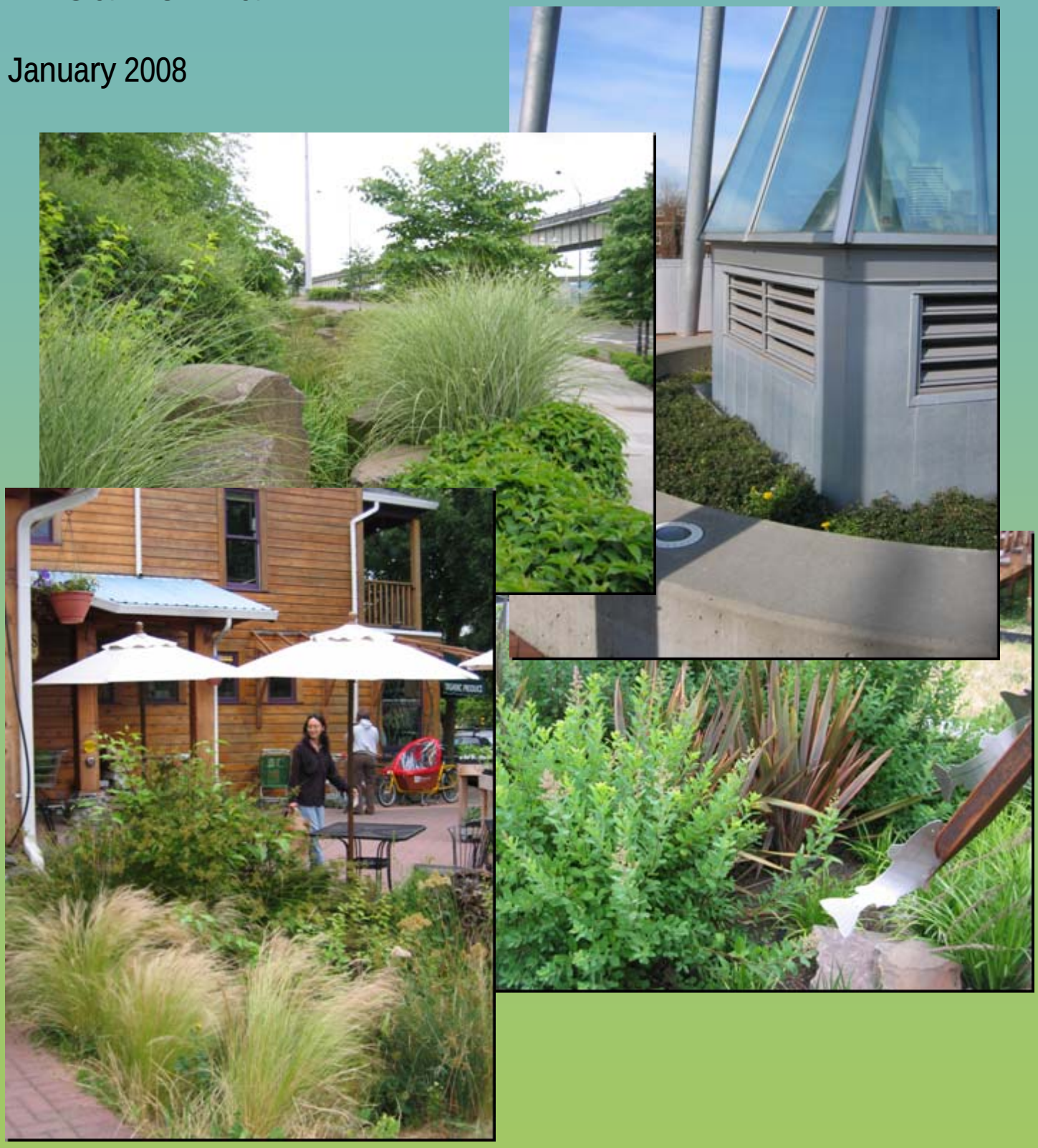
LID is also a complement to other land use planning or environmental programs. The water quality benefits of Smart Growth programs can be enhanced by using LID. LID can also be used within the Leadership in Energy and Environmental Design (LEED®) system to gain points for environmentally sensitive design. Many LID practices provide benefits like energy conservation or other site design benefits in addition to stormwater control that can contribute to the overall LEED® rating of a project.

The State and Regional Boards have begun to implement policies that will encourage LID practices. These policies will likely lead to broader implementation of distributed, on-site stormwater techniques. Other policy options that have been adopted in other jurisdictions have the potential to augment California's existing efforts and develop a more robust regulatory system. The institutional framework within the State allows for regulatory innovation and should provide the necessary platform for a water resources program that fully incorporates LID.

[33] Chris Conway, et al., *Technical Memorandum to the Central Coast Regional Water Quality Control Board and the City of Salinas – Model Low Impact Development (LID) Ordinance for Salinas and the Central Coast*, Kennedy/Jenks Consultants, January 22, 2007.

State and Local Policies Encouraging or Requiring Low Impact Development in California

January 2008



Prepared for the
Ocean Protection Council of California

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SARB_014319

State and Local Policies Encouraging or Requiring Low Impact Development in California

Final Report

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January 2008

SARB_014321

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Executive Summary

Stormwater pollution occurs when rain falls onto developed areas. Under natural conditions, much of the rainwater soaks into the soil, returning to streams, lakes, and other waterbodies through the ground. Surface runoff is usually limited and is slowed by dense vegetation. With development, specifically with the creation of impervious surface such as streets, driveways, sidewalks, and roofs, rain is prevented from infiltrating into the ground, causing it to flow over the surface in much larger quantities. Along the way this runoff mobilizes pollutants and transports them to waterbodies where they eventually flow to the Pacific Ocean.

In California, 691 waterbodies are considered impaired because water quality is too poor to support designated uses.[1] Of these impaired waterbodies, 110 are bays and harbors, 39 are estuaries, and 4 are tidal wetlands, indicating that pollution is affecting California's coastal resources. Urban runoff-related pollutants, such as pathogens, nutrients, metals (e.g., mercury, copper, lead), sediment, and toxic chemicals, are among the top causes of impairment statewide. Many California communities have issued a standing warning to avoid swimming, surfing, or other contact recreation at beaches for 72 hours after rainstorms due to high bacterial counts and increased concentrations of other potentially harmful pollutants being discharged from stormwater outfalls. Beach closures and swimming restrictions are commonly attributed to urban runoff, in some cases even during dry weather. Urban runoff can cause physical damage by accelerating stream channel erosion, modifying instream aquatic habitat, and altering riparian zones. Flood damage can also be more frequent and severe when runoff is not properly mitigated.

The effects of urban runoff have been exacerbated by stormwater management techniques popularized after World War II, in which drainage systems were designed to rapidly convey vast amounts of stormwater through gutters and pipes with no attenuation or pollutant removal. These high-volume, high-velocity flows have eroded stream channels, destroyed habitat, and caused flooding and property damage.

In the past decade a stormwater management technique called Low Impact Development (LID) has been gaining ground as the preferred method for mitigating stormwater impacts. The technique minimizes hardscape and uses the pervious surfaces on a development site, such as landscaped areas, to infiltrate and/or temporarily store runoff, allowing the site to more closely mimic a "natural" state with respect to hydrology. LID site design incorporates such diverse practices as bioswales, filter strips, flow-through planter boxes, porous pavement, cisterns, rain barrels, green roofs, and other micro-scale best management practices, allowing a great deal of flexibility in design. Widespread application of LID practices is expected to help restore the natural water balance when used in redevelopment and infill applications, which is particularly important in urbanized areas to help reverse the ill effects of past development. LID is also expected to maintain the hydrologic balance and reduce pollutants in newly developing areas, helping to ensure protection of high-quality water resources.

Regulations are in place in California and nationwide to prevent and/or mitigate the effects of stormwater pollution. The California State Water Resources Control Board and Regional Water Quality Control Boards have set requirements for municipalities and construction sites to control stormwater under the National Pollutant Discharge Elimination System regulations. Municipal stormwater permits developed by the Regional Water Quality Control Boards in Southern California and the San Francisco Bay area have begun to incorporate explicit LID requirements. These requirements are not standardized and only apply locally, however, limiting their impact statewide. The draft Construction General Permit includes incentives to incorporate LID techniques in stormwater plans statewide and will apply to most new and redevelopment. However, comprehensive state legislation could be adopted to "set the bar" for LID

[1] EPA. 2008. *2006 Section 303(d) List Fact Sheet for California.* http://iaspub.epa.gov/waters/state_rept.control?p_state=CA

incentives and requirements to ensure that all of the State's water resources are protected. Recommended language should be based on existing models within California and in other areas, integrating the "best of the best" while balancing the needs of large, urban communities with those of smaller, suburban or rural communities.

Beyond statewide legislation, other opportunities exist to integrate LID into related programs and initiatives. Stormwater concerns dovetail nicely with smart growth, watershed protection, water conservation, and green building initiatives, for example. Dialog and partnerships among State and local agencies, environmental groups, trade associations, water agencies, academia, and citizen groups will be essential for LID to become "business as usual" in California, with benefits not only to water quality but also for community livability and sustainability.

This report includes background information on stormwater pollution and impervious surface effects (Section 1). Section 2 presents an overview of LID principles and practice along with highlights of agencies and organizations that have incorporated LID. Section 3 categorizes a variety of options for state, regional, and local LID requirements, while Section 4 summarizes existing stormwater regulations in California and elsewhere and integrates these examples into recommendations for statewide LID legislation if the state were interested in adopting such requirements. Section 5 discusses ways in which LID can be incorporated into local codes, ordinances, and standards, along with programmatic steps communities can take to improve LID program administration. Key elements of progressive stormwater codes and ordinances are included as models for other communities. Finally, a procedure and criteria are presented that would assist a State agency in evaluating applications if grant funding is made available for local LID planning and implementation projects.

This report is intended to describe ways in which LID practice can be enhanced in California on state, regional, and local levels. It is meant to complement the policy analysis and recommendations outlined in the December 2007 report from the California State Water Resources Control Board Stormwater Program and The Water Board Academy, *A Review of Low Impact Development Policies: Removing Institutional Barriers to Adoption*. Other recent reports provide a different perspective on LID, such as two 2007 reports evaluating costs and benefits of LID practices: *The Economics of Low Impact Development: A Literature Review* by ECONorthwest[2] and the U.S. Environmental Protection Agency's *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*.[3] Technical guidance for LID is continually being developed on the local and regional levels, and many of these guidance manuals provide valuable, location-specific guidelines for LID applicability along with detailed design, installation, and maintenance specifications.

[2] ECONorthwest. 2007. *The Economics of Low Impact Development: A Literature Review*. http://www.econw.com/reports/ECONorthwest_Low-Impact-Development-Economics-Literature-Review.pdf.

[3] EPA. 2007. *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*. http://www.epa.gov/owow/nps/lid/costs07/documents/reducingstormwatercosts.pdf.

1 Introduction

1.1 Overview of Impervious Surfaces

The term impervious surface refers to land cover, both natural and human-made, that cannot be penetrated by water. Consequently, precipitation that falls on impervious surfaces does not infiltrate into the soil. Instead, it runs off to a pervious area where all or a portion infiltrates into the soil, or it continues to travel down-slope on impervious surfaces, including saturated soils, until it is eventually conveyed to a ditch, a storm drain network, or a receiving waterbody. Most of the impervious cover in an urban watershed or subwatershed is from rooftops, roads, sidewalks, driveways, parking lots, and recreational facilities (e.g., tennis courts, swimming pools, etc.).

Impervious surface is typically measured as total impervious area or effective impervious area. Total impervious area includes all impervious cover in the watershed and is typically represented as a percent of the entire watershed area. Effective impervious area is the portion of impervious cover that is directly connected to stormwater conveyance systems or receiving waterbodies. Effective impervious area tends to be a better proxy for hydrologic and pollutant impacts from development because flows from these areas are not infiltrated, evaporated, or otherwise treated before being discharged to waterbodies. In many cases, a large portion of total impervious area can be "disconnected" by diverting flows to pervious surfaces such as landscaped areas. For example, gutter downspouts on residential homes can be disconnected to direct flows over the lawn or into infiltration basins.

Both the amount of impervious area and the relationship between total and effective impervious areas vary according to land use.[4] For example, work in the Puget Sound area revealed that total impervious area in low-density residential sites averaged approximately 10 percent, with an effective impervious area of only 4 percent. In commercial and industrial areas, however, total impervious area averaged about 90 percent. Almost all of the total impervious area is also effective impervious area because of the lack of pervious areas to break up direct connections.

1.2 Effects of Increased Imperviousness

Watershed imperviousness plays an important role in determining the conditions in waterbodies because it leads to more runoff. Increased runoff carries more pollutants to receiving waters and transports them faster than they would normally travel with the help of streets, driveways, parking lots, rooftops, sidewalks, curbs, gutters, and storm drain pipes. Increased runoff also has physical effects on streams and rivers—the larger, faster flows are more erosive and can alter the size, shape, and habitat quality of channels. Higher runoff volumes also exacerbate flooding and property damage.

Impervious cover is an inescapable attribute of development and a permanent part of the urban/suburban landscape. As might be expected, there is a linear relationship between impervious surface in a given area and the amount of runoff generated. What is unexpected is what this means in terms of both the volume of water generated and the rate at which it exits the surface. Depending on the degree of impervious cover, the annual volume of storm water runoff can increase to anywhere from 2 to 16 times the predevelopment amount.[5] Impervious surface coverage as low as 10 percent can destabilize a stream channel, raise water

[4] Caraco, D., R. Claytor, P. Hinkle, H.Y. Kwon, T. Schueler, C. Swann, S. Vysotsky, and J. Zielinski. 1998. *Rapid Watershed Planning Handbook*. Center for Watershed Protection, Ellicott City, MD.

[5] Schueler, T. 1994. The Importance of Imperviousness. *Watershed Protection Techniques* 1(3): 100–111.

temperature, and reduce water quality and biodiversity.[6] One study found that connected imperviousness levels between 8 and 12 percent represented a threshold region where minor changes in urbanization could result in major changes in stream condition.[7] Table 1 provides a detailed summary of the effects of urbanization and increased imperviousness on streams.

Table 1. Urbanization Effects on Streams. [8]

Effect	Description
Bankfull and subbankfull floods increase in magnitude and frequency	The peak discharge associated with the bankfull flow (the 1.5- to 2-year return storm) increases sharply in magnitude in urban streams. Channels experience more bankfull and subbankfull flood events each year and are exposed to critical erosive velocities for longer intervals.
Dimensions of the stream channel are no longer in equilibrium with its hydrologic regime	The hydrologic regime that defined the geometry of the predevelopment stream channel irreversibly changes, and the stream experiences higher flow rates on a more frequent basis. The higher-flow events of the urban stream are capable of moving more sediment than before.
Channels enlarge	The customary response of an urban stream is to increase its cross-sectional area to accommodate the higher flows. This is done by streambed downcutting, channel widening, or a combination of both. Urban stream channels often enlarge their cross-sectional area by a factor of 2 to 5 depending on the degree of impervious cover in the upland watershed and the age of development.
Stream channels are highly modified by human activity	Urban stream channels are extensively modified in an effort to protect adjacent property from streambank erosion or flooding. Headwater streams are frequently enclosed within storm drains, while other streams are channelized, lined, and/or "armored" by heavy stone. Another modification unique to many urban streams is the installation of sanitary sewers underneath or parallel to the stream channel.
Upstream channel erosion contributes greater sediment load to the stream	The prodigious rate of channel erosion coupled with sediment erosion from active construction sites increases sediment discharge to urban streams. Researchers have documented that channel erosion constitutes as much as 75 percent of the total sediment budget of urban streams. Urban streams also tend to have a higher sediment discharge than non-urban streams, at least during the initial period of active channel enlargement.
Dry weather flow in the stream declines	Because impervious cover prevents rainfall from infiltrating the soil, less flow is available to recharge ground water. Consequently, during extended periods without rainfall, baseflow levels are often reduced.
Wetted perimeter of the stream declines	The wetted perimeter of a stream is the proportion of the total cross-sectional area of the channel that is covered by flowing water during dry weather, and it is an important indicator of habitat degradation in urban streams. Given that urban streams develop a larger channel cross-section at the same time that their base flow rates decline, it follows that the wetted perimeter will become smaller. Thus, for many urban streams, this results in a very shallow, low-flow channel that "wanders" across a very wide streambed, often changing its lateral position in response to storms.

[6] Schueler, T. 1995. *Site Planning for Urban Stream Protection*. Metropolitan Washington Council of Governments, Washington, DC.

[7] Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2001. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. *Environmental Management* 28(2): 255–266.

[8] U.S. Environmental Protection Agency. 2005. *National Management Measures to Control Nonpoint Source Pollution from Urban Areas*. Office of Water, Washington, DC.

Table 1. Urbanization Effects on Streams. [8]

Effect	Description
Instream habitat structure degrades	Urban streams are routinely scored as having poor instream habitat quality, regardless of the specific metric or method employed. Habitat degradation is often exemplified by loss of pool and riffle structure, embedding of streambed sediments, shallow depths of flow, eroding and unstable banks, and frequent streambed turnover.
Large woody debris is reduced	Large woody debris is an important structural component of many low-order stream systems because it creates complex habitat structure and generally makes the stream carry more water. In urban streams, the quantity of large woody debris found in stream channels declines sharply because of the loss of riparian forest cover, storm washout, and channel maintenance practices.
Stream crossings and potential fish barriers increase	Many forms of urban development are linear in nature (e.g., roads, sewers, and pipelines) and cross stream channels. The number of stream crossings increases in direct proportion to impervious cover, and many crossings can become partial or total barriers to upstream fish migration, particularly if the streambed erodes below the fixed elevation of a culvert or pipeline.
Riparian forests become fragmented, narrower, and less diverse	The important role that riparian forests play in stream ecology is often diminished in urban watersheds as tree cover is often partially or totally removed along the stream as a consequence of development. Even when stream buffers are preserved, encroachment often reduces their effective width and native species are supplanted by exotic trees, vines, and ground covers.
Water quality declines	The water quality of urban streams during storms is consistently poor. Urban storm water runoff contains moderate to high concentrations of sediment, carbon, nutrients, trace metals, hydrocarbons, chlorides, and bacteria. Although considerable debate exists as to whether storm water pollutant concentrations are actually toxic to aquatic organisms, researchers agree that pollutants deposited in the streambed exert an undesirable impact on the stream community.
Summer stream temperatures increase	The impervious surfaces, ponds, and poor riparian cover in urban watersheds can increase stream temperatures by several degrees. Because temperature plays a central role in the rate and timing of instream biotic and abiotic reactions, such increases have an adverse impact on streams. In some regions, summer stream warming can irreversibly shift a cold-water stream to a cool-water or even warm-water stream, resulting in deleterious effects on salmonids and other temperature-sensitive organisms.
Reduced aquatic diversity	Urban streams are typified by fair to poor fish and macroinvertebrate diversity, even at relatively low levels of watershed impervious cover or population density. Declines in sensitive species have been observed at levels of impervious cover as low as 4 percent. Impervious cover in highly urbanized areas comprising greater than 25 percent of a watershed may even preclude the Clean Water Act goal of "fishable" waters. The ability to restore predevelopment fish assemblages or aquatic diversity is constrained by a host of factors, including irreversible changes in carbon supply, temperature, hydrology, lack of instream habitat structure, and barriers that limit natural recolonization.

Figure 1 shows the relationship between impervious cover and aquatic insect diversity; Figure 2 shows the relationship between imperviousness and fish diversity.

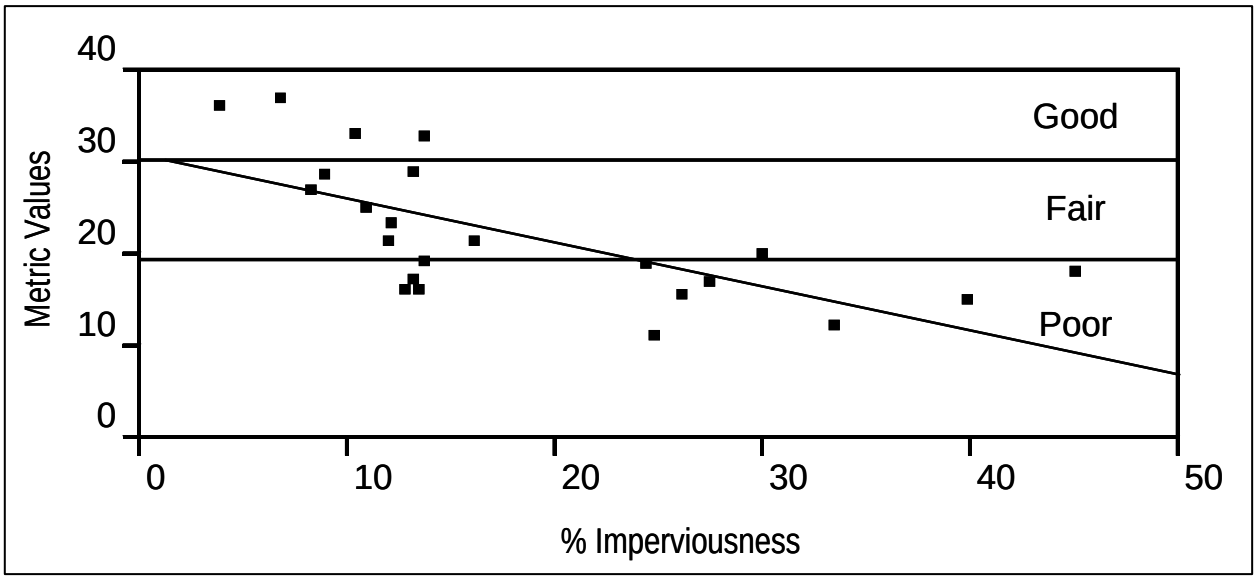

Figure 1. Relationship between impervious cover and aquatic insect diversity in Anacostia River subwatersheds (Schueler and Galli, 1992, as cited in Schueler, 1995).

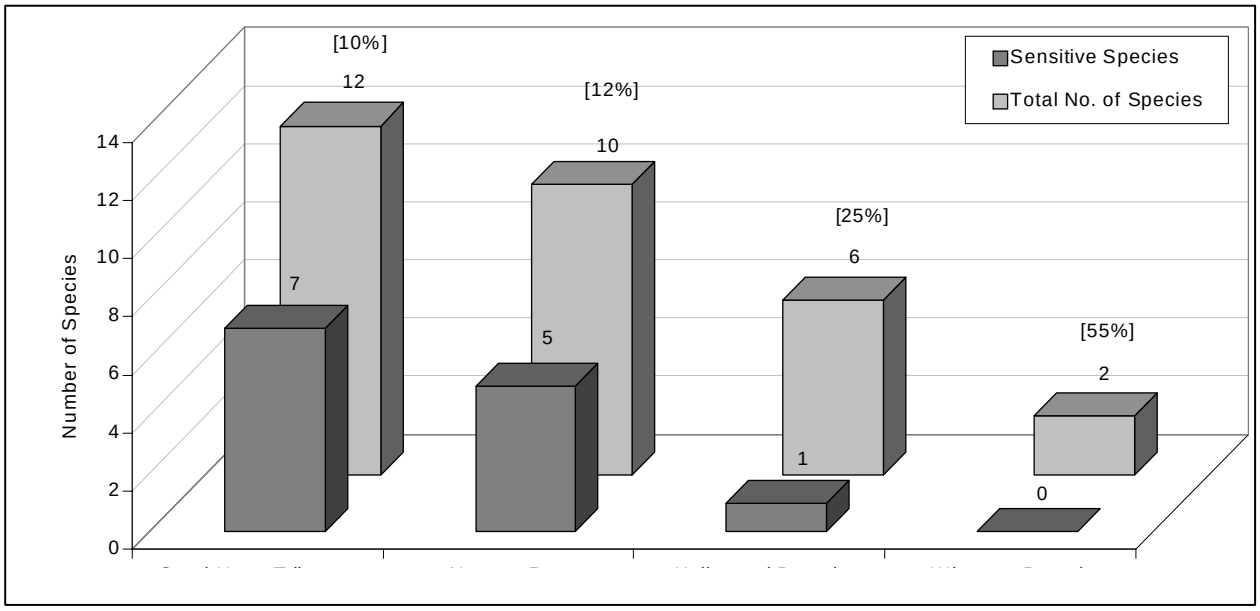

Figure 2. Fish diversity in four subwatersheds of different impervious cover in the Maryland Piedmont (Schueler and Galli, 1992, as cited in Schueler, 1995).

2 Low Impact Development

2.1 What is Low Impact Development?

According to the Low Impact Development Center, Low Impact Development, or LID, is a stormwater management strategy concerned with maintaining, mimicking or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives. LID addresses stormwater through small, cost-effective site design and landscape features that are distributed throughout the site. In shorthand, LID is often referred to as a requirement that the post-development stormwater runoff profile equal the pre-development conditions, both in terms of volume and rate.

Best management practices associated with LID typically come in the form of "green" or non-structural practices. Some conventional practices are often used, such as dry detention basins and swales. Modified landscaping is increasingly popular since cities often already have landscaping codes in place.[9] The modifications include use of engineered soils for water handling purposes, tree canopy requirements, use of native landscaping, and the use of cisterns and other runoff storage devices. In residential settings, rain gardens, coving, and storage devices such as rain barrels and cisterns are being promoted or required. While conventional house designs often directed downspouts to paved driveways, new designs for both pervious driveway surfaces and diverted flow into natural areas are likely to become standard practice.

While initial LID practices were mainly written for new residential subdivisions, a new generation of practices (and combination of practices) has emerged for commercial applications and urban settings that cannot rely on large parcels for infiltration. As such, green roofs, permeable paving, improved parking lots, and landscaping are gaining attention. In some cases, a combination of "green" techniques and structural practices (e.g., vaults) will be needed to meet performance goals.

While many communities are adopting informal guidelines on LID, regulatory recognition of LID is increasing at the State and local levels. Established LID programs exist at the State level in Maryland, Washington, and Massachusetts. Some States have adopted LID requirements for sensitive areas, for example the Pinelands region of New Jersey. Among cities, Portland, Oregon, and Chicago, Illinois, are leaders.

LID programs vary around the country, with differing performance standards, definitions, and regulatory structures. In most cases, the program first establishes the baseline natural hydrologic regime, and sets development performance based on meeting targets for runoff volume, runoff rates, and pollutant loads.

With LID, it is important to strike a balance that recognizes the impact that development has on ecology and hydrology. Establishing the baseline, pre-development condition may seem simple, but it would be unrealistic to expect that true pre-development conditions can be achieved fully. The baseline might be set higher where waterbodies are impaired, for example, requiring development to mimic the hydrology of a forest, even if the predevelopment condition provides lower ecological services. On the other end of the spectrum, some locales set the pre-development condition based on the status of the site immediate to construction. Thus, redevelopment of a 100 percent impervious site under this type of regulation need only meet minimal (or no) on-site stormwater requirements. Realistic requirements should be written to strike a balance: achieve improvement over existing conditions but take into account economic development goals and site constraints.

[9] Note that California has State standards for commercial landscaping; this code is currently being amended under 2006 legislation for water conservation.

For regulatory structures, LID can be introduced in several ways:

- A new, stand-alone code
- Integrated codes (that is, integrated into existing zoning and building codes)
- Subdivision regulations, sub-area plans, or specific plans
- Guidelines
- Alternative compliance programs

Like other planning programs, LID is constantly evolving. Research and policy options for LID at a larger scale are now underway. In fact, one of the weaknesses of early LID efforts was its confinement to individual sites and projects. Green highways and green infrastructure are commanding a great deal of attention. LID at the district scale is also likely to gain profile for development designs where individual lots are not likely to meet strict performance measures. Finally, policy options for retrofitting existing development with LID techniques will gain attention, in particular for built out watersheds draining to impaired waterways.

2.2 LID ON MULTIPLE SCALES: CONSIDERING SMART GROWTH

The intersection of development and watershed planning tends to settle upon one concept: impervious surface. As discussed in section 1, the importance of imperviousness cannot be under-stated and is well known as an indicator of watershed health. Limiting the effects of impervious surface is becoming more common in local zoning codes in the form of impervious surface caps, requirements to disconnect impervious surfaces, and infiltration requirements. Because they are contained in zoning codes, the policies tend to apply to individual sites. Thus, limiting effective impervious surface coverage on individual sites has emerged as the preferred regulatory instrument for limiting the effects of impervious surfaces.

While this approach works in some development contexts, there can be applications that limit the full potential of LID. For new development, it is possible for individual sites to meet LID specifications, even as they add to wider disturbance arising from cumulative and induced development impacts. These often-overlooked impacts arise not because of LID, but because of the underlying pattern of dispersed development. Second, site-level application of LID can pose a challenge in districts that coordinate a higher intensity of development on a compact footprint because space for infiltration may be limited, for example transit area planning, redevelopment of older downtowns, and master-planned town centers.

Early smart growth projects were isolated and did not make full use of on-site and/or distributed stormwater management. Although new designs call for narrow roads, the curbs, gutters and conveyance systems rely on conventional, untreated drainage. For developed areas, improving impaired waterways will be met through retrofits of existing development, not new development. Even though urban redevelopment projects have an implicit watershed benefit by reusing impervious surface, each project will need to contribute to stormwater management and improvement. This is often missing from urban public works planning, in part because the development operating system was built on conventional curb-and-gutter drainage.

These points illustrate the importance of scale when assessing and evaluating low impact and smart growth policies. Those scales include the watershed (or region), the subwatershed (or district), and the site, simultaneously. Successfully coordinating watershed management and reducing the impacts of development typically occur within a comprehensive plan.

2.3 LID ON THE GROUND IN CALIFORNIA

There are a number of California organizations who have made great strides in researching, implementing, and developing guidance for LID. The following are highlights from the California Department of Transportation (Caltrans) and three regional, umbrella stormwater organizations: the Santa Clara Valley Urban Runoff Pollution Prevention Program, the Contra Costa Clean Water Program, and the Alameda Countywide Clean Water Program.

2.3.1 Caltrans

Caltrans has several programs underway to address the installation and retrofit of State roads and highways, though the work can apply to non-State roads as well. Because roads traditionally represent a high degree of connected impervious cover, special attention should be devoted to retrofitting streets with LID. The following summary introduces several Caltrans programs underway that incorporate LID activity.

Best Management Practice Retrofit Pilot Program (2004, 316 pages) – This pilot program was initiated to assess the potential for large-scale retrofit of Caltrans roads with stormwater BMPs. Thirty-two pilot sites in the Los Angeles and San Diego regions were outfitted with a variety of structural and non-structural BMPs. The program produced information on the effectiveness of BMPs in pollutant removal efficiencies, as well as the technical feasibility of the BMPs as retrofits in highway and support facility settings. LID techniques, such as swales, biofiltration, and infiltration, were tested both alone and as part of a "treatment train," where several BMPs were installed in a series. http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-01-050.pdf

Storm Water Quality Handbook: Project Planning and Design Guide (2007, 354 pages) – This recently revised Handbook incorporates several "green" features, including reference to the 2004 BMP Retrofit study listed above. The foremost consideration in stormwater design is preservation of the maximum amount of vegetative condition no matter the context. The Handbook also notes up front that the requirements are minimal; any roadway within an MS4 would be subject to additional post-construction (or permanent) stormwater management practices. An important feature of the Handbook is the presentation of Accepted Water Quality Treatment BMPs and specifications for their construction, operation, and maintenance. Many techniques used in prominent "green streets" retrofits are included (for example infiltration devices and bioswales). http://www.dot.ca.gov/hq/oppd/stormwtr/Final-PPDG_Master_Document-6-04-07.pdf

2.3.2 Stormwater Management Programs

The issuance of municipal stormwater permits has created a new generation of programs dedicated to not only permit compliance, but also to integration of stormwater runoff into other watershed management and regional planning efforts. In some organizations, stormwater management is housed in traditional flood control programs, while in other programs, new, stand-alone programs were formed to address NPDES requirements. The proliferation of smaller programs has led to larger umbrella organizations like the Bay Area Stormwater Management Agencies Association (BASMAA), which serves as a regional liaison among local and regional governments and the Regional Water Quality Control Boards. Three notable local programs are the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), the Contra Costa Clean Water program, and the Alameda Countywide Clean Water Program (ACCWP).

In 2001, the San Francisco Bay Regional Water Quality Control Board reissued the NPDES permit for MS4s and included a measure called "C.3." As noted previously in this report, this measure, which was landmark, extended stormwater practices to new development and redevelopment projects. Both

SCVURPPP and the Contra Costa programs developed comprehensive program materials to address the new requirements. Details are presented below.

Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)

SCVURPPP is a program addressing water quality in thirteen cities and towns in the Santa Clara Valley. These cities and towns are responsible for implementing a municipal stormwater permit issued by the San Francisco Bay Regional Water Quality Control Board. According to the program's Website (http://www.scvurppp-w2k.com/default.htm), the five goals of the Program include:

- Permit Compliance
- Establishing Determinants of Success
- Adjusting Activities to Change
- Achieving Acceptance of Urban Runoff Management Activities
- Integrating Urban Runoff Program Elements into Other Programs

To meet these goals, the Program offers a number of services, including workshops, fact sheets, guidance manuals, interpretation of permit requirements, model language, targeted reports, and presentations. For LID, the following products are particularly helpful:

- Stormwater Pollution Control Requirements: What Developers, Builders and Project Applicants Need to Know (Fact Sheet) http://www.scvurppp-w2k.com/pdfs/0506/C3%20flyer%20update%20120505.pdf
- Understanding Hurdles To Using Better Site Designs for Water Quality Protection (PowerPoint presentation: http://www.scvurppp-w2k.com/project_reports_fy0304/Hurdles.pdf)
- Addressing Fire Department and Public Safety Concerns http://www.scvurppp-w2k.com/project_reports_fy0304/potential_hurdles_fire_dept_100803.pdf
- Developments Protecting Water Quality: A Guidebook of Site Design Examples http://www.scvurppp-w2k.com/permit_c3_docs/SCVURPPP_Site_Design_Manual.pdf
- Applicability of New C.3 Provisions – Development Flow Chart http://www.scvurppp-w2k.com/project_reports_fy0304/Stormwater_Requirements_Checklist.pdf
- Site Design Guidance for Review of Local Codes and Standards http://www.scvurppp-w2k.com/pdfs/dvlpmnt_plcs/report/III_Conc_Conflicts_and_Rcmdns.PDF

Contra Costa Clean Water Program (CCCWP)

The Contra Costa Clean Water Program (www.cccleanwater.org) was formed by representatives of Contra Costa County, nineteen of its incorporated cities, and the Contra Costa County Flood Control and Water Conservation District. The CCCWP strives to eliminate stormwater pollution through public education, inspection and enforcement activities as well as outreach to industrial dischargers, residents and businesses. The CCCWP members are responsible for implementing the requirements of a municipal stormwater permit issued by the San Francisco Bay Regional Water Quality Control Board.

CCCWP has emerged as a leader in intergration of LID into the land development process. For LID, the following products are particularly helpful:

- Stormwater Control Plans and the Development Review Process (PowerPoint Presentation: http://www.cccleanwater.org/Publications/Oct06Workshop/SWControlPlans&DevReviewProcess.ppt)
- Contra Costa Approach (I): Experience So Far Using LID to Implement Stormwater Treatment Requirements (PowerPoint Presentation: http://www.cccleanwater.org/Publications/StormCon-5-06/5-ContraCostaApproach-I-Dalziel-Cloak.ppt)

- Sizing Integrated Management Practices Sizing Calculator – this model supports site designers in choosing and sizing LID techniques http://www.cccleanwater.org/new-developmentc3/stormwater-c3-guidebook/, See Appendix I

Alameda Countywide Clean Water Program (ACCWP)

Like other stormwater programs, the Alameda Countywide Clean Water Program (ACCWP, http://www.cleanwaterprogram.org/indexFlash.htm) has been active in developing information on meeting the C.3 provisions for new development and redevelopment. For LID, ACCWP has addressed one of the thornier issues related to both structural and non-structural BMPs—maintenance. The following templates have been developed and are applicable to any stormwater program.

- How to Use the Templates http://www.cleanwaterprogram.org/uploads/6.0%20Template%20Intro%20FINAL.pdf
- Vegetated Swale Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.1%20Veg%20Swale%20template%20FINAL.doc
- Vegetated Buffer Strip Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.2%20Buffer%20Strip%20template%20FINAL.doc
- Tree Well Filter Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.3%20Tree%20well%20filter%20template%20FINAL.doc
- Media Filter Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.4%20media%20filter%20template%20FINAL.doc
- Flow-Through Planter Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.5%20flo-thru%20plntr%20template%20FINAL.doc
- Bioretention Area Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.6%20Bioretention%20Area%20template%20FINAL.doc
- Infiltration Trench Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.7%20Infiltration%20Trench%20template%20FINAL.doc
- Extended Detention Basin Maintenance Plan Template http://www.cleanwaterprogram.org/uploads/6.8%20Detention%20Plan%20template%20FINAL.doc

Emeryville is a member of ACCWP and is recognized nationally as a leader in ultra-urban LID. In 2003, the City obtained a grant to develop "Guidelines for Dense, Green Development" (http://www.ci.emeryville.ca.us/planning/pdf/stormwater_guidelines.pdf). Emeryville faces a built environment that appears to preclude many LID techniques, including clay soils, legacy contaminants, and few green spaces. However, the City used the research behind the guidelines, the planning process, a BMP sizing spreadsheet, and code changes to institute reform. Note that the City did not only focus on new development and redevelopment, but also looked to the city's infrastructure for opportunities.

2.4 REGULATIONS GOVERNING NEW AND REDEVELOPMENT IN CALIFORNIA

2.4.1 Background

California has been delegated the authority to develop and administer Clean Water Act programs. Because the State's landscape varies dramatically, the responsibility has been divided among nine regional water quality control boards (RWQCBs). The State Water Resources Control Board (SWRCB) is the agency that oversees the nine regional boards. Under the SWRCB, each RWQCB acts as a semi-autonomous water quality agency. Under the State Porter-Cologne Water Quality Act (Porter-Cologne), each RWQCB is required to develop its own Basin Plan that contains water quality objectives and criteria for the region. The RWQCBs must use their judgment to determine water quality objectives that provide for "reasonable protection of beneficial uses and the prevention of nuisance." Within their Basin Plans, the RWQCBs must also specify plans for meeting the objectives, which include actions to be taken, a timeline for proposed actions, and a plan for evaluating success with achieving the objectives.

The State Water Quality Control Board and the nine RWQCBs have begun work on a number of LID initiatives[10] including:

- Requiring use of LID through site-specific and general permits
- Advocacy and outreach to local governments through the Water Board's Training Academy and regional workshops
- Research on incorporating LID language into Standard Urban Storm Water Mitigation Plan (SUSMP) requirements
- Funding of LID-related projects through consolidated grants program
- Funding through CWA 319 funds to support research on the applicability of the Impervious Surface Analysis Tool (ISAT) for land use planners and for the California Water and Land Use partnership (CaWaLUP) through the Center for Water and Land Use at U.C. Davis Extension

2.4.2 California Regulations

The integration of LID into local development codes will not occur in a regulatory vacuum. As localities draft land development codes, there are many, often competing, objectives involved with each and every parcel. Stakeholders interested in economic development, traffic, neighborhood preservation, housing, and equity, are among many players who shape decisions both at the larger policy level and during individual approval processes. As such, new requirements for stormwater management will enter an already complex regulatory environment, and California is no exception. In fact, there are several legal and policy issues unique to California that must be considered if LID is to be successfully integrated into State and local land development codes.

Stormwater Construction General Permit

The Construction General Permit is issued by the State Water Resources Control Board (SWRCB) and regulates stormwater discharges from construction activities (new development and redevelopment) at sites that disturb one or more acres. All construction projects in the state meeting the size criterion must submit a notice of intent to the RWQCB to obtain coverage under the permit. NOI submission requires development of a stormwater pollution prevention plan (SWPPP) that specifies how stormwater and

[10] SWRCB. 2003. *Low Impact Development - Sustainable Storm Water Management*. http://www.waterboards.ca.gov/lid/index.html. Accessed October 18, 2007.

pollutants will be managed during and after construction. A revised Construction General Permit has been proposed but is not yet approved. The following are features of the draft permit:

The permit seeks to limit hydromodification impacts that can adversely affect downstream channels and habitat. Specifically, for all projects disturbing one acre or more, the permit requires that the post-development volume of runoff from impervious surfaces approximates the pre-project runoff volume. Projects that disturb more than two acres have additional requirements to (1) preserve post-construction drainage divides and (2) maintain or extend pre-project time of concentration. Projects that disturb more than 50 acres must (1) preserve pre-construction drainage patterns by distributing their non-structural and structural controls within all drainage areas serving first order streams or larger and (2) maintain or extend pre-project time of concentration.

Applicants for coverage under the permit are required to submit a map and worksheets that demonstrate compliance with the above requirements. Detailed instructions are provided for calculating the volume of runoff that needs to be managed (or more sophisticated watershed models can be used).

LID is specifically incorporated into the draft permit in that it offers volume credits for the following types of nonstructural practices:

- Tree canopy cover
- Downspout disconnections
- Impervious area disconnection
- Vegetated swales
- Permeable pavers

The Construction General Permit is an important tool for stormwater management and LID promotion because it covers the entire state, whereas municipal stormwater regulations only apply to municipalities with populations greater than 10,000, small communities located within major metropolitan areas, and towns and cities specifically identified by the State based on projected growth rate or special water quality concerns.

Municipal Stormwater Permits

The Regional Water Quality Control Boards have issued permits to large, medium, and small municipalities throughout California to develop and implement multi-faceted stormwater management programs. Many of these programs, particularly those in large metropolitan areas, have been in place since the early 1990s. One of the main components of stormwater management programs is to regulate stormwater impacts from new development. Municipalities accomplish this by setting minimum runoff control and treatment requirements and reviewing and approving development plans that specify appropriate stormwater best management practices (BMPs).

On October 5, 2000, the SWRCB adopted Order WQ 2000-11, a precedential decision concerning the use of Standard Urban Storm Water Mitigation Plans (SUSMP) [11] in MS4 permits for new development and significant redevelopment projects. The SWRCB found that the SUSMP standards, which essentially require that urban runoff generated by 85 percent of storm events from specific development categories be infiltrated or treated, reflected the MEP standard. The SUSMP requirements were initially adopted by the Los Angeles RWQCB to require treatment controls for new and significant redevelopment projects. Because of the precedent set by Order WQ 2000-11, the RWQCBs' MS4 permits must be consistent with applicable portions of the State Board's decision and include SUSMP requirements. A statewide policy

[11] The term SUSMP is used by the Los Angeles and San Diego Regional Water Boards, but other Boards have adopted different terms for the new development requirements (such as Water Quality Management Plans, Development Standards, or Stormwater Quality Urban Implementation Plans).

memorandum (dated December 26, 2000) interprets the Order to provide broad discretion to RWQCBs and identifies potential future areas for inclusion in SUSMPs and the types of evidence and findings necessary. Such areas include ministerial projects, projects in environmentally sensitive areas, and water quality design criteria for retail gasoline outlets. Because each RWQCB has discretion to interpret and modify the requirements in the State Board order, each permit can have slightly different SUSMP requirements.

A number of RWQCBs have explicitly required the preferential use of LID to manage stormwater. The following are examples of LID provisions from recent permits or draft permits:

Los Angeles Municipal Stormwater Permit

The Los Angeles Municipal Stormwater Permit (Order 01-182, NPDES Permit # CAS004001) specifies that development projects are required to

- Maximize the percentage of pervious surfaces to allow percolation of stormwater into the ground
- Minimize the quantity of stormwater directed to impervious surfaces and the MS4
- Minimize pollution emanating from parking lots through the use of appropriate Treatment Control BMPs and good housekeeping practices
- Properly design and maintain Treatment Control BMPs in a manner that does not promote the breeding of vectors
- Provide for appropriate permanent measures to reduce stormwater pollutant loads in stormwater from the development site

The permit requires control of the post-development peak stormwater runoff discharge rates, velocities, and duration (peak flow control) in natural drainage systems that mimic pre-development hydrology to prevent accelerated stream erosion and to protect stream habitat.

Under SUSMP provisions, single-family hillside homes are required to:

- Conserve natural areas
- Protect slopes and channels
- Provide storm drain system stenciling and signage
- Divert roof runoff to vegetated areas before discharge unless the diversion would result in slope instability
- Direct surface flow to vegetated areas before discharge unless the diversion would result in slope instability

SUSMP requirements apply to sites that discharge to an Environmentally Sensitive Area (ESA), create 2,500 square feet or more of impervious surface area, and discharge stormwater that is likely to impact a sensitive biological species or habitat.

The permit allows municipalities to establish alternative compliance programs that offer participation in regional or sub-regional stormwater mitigation projects for development sites that receive a waiver for impracticability in meeting the performance requirements.

San Diego Municipal Stormwater Permit

The San Diego Municipal Stormwater Permit (Order No. R9-2007-0001, NPDES No. CAS0108758) specifies that municipalities develop requirements for all development projects that include LID BMPs where feasible that "maximize infiltration, provide retention, slow runoff, minimize impervious footprint, direct runoff from impervious areas into landscaping, and construct impervious surfaces to minimum

widths necessary." There is also a requirement to establish or maintain buffer zones for natural waterbodies, where feasible. Where buffer zones are infeasible, project proponents are required to implement other buffers such as trees, access restrictions, etc., where feasible.

The permit further specifies LID BMP requirements to collectively minimize directly connected impervious areas and promote infiltration at Priority Development Projects[12] as follows:

- For Priority Development Projects with landscaped or other pervious areas, drain a portion of impervious areas (rooftops, parking lots, sidewalks, walkways, patios, etc) into pervious areas prior to discharge to the MS4. The amount of runoff from impervious areas that is to drain to pervious areas shall correspond with the total capacity of the project's pervious areas to infiltrate or treat runoff, taking into consideration the pervious areas' soil conditions, slope, and other pertinent factors.
- For Priority Development Projects with landscaped or other pervious areas, properly design and construct the pervious areas to effectively receive and infiltrate or treat runoff from impervious areas, taking into consideration the pervious areas' soil conditions, slope, and other pertinent factors.
- For Priority Development Projects with low traffic areas and appropriate soil conditions, construct a portion of walkways, trails, overflow parking lots, alleys, or other low-traffic areas with permeable surfaces, such as pervious concrete, porous asphalt, unit pavers, and granular materials.

The permit specifies other LID BMPs to be implemented at all Priority Development Projects where applicable and feasible:

- Conserve natural areas, including existing trees, other vegetation, and soils
- Construct streets, sidewalks, or parking lot aisles to the minimum widths necessary, provided that public safety and a walkable environment for pedestrians are not compromised
- Minimize the impervious footprint of the project
- Minimize soil compaction
- Minimize disturbances to natural drainages (e.g., natural swales, topographic depressions, etc.)

Municipalities must update SUSMP BMP requirements to add LID and source control BMPs (including siting, design, and maintenance criteria) and to define minimum requirements to maximize the use of LID practices and principles.

Restrictions are set forth for infiltration of runoff from areas that generate high levels of pollutants to protect groundwater. Specifically, this entails pretreatment (e.g., sedimentation, filtration) for infiltration BMPs, diversion of polluted dry weather flows, a minimum distance from seasonally high groundwater table, a minimum horizontal distance from wells, and restrictions on land uses that can drain to infiltration

[12] Priority Development Projects include housing subdivisions of 10 or more dwelling units, commercial developments and developments of heavy industry greater than one acre, automotive repair shops, restaurants, all hillside development greater than 5,000 square feet, ESAs, parking lots 5,000 square feet or larger or with 15 or more parking spaces and potentially exposed to urban runoff, streets, roads, highways, freeways, and retail gasoline outlets. Priority Development Projects also include those redevelopment projects that create, add, or replace at least 5,000 square feet of impervious surfaces on an already developed site that falls under the project categories or locations listed previously. Within three years of adoption, Priority Development Projects will also include all other pollutant generating projects that result in the disturbance of one acre or more of land.

BMPs (e.g., industrial or light industrial activity, high vehicular traffic areas, automotive repair shops, car washes, fleet storage areas, nurseries).

Redevelopment projects that create, add or replace at least 5,000 square feet of impervious surfaces on an already developed site that falls under the Priority Development Project categories are subject to tiered requirements as follows:

- If redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to SUSMP requirements, the numeric sizing criteria applies only to the addition and not to the entire redevelopment site.
- Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing development, the numeric sizing criteria applies to the entire development.

Waivers of numeric sizing criteria can be granted when all available BMPs have been considered and rejected as infeasible. Alternative compliance for waiver recipients can be allowed by contributing the cost savings to a storm water mitigation fund that can be used on projects to improve urban runoff quality within the watershed of the waived project.

Draft Ventura Stormwater Permit

The Draft Ventura Stormwater Permit sets overall goals for stormwater management at regulated development sites[13] as follows:

- Minimize the percentage of impervious surfaces on land developments to support the percolation and infiltration of storm water into the ground.
- Minimize pollutant loadings from impervious surfaces such as roof-tops, parking lots, and roadways through the use of properly designed, technically appropriate BMPs (including Source Control BMPs such as good housekeeping practices), Low Impact Development Strategies, and Treatment Control BMPs.

All regulated projects are required to integrate LID principles into project design. LID strategies are required to be the first BMPs considered for a development site, followed by integrated water resources management strategies and multi-benefit landscape features, all of which contribute to the overall goals of LID. The least preferred BMP type is modular/proprietary treatment control BMPs.

The draft permit requires that all new and redevelopment projects reduce "the percentage of Effective Impervious Area (EIA) to less than 5 percent of total project area." Impervious surfaces may be rendered "ineffective" if the storm water runoff is

- Drained into a vegetated cell, over a vegetated surface, or through a vegetated swale, having soil characteristics either as native material or amended medium using approved soil engineering techniques; or

[13] Projects required to meet new development standards include all development projects equal to 1 acre or greater of disturbed area; industrial parks, commercial strip malls, retail gasoline outlets, restaurants, streets, roads, highways, freeway construction, and automotive service facilities with 5,000 square feet or more of surface area; parking lots with 5,000 square feet or more of surface area or with 25 or more parking spaces; redevelopment that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site on development categories listed previously; projects located in or directly adjacent to, or discharging directly to an Environmentally Sensitive Area (ESA), where the development will discharge storm water runoff that is likely to impact a sensitive biological species or habitat or will create 2,500 square feet or more of impervious surface area; and single-family hillside homes.

- Collected and stored for beneficial use such as irrigation, or other reuse purpose; or
- Discharged into an infiltration trench.

Redevelopment requirements are based on the extent to which redevelopment activities[14] alter the site, as follows:

- Where redevelopment results in an alteration to more than fifty percent of impervious surfaces of a previously existing development, and the existing development was not subject to post development storm water quality control requirements, the entire project must be mitigated.
- Where redevelopment results in an alteration to less than fifty percent of impervious surfaces of a previously existing development, and the existing development was not subject to post development storm water quality control requirements, only the alteration must be mitigated, and not the entire development.

Local jurisdictions can develop Redevelopment Project Area Master Plans (RPAMPs) for redevelopment projects within redevelopment project areas[15] to set unique requirements to balance water quality protection with the needs for adequate housing, population growth, public transportation and management, land recycling, and urban revitalization. Goals for hydromodification control are to prevent accelerated downstream erosion and to protect stream habitat in natural drainage systems. The permit specifies that a project's pre-development storm water runoff flow rates and durations be maintained based on a stream's Erosion Potential. Controls may include on-site, regional, or subregional hydromodification control BMPs, LID strategies, or stream restoration measures, with preference given to LID strategies and hydromodification control BMPs. A hydromodification control study is underway to determine an appropriate hydromodification management plan for the region. Until that plan is complete, projects under 50 acres are required to match within 1 percent the 2-year, 24-hour pre-development hydrograph and projects larger than 50 acres are required to implement a Hydromodification Analysis Study.

Local jurisdictions can establish a regional or sub-regional storm water mitigation program to substitute in part or wholly for on-site post-construction requirements. Conditions for the mitigation program are that the projects result in equivalent or improved storm water quality, protect stream habitat, are fiscally sustainable and have secure funding, promote cooperative problem solving by diverse interests, and be completed in four years or less including the construction and start-up of treatment facilities. Local jurisdictions can also set up mitigation funding to fund regional or subregional solutions to stormwater pollution where a waiver for impracticability is granted, funds become available, off-site mitigation is required because of loss of environmental habitat, or where an existing water resources management plan exists that has an equivalent or improved strategy for stormwater pollution mitigation.

Local jurisdictions are required to provide outreach to stakeholders and develop a LID technical guidance section for the regional stormwater guidance manual, which includes objectives and specifications for integration of LID strategies, including LID credits.

Draft San Francisco Bay Area Municipal Regional Permit

Provision C.3 of the Draft Municipal Regional Permit for the San Francisco Bay Region (RWQCB 2) requires that all new development and redevelopment projects encourage the inclusion of the following

[14] Routine maintenance activities, emergency redevelopment activities required to protect public health and safety, and existing single-family structures that do not create, add, or replace 10,000 square feet of impervious area are exempted from redevelopment requirements.

[15] Redevelopment project areas include city center areas, historic district areas, brownfield areas, infill development areas, and urban transit villages.

LID-related measures: minimizing land disturbance and impervious surfaces (especially parking lots); clustering of structures and pavement; disconnecting roof downspouts; use of micro-detention, including distributed landscape detention; preservation of open space; protection and/or restoration of riparian areas and wetlands as project amenities.

New development and redevelopment projects that create and/or replace 10,000 square feet or more of impervious surface are considered "regulated projects" and are subject to post-construction stormwater management requirements. This includes commercial, industrial, residential developments as well as road and paved trail projects, with some exclusions. Starting July 1, 2010, the 10,000 square foot threshold will lowered to 5,000 square feet.

For redevelopment projects where more than 50 percent of the impervious surface of a previously existing development is altered, the entire project, consisting of all existing, new, and/or replaced impervious surfaces, must be included in the treatment system design. Where less than 50 percent of the impervious surface is altered, only the new and/or replaced impervious surface of the project must be included in the treatment system design.

Projects that meet EPA's Brownfield Sites definition, low-income and senior citizen housing developments, and Transit-Oriented Development projects that minimize the new or replaced impervious surface onsite can provide alternative compliance by installing, operating and maintaining equivalent offsite treatment at an off-site project in the same watershed or contributing equivalent funds to a regional project, to be completed within 3 years after the end of construction.

Regulated projects are required to implement the following LID measures:

- Install landscaping that minimizes irrigation and runoff, promotes surface infiltration, and minimizes the use of pesticides and fertilizers.
- Conserve natural areas, to the extent feasible, including existing trees, other vegetation, and soils.
- Minimize the impervious footprint.
- Minimize disturbances to natural drainages.
- For regulated projects with landscaped or other pervious areas, drain a portion of impervious areas into pervious areas before discharging to the storm drain and properly design and construct pervious areas to effectively receive and infiltrate or treat runoff from impervious areas, taking into consideration the pervious areas' soil conditions, slope and other pertinent factors.
- For regulated projects with low traffic areas and appropriate soil conditions, construct a portion of walkways, trails, overflow parking lots, alleys, or other low-traffic areas with permeable surfaces, such as pervious concrete, porous asphalt, unit pavers, and granular materials.

Regulated projects are required to select stormwater treatment systems in the following order of preference:

- Stormwater treatment systems that reduce runoff, store stormwater for beneficial reuse, and enhance infiltration to the extent that is practical and safe.
- Multi-benefit natural feature stormwater treatment systems, such as landscape-based bioretention systems, vegetated swales, tree wells, planter boxes, and green roofs.
- Prefabricated and/or proprietary stormwater treatment systems.

The permit stipulates that stormwater discharges from hydromodification projects, which create and/or replace one acre or more of impervious surface, "shall not cause an increase in the erosion potential of the receiving stream over the pre-project (existing) condition. Increases in runoff flow and volume shall be managed so that post-project runoff shall not exceed estimated pre-project rates and durations, where such

increased flow and/or volume is likely to cause increased potential for erosion of creek beds and banks, silt pollutant generation, or other adverse impacts on beneficial uses due to increased erosive force." Hydromodification controls include onsite, regional, and instream controls and measures.

Single-family home projects that create and/or replace 5,000 square feet or more of impervious surface are required to implement one or more of the following LID-related BMPs:

- Diverting roof runoff to vegetated areas before discharge to storm drain.
- Directing paved surface runoff flow to vegetated areas before discharge to storm drain.
- Installing driveways, patios and walkways with pervious material such as pervious concrete or pavers.

The permit requires that groundwater be protected through site evaluation and source control measures when infiltration practices are used. Infiltration devices are prohibited unless pretreatment is used in industrial and light industrial applications, areas subject to high vehicular traffic, automotive repair shops; car washes, fleet storage areas, nurseries, and other land uses that pose a high threat to water quality.

The permit requires regulated municipal permittees to update their General Plans to integrate water quality and watershed protection with water supply, flood control, habitat protection groundwater recharge, and other sustainable development principles and policies.

City of Salinas MS4 Permit

The City of Salinas MS4 Permit (Order R3-2004-0135, NPDES Permit # CA0049981) was issued by the Central Coast RWQCB in 2004. The permit includes provisions that, though not called low impact development, are intended to achieve results similar to low impact development requirements. Relevant provisions include a requirement to incorporate water quality and watershed protection principles into planning procedures and policies. The permit defines such procedures/policies as the General Plan or equivalent plans. The identified goal is "to direct land use decisions and require implementation of consistent water quality protection measures for all development projects."

The permit specifies that watershed protection principles and policies consider:

- Minimizing the amount of impervious surfaces and directly connected impervious surfaces in areas of new development and redevelopment
- Using on-site infiltration of runoff in areas with appropriate soils where there is no threat to groundwater quality
- Preserving and creating/restoring riparian corridors, wetlands, buffer zones, and other areas that provide important water quality benefits
- Limiting disturbance of natural waterbodies and natural drainage systems
- Requiring developers to prepare and submit studies analyzing pre- and post-project pollutant loads and flows resulting from projected future development
- Requiring incorporation of structural and non-structural BMPs to mitigate the projected increases in pollutant loads in runoff

The permit also specifies that restrictions be in place for infiltration BMPs to ensure that groundwater quality standards are not violated.

Waivers can be granted on a project-by-project basis for infeasibility. As specified by the order, Salinas "may propose a waiver program that would require any developers receiving waivers to transfer the savings in cost, as determined by the Permittee, to a storm water mitigation fund" subject to RWQCB approval. Funds are to be used for urban runoff quality improvement projects in the same watershed as

the waived project. Waivers can only be granted "when all appropriate structural treatment BMPs have been considered and rejected as infeasible."

The permit also requires Salinas to provide a description of necessary modifications to existing codes and ordinances and an implementation schedule for these modifications.

General Plans

General Plans (required under Government Code section 65300 *et seq*) were first introduced in the 1920's to plan and coordinate development. Like other areas of the country, the General Plan orchestrates local government Departments, their budgets and community goals, and is implemented by the zoning code and subdivision regulations. In California, State law mandates several required elements: Land Use, Circulation, Housing, Conservation (including Air and Water Quality), Open Space, Noise and Safety. Cities may also include other elements, such as Economic Development. In addition to required elements, the State required study, identification and presentation of detailed information, for example, the allowable uses within zoning codes and land subject to flooding. In 1971, a consistency requirement strengthened the elements within General Plans; development and zoning amendment need to be consistent with the General Plan. Thus, legal decisions affecting growth and development often hinge on the content and exact wording contained within General Plans.

Cities often adopt "Specific Plans" within the General Plan, which act like a special zoning code for a specific area, such as a Downtown Plan or a Master Planned Community.

All General Plans must comply with State law, and be updated as State laws are updated or revised. Finally, General Plans must go through a rigorous review under the California Environmental Quality Act.

Specific Area Plans

California, like other areas around the country, is addressing the shortcomings of conventional zoning and the associated environmental impacts. Successfully addressing impacts tends to occur not from adjusting parameters within codes, but with wholesale change to the alignment of public and private space within districts, such as downtowns, Master Plans, and corridors. Specific area plans are essentially "overlay" zones that orchestrate the relationships among sites, infrastructure, open space, drainage, and uses. Specific area plans have been increasingly used to introduce use mix (and hence reduce trip-making), encourage walkability, redevelop older towns and cities, and develop master-planned communities.

California Environmental Quality Act

California Environmental Quality Act (CEQA) analysis is a major part of the development landscape in California. The purpose of CEQA is to fully vet environmental impacts related to land development decisions and determine whether environmentally preferred options exist. CEQA is perhaps best presented as a step-wise process:

Step 1: The Application of CEQA – CEQA applies to "projects," which are defined as actions approved at the discretion of a local government (such as issuing a permit). In some instances the discretionary action can involve very small projects, and in others, large ministerial projects need to no CEQA review at all. There is a list of exemptions, such as demolition permits, small infill sites, and affordable housing projects in urban areas. In addition, there are categorical exemptions, such as projects less than 10,000 square feet, and projects of three homes or fewer.

Step 2: The Initial Study – If CEQA applies, an initial study is undertaken to determine whether there will be "significant environmental effects. This is among the most litigated parts of the process and is loosely defined. For stormwater, note that thresholds and checklists have been turned down in

Courts for determining significance, even as checklists and thresholds gain in popularity for stormwater management programs.

Step 2a: Mitigated Negative Declaration – If the environmental impacts are easily identified and mitigated, a developer is often asked to mitigate those impacts up front, in essence reducing the impacts below the "significance" threshold that triggers further CEQA review. LID requirements may come into play for this step in CEQA.

Step 3: The Environmental Impact Report (EIR) – If the Initial Study shows the potential for significant impacts, an EIR must be prepared. EIRs are at the "public information" core of CEQA and can be far-ranging in detail and scope. Because EIRs can take months to prepare and significant up-front cost, there is some evidence that the process drives smaller projects and players out of contention. In presenting impacts to the public, the EIR must present the following:

- Significant environmental effects
- Unavoidable environmental effects
- Significant irreversible environmental change
- Alternatives to the project (for example, an alternative design or a "no build: alternative)
- Cumulative Impacts arising in combination with other projects
- Growth-inducing impacts
- Mitigation measures that will be adopted

Step 4: Local Government Action – Even with significant impacts a local government may approve a projects. However, the government may also deny the project, approve one of the alternatives, or specify mitigation measures.

At the State level, the Office of Planning and Research issues CEQA guidelines, which, despite the name, are mandatory. They spell out rules on process and content. For stormwater, the new NPDES regulations, as well as emerging research on LID and BMPs, will likely enter into State language on data collection and analysis, in particular for General Plans.

CEQA is also recognized for what it does not do. Regional (or watershed) cooperation is not among the outcomes sought. Alternatives analyses are typically not informative, and there is little direction (other than often contradictory Court decisions) that helps streamline CEQA. Moreover, the data most related to watershed-wide impacts (analysis of cumulative and growth-inducing impacts) are the weakest elements within CEQA review.

Subdivision Map Act

The original intent of the Subdivision Map Act was to denote clear title to plots of land. Over the years, the Act was used by land speculators who would produce older maps to claim rights to subdivision as land development rules tightened. However, the strongest attribute of the Act is the establishment of fees and exactions. The ability to impose impact fees, require dedication of land, and provision of infrastructure have their roots in the Act; LID requirements may need to be framed within this exaction process.

Exactions in California have been at the center of legal activity for decades, and will shape effective LID requirements, in particular the dedication of land for infiltration or stormwater management. In a nutshell, the cases have been:

Erlich v. Culver City – This case tried to resolve a myriad of loosely related decisions on impact fees. In the end, tests were established for different project types. A "reasonable relationship" test must be met when exactions are required of all developers as a matter of broad policy. The stricter rough proportionality/essential nexus test is to be used with single developers.

Nollan v. California Coastal Commission – This Supreme Court case established the "direct nexus" test between a project and the exaction required. (The same year, AB 1600 was passed, which requires local governments to identify how fees and exactions are to be used). "Nexus studies" are now a routine part of the development approval process; for supra-site level LID, measuring the wider stormwater impacts and how they are addressed beyond site level impacts will likely loom large.

Dolan v. Tigard – This Supreme Court Case decision builds on the Nollan case, and specifies that not only does a local government need to show a nexus, but also the final exaction must have a "rough proportionality" to the project. This will likely come into play with CEQA analyses that show induced growth, and LID assignments that might be required outside the boundaries of the project (the logic will follow the process of determining developer exactions for an off-site Highway interchange *and* the roads within the boundaries of a project).

The end result of all these cases strengthens the role of the General Plan. Thus, if the State requires LID via General Plans, the reasonable relationship test must be met. However, cities and Counties that do not include LID in General Plans may need to perform a higher level of analysis to link exactions and project review.

The use of maps in planning and zoning is widespread but has legal bearing in decisions on subdividing land. Developers often produce a "tentative map" to show lots, improvements, and response to initial feedback from regulators Local governments at this stage have leverage over site design, land conservation, and other matters. Developers will often seek a "vested tentative map," which grants entitlements for a period of time. Once approvals are accepted, the developer produces a final map. Note that localities can deny maps based on incompatibility with the General Plan, physical unsuitability of the site, or environmental damage.

Affordable Housing

Affordable housing in California is not only the grist of national headlines but is now firmly established in State law. Cities are required to develop density bonus programs for affordable housing and provision of second units. The nexus between affordable housing and environmental protection is also well recognized. California's 2003 "Environmental Goals and Policy Report[16]" clearly links low density housing, sprawl, and environmental degradation. The city of San Jose has established policies that essentially recognize certain affordable housing projects as stormwater BMPs. The logic behind this is that if affordable housing is not provided on a small footprint near jobs and services, the demand will exert itself elsewhere in the watershed, most likely on a much larger footprint and on land providing watershed services.

This linkage is likely to emerge in LID policymaking in several ways. First, laws allowing second units on a property will run squarely into strict on-site LID requirements, especially if local rules cap impervious coverage in areas with traditionally small home sites. Opponents of the new stormwater rules are already raising affordable housing shortages as the primary consequence of potential policies. However, a second linkage will emerge as variations of the San Jose policy. If affordable and workforce housing are primary drivers of imperviousness, then "housing as a low impact strategy" will emerge as a powerful practice. The key will be quantifying the relationship. Finally, in largely built-out areas, particularly in coastal California, where improving stormwater will primarily arise from retrofit, any successful LID policy may need to pull together other programs to help underwrite on-site BMPs, in particular for areas struggling to attract redevelopment interest under current rules.

[16] California Office of Planning and Research. 2003. *Governor's Environmental Goals and Policy Report*. http://opr.ca.gov/planning/publications/EGPR--11-10-03.pdf. Updated November 10, 2003. Accessed October 18, 2007.

Roadways

According to the Center for Watershed Protection, "habitat for cars" comprises more than half of all impervious surface coverage. Overly wide road standards (sometimes referred to as "geometric standards) are a culprit. In California, road standards tend to follow the Institute for Transportation Engineers guidebooks and standards established by local Fire Protection Districts.

Advocates for smart growth, climate change, and watershed health agree that road standards need to change for a reduced impact. Work over the past decade has revealed the impetus for over-engineered roadways: (1) national standards provide local governments with a tested and low-risk model, (2) emergency responders direct standards to maximize access for equipment and maneuverability, (3) a sprawling pattern dictates the hierarchical systems of increasingly wide roadways to funnel traffic (as opposed to a grid, which disperses traffic), even though developers provide local roads, and (4) seismic requirements for highly engineered roadbeds and shoulders.

The October 2007 California fires and earthquakes highlighted the role of roads and access; thus discussions on lower-impact roads in rural areas might not gain traction. This may, however, strengthen the argument for lesser road impact in areas inside the urban/wild interface. The U.S. Environmental Protection Agency's Smart Growth program recently awarded the Congress for New Urbanism a grant to address road widths and design nationwide because mandating new road geometry in legislation is not likely to succeed given the competing safety, community, and environmental goals. This will dovetail with previous work by the Sacramento-based Local Government Commission and the Sustainable Streets effort within the University of California-Irvine (UC Irvine). In addition, Caltrans is developing a "smart mobility" scorecard that will be used in future funding decisions, and researchers at UC Davis are working on a green streets initiative and, in cooperation with Caltrans, incorporation of trees into highway systems that can aid in stormwater mitigation.

Initial research from UC Irvine shows that the environmental street design discussion is bifurcated into two areas: (1) sustainable streets with an emphasis on stormwater, or (2) mobility and design. There is a need to shepherd the two into one effort to achieve both objectives.

3 Types of LID Requirements

There are a number of ways in which LID criteria can be incorporated into statewide, regional, or local stormwater requirements. Table 2 lists the different approaches and briefly describes advantages and disadvantages of each.

Table 2. Types of LID Criteria

Type	Advantages	Disadvantages
Uniform Performance Standards		
Uniform performance standards	Ease of administration	Insensitive to site constraints, unique conditions, and development context
Uniform performance standards with list of accepted BMPs	• Ease of administration • Certainty for planners/ developers	BMP lists may be outdated, in particular for emerging LID BMPs
Uniform performance standards with list of accepted BMPs and predetermined list of exemptions	• Ease of administration • Certainty for planners/ developers • Exemptions can be tailored	• BMP lists may be outdated • Exemption list may no include full range of constraints • Exemption process can be resource intensive • Potential for exemptions to become rule if not carefully crafted
Tiered Performance Standards		
Tiered criteria based on subwatersheds	• Criteria can be established based on pollutants/ development context of subwatershed • Can address flooding within the subwatershed	• Subwatershed mapping needs to be developed and supported by strong data collection program. • Subwatersheds may lie across several jurisdictions, which would require cooperation or uniform rules
Tiered criteria based on predetermined geographical areas	Criteria can be established within established geographical or jurisdictional boundaries	Rules established for a jurisdiction may not capture entire subwatershed
Tiered criteria based on development parameters: infill, new development, and redevelopment	Criteria can be targeted based on watershed function lost or designed to match BMPs to development contexts	May be seen as relaxing rules for one type of development
Tiered criteria based on economic development parameters	• Can be used to attract development to distressed areas (in particular where watershed benefits would be achieved via redevelopment) • Ease of administration where economic development areas are supported by existing programs • Can be used to attract investment for repairing infrastructure.	Some economic development districts lie in areas in most need of higher performance standards for volume or pollutant removal

Table 2. Types of LID Criteria

Type	Advantages	Disadvantages
With Supporting Credit System		
Hydrology criteria supported by credit manual	Credits can be advantageous for practices that are not easily measured or for which performance has not been established. Credits typically easier to administer than exemptions since they are front-loaded into the process.	Relief provided by credits may not be justified by analysis, paperwork or application fee. Credits may not apply to all development contexts and may result in uneven regulatory playing field. Small stormwater programs may not have resources to develop credit manual.
With Alternative Compliance Process		
Limited alternative compliance options with prescribed triggers and process for developing a "Finding of Impracticability"	• Alternative compliance is advantageous where there are numerous site constraints or varying landscape considerations • Alternative compliance programs can be used to fund district or regional BMPs • Alternative compliance programs can be written to support preferred practices where on-site BMPs are not practical	• The list of triggers may not encompass entire range of conditions or constraints • The process for "Finding of Impracticability" may be burdensome for smaller developers/sites • Widespread use can lead to lesser application of BMPs on individual sites
Case-by-case	Case-by-case application may be needed where a "Finding of Impracticability" or need is not apparent or where there are a number of constraints	Evaluation process is resource-intensive
With Exemptions		
Exemption process spelled out in regulations or technical manual	• Exemptions allow flexibility in *de minimis* situations • Exemption process can ease administration and add certainty	Widespread use of exemptions can erode the effectiveness of the BMP program
Case-by-case	Case-by-case assessment allows for closer examination of site conditions and considerations	Evaluation process is resource-intensive
Tied to Other Water Performance Standards and Programs (e.g., TMDLs, Anti-Degradation)		
LID criteria with reference to methodology for determining BMP performance required	Integrating Clean Water Act programs can make use of existing data and improve efficiency of administration	CWA programs have differing legal processes that may be challenged with integrated program requirements
LID criteria with monitoring and triggers	Monitoring results can tailor BMP response to specific pollutant reduction or elimination needs	• Monitoring results subject to challenge, which may extend process • May not be sensitive to upstream/downstream considerations (i.e. downstream permittees carry BMP responsibility for upstream loadings) • Response may need larger action than additional triggers for on-site BMPs

Table 2. Types of LID Criteria

Type	Advantages	Disadvantages
LID Criteria included in Technical Manual	• Only bare-boned ordinance, with reference to technical manual, needed • Technical manual can be a better vehicle for presenting information on size, type, and installation of BMPs that respond to wider variety of environmental pressures (such as habitat or land conservation) • Eliminates multiple manuals for different programs • Technical manuals can be written for a specific plan (e.g. downtown) to coordinate and integrate land development and BMP designs	More than one manual may be needed when there is a wide variety of environmental or development circumstances
LID criteria included in technical manual with levels of service (LOS)	• Setting LOS can help establish benchmarks within the program manual itself and assist in measuring results and reporting • LOS can either be environmental LOS or programmatic LOS (or both)	Benchmarks may be viewed as non-compliance triggers
Other		
Tied to other environmental performance standards and programs (e.g. greenhouse gas, energy, anti-sprawl)	• Best practices for other environmental programs offer watershed benefits (e.g., reduction of auto use) • Can help attract grant dollars for multi-objective programs	Ties to other mandates may be challenged as over-reaching in terms of achieving CWA compliance
Developed via inter-jurisdictional programs	• Can help avoid shifting development to areas with lesser standards and criteria • Coordination can allow better leveraging of resources • Many California jurisdictions have already formed regional alliances, thus models exist	• Smaller jurisdictions may be reluctant, in particular where larger jurisdictions have adopted stringent rules • May require development of unified land development regulations, which is time consuming • Administration requires frequent collaboration, which can be time-intensive

4 Options for State LID Statute Requirements

California has yet to implement a statewide policy governing LID or smart growth, though both regulatory and non-regulatory approaches can be used to promote LID implementation. (Non-regulatory approaches that build on existing initiatives are described in Appendix A.) In major metropolitan areas of the state, LID and smart growth policies are being incorporated into municipal stormwater permits; however, these requirements are not being applied to rapidly growing exurban areas. The Construction General Permit, currently undergoing revision, will apply to construction activities disturbing greater than one acre in all areas of the state and is expected to include a more progressive LID approach to stormwater management. Because California already has mechanisms in place or soon to be in place that require or encourage the use of LID, proposed state statute requirements should draw from these precedent approaches. A major benefit of a state statute for LID would be to provide consistency for how LID is addressed in stormwater Phase I communities, Phase II communities, and those areas not regulated under the municipal stormwater program.

Low impact development techniques and natural drainage are a logical first step for the design of any area planning. Care must be taken, however, in crafting regulatory language related to LID. Where regulations and performance standards are written exclusively for individual sites, the ability to credit the collective natural system can be lost, giving developers little incentive to use natural systems for multiple sites. Even where the regulations note that natural drainage should be given preference, the performance standards for individual parcels form the legal baseline. Likewise, the most effective water quality and runoff management program may be a shared system, not the additive effects of plot-level BMPs. Watershed planners and localities need to be given this option.

Any state statute requiring LID needs to be crafted with extensive stakeholder input, particularly from the Regional Water Quality Control Boards and regulated stormwater municipalities who have already done extensive work incorporating LID into permits and programs. The State should make every effort to avoid undermining progressive requirements already in place in some areas (particularly southern California and the Bay area) by setting performance standards that are less stringent than current requirements. On the other hand, the requirements should not be so stringent that smaller municipalities that have less experience with LID and stormwater management will have trouble implementing them. New legislation should balance water quality needs with existing and future capacity to implement LID requirements.

The following is a set of key concepts, including regulated projects, requirements, credits, waivers, and alternative compliance mechanisms, that a state statute on LID could address. It is important to note that this text is not intended to be statute language, per se, but it could serve as a foundation for a set of legal requirements that define minimum, progressive standards while allowing flexibility at regional and local levels to account for existing regulatory mechanisms and differing environmental conditions and management objectives. These recommendations are based on precedents from within California (described in Section 2.4) and from other states (a compendium of LID requirements from other states can be found in Appendix B).

4.1 Recommended Low Impact Development Requirements for California

A state statute on LID will likely need to address the following key concepts:

- **General Plans** – provide language on low impact development into the Land Use and Conservation Elements of General Plans
- **Specific Plans** – inserts language on establishing tiered design review for specific plans requiring an assessment and use, to the extent practicable, of natural drainage systems

- **Regulated projects** – defines the threshold for projects that need to address the LID requirements, including schools, universities, and other public facilities (i.e., no exemptions for non-traditional MS4s)
- **Requirements** – describes the requirements for LID statewide (will likely be further specified in NPDES permits or local regulations)
- **Stormwater credits** – provides the authority to issue credits that encourage better stormwater practices
- **Waivers** – provides the authority to waive requirements when certain conditions are met
- **Alternative compliance** – provides authority for innovative practices, in lieu of payments or mitigation
- **Definitions** – defines key terms

The key concepts above are further discussed below in the format of a hypothetical state statute. Each element is intended to encourage, facilitate, or require implementation of LID and is based on precedents from within California and from other states. Additional areas that might be included in an LID statute are penalties for noncompliance, enforcement, and regional variations.

4.1.1 General Plans

Local jurisdictions shall incorporate low impact development and natural drainage techniques into the Land Use and Land Conservation Elements of General Plans.

4.1.2 Specific Plans

Local jurisdictions shall amend procedures regulating the development of specific planning to include opportunities to incorporate and preserve natural drainage into the overall design of specific areas. This shall also apply to Master Plans.

4.1.3 Regulated Projects

Regulated development projects include (1) new development creating at least 5,000 square feet of total impervious surface area and (2) redevelopment that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site, not including road resurfacing or repair projects.

Local jurisdictions shall have the authority to set a lower threshold of total impervious surface area to be more inclusive of sites that discharge to environmentally sensitive areas or impaired waterbodies, hillside sites, sites with a high likelihood of pollution generation, sites with highly erodible soils, or other areas requiring special protection from stormwater impacts.

4.1.4 Requirements

Regulated development projects shall be required to implement site design, source control, and stormwater treatment measures to control post-development stormwater volume and peak flows (stormwater discharge rate, velocity, and duration) to mimic pre-development hydrology, prevent accelerated stream erosion, protect stream habitat, and provide for the reuse of stormwater.

Source controls and low impact development techniques shall be the primary methods for managing post-construction stormwater on a development site. Additional stormwater detention, retention, and treatment practices shall be implemented as needed to manage excess stormwater to meet water quality and hydrologic goals.

Regulated development projects shall reduce the percentage of effective impervious area to less than five percent of total project area by draining stormwater into landscaped, pervious areas. The pervious areas shall be designed and constructed to effectively receive and infiltrate or treat runoff from impervious areas, taking into consideration the pervious areas' soil conditions, slopes, and other pertinent factors.

For redevelopment projects where the redevelopment results in an alteration to 50 percent or more of impervious surfaces of a previously existing development, the entire project, consisting of all existing, new, and/or replaced impervious surfaces, shall be required to meet these performance requirements.

For redevelopment projects where the redevelopment results in an alteration to less than 50 percent of impervious surfaces of a previously existing development, only the new and/or replaced impervious surface of the project shall be required to meet these performance requirements.

Note: an alternate requirement would be to require that redevelopment projects reduce impervious surface by 20 percent or provide water quality treatment of 20 percent of the site's imperviousness, or achieve a combination of both imperviousness reduction and water quality treatment equal to 20 percent.

4.1.5 Stormwater Credits

Local jurisdictions shall have the authority to reduce the required capture volume of stormwater retention practices by offering credits for low impact development techniques implemented on a development site that reduce total and effective impervious surface area and intercept, capture, infiltrate, evaporate, or reuse stormwater. Local jurisdictions that choose to employ a stormwater credit system shall develop and submit to the Regional Water Quality Control Board for approval a methodology for applying credits to stormwater management sizing calculations. The methodology shall include a procedure for verifying that low impact development techniques were implemented as described in the site design.

4.1.6 Waivers

Local jurisdictions shall have the authority to grant a waiver of the performance requirements on a project-by-project basis if a development site owner demonstrates that all available best management practices have been considered and rejected as infeasible due to site constraints. Local jurisdictions shall notify the Regional Water Quality Control Board within 60 days of granting a waiver for infeasibility. The notification shall include the evidence of infeasibility and the nature of the alternative compliance payment or activity to be implemented.

Alternative and Innovative Compliance

Local jurisdictions shall have the authority to establish joint low impact development and stormwater planning practices that can be shown to deliver superior protection to the applicable stormwater performance standards.

Payment in Lieu

Local jurisdictions shall have the authority to establish a regional or subregional stormwater management fund to pay for watershed projects that have stormwater benefits (e.g., regional stormwater management systems; riparian, wetland, or coastal restoration projects). Development site owners that have been granted waivers for infeasibility may be offered the option of a payment to this fund in lieu of meeting the performance requirements. The amount of this payment shall be determined by the local jurisdiction and shall be based on the estimated water quality and hydrologic impacts of stormwater discharges from the development site.

Mitigation Projects

Local jurisdictions shall have the authority to establish an alternative compliance program that offers development site owners who have received a waiver for infeasibility the option to participate in regional or sub-regional stormwater mitigation projects. Mitigation projects shall impact the same receiving water as the development site wherever possible and offer an equivalent level of environmental benefits.

4.2 DEFINITIONS

Best Management Practices – Methods, measures, or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and nonpoint source discharges including storm water. BMPs include structural and nonstructural controls, and operation and maintenance procedures, which can be applied before, during, or after pollution-producing activities.

Effective Impervious Surface Area – The area of hardened surfaces that do not infiltrate stormwater and drain directly to a storm drain system, open channel, or natural stream.

Low Impact Development – A stormwater management strategy concerned with maintaining, mimicking or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives. It involves implementing small-scale, site design and landscape features that are distributed throughout a development site and result in the infiltration and treatment of runoff from impervious surfaces.

Regulated Development Projects – New development creating at least 5,000 square feet of total impervious surface area and (2) redevelopment that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site, not including road resurfacing or repair projects.

Specific Area Plan – A specific area plan is a relatively detailed plan for the development of a particular part of a city (both new development and redevelopment), which may include a master environmental impact review.

Total Impervious Surface Area – The total area of hardened surfaces that do not infiltrate stormwater, including paved streets, sidewalks, parking lots, buildings, and roofed areas.

5 LID in Local Codes and Ordinances

5.1 OPTIONS FOR INCORPORATING LID

Many land use and development decisions take place at the local level, so managing the impacts of impervious cover first requires an understanding of the local codes and standards that direct the size and placement of hardscape. Land development codes tend to operate at both the site level and at the larger city or county scale. The larger scale codes can be found in subdivision regulations, geometric dimensions for streets, and general plans. In California, master plans and specific plans coordinate the "footprint" of both the public realm (streets, parks) and individual lots even when the entire site is carried out as one project.

At the site scale, zoning ordinances, landscape codes, and building codes direct a building's bulk dimensions, parking, placement, and landscaping. Parking codes merit special attention because parking looms as one of the larger features in the built environment. Parking may be included within individual zoning codes, within specific or master plans, or in a city-wide code.

Municipalities have a number of options for integrating LID and smart growth into codes and the development approval process. For example, they can choose to implement a voluntary or regulatory approach, or they can choose a hybrid program that incorporates both voluntary and required elements. Table 3 describes options for integrating LID into existing land development ordinances, including some advantages and disadvantages of each approach.

Table 3. Approaches for Integrating LID Into Local Codes and Ordinances

Approach	Advantages	Disadvantages
Voluntary Measures – The least rigid process for implementation is to establish voluntary guidelines.	Since some LID measures reduce costs, or have benefits that exceed conventional practices, developers and homeowners may gravitate to LID. Voluntary measures also have the benefits of allowing flexibility and creativity since prescribed practices are not in place. Because the practices are voluntary, developers do not have to worry about sanctions for improperly installed or maintained BMPs.	As implied by the name, adoption is voluntary, and may require extensive outreach and education of the benefits.
Incentives-Based Approach – Communities may adopt voluntary or regulatory LID practices that are accompanied by an incentives program.	Incentives can help introduce new practices, or help bridge costs where LID installations are higher (as compared to conventional practices). Incentives can also be offered to induce developer interest in neighborhoods targeted for redevelopment.	Departments would have to establish new funding streams, which can be a challenge.
LID Ordinance – Communities may adopt stand-alone LID ordinances.	Stand-alone ordinances are easy to draft and enact.	A separate code may be confusing because it may not consider (or even conflict with) similar regulations on stormwater performance criteria or landscaping codes. Developers and site designers must refer to multiple codes. If changes to the code are needed, improvements must go through the sometimes lengthy process of code change.

Table 3. Approaches for Integrating LID Into Local Codes and Ordinances

Approach	Advantages	Disadvantages
Stormwater Management Ordinance – May require or encourage LID as part of a stormwater management ordinance.	Phase II communities are adopting post-construction ordinances to fulfill MS4 permits. LID can be incorporated into these ordinances without having to create a separate ordinance. Stormwater management performance standards can be key to the implementation of LID.	Communities will still need to review and revise development codes to eliminate or minimize barriers to LID.
LID Ordinance with Reference to Design Manual – Many communities oversee site and district design through design manuals.	Design manuals can go into more detail on LID selection and sizing. Design manuals can also integrate several development objectives at once, for example, combining LID with transportation-oriented development, use mix and/or redevelopment. Established design guidelines may be readily adapted to integrate natural drainage and LID. Perhaps the biggest benefit is that any fine-tuning of a design guideline does not need to go through that same process as code change.	Guidelines can be resource and time intensive. Cities with a variety of landscapes, development formats, and terrain will likely need to develop several guidelines.
Rezoning to Match General Plan Updates or NPDES MS4 Permit Requirements – Some cities use the General Plan process to introduce new zoning and land development regulations.	Applying new zoning codes clearly denotes site design and construction parameters. Emerging NPDES permits with on-site or LID requirements require a coordinated change in General Plans and ordinances.	The rezoning kicks in only where a property is developed or redeveloped (as opposed to a building rehabilitation). New zoning code requirements on LID could result in many non-conforming properties. If new LID requirements are viewed as a downzoning, cities and counties will be faced with addressing these concerns.
Building Code Changes – Building code changes can also be modified to integrate LID practices.	This is an option in cities or counties without zoning. In addition, building code changes may be more easily passed than a zoning code overhaul. Where the minimum land disturbance triggers are not met with NPDES permitting, building code changes can be changes to trigger LID with building rehabilitation. Even where rezoning occurs, building code changes may be necessary for green roof and onsite storage (e.g., cisterns and vaults).	Building code changes may not cover site design. In addition, LID at the district scale would not be thoroughly addressed if only building codes are amended.
Overlay Zoning – Overlay zoning is an increasingly popular method of introducing new requirements. While some overlay codes supersede the underlying zoning, in many cases, the overlay zoning is an option.	Overlay zoning can be matched to Master Planned development and Specific Plans to overcome the disadvantages of older, conventional zoning codes. For LID, an overlay zone can match BMPs to specific stressors, TMDLs or restoration needs.	Where the overlay is an option, cities or counties may need to offer incentives to increase the chances that the overlay will be adopted.

Table 3. Approaches for Integrating LID Into Local Codes and Ordinances

Approach	Advantages	Disadvantages
Alternative Compliance – Alternative compliance (including "fee in-lieu-of" programs and waivers) are a universal feature of any land development code.	Alternative compliance recognizes the wide variety of environmental or development conditions. While infiltration is a key feature of LID, many areas are unsuitable for infiltration practices (e.g., where the water table is high or where legacy contaminants pose a risk). "Fee in-lieu-of programs" can be designed to address the highest priority stormwater or flooding problems first.	Widespread waivers of alternative compliance can undermine the original environmental program. Cities must be able to quantify the fee associated with in-lieu-of programs. Some programs are seen as a developer giveaway.
Credit System – Credits for LID are increasingly popular, especially for stormwater and drainage requirements.	Credits are often used to promote environmentally preferable practices. They can also be used where the water resource benefits are difficult to fully quantify (e.g., preventative BMPs and smart growth practices). Where financial incentives are unavailable, credits can be used since they often lower costs. Cities and counties can use credit systems to attract development to certain areas (depending on how the credit system is structured).	Credits tend to put pressure on quantification to ensure fairness and environmental compliance. Thus, the advantage of crediting practices that are difficult to quantify is reduced. Credit systems can be resource intensive and are difficult to rescind once practices become commonplace. Where localities set strict initial performance standards, a credit system can be viewed as "going backwards" since the performance standard is viewed as the starting point for all projects.

While it may seem that instituting LID performance standards into zoning codes is straightforward, reducing and eliminating excess impervious cover is typically a multi-stage effort. This is because established zoning and land development codes have been built over time with input from a variety of parties with an interest in zoning parameters. Municipalities undertaking code and ordinance changes to incorporate LID should tailor their approach to the local context, taking into consideration existing development patterns, watershed conditions, stakeholder input, and other factors that will affect the opportunities for BMP implementation. Table 4 describes changes to codes that are appropriate for different types of development in urban, suburban or edge, and rural settings.

Table 4. Code Changes for Different Development Types and Settings

Development Type	Urban Codes	Edge Codes	Rural Codes
New Development	In highly developed urban areas, new development is likely to install impervious cover in the last absorptive places, though lot sizes are likely to be small. Codes should look at the stormwater functions lost and whether there are "hotspot" issues related to legacy contaminants. In urban areas, combinations of structural techniques (vaults) and small scale distributed landscaping are emerging practices to balance stormwater handling and water conservation. Code amendments will need to balance structural/non-structural techniques. Green roof technology improvements are responding to the range of environmental conditions. In Southern California, there is fear that green roofs would require irrigation most of the year. Moreover increased roof weight can trigger additional seismic requirements.	On the edge, new development is likely to consist of Master Planned Communities that are urban in nature (i.e., high levels of trip-making, demand for mix of uses, school travel). Reducing the impacts of impervious surface will come from both community design and onsite practices. Where urban boundaries are not in place, there may be opportunities to tie open space proffers to stormwater management. For new development in edge and rural areas, street designs should be carefully addressed. Where the format is mainly urban, narrow connected streets will better support activities. Where the format is more rural in nature, fewer engineered factors (i.e., no sidewalks) will form design. Note that "Campus Zoning" is replacing office park zoning. While the new designs emphasize green features onsite, the transportation remains auto-dominant.	Many rural areas of California lie outside of NPDES regulations. Some new low impact designs reduce developer costs (less street infrastructure). This can assist in provision of affordable housing, but also may attract development from regulated areas. Currently, 10 to 20 acre ranchettes are emerging as a popular housing type. The environmental impacts are not well-defined, however there are rural design/code options to lessen those impacts (e.g., shared facilities for stables, RV parking on a smaller footprint). New development in rural areas is likely to undergo increased CEQA scrutiny, in particular for induced growth, cumulative impacts and transportation-related climate change.
Redevelopment	Redevelopment projects in urban areas are likely to be part of a specific plan. Reducing the impacts of replaced imperviousness thus will rely on coordination of hardscape and open spaces. There may be socioeconomic factors in addressing redevelopment via NPDES. The additional requirements may further depress development interest in certain neighborhoods, thus cities may need to combine stormwater control with economic incentives.	Redevelopment at the urban edge may consist of a mix of new development and redevelopment. Thus, reducing the effects of imperviousness may involve reviews of specific plans, corridor redevelopment planning, use of remaining natural drainage and onsite measures. Parking codes are likely to dominate discussions where auto-dominant landscapes are being retrofitted with pedestrian features.	Rural "smart growth" designs often focus on historic downtown areas, crossroads and corridors. Code changes will need to recognize the watershed benefits of compact design.

Table 4. Code Changes for Different Development Types and Settings

Development Type	Urban Codes	Edge Codes	Rural Codes
Infill	Like new development, infill may involve a net increase in impervious surface. In urban areas, the increasing size of infill housing and its character are the subject of code changes; the stormwater regulations may also fit in these discussions and might be used as a tool to negotiate better housing and landscape design. New stormwater regulations are likely to put pressure on the construction of second units, in particular in areas with smaller lot sizes.	Infill projects need to be assessed for proximity to existing centers to determine community design features. Like urban areas, the character of infill housing in older neighborhoods is entering code change discussions. Form-based codes were authorized in State law, and are being adopted. Their role in stormwater management is to lessen the impact of vacant properties (since reuse is made easier with flexible form). Likewise FBCs are typically part of a coordinated district, which necessarily includes shared drainage.	Rural infill may be most common in rural industrial centers where transportation and water infrastructure were constructed to support past/current industrial uses. These areas may be candidates for small industry seeking attractive sites with green amenities.
Retrofits	In urban areas, the most important stormwater improvements, especially coastal cities, may arise from retrofitting properties and infrastructure with LID techniques in areas important for volume control and treatment. However, since NPDES permits only apply to new development and redevelopment, cities may want to use alternative compliance or "in-lieu-of fees" to address retrofit directly. In addition, cities will need to address retrofits through non-NPDES programs. Note that code changes were required to encourage use of solar devices. Local governments may need to add similar language to balance onsite practices in built out areas with property protection from runoff.	Retrofits on the urban edge are likely to focus on residential areas (since they comprise the largest area of developed land). Thus, both NPDES and non-NPDES programs will be needed. Like other retrofit programs, "punching holes" in existing impervious areas can direct improvements. There is also more opportunity for riparian buffers in areas that are less than built out.	The issue of retrofits for rural areas is small, though there may be increased opportunities for transfer of development rights for water harvesting or watershed water balance (for example where increased densification is balanced by an "offset"). However, in agricultural areas, the combined mandates for low impact development and water conservation will drive demand for different stock for commercial landscaping in urban and edge areas.

5.2 LID Elements of Codes and Ordinances

As described in Section 5.1, municipalities can employ a variety of approaches for integrating LID into codes and ordinances. A review of codes and ordinances that encourage or require LID from progressive stormwater programs around the country (summarized in Appendix C) shows that there are a number of common elements to the codes and ordinances. Based on these findings, the following are initial steps that communities can take to incorporate LID into their local codes and ordinances:

- Adopt goals and objectives for stormwater management.
- Conduct technical analyses to evaluate and determine appropriate performance standards that help you meet goals and objectives.
- Finalize performance standards.
- Conduct a review of existing ordinances and manuals to identify (1) the need for additional ordinances and (2) needed revisions to existing ordinances to create requirements or incentives for LID and remove barriers to LID. This includes review of existing stormwater, sedimentation and erosion control, subdivision, zoning, and/or unified development ordinances. (A checklist is presented in Appendix D that outlines key features of ordinances and common elements where LID can be incorporated or where barriers may exist.)
- Conduct roundtable discussion of needed ordinance revisions. This discussion should include sectors of the development community, bankers, DOT officials, environmentalists, and local government departments, etc.
- Based on recommendations from the roundtable discussions, draft new ordinance (e.g., stormwater management ordinance) and proposed text revisions for existing ordinances.
- Hold public meetings and public hearings.
- Adopt ordinances.

5.3 Overcoming Process Barriers to Code Reform

In addressing aspects of codes and development regulations that may pose a barrier to LID, it is important to recognize that the code parameters were put in place to address a particular policy or development matter. Established codes and standards can be difficult to change for a variety of reasons:

- *Fair application of development rules.* One broad standard may be viewed as serving any project that meets size or use standards.
- *Ease of administration*. One enforced standard is easier to implement than several codes.
- *Investment in the status quo.* Stakeholders adjust operations to existing zoning and anticipate financial loss or risk in any change.
- *Legal support*. By using a recognized national code, cities and counties may feel "covered" when safety or other concerns are brought forward with development projects.
- *Margin of safety*. The over-design of infrastructure and development is often attributed to risk reduction for extreme weather or emergency response events.
- *Resource constraints.* Amending standards or offering a choice of codes and standards requires human and financial resources. During project or site review, there are resource implications for training staff or altering engineering models.

- *Lack of outreach and education*. Even as models for better development emerge, there can be a lag time in obtaining buy-in from developers, the public and local Departments.
- *The desire for uniformity and predictability among development projects*. The desire for uniformity is evident in both the public and private sectors. Developers and their financial backers often associate a uniform development style with reduced risk. For cities and the larger public, a move away from conventional development can also be viewed as a risk to the tax base and property values.

5.4 PROGRAM-BUILDING STEPS

Before the effective date of ordinance revisions, a new local program needs to be established to implement the LID provisions. In fact, depending on the degree of local support, work should begin on building program elements during the period of public discussion if the effective date of the ordinance revisions is to be soon after their adoption. Otherwise, the effective date of the ordinance revisions should be delayed by 6 months to one year to allow for capacity building.

The local government is encouraged to have implemented the following steps prior to the effective date of the ordinance revisions:

1. Develop stormwater design manual or revise existing manual to incorporate LID techniques.
2. Develop tools or standardized methods for evaluating compliance with the Performance Standards. These are to be used by project applicants and staff.
3. Develop Standard Operating Procedures for
    - Development review
    - Inspections (including inspections check list; inspections/maintenance documentation procedures; database to manage inspection/maintenance history)
    - Enforcement
4. Conduct analysis of new staffing requirements. Hire staff as needed.
5. Train new and/or existing staff on use of the Design Manual; evaluation methods; standard operating procedures.
6. Conduct workshops for the development community on new requirements. This should ease the transition and minimize mistakes in early submittals.
7. Develop program evaluation framework, including benchmarks to ensure that goals are being met.
8. Be patient and creative. Work with the applicant to find solutions. Remember there is a transition phase when staff and project applicants are learning and helping work out the “kinks” in the manual, evaluation methods, and Standard Operating Procedures. Treating the program as a partnership will increase the likelihood of long-term support and success.

Appendix A: Options for Enhancing LID in California Policies

The following is a list of policies and programs in California through which LID can be promoted or enhanced. The list includes a description of the policy or program, including how it is related to LID, and action items that might be considered to remove barriers to LID implementation and better integrate LID into planning and development policies and practices. This list is intended to be fairly comprehensive, and as a result some of the options may be determined to be infeasible in California for a variety of reasons. This list is not static, as new policies and programs arise regularly. Discussions with other LID stakeholders will likely generate additional policies/programs and action items that should be added to this list.

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A. State Environmental Policies
B. Building and Zoning Standards
C. Streets, Roads, and Highways
D. Parking Lots
E. Landscaping
F. Open Space
G. Schools
H. District Planning, Redevelopment, and Infill

A. STATE ENVIRONMENTAL POLICIES

Like many states, California has delegated oversight of infrastructure and the built environment to many entities. As such, many policies can work at cross-purposes and funding priorities may be misaligned. To ensure adequate coordination and mutual support for LID and other environmental goals, State policies should be reviewed and aligned.

Issues

A1. ***Blanket application of a "Meadow" Performance Standard for LID may result in degradation***
Many LID equations set a baseline, pre-development condition against which stormwater management performance can be gauged. A common requirement is that the hydrology of a development site mimics that of a meadow. The "meadow" equation has the effect of treating conversion of a meadow and conversion of an abandoned parking lot as equal in terms of runoff. While this might be desirable in some situations, there could be degradation in other cases, for example if the pre-development condition is a forest, which has greater stormwater attenuation than a meadow. This approach to LID performance also fails to recognize receiving water condition. It may be necessary to institute a two-tiered approach where the first line of questions examines loss of ecosystem services. Thus, conversion of a meadow or forest would require a higher level of treatment and control than conversion of an impacted site.

A2. ***Many State agencies have recently updated codes and standards to include "green practices," though LID is not well represented***
Many improved guidance documents, manuals and directives were recently released (in 2006 and 2007), representing enormous efforts to integrate environmental planning, site design, and operations. Erosion controls for the construction phase of development seem to be the top stormwater priority, as exemplified in the new scorecard for High Performing Schools and the General Services manual.

A3. ***General Plans do not explicitly address LID***
General Plans guide land use and future development and can affect the amount and placement of impervious surfaces in watersheds. General Plans that do not integrate stormwater concerns with other pressing environmental issues such as water supply, total maximum daily loads (TMDLs), water conservation and

infrastructure might allow or encourage development patterns that adversely impact waterbodies. Explicitly incorporating LID goals into General Plans will help to ensure that watershed impacts will be considered on a regional planning scale.

A4. ***Communities require education on LID approaches***
Many local governments have not been educated on the benefits of LID and how to incorporate LID approaches into stormwater management plans, codes, or ordinances.

A5. ***LID not integrated into State Environmental Goals and Policy Report***
Every four years the Governor is required by State law to update the State Environmental Goals and Policy Report. The report was last updated in 2004. The top three priorities in the Report are summarized as follows: (1) to promote infill development and equity, (2) to protect environmental and agricultural resources, (3) to encourage efficient development patterns. Using LID approaches, these three priorities can be addressed to meet State environmental goals.

A6. ***LID projects using CWA §319 funds require a 40 percent non-federal match***
This federal program is among the most popular sources of money for model or pilot projects to mitigate runoff. However, the program requires a 40 percent non-federal match. Over $5 million has been available for projects, which must be implementation projects of between $250,000 and $1 million.

A7. ***Proposition 218 limits stormwater utility formation***
Stormwater utilities are widespread and growing as a way to manage stormwater and drainage. In California, stormwater utility formation is limited due to Proposition 218. Legislation has been introduced to place stormwater funding outside of Proposition 218. In many areas of the country, utilities (actually credits from utility fees) have been an effective means for fostering LID based on monetary incentives (especially for larger businesses and lots).

A8. ***LID is not incorporated into Clean Water Revolving Loan Funds***
The State Water Resources Control Board (SWRCB) sets priorities for the use of funds under the Clean Water State Revolving Loan Fund through annual "Intended Use Plans," in general directing money to the most pressing health and environmental problems first.

Opportunities and Action Items

Legislative

A9. Establish through legislation a statewide requirement that new State-owned buildings and those undergoing renovation to buildings/grounds meet the standard that post-development stormwater peak flow rate and volume from the site match the pre-development stormwater peak flow rate and volume. Note that this is a stringent requirement that may be controversial because this standard may not be feasible where soils are contaminated, in ultra-urban areas, or where the groundwater table is high. An alternative compliance option should be offered to allow developers to provide equivalent watershed benefits where site limitations prevent achievement of the performance standard onsite.

A10. For General Plans, require a new "Water Element" to combine water supply, stormwater, TMDLs, watershed planning, water conservation, LID, water infrastructure, and floodplain management. If legislation to require a Water Element is too aggressive, provide policy support for communities that choose to adopt a water element, including LID. The Local Government Commission's handbook on the Ahwahnee Water Principles (http://www.lgc.org/ahwahnee/principles.html) includes model policy language and information on the initial content for a Water Element.

Aspirational

A11. Develop a prototype two-tiered approach to stormwater that tiers post-construction best management practice (BMP) requirements based on the loss of ecosystem services.

A12. Sponsor a review of California State programs based on barriers or support for joint LID/planning, policy, funding and regulation. Provide suggestions to overcome barriers and highlight best practices. The review may cross-reference the top priorities and include LID.

A13. Sponsor or co-sponsor a regional Low Impact Development Conference to aid in education and training. OPC, in coordination with the State and Regional Water Boards, could develop workshops and training seminars to educate planning authorities and communities on how to incorporate LID approaches into growth strategies; how to design, implement, and evaluate LID approaches; and how to ensure long-term maintenance of LID practices.

A14. Sponsor a mock or pilot CEQA analysis of build-out for a region comparing an LID scenario with current zoning to provide a "ready alternatives analysis" based on LID.

A15. Contact the State's Office of Planning and Research to begin work on integrating low impact designs and development into the State Environmental Goals and Policy Report. This would strengthen the priority to "protect environmental and agricultural resources," which is now geared towards preserving farmland and open space, and should be a complement to the priorities of promoting infill and encouraging efficient land use.

Funding

A16. Support efforts to exempt stormwater funding from Proposition 218 limitations.

A17. Provide part of the 40 percent match for section 319 funding for LID pilot projects, LID planning or other activities covered under Clean Water Act §319.

A18. Work with the SWRCB to assess where changes to the "Intended Use Plans" for the Clean Water State Revolving Loan Fund might be combined with LID to improve water quality. The SWRCB notes in their 2007 Annual Report, Section II, that only 6 percent of funds were delivered to nonpoint source programs, though they will pursue increasing this amount because nonpoint source projects are critical to water quality. In addition, the SWRCB may be open to a "fix it first" alignment of funds for certain water funding programs.

A19. Assist municipalities in seeking grants from the Proposition 84 Storm Water Grant Program that provide matching grants to local public agencies for the reduction and prevention of storm water contamination of rivers, lakes, and streams.

A20. Work with the SWRCB to see where LID can be inserted into Supplemental Environmental Projects, which are financial contributions made as part of an enforcement action under the Clean Water Act. These projects must address the harm reported in the violation. Thus, an enforcement action for lack of sediment control at a construction site might include a LID retrofit for a public park experiencing erosion problems.

B. BUILDING AND ZONING STANDARDS

Building codes and standards are used to prescribe an expected level of health, safety and structural safeguards. These codes are commonly adopted by reference or integrated into local zoning codes. While these codes are vital for numerous reasons, inflexible "one-size-fits-all" codes tend to dictate a development format that cumulatively does not meet new or emerging challenges, in particular environmental challenges. For example, within building codes, traditional drainage parameters are written to move water away from building foundations and into streets through as direct a route as possible. Cities in California are in the process of revising their building codes to adopt new standards based on updates to the California Building Code, as well as other codes such as plumbing, electrical and fire.

Issues

B1. ***Provisions of the California Building Code preclude LID implementation***
The California Building Code includes many site, building and foundation codes, some of which may limit the use of infiltration BMPs. For example, limitations associated with expansive soils, seismic requirements and foundation integrity could all limit onsite infiltration, in particular on small sites where area for infiltration is limited. The new codes include language that allows localities to designate alternative drainage requirements, though this language is vague and does not specifically promote LID.

B2. ***Building footprint limits can drive imperviousness on a larger scale***
Maximum building footprint limitations place an upper bound on the building footprint size (e.g., a footprint can be no more than 30 percent of site coverage). While this is often a strategy for LID because it ostensibly reduces the impervious area attributed to a building, lower caps can drive inefficient land development at a larger scale by spreading out building imperviousness. In addition, parking often ends up occupying the space not used for the building.

B3. ***Building height limits and minimum frontage requirements can spread development outward***
Where development demand is high, building height restrictions tend to spread development outward. Where setbacks are small, this can lead to "horizontal density," which leaves little room to manage stormwater and forces an overall larger degree of low-density, highly impervious development. Minimum frontages (e.g., 100 feet) mandate a large parcel footprint for even smaller establishments.

B4. ***Rigid setbacks can limit LID application***
A setback is the minimum distance a building's side may be constructed from the front right-of-way and adjoining properties. Small setbacks have advantages (they support compact formats) and disadvantages (they leave little room for landscaping and aesthetics). Large setbacks of 30 feet or more add to driveway, walkway and other impervious infrastructure lengths. On the other hand, the larger the setback, the greater the opportunity for infiltration. Setbacks also tend to be rigid, preventing site designers from optimizing infiltration depending on individual site characteristics.

B5. ***New guidance for State buildings includes little direction on post-construction stormwater control***
The California Department of General Services updated its Best Practice Manual for State Buildings (http://www.documents.dgs.ca.gov/green/BPM-bbmbt.pdf) in 2006. The new manual includes information on managing construction site runoff but offers little information on managing post-construction stormwater onsite and provides no information on performance standards.

Opportunities and Action Items

Legislative

B6. Require all State buildings (new and substantial remodeling) to institute LID requirements for buildings, grounds and parking. Work with stakeholders to determine the development and redevelopment thresholds for LID requirements and retrofits.

Aspirational

B7. Sponsor an examination of the California Building Code to see which provisions might impede infiltration and LID, or which provisions require clarification on the use of LID. Use the review to suggest changes to the Building Code to meet multiple goals and provide assistance to local governments that have adopted the California Building Code by reference or are in the process of adopting the updated codes.

B8. Support a program for municipal building and zoning code audits to support environmental improvement (i.e., the audits would address not only stormwater via LID, but watershed, transportation, and heat island issues through more efficient forms of development and redevelopment).

Funding

B9. Provide incentives (i.e., funding for LID and stormwater-related implementation projects) and guidance to communities who agree to audit and modify local codes and standards to allow or promote LID.

C. STREETS, ROADS, AND HIGHWAYS

The design of highways, streets and roads has a high degree of impact on watersheds. The location of new roads, the geometric standards that govern road construction, the width of rights-of-way, and the connections among sites to the larger stormwater conveyance system are all factors that affect the degree of stormwater impacts from development. In addition, roads, even small roads with minimal shoulders, fracture important drainage networks and alter local hydrology.

One emerging issue is construction and improvement of roads in rural areas at the urban-wildland interface. On the one hand, improved roads assist in firefighting response, which is a pressing issue in developed areas adjacent to forests and scrubland. However, improved roads in rural areas can send signals that the areas are prepared to handle more development, which can contribute to sprawl and increased regional imperviousness.

Issues

C1. ***Overly wide street widths***

Street width in California is written into the State Streets and Highway Code, Section 1805 (http://www.legaltips.org/california/california_streets_and_highways_code/). The code requires that the width of all city and county streets and county highways (other than bridges, alleys, lanes and trails) shall be at least 40 feet wide. A county board of supervisors may elect smaller streets only by a unanimous vote of its members; within cities the requirement is a 4/5 vote. Also, emergency responders tend to request overly large street widths for maneuvering large equipment and vehicles. Engineering guides used throughout California establish minimum street and right-of-way widths, which can also include bike lanes, sidewalks, medians and planters. Efforts to reengineer streets, including reduced widths, are underway, mainly through Specific Area Plans.

C2. ***Overly wide sidewalks and sidewalks on both sides of the street***

While walkability is a popular amenity and even integral to transportation, wide sidewalk requirements on both sides of the street add impervious cover. In addition, the Americans with Disabilities Act requirements direct sidewalk placement and widths, which are needed for accessibility.

C3. ***Inefficient street layouts***

Most states, including California, have built highway systems based on a hierarchical model. This model funnels traffic from residential projects to local streets, to arterials and then to freeways. The system tends to arise where development is unconnected and scattered throughout a watershed. This adds to imperviousness and congestion, reduces options for alternative routes, and limits non-auto modes of travel.

Title 14 of California's Public Resource Code includes minimum road standards for wildland areas. Many county manuals mandate certain concrete, asphalt and substrate materials, in part to bear the weight of larger vehicles (often up to 40,000 pounds). Many cities and counties adopt standards developed by Fire Protection Districts (for example Ventura County's access standards, http://fire.countyofventura.org/departmentservices/fireprevention/standards/index.asp). These rules require certain paving materials and can prohibit the use of pervious pavers and alternative materials for access ways, parking lots, shoulders and turnarounds. Even where codes only apply to certain fire-prone areas, the standards are sometimes adopted for the entire county or city.

C4. ***Funding for streets and highways from the California State Controller does not encourage LID***

In 2004, the California State Controller's Office issued Guidelines Relating to Gas Tax Expenditures For Cities and Counties (http://www.sco.ca.gov/aud/gastax/gastax2004.pdf) to describe how funds collected for vehicles and gas, the major source of transportation infrastructure funding for localities, may be used. This authoritative document was developed to assist cities in determining how gas taxes may be used for street and highway improvement. While LID techniques appear to be included in the narrative, the definitive list of techniques that may be used, even for environmental mitigation and retrofits, is dominated by engineering approaches.

Opportunities and Action Items

Legislative

C5. Require that LID be incorporated into any new Caltrans road project, where feasible. Work with Caltrans planners to identify appropriate BMPs and performance standards for different types of road projects.

C6. Require LID retrofitting with any State-sponsored repair or maintenance project. This may include new materials for shoulders, the use of paving alternatives or improvements to stormwater management. Work with stakeholders and Caltrans to determine repair/maintenance project thresholds for the use of LID retrofits.

C7. Remove the 40-foot minimum street width from the Street and Highway Code for city and county streets.

Aspirational

C8. Work with Caltrans planners on the following programs that can include an LID or "green streets" component:

- Add an LID component or develop an LID matrix for "Corridor System Management Planning" projects intended to retrofit major corridors (http://www.dot.ca.gov/dist3/departments/planning/corridorplanning.html)
- Incorporate LID goals and objectives into the "Regional Blueprint Project" and the "Blueprint Learning Network" (http://www.dot.ca.gov/hq/tpp/offices/orip/bln.html).

C9. The Congress for the New Urbanism recently was awarded a grant to work with emergency responders nationwide on the issues of street widths, design and access. The State could support work on the paving materials and street design aspects of the project, since these should be part of the larger discussion. The State may also want to explore discussions on vehicle and apparatus design, since road designs are driven by the need to support vehicle size and weight. In California, the Local Government Commission has developed State-specific materials and training.

C10. Develop a High Performing Infrastructure report that integrates all utilities and infrastructure located in public rights-of way, including natural drainage (similar to that developed by New York City, http://www.designtrust.org/publications/publication_03hpig.html).

C11. Contact the California State Controller's Office to update and clarify language related to use of gas tax funding for environmental improvements and LID. Note that the Controller's Office has also issued Guidelines on use of Traffic Congestion Relief Funds (http://www.sco.ca.gov/aud/traffic/ab2928.pdf), which states that:

> Funds may also be used for the cost of work that is associated with and incidental to a street or road maintenance or reconstruction project within the street or road right-of-way, provided the work is necessary and/or required to bring the street or road to current design standards.

Further language refers to "associated curb and gutter work," though the overall wording tends to imply engineering approaches. The State can approach the Controller to see if specific guidance on "green streets" can be developed.

Funding

C12. Caltrans is developing a "smart mobility" scorecard to institute a new prioritization system for allocating funds. This scorecard will be used to underwrite investments in street systems that better support existing developments and pedestrian and bike infrastructure and improvements. This same type of scorecard might be used in distribution of stormwater infrastructure and nonpoint source funding.

D. PARKING LOTS

The impact of parking cover tends to fall into two categories: (1) decisions on overall parking supply and (2) the design of individual spaces and lots. In general parking is oversupplied due to the use of high minimum standards, requirements from financial lenders, and the lack of incentives to share parking among individual land uses. In general, workable reductions in the footprint of parking require a multi-disciplinary, planning approach.

Issues

D1. ***Parking lot landscaping requirements preclude infiltration***
Many parking lot codes require a continuous elevated curb around landscaped areas, which eliminates the ability to direct runoff into natural areas.

D2. ***Parking lot surface requirements limit porous pavement application***
Some parking codes limit the material selection to asphalt and concrete, prohibiting the use of permeable pavements.

D3. ***Overly large parking space dimensions***
Many codes require minimum space dimensions, as well as dimensions for drive aisles. In some cases, residential codes require a minimum number of spaces for recreational vehicles in addition to automobiles. Overly generous stall dimensions can increase parking lot imperviousness by 15 percent.

D4. ***Minimum required number of parking stalls leads to too many spaces***
Parking allotments often overstate actual demand and a minimum standard allows for more parking at the developer's discretion. The Institute for Transportation Engineers' "Parking Generation" establishes minimum number of parking stalls rather than maximum. Financial institutions tend to require extra parking as a margin of safety for overflow, even though extra spaces tend to be factored into the minimums. All of these factors contribute to increased parking lot impervious surface.

D5. ***Shared/joint parking and loading prohibited or not incentivized***
Many local codes either prohibit joint/shared parking, or give little incentive to do so. As such, the system errs on the side of oversupply for each project that is built or redeveloped, resulting in additional impervious surface.

D6. ***Zoning code limitations on charging for parking***
Many California cities prohibit charging for parking for any spaces that are required by code. This eliminates a market-based tool for to manage parking demand.

D7. ***Parking costs are "bundled" into rents***
Parking costs are "bundled" into rents, which (1) charges parking costs to renters who do not own cars and (2) conceals the true cost of parking. One strategy being used across the country is the unbundling of parking and rent costs, which provides more transparency on the costs of parking and can reduce parking demand. Lower demand means smaller lots.

Opportunities and Action Items

Legislative

D8. For parking lots serving State buildings, require that any maintenance or resurfacing project affecting more than 20 percent of the lot include LID retrofits that address runoff for the entire lot (or some negotiated percentage of the lot based on site constraints).

D9. Require that all sections within municipal zoning codes related to parking present both a minimum and maximum parking space allotment. Alternatively, require all State buildings to adhere to both minimum and maximum parking numbers.

D10. Draft enabling legislation allowing cities and counties to treat any surface parking over and above the minimum prescribed amount differently in stormwater management calculations. For example, developments

with excess parking space would be required to manage 150 percent of the stormwater volume or provide an equivalent degree of off-site management/retrofit.

D11. Prohibit the practice of limiting parking charges for any parking required under code.

D12. Craft legislation requiring the unbundling of parking costs for residential sites that are within one mile of heavy rail or fixed guideway transit stations, one half mile of bus transfer stations and one quarter mile of bus stops. Proximity to public transit offers residents alternatives to driving/parking, allowing them to choose not to pay for parking once costs become transparent.

Aspirational

D13. Provide a model parking sharing arrangement to foster joint and shared parking.

Funding

D14. Provide funding for communities to conduct parking demand studies.

D15. Fund pilot projects testing innovative parking lot designs and the use of innovative materials.

E. LANDSCAPING

The landscaped areas of development and redevelopment sites offer opportunities for stormwater management, even on small parcels in ultra-urban areas. However, cities often develop guidance documents and zoning code language that result in undesired environmental practices (e.g., the use of fertilizer- and water-dependent plants, limitations on efficiently using open space for infiltration, and engineering requirements that inhibit runoff capture and treatment).

Issues

E1. ***Landscaping codes and ordinances can conflict with LID***
Most California localities include landscaping ordinances within their zoning codes. LID in urban areas generally applies to commercial landscaping, including multi-family residential projects and landscaping within parking lots. Some landscaping codes reduce areas for stormwater infiltration by not specifying appropriate infiltrative soils. Others encourage raised landscaping by requiring planting areas be protected by curb or wheel stops, which eliminates the ability to treat runoff in landscaped beds. In addition, some codes limit the use of non-plant materials, such as gravel, to 10 percent of the area. This limits the ability to use rocks and gravel for energy dissipation, which is essential for hydromodification control. The lack of understanding how LID approaches can be incorporated into landscaped areas often result in a greater amount of land area dedicated for traditional stormwater controls and conveyance.

E2. ***Water conservation is not explicitly linked to LID and stormwater management***
In 2006 new legislation took effect under the Water Conservation in Landscaping Code (http://www.cuwcc.org/ab2717_landscape_task_force.lasso). Language on stormwater infiltration and reuse is in the legislation, though it is not strong. As new stormwater permits are issued, a bond will need to be forged among LID, permit performance standards, and the landscaping rules. Note that much of the language on water conservation in landscaping pivots on water budgets and irrigation. The use of LID will affect these budgets, though little research has been done to determine how stormwater infiltration will ultimately be factored into these budgets.

E3. ***Many exemplary landscaping codes include requirements for maintenance***
Maintenance of stormwater BMPs, including LID techniques, is often overlooked, resulting in reduced performance in handling volume and removing pollutants. Audits of the Phase I program by EPA showed that lack of maintenance was the top weakness of the stormwater program. As such, zoning codes that include maintenance (including inspection and enforcement) can be modified and used to sustain the benefits of LID.

Opportunities and Action Items

Legislative

E4. Require greater minimum area dedicated to landscaping in development and redevelopment codes. Require that a Landscape Plan include a site evaluation of existing conditions (soil hydrology, vegetation) to consider in designs before grading or other impacts to the site have taken place. Provide model ordinance for these changes.

Aspirational

E5. Contact the California Urban Water Conservation Council (http://www.cuwcc.org/home.html) on integrating LID into new guidance and model codes. The language on infiltration exists and provides an "in" for LID, but it is not strong. The potential exists for codes to be written without factoring in water budget changes that arise from capturing water onsite. Some work is underway: the Urban Water Conservation Council must develop a model code by January 1, 2009, with local ordinance adoption within one year.

E6. Develop a cross-program education and communications strategy for LID, including options for urban areas, master planned areas, new development, redevelopment and infill.

E7. Provide technical assistance (e.g., guidance, trainings) for incorporating LID into local codes and for design, installation, and long-term maintenance of landscape-based BMPs, including pesticide, fertilizer, and herbicide use.

E8. Work with the California Nursery Growers Association on ramping up plant selection and practices to meet both LID and upcoming water conservation standards. http://www.nurserygrowers.org/index.html.

F. Open Space

California has many programs devoted to preservation of open space, forests, park land, and desert land. Last year, legislation limiting development in floodplains increased protection of streamside open space. Urban open space, parkland and forestry are important but often overlooked opportunities to manage runoff. To make the most efficient use of open space for stormwater management, areas that have natural drainage properties amenable to LID should be dedicated for this use. Minimum open space requirements that do not take into consideration these site properties may not provide adequate stormwater management benefits.

Issues

F1. ***Minimum open space requirements might drive inefficient land use***
California requires minimum open space for multi-family residential projects. While open space is an important component for urban areas, large minimums may be driving inefficient land use without providing meaningful natural or recreational spaces. The open space requirements for multi-family residential projects are often in addition to other requirements such as parking, setbacks, internal circulation, sidewalks, club houses and other amenities. In addition, many local codes disallow land devoted to onsite stormwater management to count towards the minimum open space provisions. However, reducing open space is likely to be controversial because most assessments of the value of open space do not consider any countervailing effects on efficient use of land.

F2. ***Inconsistent and inadequate buffer widths***
Aquatic buffers serve as natural boundaries between local waterways and existing development. They help protect water quality by filtering pollutants, sediment, and nutrients from runoff. Other benefits of buffers include flood control, stream bank stabilization, stream temperature control, and room for lateral movement of the stream channel. Good aquatic buffer ordinances specify the size and management of the stream buffer and are a specific planning tool to protect stream quality and aquatic habitat. Buffers can be multifunctional, serving as areas for sheet flow and infiltration to reduce stormwater pollutants and volume, improve baseflow conditions and increase groundwater recharge.

F3. ***The Williamson Act can be used to prioritize preservation of infiltration areas***
The California Land Conservation Act of 1965 (Williamson Act) enables local governments to enter into contracts with private landowners for the purpose of restricting specific parcels of land to agricultural or related open space use. Landowners receive property tax assessments based upon farming and open space uses as opposed to developed market value. Local governments receive an annual subvention of forgone property tax revenues from the State via the Open Space Subvention Act of 1971.

Opportunities and Action Items

Legislative

F4. Create a Williamson Act/Open Space Subvention Act of 1971 counterpart for infiltration and aquifer recharge. Base the program on areas best suited for infiltration. Alternatively, allow localities to include infiltration as "production" under the Williamson Act in areas delineated for aquifer protection.

F5. Require that open space designations be reviewed during local plan review to assure that the area is used in the most efficient manner for present and future needs, including stormwater management and groundwater recharge. The State can provide model ordinance language to require open space designation review.

Aspirational

F6. Provide examples of supplying land-efficient open space from other parts of the country, in particular for dense urban districts. Alternatively, develop and promote examples of open space landscaping that supports both stormwater handling and active/passive recreation (e.g., using soccer fields as infiltration basins, developing water gardens with aesthetic and stormwater treatment functions).

F7. Encourage local governments to adopt ordinances that apply minimum buffer widths and maintenance requirements to all lots that are contiguous with or directly adjoin an intermittent or perennial stream or river, particularly those identified in and consistent with impairments or threatened/sensitive species.

G. SCHOOLS

School building and renovation offer LID opportunities. The decision of whether to redevelop an existing school or build anew at another location has broad watershed implications. First, older schools tend to be located on smaller sites. Secondly, the increasing costs of land and construction exert financial pressure to build on cheaper, more distant, and undeveloped land. A variety of factors then feed into the ultimate footprint of the school, including parking, pick-up, fields, classroom size and the like. California has been a national leader in school siting reform, including a push to use schools as centers of community and voter approval of funding to provide green retrofits.

Schools provide an ideal opportunity to demonstrate LID approaches to the public because they serve as polling places and meeting locations in addition to educational facilities. Operation and maintenance can generally be assured at schools. Placement of stormwater management features on school grounds can provide opportunities for LID outreach and education to children and adults. There are still areas of improvement needed, in particular as it relates to the overall stormwater and carbon footprints of new schools.

Issues

G1. ***"Schools as Centers of Community" policies can be used to promote LID***
California has instituted "Schools as Centers of Community" policies over the past decade to efficiently supply services, parks and facilities. School parking lots, fields, land and landscaping may provide capacity to address local flooding, provide land or storage for stormwater and otherwise address stormwater hotspots.

G2. ***School Facility Hardship Grant Program might discourage LID and/or redevelopment***
California's School Facility Hardship Grant Program, which provides grants to correct safety problems, discourages school districts from considering renovation options for historic schools by limiting funding if renovation costs exceed 50 percent of the cost of new construction. This can limit renovation of already

developed properties, which might include incorporation of LID into landscaped areas. This policy may encourage school construction on undeveloped lands, which increases impervious area (newer schools typically have a larger footprint), requires additional infrastructure and can increase brownfield or vacant land(if the old school property is not redeveloped.

Opportunities and Action Items

Legislative

G3. Require LID for new school construction. Where feasible, require use of school property for collective drainage and infiltration. For new and existing schools, require water harvesting equal to a locally preferred design storm (for example the design storm used for transportation projects). Where possible encourage school construction or reconstruction on infill or redeveloped lands and discourage construction on undeveloped lands. The State can provide incentives (i.e., funding for LID and stormwater-related implementation projects) and guidance to communities who agree to modify local codes and standards to promote infill and redevelopment.

Note that the California Department of General Services and California High Performing Schools initiative recently launched its $100 million High Performing Schools Program, funded by Proposition 1D in 2002. The criteria for selection and level of funding is based on a scorecard (http://www.chps.net/manual/documents/CHPS-NewConstruction_Scorecard_060821.xls), which only has a non-required stormwater item for "minimizing runoff," although other factors might reduce runoff, such as a factor to "minimize parking."

Aspirational

G4. Under recent legislative changes, school districts may develop Master Environmental Impact Reports (EIRs). The State can work with the Department of Education's facilities group to integrate LID into all master EIRs for educational facilities.

G5. Encourage passage of State legislation to require new school construction to meet LEED Silver standards.

Funding

G6. Sponsor water infrastructure upgrades to include LID in existing schools. By underwriting new infrastructure for historic schools, energy and water costs can decrease and in some cases they can address deferred maintenance that might otherwise feed into the renovation cost calculation and tip the decision to new construction. One group that has been effective at this is TreePeople in Los Angeles.

H. District Planning, Redevelopment, and Infill

Increasingly, cities and counties are turning to district planning for efficient delivery of services, coordinated infrastructure, and economic development. Although most LID codes and examples have been applied to individual sites, one key to effective implementation is how the larger area performs for watershed health and restoration. This involves how streets are designed; what the use mix is; how accessible common trips are to jobs, home and school; the extent to which site elements are shared; the footprint of development; and how open space is used (or set aside).

In California, there has been an upsurge in district planning. New models of district planning have been launched and fine-tuned in California, including form-based codes, new urbanism, transit-oriented development, and a new Leadership in Energy and Environmental Design (LEED) pilot for neighborhood development (LEED-ND). For redevelopment, main streets, infill and highway corridors have been the focus of activity. For new development, traditional neighborhood design, master-planned communities, conservation or cluster subdivisions, mixed-use projects (sometimes called "lifestyle centers"), and planned unit development projects, are common formats.

The regulatory structure for district planning typically rests on specific area planning. These plans often occupy a separate section within zoning codes and have detailed maps and infrastructure plans. Financing for districts is complex. For redevelopment, redevelopment agencies usually oversee special financing through tax-increment

financing. Impact fees can pay for new development, though "community financing districts," or Mello-Roos districts (see http://www.mello-roos.com/pdf/mrpdf.pdf), are increasingly used to pay for construction, operation and maintenance. Note that Mello-Roos districts can also be formed for redevelopment districts, though the more common application is for new development.

Issues

H1. ***LID requirements are often written to apply to individual projects, which results in uneven application***
LID is often defined as a site-level approach, and as such, many LID regulations set one uniform performance standard across all "projects" that are part of a "common development plan." Developers of large greenfields projects have leeway in arranging lots and open space to meet the performance standard. For example, if a new development must be limited to no more than 10 percent impervious cover, individual home sites need not meet this requirement as long as the overall development plan has less than 10 percent cover. However, for redevelopment, most projects are individual sites with little or no space or flexibility for BMP design. This creates a situation where a large greenfield project allows flexibility as a common development plan, but redevelopment must meet the entire performance standard within the site boundaries.

H2. ***Research on district-level LID is limited***
Most research on LID efficacy has been conducted on individual sites. The most robust data for a subdivision, from the Jordan Cove National Nonpoint Source Monitoring Program project in Connecticut (http://www.jordancove.uconn.edu/), was only recently released.

H3. ***LID often designates hydrology as the indicator of environmental impacts***
By their regulatory nature, stormwater rules have the farthest reach into zoning codes. These rules tend to emphasize stormwater peak flow attenuation and volume capture, causing hydrologic performance to outweigh other important environmental issues that are considered in non-regulatory planning documents, such as infill and redevelopment priorities and regional growth patterns that can affect watershed health.

H4. ***Suburban-style LID requirements can run counter to the planning, transportation and climate emphasis on compact design***
Meeting strict stormwater performance standards in urban areas can be much more difficult than in open areas with room for swales, infiltration and detention. While LID techniques can decrease costs for greenfields applications, they can pose higher costs for urban developers, since underground vaults are often needed to augment urban green building, streetscape and landscape BMPs to meet performance standards.

H5. ***Barriers to redevelopment***
Many barriers stand in the way of redevelopment projects compared to new development in greenfield areas. Developers who undertake redevelopment face different (and almost always more) barriers to redevelop a parcel than those who build new projects in greenfields. Barriers include small, odd-shaped lots, multiple ownership, localized economic blight, outdated infrastructure, increased number of required permits and opposition from existing residents and businesses.

H6. ***Redevelopment sites may not offer the same level of receiving water and flood mitigation benefits***
Redevelopment sites differ based on a number of factors that affect LID applicability and efficacy, such as the condition of infrastructure, pollutants of concern, economic development prospects, restoration potential and degree of impervious cover. Most LID requirements apply a blanket threshold and performance level based one or more gross categories (e.g., "new development" or "significant redevelopment"). This blanket approach does not account for constraints at individual redevelopment sites that might limit LID implementation. Strict performance rules might preclude redevelopment of an infill property, despite significant community benefits and the regional benefit of concentrating imperviousness in the urban center and reducing sprawl. Also, some receiving waters in heavily urbanized areas are so impaired that only through redevelopment will there be opportunities to install onsite practices and provide restoration opportunities.

H7. ***There is growing belief that subwatershed planning is the best structure for matching BMPs to runoff stressors***
The easiest method for developing regulations is through uniform performance standards that apply equally to all sites within a jurisdiction. However, this may not adequately match BMPs to the development context, economic factors, and specific stormwater problems, especially related to redevelopment and retrofits.

Moreover, the Basin Plans developed by Regional Water Quality Control Boards often do not align with land development plans, Integrated Regional Watershed Management Plans, and NPDES stormwater requirements.

H8. ***General Permits discourage infill***
Construction Activities Stormwater General Permit (or local grading permits) are often inflexible in their stormwater management requirements and as a result discourage infill and redevelopment that could incorporate LID. Many stormwater codes do not encourage infiltration practices because of the perceived potential contamination issues. Also, some developers perceive that LID practices require a much greater area and that they dramatically reduce the buildable area. These misperceptions, along with a lack of recognition that integrated management practices can be shoehorned into required landscaping (i.e., stormwater planters), leads developers to dismiss the LID approach.

Opportunities and Action Items

Legislation

H9. Create legislation directing the SWRCB to more fully develop "Redevelopment Project Area Master Plans" as described in the draft Ventura County Municipal Stormwater Permit.

H10. Introduce legislative language to classify certain affordable housing/infill projects as post-construction BMPs based on their location and configuration in the watershed (according to General Plans and local housing plans). This program might be based on the spreadsheet model such as that developed by Grand Rapids, Michigan, or others, which estimate the impervious cover prevented by directing housing construction to infill areas identified for growth.

H11. Sponsor legislation to require consideration of natural drainage as an initial step within Subdivision Map Act, as well as rules on Master Plans and Specific Area Plans.

Aspirational

H12. Sponsor an analysis of pilot neighborhoods in the LEED-ND program to see if they meet stringent stormwater requirements (for volume, treatment and flow control). Similarly, conduct a survey of LEED-certified buildings to see how they perform relative to stormwater performance standards in permits. Note that this may be somewhat risky if the first generation of buildings fail to meet recent performance standards. For a list of projects in LEED-ND, see http://www.usgbc.org/ShowFile.aspx?DocumentID=2960.

H13. Sponsor a pilot analysis of the stormwater, climate, and other environmental impacts of vacant property (i.e., the runoff volume created and miles traveled past "dead" sites). Develop strategies to encourage redevelopment and improvement of these sites (requiring LID where feasible). Alternatively or in addition, lobby for the establishment of a program, such as a neighborhood improvement initiative, to convert these sites to parks/open spaces that act as "urban sponges" that capture and infiltrate stormwater from adjacent properties.

H14. Sponsor a pilot study to align major water planning documents (e.g., Basin Plan, Integrated Regional Watershed Management Plan) with regional and local requirements (e.g., stormwater permit requirements and local zoning codes) with respect to LID goals and requirements.

H15. Sponsor a study of "community facilities districts" or Mello-Roos, to see how LID would be treated (or constrained) for new development, infill and redevelopment. Investigate the legal structure and issues related to construction, operation and long-term maintenance under such districts. Because the maximum term and maximum bond amount must be specified up front, this research could provide guidance on assessing this cost. Finally, the study should include an analysis of costs for LID versus traditional conveyance systems as they relate to overall costs for the district.

H16. Create a tool similar to "redevelopment ready" districts that pools existing and planned stormwater improvements for multiple redevelopment sites and considers shared drainage and LID for a pre-permitted district. This will help "level the regulatory playing field" between greenfield and infill development sites by allowing more flexibility for placement of stormwater features in the redevelopment district.

Funding

H17. Fund a project to better describe LID techniques based on development settings in California similar to the effort underway within the Congress for New Urbanism based on the "transect." The transect establishes seven transect zones based on intensity of development and urban form. This approach was used to develop new street standards and could serve as a model for stormwater management as well.

H18. Provide funding for localities that are taking a subwatershed approach to matching BMP selection, development context and pollutants of concern.

H19. Provide matching funds for BMPs installed in mixed-use housing projects. Such a program would need to prioritize funding based on multi-objective planning needs, location in a watershed or alignment with redevelopment/housing program needs.

H20. Provide funding to retrofit or supply LID for small-scale, stand-alone businesses or business districts in economically challenged neighborhoods.

Appendix B: LID Policies Outside of California

The following is a brief summary of stormwater- and LID-related policies from other states that have relatively innovative requirements. It also includes a new requirement for federal buildings and a summary of the LEED-ND standards.

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Connecticut
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Massachusetts
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Ohio
Pennsylvania
Rhode Island
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Virginia
Wisconsin
Federal Government
Leadership in Energy and Environmental Design Neighborhood Development (LEED-ND)

CONNECTICUT

Policy Structure	The Connecticut Clean Water Act (CCWA) of 1967 (P.A. 67-57) launched Connecticut's modern water pollution control program. This statute (Chapter 446k of the Connecticut General Statutes (CGS)) forms the authority for Connecticut's Department of Environmental Protection to regulate discharges to surface waters under both the CCWA and the federal NPDES Program.
Impervious Surface	Stormwater management requirements are triggered for projects one acre or larger or industrial development creating 10,000 square feet or more of impervious cover. Residential projects with fewer than 5 dwelling units are required to manage stormwater only if final impervious cover will exceed 30%. Impervious cover should be measured from the site plan and includes all impermeable surfaces that are directly connected to the stormwater treatment practice such as paved and gravel roads, rooftops, driveways, parking lots, sidewalks, pools, patios and decks.
Infiltration	Developers are required to maintain predevelopment groundwater recharge volume to the MEP through the use of infiltration measures. The groundwater recharge volume (GRV) is the post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual pre-development groundwater recharge. The GRV is determined as a function of annual pre-development recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site.
Innovative Measures	Typical of other states
LID Requirements	No requirements, but the 2004 Connecticut Stormwater Quality Manual contains summary descriptions of small-scale LID practices. The design sections of this Manual contain more detailed guidance for similar, larger-scale stormwater treatment practices such as bioretention, infiltration, and filtration system.
LID Incentives	N/A
Redevelopment	N/A
Links to Language	Statute: http://www.cga.ct.gov/2005/pub/Chap446k.htm Connecticut Stormwater Quality Manual: http://www.ct.gov/dep/cwp/view.asp?a=2721&q=325704

DELAWARE

Policy Structure	The Delaware Sediment and Stormwater Regulations set forth requirements for post-construction stormwater management.
Impervious Surface	N/A
Infiltration	The regulations include guidelines and technical standards for the use of infiltration practices but do not require a particular level of infiltration.
Innovative Measures	The Delaware Sediment and Stormwater Regulations state that the state's overall goal is to utilize stormwater management as a means to minimize water quantity and water quality impacts and to mimic pre-development hydrology to the MEP in regards to the rate, volume, and duration of flow. Projects in certain watersheds (Mill Creek, Little Mill Creek, Red Clay Creek, White Clay Creek, Persimmon Creek, and Shellpot Creek) need to control runoff volume to mimic pre-development land use conditions using recharge, infiltration, and reuse where site conditions allow.
LID Requirements	The state's preferred option for water quality protection is the use of "Green Technology BMPs." Other practices can only be considered after the preferred practices have been eliminated for engineering or hardship reasons as approved by the plan approval agency.
LID Incentives	N/A
Redevelopment	N/A
Links to Language	Delaware Sediment and Stormwater Regulations: http://www.dnrec.state.de.us/dnrec2000/Divisions/Soil/Stormwater/Regs/SSRegs_4-05.pdf Green Technology Guidance: http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/DURMM_TechnicalManual_01-04.pdf

DISTRICT OF COLUMBIA

Policy Structure	The District of Columbia is working with EPA to revise its NPDES permit to add innovative LID features. These were outlined in a letter to EPA dated November 27, 2009. Permit language had not been finalized at the time of this report's publication.
Impervious Surface	N/A
Infiltration	The regulations include guidelines and technical standards for the use of infiltration practices but do not require a particular level of infiltration.
Innovative Measures	Initiatives include • A tree-planting goal of planting and maintaining 13,500 trees in the manner recommended by the Green Build-Out Model. Current tree planting rate is more than 4,000 trees per year. • Development of a master LID implementation list and construction of 17 LID projects by August 2009. • Conversion of paved or hardened areas throughout the District, such as traffic street medians and large sidewalk areas into green space in the form of pocket parks or green streets. • LID incentives will be extended to include rain barrels and downspout disconnections. • Installation of approximately 50 rain gardens and 125 rain barrels and disconnection of 200 downspouts. Review of District properties for feasibility of green roof retrofits. Commitment to include green roofs on new buildings and major renovations where feasible.

DISTRICT OF COLUMBIA

LID Requirements	N/A
LID Incentives	The District plans to develop legislation to establish tax credits or other incentives programs for installation of green roofs on non-governmental buildings.
Redevelopment	N/A
Links to Language	Letter of agreement sent from the District to EPA outlining new LID measures (and other changes to their NPDES permit requirements): http://www.epa.gov/reg3wapd/npdes/dcms4.htm

MARYLAND

Policy Structure	The state recently adopted the Stormwater Management Act of 2007 that requires that Environmentally Sensitive Design (ESD), which is similar to LID, be implemented to the MEP. The Act also specifies the practices considered to be ESD. Previously, ESD had been encouraged through stormwater credits (see LID incentives). The purpose and scope of the previous (adopted in 1983) stormwater regulations (Code of Maryland Regulations 26.17.02,) states that "the primary goal of the State and local stormwater management programs is to maintain after development, as nearly as possible, the predevelopment runoff characteristics." Under the state stormwater regulations, all counties are required to adopt stormwater ordinances. The stormwater regulations specify minimum requirements for the county stormwater ordinances. The stormwater design manual interprets the stormwater regulations and provides guidelines and credits towards compliance.
Impervious Surface	From 2000 SW Design Manual page 1.13: Performance Standard 1: Site designs shall minimize the generation of stormwater and maximize pervious areas for stormwater treatment.
Infiltration	Recharge volume required as part of BMP design. The goal of this requirement is to maintain existing or predevelopment recharge rates.
Innovative Measures	Typical of other states
LID Requirements	The 2007 Act is likely to result in LID-related requirements.
LID Incentives	From page 5.17 of 2000 Stormwater Design Manual: Developments less than 15% impervious can be exempt from structural practices if they employ environmentally sensitive development techniques, which have LID elements including disconnection of rooftop runoff, use of grass swales, and dedication of natural areas. The manual provides other credits under the broader umbrella of Innovative Site Planning.
Redevelopment	From Code 26.17.02.05: Reduce existing imperviousness by 20%, or provide water quality treatment for 20% of site's imperviousness, or use a combination of imperviousness reduction and water quality treatment equal to 20%, or implement a locally approved practical alternative (e.g., fees, off-site implementation, watershed or stream restoration or retrofitting).
Links to Language	Stormwater Management Act of 2007: http://mlis.state.md.us/2007RS/chapters_noln/Ch_121_sb0784T.pdf

MASSACHUSETTS

Policy Structure	EPA is responsible for issuing stormwater general permits for construction sites disturbing more than one acre under the NPDES General Permit for Stormwater Discharges from Construction Activities. Although EPA is issuing authority, the MADEP reviews the conditions of each permit, certifies the program unconditionally, or with specific conditions according to requirements of Section 401 of the Federal CWA. In addition to the EPA NPDES requirements, the MADEP has state standards for stormwater discharges which are enforced through different MADEP regulations, including, but not limited to, the Mass. Wetlands Protection Act regulations (310 CMR 10.00), Mass. 401 Water Quality Certification regulations (314 CMR 9.00), and Mass. Surface Water Quality Discharge Standards (314 CMR 3.00 and 4.00).
Impervious Surface	N/A
Infiltration	From the Stormwater Management Policy Handbook: "Recharge must be provided to offset the recharge lost due to site development to the maximum extent practicable and determined using the existing (pre-development) soil conditions [according to hydrologic soil group]."
Innovative Measures	Typical of other states
LID Requirements	N/A
LID Incentives	N/A
Redevelopment	From the Stormwater Management Policy Handbook: Redevelopment of previously developed sites must meet the Stormwater Management Standards to the maximum extent practicable. However, if it is not practicable to meet all the Standards, new (retrofitted or expanded) stormwater management systems must be designed to improve existing conditions. Definition -- Redevelopment projects include: Maintenance and improvement of existing roadways, including widening less than a single lane, adding shoulders, and correcting substandard intersections and drainage, and repaving; and Development, rehabilitation, expansion, and phased projects on previously developed sites, provided the redevelopment results in no net increase in impervious area.
Links to Language	SW Management Handbooks and other documents: http://www.mass.gov/dep/water/laws/policies.htm#storm

NEW JERSEY

Policy Structure	Stormwater management requirements are specified in the New Jersey Administrative Code (NJAC), Title 7, Chapter 8 Stormwater Management. Major developments (defined as disturbing one or more acres of land or increasing impervious surface by one-quarter acre or more) are required to comply with the stormwater management rules. When municipalities, counties, or regional governments develop stormwater management plans, they must use the stormwater rules as minimum standards.
Impervious Surface	*7:8-5.3 Nonstructural stormwater management strategies* requires that standards be met using nonstructural practices to the MEP, including minimizing and disconnecting impervious surface.
Infiltration	The state requires that developers demonstrate through hydrologic and hydraulic analysis that (1) the site and its stormwater management measures maintain 100 percent of the average annual preconstruction groundwater recharge volume for the site, or (2) that the increase of stormwater runoff volume from pre-construction to post-construction for the 2-year storm is infiltrated. This groundwater recharge requirement does not apply to

NEW JERSEY

	projects within the "urban redevelopment area," or to projects subject to restrictions related to industrial uses and other land uses producing potentially high pollutant concentrations that could impact ground water quality; also see exemptions under 7:8-5.2d.
Innovative Measures	Typical of other states
LID Requirements	*7:8-5.3 Nonstructural stormwater management strategies* requires, to the maximum extent practicable, that performance standards (N.J.A.C. 7:8-5.4 and 5.5) be met by incorporating nonstructural stormwater management strategies into the design that: • Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss. • Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces. • Maximize the protection of natural drainage features and vegetation. • Minimize the decrease in the time of concentration from pre-construction to postconstruction. • Minimize land disturbance including clearing and grading. • Minimize soil compaction. • Provide low-maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers and pesticides. • Provide vegetated open-channel conveyance systems discharging into and through stable vegetated areas. The State has developed a Nonstructural Strategies Point System to assess whether developers have implemented nonstructural controls to the MEP. Alternative compliance is available with justification. Any land area used as a non structural stormwater management measure to meet the performance standards in N.J.A.C. 7:8-5.4 and 5.5 shall be dedicated to a government agency, subjected to a conservation restriction filed with the County Clerk's office, or subject to Department approved or equivalent restriction that ensures that measure or an equivalent stormwater management measure approved by the reviewing agency is maintained in perpetuity.
LID Incentives	N/A
Redevelopment	Urban redevelopment areas are exempt from recharge requirements. For redevelopment, the water quality provisions of the Stormwater Management rules only apply if the impervious surface onsite increases by at least 0.25 acres.
Links to Language	Stormwater Management Rule Related Information: http://www.state.nj.us/dep/watershedmgt/rules.htm Stormwater Management Rule: N.J.A.C. 7:8 text: http://www.nj.gov/dep/rules/adoptions/2004_0202_watershed.pdf New Jersey Stormwater Best Management Practices Manual: http://www.njstormwater.org/bmp_manual2.htm Nonstructural Strategies Point System Information: http://www.nj.gov/dep/rules/adoptions/2004_0202_watershed.pdf

OHIO

Policy Structure	In Ohio, responsibility for regulating storm water is held by both local and state authorities. Locally, municipalities, townships and counties all have authority to regulate storm water. Ohio EPA, authorized by the regulations at Chapter 6111 of the Ohio Revised Code (ORC), administers the state regulations that require storm water permits for construction sites. These requirements established the basis of the permit requirements contained in the 2003 Ohio Environmental Protection Agency General Permit for Storm Water Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System. Draft permits specific to portions of the Olentangy River watershed and portions of the Big Darby Creek Watershed are in development. In addition to the rules and general permit, Ohio specifies stormwater performance and design criteria and sediment and erosion control standards in the 2006 Rainwater and Land Development Manual. Ohio also specifies stormwater control standards in the 1980 Ohio Stormwater Control Guidebook.
Impervious Surface	N/A
Infiltration	N/A
Innovative Measures	Typical of other states
LID Requirements	N/A
LID Incentives	N/A
Redevelopment	Under General NPDES permit requirements in Appendix of 2006 manual: Redevelopment projects are required to either reduce the existing, pre-construction impervious area of the site by 20%, or capture and treat 20% of VWQ. Linear projects, which do not creation new impervious surfaces, are exempt from post-construction stormwater management requirements, although they are required to minimize the number and width of stream crossings.
Links to Language	Ohio Revised Code Chapter 6111: http://codes.ohio.gov/orc/6111 Rainwater and Land Development Manual: http://www.dnr.state.oh.us/default/water/rainwater/default/tabid/9186/Default.aspx

PENNSYLVANIA

Policy Structure	The Pennsylvania Storm Water Management Act of 1978 (Act 167) provides the legislative basis for statewide stormwater management. Stormwater management plans must be developed by the respective counties in a given watershed and be implemented by the affected municipalities through the adoption of stormwater ordinances. Pennsylvania provides design and review guidelines for stormwater management in its 2006 Pennsylvania Stormwater Best Management Practices Manual.
Impervious Surface	N/A
Infiltration	Strongly encouraged in the stormwater manual
Innovative Measures	Typical of other states
LID Requirements	N/A
LID Incentives	N/A

PENNSYLVANIA

Redevelopment	Though not required, the stormwater manual recommends the following guideline: 20 percent of existing impervious area, when present, shall be considered meadow (good condition) in the model for existing conditions for redevelopment. Ch 7 of the Stormwater manual provides guidelines for Brownfield redevelopment.
Links to Language	Pennsylvania Stormwater Management Act: http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/StormwaterMgmtAct.pdf Pennsylvania Stormwater Best Management Practices Manual and related documents: http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/stormwatermanagement/default.htm

RHODE ISLAND

Policy Structure	The State of Rhode Island recently passed An Act Relating to Towns and Cities—Establishing the Smart Development for a Cleaner Bay Act of 2007. An updated stormwater design manual, which will incorporate these requirements, is under development. These requirements will apply to any development previously subject to stormwater review, including development within MS4s under NPDES Phase I and II jurisdiction. In addition, the Coastal Resources Protection Council administers the Special Area Management Plans (SAMPs) that include more stringent stormwater and buffer requirements. The Urban Coastal Greenways Policy applies to the cities of Cranston, East Providence, Pawtucket, and Providence.
Impervious Surface	N/A
Infiltration	Maintain pre-development groundwater recharge and infiltration on site to the MEP.
Innovative Measures	Typical of other states
LID Requirements	The state requires that low impact-design techniques be used as the primary method of stormwater control to the MEP. Under the Urban Coastal Greenways Policy, development plans must be reviewed by a professional who has completed an LID training course and has received an LID Master Design Certificate. The draft stormwater manual sets Minimum Standard 1: Nonstructural and Small-Scale Upland Management, which states that nonstructural and small-scale upland management designs must be used to the fullest extent practicable in order to reduce the generation of the water quality volume. It also requires that structural control use be avoided where the water quality volume cannot be managed via nonstructural and small-scale practices (i.e., pollution hot spots).
LID Incentives	The volume required for the permanent pool of a wet pond can be reduced if rooftop runoff is infiltrated on-site. This procedure allows rooftops to be subtracted from total impervious areas, thus reducing the total amount of runoff routed to the permanent pool. Infiltration of rooftop runoff should be restricted to residential buildings or other buildings that do not have air pollution, venting, cooling, or heating equipment located on the roof.
Redevelopment	Redevelopment appears to be treated the same as new development, where only the increase in disturbance and imperviousness is required to be treated.
Links to Language	An Act Relating to Towns and Cities—Establishing the Smart Development for a Cleaner Bay Act of 2007: http://www.rilin.state.ri.us/BillText07/SenateText07/S0808Aaa.pdf Draft Rhode Island Stormwater Design & Installation Standards Manual, Chapter 4—Nonstructural and Small-Scale Upland Management: http://www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/pdfs/upman.pdf

VERMONT

Policy Structure	Vermont Statues Annotated (VSA) Title 10 § 1264 authorizes the creation of state stormwater permits. Chapters 18 and 22 of the Environment Protection Rules regulate the discharge of post-construction stormwater. State post-construction stormwater standards are specified in one of two general permits depending upon the condition of the receiving water – General Permits 3-9010 and 3-9015. The Vermont Stormwater Management Manual Volumes 1 and 2 describe regulatory requirements and technical guidance, respectively.
Impervious Surface	For new development and applicable redevelopment, either (a) the existing impervious surface shall be reduced by 20% or (b) a stormwater treatment system shall be designed to capture and treat 20% of the water quality volume from the existing impervious area or (c) a combination of (a) and (b) can be used such that, when combined, a minimum 20% reduction/treatment is achieved.
Infiltration	According to the Stormwater Manual Volume I, the average annual recharge rate for the prevailing hydrologic soil group(s) shall be maintained in order to preserve existing water table elevations.
Innovative Measures	Typical of other states
LID Requirements	N/A
LID Incentives	Stormwater credits are offered for the use of: • Natural Area Conservation • Disconnection of Rooftop Runoff • Disconnection of Non-Rooftop Runoff • Stream Buffers • Grass Channels • Environmentally Sensitive Rural Development
Redevelopment	Impervious surface and water quality treatment requirements apply to the portion of existing impervious surface that is redeveloped; the existing impervious surface only needs to comply with any previous permit requirements.
Links to Language	Stormwater Management Rule for Unimpaired Waters: http://www.vtwaterquality.org/stormwater/docs/sw_rule-unimpaired.pdf Stormwater Management Rule for Impaired Waters: http://www.vtwaterquality.org/stormwater/docs/sw_rule-impaired.pdf The Vermont Stormwater Management Manual Volume 1: http://www.anr.state.vt.us/dec/waterq/stormwater/docs/sw_manual-vol1.pdf

VIRGINIA

Policy Structure	Stormwater management standards can be found at erosion and sediment control law [Title 10.1, Chapter 5, Article 4] and regulations [4VAC50-30] as amended by the Virginia General Assembly in July 2006. These rules establish the requirements for the state and local erosion and sediment control and storm water management programs that regulate land-disturbing activity greater than 10,000 square feet. The Chesapeake Bay Preservation Area Designation and Management Regulations [9 VAC 10-20-10 et seq.] (also known as the Bay Act), adopted in 1990 and amended in December 2001, regulate development impacts, including storm water management, within the Chesapeake Bay watershed. The Virginia Department of Environmental Quality and Department of Conservation and Recreation jointly administer the regulations. The Department of Conservation and Recreation administers the resource protection and management area regulations.

VIRGINIA

Impervious Surface	Performance-based criteria are based on a site's pre-project impervious cover compared to the average impervious cover for that land use. More stringent pollutant controls are required if the proposed development is expected to increase impervious cover over the average cover for that land use. Development is required to minimize impervious area in Resource Management Areas.
Infiltration	N/A
Innovative Measures	Typical of other states
LID Requirements	§ 10.1-603.4 of The Virginia Soil and Water Conservation Board is required by state law to: "Encourage low impact development designs, regional and watershed approaches, and nonstructural means for controlling stormwater."
LID Incentives	N/A
Redevelopment	Redevelopment is allowed in Resource Protection Areas, but no increase in imperious cover is allowed. Under Virginia Stormwater Management Regulations, local governments must enact ordinances that require redevelopment, as well as new development, to control and treat stormwater runoff beyond pre-development conditions.
Links to Language	Virginia Stormwater Management Law: http://www.dcr.virginia.gov/soil_&_water/documents/vaswmlaw.pdf Virginia Stormwater Management Regulations: http://www.dcr.virginia.gov/soil_&_water/documents/vaswmregs.pdf Virginia Stormwater Management Handbook: http://www.dcr.virginia.gov/soil_&_water/stormwat.shtml#pubs

WISCONSIN

Policy Structure	State Statute 281.16 (2) (a) authorizes the Wisconsin Department of Natural Resources (WDNR) to promulgate water quality performance standards. Under this law, WDNR established Chapter NR 151 of the state code, which contains runoff pollutant performance standards.
Impervious Surface	N/A
Infiltration	Requirements to infiltrate to the MEP a percentage of the predevelopment runoff volume; Residential 90%; Non-residential 60% or 10% of the 2-yr, 24-hour event. As a cap, no more than 2% of the site is required as an effective infiltration area. Some exemptions apply.
Innovative Measures	Typical of other states
LID Requirements	N/A
LID Incentives	N/A
Redevelopment	For all redevelopment and infill under 5 acres, BMPs are required to control to the MEP 40% of the total suspended solids that would normally run off the site based on an average annual rainfall. Infill occurring 10 or more years after Oct. 2002 is required to meet the new development standard of 80% TSS.
Links to Language	State Code Chapter NR 151—Runoff Management: http://www.legis.state.wi.us/rsb/code/nr/nr151.pdf

FEDERAL GOVERNMENT

The "Energy Independence and Security Act of 2007," which was signed into law December 19, 2007, contains a provision in Title IV, Energy Savings in Building and Industry, Subtitle C, High Performance Federal Buildings:

Sec. 438. Storm Water Runoff Requirements for Federal Development Projects.

The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

This provision requires all Federal development and redevelopment projects with a footprint above 5,000 square feet to achieve predevelopment hydrology to the "maximum extent technically feasible." This standard may differ from the MEP standard set forth in stormwater regulations.

This provision will likely result in much more focus on LID ,with more companies interested in learning how to develop and apply "design, construction, and maintenance strategies" that preserve pre-development technology, so that they can maintain existing, or obtain new, Federal government construction contracts. Also, the establishment of these requirements for Federal facilities is expected to have the effect of "mainstreaming" LID BMPs for non-federal facilities.

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN NEIGHBORHOOD DEVELOPMENT STANDARDS

The U.S. Green Building Council develops and maintains the Leadership in Energy and Environmental Design (LEED) rating systems that promote energy conservation and sustainable design within the building industry. USGBS formed a partnership with the Congress for the New Urbanism and the Natural Resources Defense Council to develop a LEED rating system at the neighborhood scale. A pilot version of the LEED for Neighborhood Development (LEED-ND) Rating System has been released by the partnership[17] that seeks to promote neighborhood designs that minimize resource consumption and pollution and achieve sustainability. The pilot program will be used to test and refine the standards before they are released for industry-wide application. Of the 238 pilot projects selected for the program, 40 projects are located in California.[18]

The ND standards are divided into four categories:

- The **Smart Location and Linkage (SLL)** category evaluates how a development's location impacts urban sprawl, resource use, and environmental impacts.
- The **Neighborhood Pattern and Design (NPD)** category evaluates the layout of the neighborhood and the extent that each use provides social and environmental benefits.
- The **Green Construction and Technology (GTC)** category evaluates the construction process and the design of the structures within the neighborhood, seeking to reduce environmental contamination and site disturbance while promoting resource conservation and energy efficiency.
- **Innovation and Design Process (IDP)** category provides credit to neighborhood projects that achieve greater innovation than what is required or credited in the rating system. This category also gives credit for the involvement of an accredited professional.

Under each category, the rating system specifies prerequisites and credits. Prerequisites are required before an applicant is eligible for the certification, and credits provide the applicant with points towards different certification levels (certification, silver, gold, and platinum).

[17] USGBC, CNU, and NRDC. 2007. Pilot Version LEED for Neighborhood Development Rating System. A Partnership of the U.S. Green Building Council (USGBS), the Congress for New Urbanism (CNU), and the Natural Resources Defense Council (NRDC). http://www.usgbc.org/DisplayPage.aspx?CMSPageID=148.

[18] USGBC, CNU, and NRDC. 2007b. LEED for Neighborhood Development Registered Pilot Project List. A Partnership of the U.S. Green Building Council (USGBS), the Congress for New Urbanism (CNU), and the Natural Resources Defense Council (NRDC). https://www.usgbc.org/ShowFile.aspx?DocumentID=2960.

Standards that Directly Contribute to Stormwater Management

The ND standards contain a number of prerequisites and credits related to stormwater management. The following paragraphs describe each prerequisite or credit in more detail.

- **SLL Prerequisite 4: Wetland and Waterbody Conservation:** An applicant meets this standard if the site includes no land within 100 feet of wetlands or waterbodies. The standard can also be met if 1) the site is located on a previously developed site; and 2) any wetland or waterbody impacts are compensated through on-site or off-site restoration. For sites that are not previously developed and contain wetlands or waterbodies, the rating system limits the percent of on-site impacts allowed according to the street grid density of the development. The applicant is also required to retain at least 90 percent of the average annual rainfall or 1 inch of rainfall from 75 percent of the development footprint within the impacted area. Retention methods must infiltrate, reuse, or provide for the evapotranspiration of the rainfall amount. This standard contributes to stormwater management by reducing the impact to the natural hydrology and water quality functions of a development site.
- **SLL Prerequisite 6: Floodplain Avoidance:** Similar to the above prerequisite, the Floodplain Avoidance standard is met if the site does not contain any land within the 100-year floodplain. The standard is also met if the site is located on an infill or previously developed site and the National Flood Insurance Program (NFIP) requirements are followed when developing land within the 100-year floodplain. For sites that do not meet these conditions, the standard can only be met if land within the 100-year floodplain is not developed. This standard contributes to stormwater management by reducing the impact to the natural hydrology and water quality functions of a development site.
- **SLL Credit 8: Steep Slope Protection:** This standard provides credit for either avoiding development on steep slopes or restoring vegetation to previously developed steep slopes. Credit is provided according the severity of the slopes and the proportion of steeped sloped land that is protected or restored. An exemption is included for steep slopes that are isolated by more than 30 feet from other steeply sloped areas. This standard contributes to stormwater management by reducing the runoff and erosion generated on steep slopes during storm events.
- **SLL Credits 9, 10 and 11: Habitat or Wetland Conservation:** These standards provide credits for habitat or wetland conservation on the development site. To receive credit under SLL Credit 9, the applicant must inquire with a state's Natural Heritage program and other wildlife or fish agencies to determine whether significant habitat exists on the development site. The applicant must protect in perpetuity the habitat and an appropriate buffer, as delineated by a qualified professional. For previously developed sites, the applicant can receive credit for using native plants for 90 percent of the site vegetation and refraining from the use of invasive plants. The standard also provides credit for conserving wetlands and waterbodies and planning buffers around the development footprint to protect water quality, habitat, and hydrologic functions. SLL Credit 10 provides credit for habitat or wetlands restoration on an area equal to or greater than 10 percent of the development. Invasive species removal is required to achieve credit for restoration. SLL Credit 11 provides credit for developing a long-term management plan for on-site habitat, wetlands, or waterbodies. Through the conservation of habitat and wetland areas, these standards contribute to stormwater management by preserving pervious areas, natural drainage paths, and other areas that maintain pre-development hydrology and water quality functions.
- **NPD Credit 6: Reduced Parking Footprint:** This standard provides credit for limiting surface parking and using multistory or underground parking, carpool spaces, and bicycle parking. To receive credit, the applicant must limit surface parking facilities to no more than 20 percent of the total development footprint. The intent of the credit is to reduce the negative social and environmental impacts of parking areas. This standard contributes to stormwater management through reduction of impervious surface.
- **GCT Credit 6: Minimize Site Disturbance through Site Design:** Under this standard, an applicant can receive credit for preserving, in perpetuity, undeveloped land, including tree canopy, native vegetation, and pervious surfaces. The credit award depends on the extent of pervious development on the site and the planned density of the site. This standard contributes to stormwater management by reducing the impact to the natural hydrology and water quality functions of a development site.

- **GCT Credit 7: Minimize Site Disturbance during Construction:** This standard provides credit for establishing limits of disturbance for natural areas or preserving significant trees on the site. The standard contains specific distances required for the limits of disturbance as well as the type of trees that qualify for preservation credit. This standard contributes to stormwater management by reducing the impact to the natural hydrology and water quality functions of a development site.
- **GCT Credit 9: Stormwater Management:** This standard provides credit for applicants who implement a comprehensive stormwater management plan. The plan must effectively retain a specified amount of rainfall from the project's development footprint. The rainfall amounts vary by the humidity of the watershed's climate; developments in more humid watersheds are required to retain a greater rainfall amount than more arid watersheds. The applicant can receive from 1 to 5 points depending on how much rainfall is retained. Retention methods must infiltrate, reuse, or provide for the evapotranspiration of the rainfall amount. This standard contributes to stormwater management by reducing the stormwater runoff generated by development.

Additional Standards that Contribute to Stormwater Management

In addition to the above standards, the ND rating system contains several prerequisites and credits that more directly target smart growth and air quality goals but contribute to stormwater management in the process. Many of the credits relating to smart growth may contribute to reduced impervious surface, provided that undeveloped land is conserved in the process. Several credits promote infill and brownfield development, which decreases pressure on undeveloped land and ultimately leads to reduced stormwater impacts. Several standards promote compact development, which could lead to improved stormwater management if stormwater is controlled and treated and the compact development conserves undeveloped land in other locations. The ND standards that target automobile dependency could lead to reducing transportation-related pollutant loading as well.

Appendix C: Key Elements of Progressive Ordinances

DEVELOPMENT OF STORMWATER MANAGEMENT GOALS AND OBJECTIVES

In the case study areas, often draft goals and objectives were used to help develop stormwater management criteria and craft "scenarios" to test in watershed modeling and/or pilot-project development. Local advisory groups or boards were used to help draft the preliminary goals and objectives.

Clearly, different communities have different goal and objective statements depending on local circumstances and requirements. For example, some communities may only wish to meet Phase II requirements, while others may set higher goals than state minimum requirements due to local concerns, such as drinking water supply or habitat protection. Following are examples of goals and objectives statements from several of the case study communities. Examples 1 and 2 draw on general police powers granted local governments: protect, maintain and enhance the public health, safety, and welfare. Example 3 goes further to establish a local non-degradation goal. Finally, Example 4 sets the highest goal: maintaining and improving existing water quality.

Example Goals Statements

Example 1 (modified from Town of Chapel Hill's Land Use Management Ordinance)

"The purpose of this section is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within this jurisdiction. This ordinance seeks to meet that purpose through the following objectives:"

Example 2 (from Charlotte-Mecklenburg Post-Construction Storm Water Ordinance, draft under public review)

"The purpose of this ordinance is to protect, maintain and enhance the public health, safety, environment and general welfare by establishing minimum requirements and procedures to control the adverse effects of increased post-development storm water runoff and non-point source pollution associated with new development and redevelopment. It has been determined that proper management of construction related and post-development storm water runoff will minimize damage to public and private property and infrastructure, safeguard the public health, safety, and general welfare, and protect water and aquatic resources."

Example 3 (modified from the Town of Huntersville Water Quality Ordinance)

"The purpose of this regulation is to establish stormwater management requirements and controls to prevent surface water quality degradation to the extent practicable in the streams and lakes within the Town Limits and Extraterritorial Jurisdiction of Huntersville and to protect and safeguard the general health, safety, and welfare of Huntersville's residents. This regulation seeks to meet this purpose by fulfilling the following objectives:"

Example 4 (modified from the City of Portland's Stormwater Management Ordinance)

"The purpose of this Stormwater Management Ordinance is to provide for the effective management of stormwater and drainage and to maintain and improve water quality in the watercourses and waterbodies within and leaving the City. This ordinance seeks to meet that purpose through the following policies and standards:"

Example Objectives Statements

Example 1 – City of Charlotte-Mecklenburg County (Note all municipalities within Mecklenburg County worked jointly with the County to develop a unified post-construction ordinance, which is currently under public review.)

"This ordinance seeks to meet its general purpose through the following specific objectives and means:

1. Establishing decision-making processes for development that protect the integrity of watersheds and preserve the health of water resources.
2. Requiring that new development and redevelopment maintain the pre-development hydrologic response in their post-development state as nearly as practicable for the applicable design storm in order to reduce flooding, streambank erosion, non-point and point source pollution and increases in stream temperature, and to maintain the integrity of stream channels and aquatic habitats.
3. Establishing minimum post-development storm water management standards and design criteria for the regulation and control of storm water runoff quantity and quality.
4. Establishing design and review criteria for the construction, function, and use of structural storm water control facilities that may be used to meet the minimum post-development storm water management standards.
5. Encouraging the use of better management and site design practices, such as the preservation of greenspace and other conservation areas, to the maximum extent practicable.
6. Establishing provisions for the long-term responsibility for and maintenance of structural and nonstructural storm water BMPs to ensure that they continue to function as designed, are maintained appropriately, and pose no threat to public safety.
7. Establishing administrative procedures for the submission, review, approval and disapproval of storm water management plans, for the inspection of approved projects, and to assure appropriate long-term maintenance."

Example 2 – (adapted from Town of Huntersville Water Quality Ordinance and from Town of Chapel Hill Land Use Management Ordinance)

a. "Minimize increases in storm water runoff from development or redevelopment in order to reduce flooding, siltation and streambank erosion, and maintain the integrity of stream channels;
b. Minimize increases in nonpoint source pollution caused by stormwater runoff from development or redevelopment that would otherwise degrade local water quality;
c. Minimize the total volume of surface water runoff that flows from any specific site during and following development in order to replicate pre-development hydrology to the maximum extent practicable;
d. Reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, to the extent practicable, through stormwater management controls (BMPs) and ensure that these management controls are properly maintained and pose no threat to public health or safety; and
e. Meet the requirements of the National Pollution Discharge Elimination System (NPDES) Storm Water Permit and other requirements as established by the Clean Water Act."

Example 3 – Policies and Standards (adapted from City Code, City of Portland, Oregon)

The City of Portland code lists policies rather than objectives.

a. "Stormwater shall be managed as close as is practicable to development sites, and stormwater management shall avoid a net negative impact on nearby streams, wetlands, groundwater, and

other waterbodies. All local, state, and federal permit requirements related to implementation of stormwater management facilities must be met by the owner/operator prior to facility use. Surface water discharges from onsite facilities shall be conveyed via an approved drainage facility.

b. The quality of stormwater leaving the site after development shall be equal to or better than the quality of stormwater leaving the site before development, as much as is practicable.

c. The quantity of stormwater leaving the site after development shall be equal to or less than the quantity of stormwater leaving the site before development, as much as is practicable."

As shown in the above examples, the goal or purpose statement is very general. The objectives provide more detail on what implementation of the ordinance is intended to accomplish. The objectives can be regulatory based (e.g., meet Phase II requirements), resource based (e.g., minimize increases in nonpoint source pollution), or both. Importantly, the goals and objectives set the stage for selecting appropriate performance standards and criteria, and for encouraging LID.

PERFORMANCE CRITERIA ENCOURAGING LID TECHNIQUES

The examples below reflect key elements of progressive stormwater programs' approaches to using performance criteria to encourage LID.

Example 1 – Huntersville, North Carolina's Performance Standards

The Town of Huntersville is a developing community of about 35,000 residents and part of a regional commuter rail system planned for the metropolitan area. The town has experienced a rapid conversion from a farming community to a developing residential and commercial area. In February 2002, The Town of Huntersville adopted a moratorium on the approval of new major development plans. The moratorium allowed the town to focus on writing zoning ordinance amendments that would protect the Town's rural character and open space while allowing for high density and mixed-use development in centralized locations. Huntersville's updated zoning ordinance established 15 zoning districts.

Huntersville protects open space in the rural residential, transitional residential, and traditional neighborhood-rural districts. In these districts, permitted density depends on the amount of open space preserved. The transitional zoning district doubles the density allowed per open space percentage compared to the rural districts, but a minimum of 25 percent open space is required

The updated ordinance provides incentives for developers to dedicate permanent conservation easements. Termed conservation subdivisions, these developments will preserve the rural appearance of the land when viewed from public roads and adjacent properties. In turn, the developments are exempt from lot frontage, sidewalk, planting, and other requirements. The preservation of existing, mature trees is emphasized in the conservation easement provisions.

The Huntersville zoning districts include several mixed-use and residential districts designed to encourage quality of life and convenient access to employment and services. These districts include the Neighborhood Residential, Neighborhood Center, Town Center, and Transit-Oriented districts. Automobile-oriented and industrial developments are restricted to other zoning districts so that the Town can develop pedestrian-friendly town and neighborhood centers. These zoning districts were designed to encourage convenient walking distances between residential and commercial uses. Three zones allowing varying development intensity were designated (see Figure A-1).

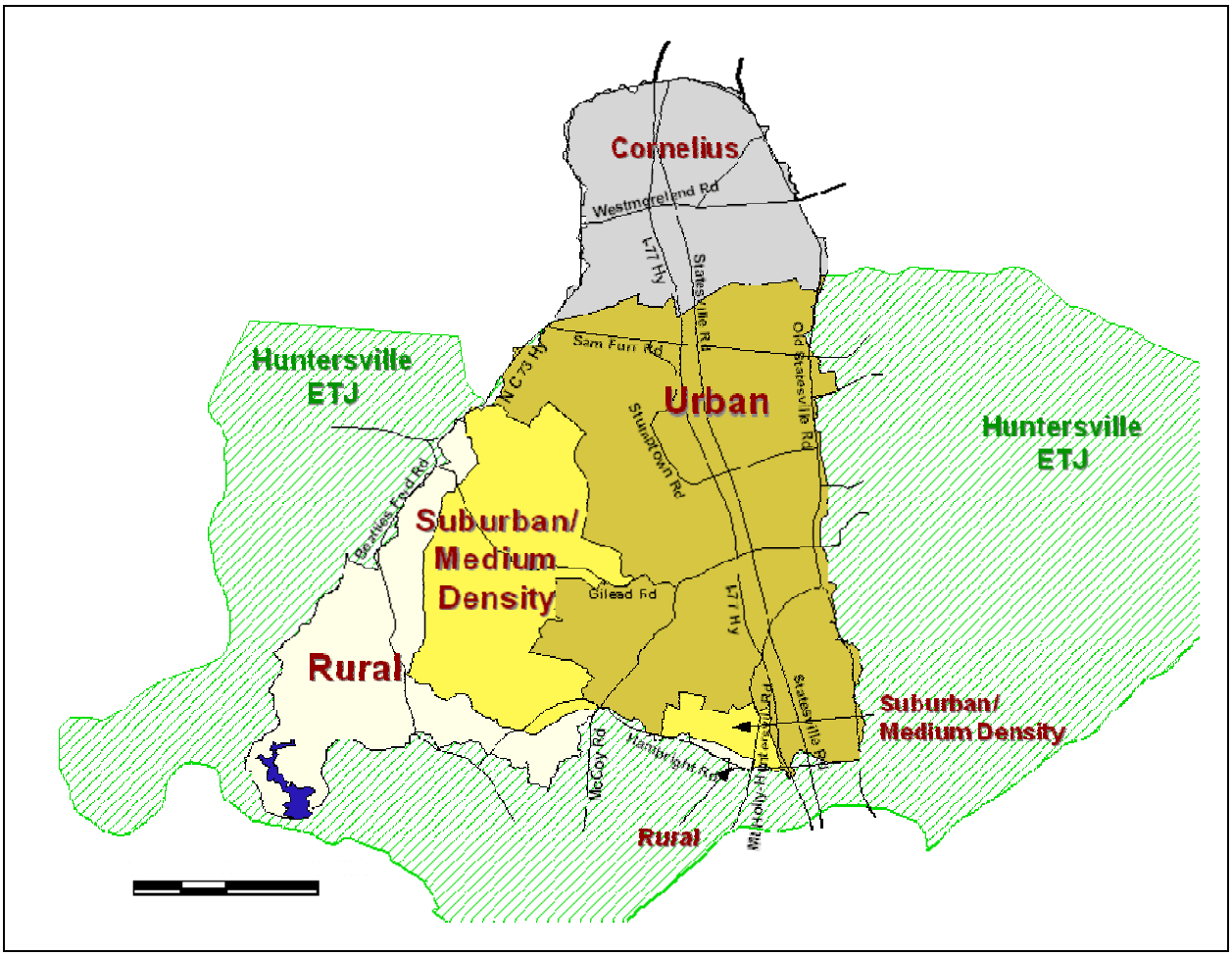

Figure A-1. Town of Huntersville's Development Zones

Huntersville included water quality measures in its ordinance, and adopted a water quality goal of no future degradation. The Town analyzed the water quality and hydrology benefits of alternative performance standards as well as the estimated cost to the landowner or developer in meeting the performance criteria and to build understanding about the cost implications of adopting more protective stormwater requirements in the Town's Ordinance. After that analysis, the Town adopted the following performance standards and required the use of LID in meeting these standards.

a. "All stormwater treatment systems used to meet these performance criteria shall be designed to achieve average annual 85 percent Total Suspended Solids (TSS) removal for the developed area of a site. Areas designated as open space that are not developed do not require stormwater treatment. All sites must employ LID practices to control and treat runoff from the first inch of rainfall.

b. LID practices or a combination of LID practices and conventional stormwater management practices shall be used to control and treat the increase in stormwater runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the 2-yr frequency, 24-hr duration storm event in the Rural and Transitional Zoning Districts. All other zoning districts shall meet this standard for the 1-yr frequency, 24-hr duration event.

c. Where any stormwater BMP employs the use of a temporary water quality storage pool as a part of the treatment system, the drawdown time shall be a minimum of 48 hours and a maximum of 120 hours.

d. Peak stormwater runoff rates shall be controlled for all development above 12 percent imperviousness (for the 2-yr, 24-hr and the 10-yr, 24-hr storm events). The emergency overflow and outlet works shall be capable of safely passing a discharge with a minimum recurrence frequency of 50 years.

e. No one BMP shall receive runoff from an area greater than 5 acres."

The town's Open Space performance standards are shown in Table A-1. Note that both the open space and water quality performance standards vary by planning district to meet the Town's overall smart growth objectives.

To ease overall administration and to ensure accountability, the Town developed a Stormwater BMP Design Manual and a Site Evaluation Tool that developers are required to use in project design and documenting compliance with the performance standards. (See Program Administration for more information on the Site Evaluation Tool).

Table A-1. Open Space and Density Requirements for Huntersville's Rural Residential and Traditional Neighborhood-Rural Zoning Districts

Amount of Open Space Provided	Density Permitted
0% unless tract is within a proposed greenway in which case the greenway shall be designated as open space	0.33 units per Adjusted Tract Acreage
25% - 29.9% Open Space	0.4 units per Adjusted Tract Acreage
30% - 34.9% Open Space	0.6 units per Adjusted Tract Acreage
35% - 39.9% Open Space	0.8 units per Adjusted Tract Acreage
40% - 44.9% Open Space	1.0 unit per Adjusted Tract Acreage
45%+ Open Space	1.2 units per Adjusted Tract Acreage

The performance standards required by the Town of Chapel Hill are similar to the Huntersville standards, with the following exceptions: Chapel Hill requires volume control for the 2-yr, 24-hr storm event throughout its jurisdiction. The stormwater runoff rate is controlled for the 1-, 2-, and 25-yr, 24-hr storm event (rather than the 2-yr and 10-yr storm events). The Town of Chapel Hill encourages rather than requires LID to meet its performance standards.

Each of the programs described above stipulates certain activities or types of development that are exempt from the guidelines and regulations described above. Those regulatory exemptions are as follows:

Town of Huntersville: Any new development, redevelopment or expansions that include the creation or addition of less than 5,000 sq ft of new imperviousness.

Town of Chapel Hill: Single family and two family developments and redevelopments that do not disturb more than 5,000 sq ft of land area, provided they are not part of a larger common development plan, are exempted.

Example 2 – City of Charlotte, NC and Mecklenburg County

The Charlotte-Mecklenburg Post-Construction Storm Water Ordinance (draft under public review) divides the County into five districts, each having unique performance standards. As discussed below, the performance standards necessitate the use of LID in order to meet the standards on site.

One of the first items agreed to by the stakeholders' group helping to guide development of the post-construction ordinance was the need to divide Mecklenburg County into districts. It was decided that a one size fits all approach was not appropriate, but instead districts should be drawn based upon need for protection and other criteria. An example of one of the criteria used was the presence of a federally endangered species in Goose Creek District and the Yadkin-Southeast Catawba District, which resulted in more stringent controls on new development. Areas with a very high percentage of existing development (i.e., the City of Charlotte) resulted in less stringent controls in new development. Figure A-2 shows the configuration of the districts, which were drawn along watershed boundaries. Other factors, such as close proximity to drinking water reservoirs, resulted in more stringent levels of control. Recognizing that certain areas in Mecklenburg County had unique characteristics and needs, the stakeholder group then debated basic criteria that would provide the foundation of the ordinance and meet the goals and objectives. The main categories for new performance standards were:

- Structural Water Quality BMPs: These controls are intended to remove water quality pollutants from stormwater runoff. The ordinance targets Total Phosphorus (TP) and Total Suspended Solids (TSS).
- Stream Buffers: These controls require that areas directly adjacent to streams be set aside as natural areas. Limited disturbance many be allowed depending on the distance from the stream.
- Volume and Peak Control: The controls require that the additional stormwater runoff volume and peak flow rates generated by land development activities be held back and released slowly over time so as to not cause downstream erosion and flooding.
- Open Space Requirements: These controls require that a certain percentage of a developed site be preserved as undisturbed area unless mitigation is provided.

Each District has a unique combination of these controls, depending on the level of protection needed. (See Table A-2, Summary of Performance Criteria for the Charlotte-Mecklenburg Post Construction Ordinance). It is important to note, however, that the performance standard for phosphorus removal (70 percent removal for runoff from the first inch of rainfall) applies to 4 of the 5 districts and necessitates the use of a treatment train approach using LID techniques in order to meet this standard onsite. The TP performance standard was based on an evaluation of streams in the County and loading rates needed to support designated uses (including healthy aquatic communities).

Because meeting the TP performance standard can be quite expensive for developments with high imperviousness (much more expensive on a cost per pound removed basis than developments with lower imperviousness), the Ordinance allows a flexible "buy down" option from 70 percent TP removal to 50 percent removal, and allows the City or County to use the revenue to construct BMP retrofits offsite to "make up the difference" in phosphorus loading. To reduce the cost of meeting the open space requirements, the Ordinance has offsite mitigation and onsite mitigation techniques, as well as payment-in-lieu.

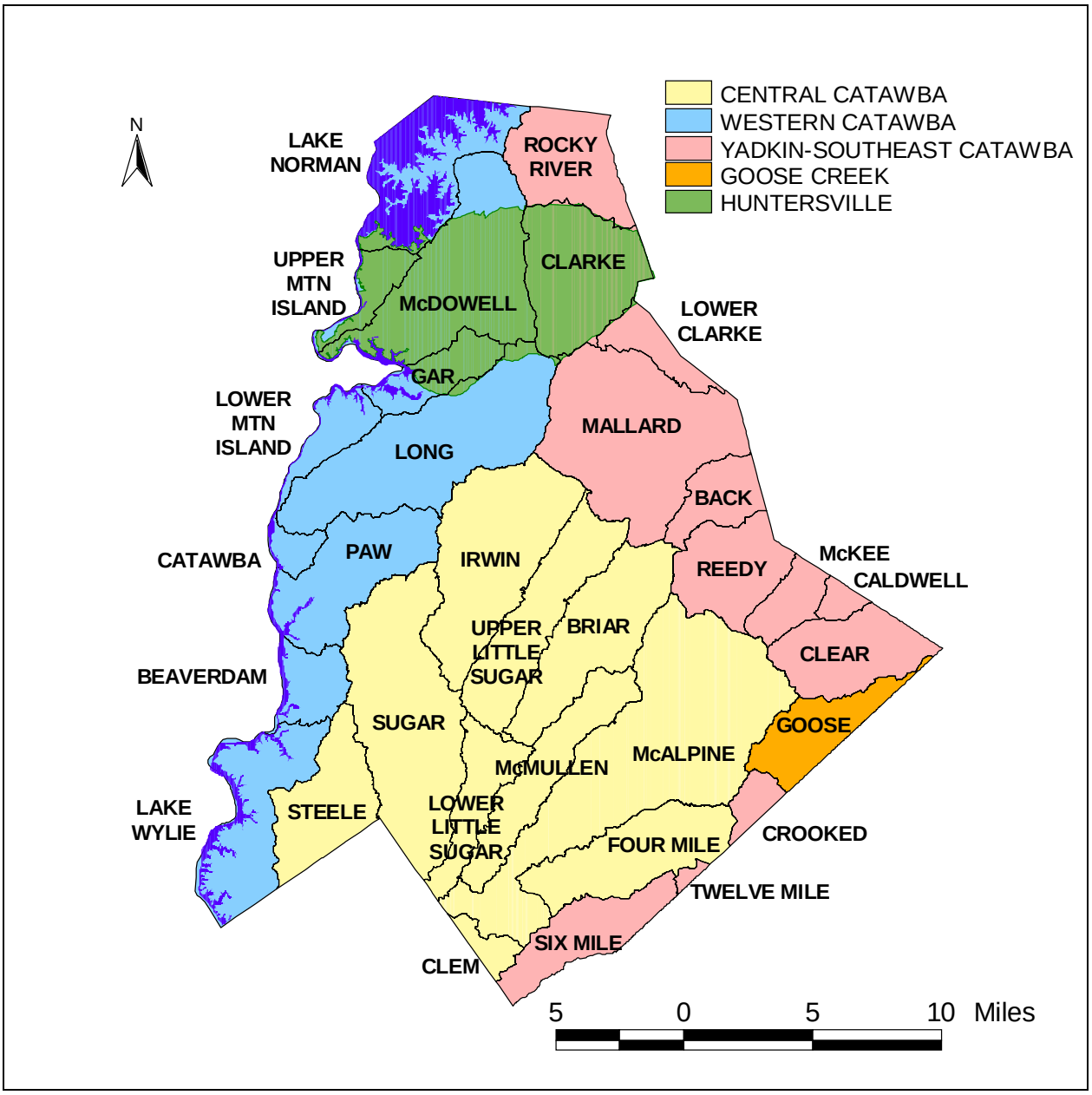

Figure A-2. Watershed Districts for Charlotte Mecklenburg Post Construction Ordinance

Table A-2. Summary of Performance Criteria for the Post-Construction Ordinance

Watershed District	Structural Water Quality BMPs	Buffers[(1)]	Volume & Peak Control	Open Space Requirements
Central Catawba	>24% BUA requires 85% TSS removal for runoff from 1st inch of rainfall; LID optional	30 ft. no build zone on intermittent and perennial streams draining < 50 acres 35 ft. (2 zones) on perennial streams draining <300 acres 50 ft (3 zones) on streams draining ≥300 acres 100 ft + 50% of floodfringe on streams draining ≥640 acres	Volume (Commercial & Residential): >24% BUA control entire volume for 1-yr, 24-hr storm Peak for Residential: >24% BUA perform a downstream flood analysis to determine whether peak control is needed and if so, for what level of storm frequency (i.e., 10, 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms Peak for Commercial: >24% BUA control the peak for the 10-yr, 6-hr storm **AND** perform a downstream flood analysis to determine whether additional peak control is needed and if so, for what level of storm frequency (i.e., 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms	Open space is undisturbed area <24% BUA = 25% open space ≥24% and <50% BUA = 17.5% open space ≥50% BUA = 10% open space
Western Catawba	>12% BUA requires 85% TSS and 70% TP removal for runoff from 1st inch of rainfall; LID optional; BUA area caps apply in water supply watersheds	30 ft. no build zone on intermittent and perennial streams draining < 50 acres 35 ft. (2 zones) on perennial streams draining <300 acres 50 ft (3 zones) on streams draining ≥300 acres 100 ft + 50% of floodfringe on streams draining ≥640 acres	Volume (Commercial & Residential): >12% BUA control entire volume for 1-yr, 24-hr storm Peak for Residential: >12% BUA perform a downstream flood analysis to determine whether peak control is needed and if so, for what level of storm frequency (i.e., 10, 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms Peak for Commercial: >12% BUA control the peak for the 10-yr, 6-hr storm **AND** perform a downstream flood analysis to determine whether additional peak control is needed and if so, for what level of storm frequency (i.e., 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms	Same as Central Catawba
Yadkin-Southeast Catawba	>10% BUA requires 85% TSS and 70% TP removal for runoff from 1st inch of rainfall; LID optional	50 ft undisturbed forested buffers on intermittent and perennial streams draining < 50 acres 100 ft undisturbed forested buffers plus remainder of floodplain on perennial and intermittent streams draining	Volume (Commercial & Residential): >10% BUA control entire volume for 1-yr, 24-hr storm Peak for Residential: >10% BUA perform a downstream flood analysis to determine whether peak control is needed and if so, for what level of storm frequency (i.e., 10, 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms	Same as Central Catawba

Table A-2. Summary of Performance Criteria for the Post-Construction Ordinance

Watershed District	Structural Water Quality BMPs	Buffers[1]	Volume & Peak Control	Open Space Requirements
		≥ 50 acres	Peak for Commercial: >10% BUA control the peak for the 10-yr, 6-hr storm **AND** perform a downstream flood analysis to determine whether additional peak control is needed and if so, for what level of storm frequency (i.e., 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms	
Goose Creek	>6% BUA requires 85% TSS and 70% TP removal for runoff from 1st inch of rainfall; LID optional; 24% BUA cap on single family residential, 50% on all other development	100 ft. undisturbed forested buffer on perennial and intermittent streams draining < 50 acres 200 ft. undisturbed forested buffer plus remainder of floodplain on perennial and intermittent streams draining ≥ 50 acres	Volume (Commercial & Residential): >6% BUA control entire volume for 1-yr, 24-hr storm Peak for Residential: >6% BUA perform a downstream flood analysis to determine whether peak control is needed and if so, for what level of storm frequency (i.e., 10, 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms Peak for Commercial: >6% BUA control the peak for the 10-yr, 6-hr storm **AND** perform a downstream flood analysis to determine whether additional peak control is needed and if so, for what level of storm frequency (i.e., 25, 50 or 100-yr, 6-hr) **OR** if a downstream analysis is not performed control the peak for the 10-yr and 25-yr, 6-hr storms	Same as Central Catawba
Huntersville	For developments with greater than or equal to 5,000 square feet of BUA, install LID practices to achieve 85% TSS removal for runoff from the 1st inch of rainfall; BUA area caps apply in water supply watersheds	30 ft. no build zone on intermittent and perennial streams draining < 50 acres[2] 35 ft. (2 zones) on perennial and intermittent streams draining <300 acres 50 ft. (3 zones) on streams draining ≥300 acres 100 ft. or entire floodplain on streams draining ≥640 acres	Volume: For developments with greater than or equal to 5,000 square feet of BUA, control increase in volume for 1-yr, 24-hr storm or 2-yr, 24-hr storm, depending on zoning district Peak: >12% BUA control 2-yr & 10-yr, 24-hr storm	Varies by zoning district

[1] Water supply watershed buffer requirements apply in the Western and Huntersville districts. These buffers are sometimes more restrictive than the S.W.I.M. buffer requirements, in which case the watershed buffers would apply.

[2] Will require a change to the existing Huntersville Ordinance in order to comply with minimum Phase II Post-Construction rules.

Rockdale County, GA combines the Charlotte-Mecklenburg County and Town of Huntersville approaches. Based on its watershed study, the county established performance standards for new development by planning district:

- *Urban Area.* 56 percent removal TP, 78 percent removal TSS, 57 percent removal Copper. These standards must be met by new developments in the City of Conyers (existing municipal jurisdiction and planned, long-term sewer service area).
- *Suburban/Rural Area*. 52 percent removal TP, 72 percent removal TSS, 51 percent removal Copper. These standards must be met by new developments in the county jurisdiction, excluding the drinking water supply watershed and urban area.
- *Rural Residential (Water Supply Watershed) Area.* 1 unit / 3 acres.

Rockdale County encourages LID in meeting these standards.

Each of the programs described above stipulates certain activities or types of development that are exempt from the guidelines and regulations described above. Those regulatory exemptions are as follows:

- *Charlotte-Mecklenburg, NC.* Residential development that cumulatively disturbs less than one acre and cumulatively creates less than 24% built upon area based on lot size or the lot is less than 20,000 square feet; commercial and industrial development that cumulatively disturbs less than one acre and cumulatively creates less than 24% built upon area based on lot size or the lot is less than 20,000 square feet; redevelopment that disturbs less than 20,000 square feet, does not decrease existing stormwater controls, and renovation costs do not exceed 100% of the tax value of the property; common law vested right established.
- *Rockdale County, GA.* Any development or redevelopment less than 7 percent imperviousness is exempted from enhanced volume control. Otherwise, GA Phase II stormwater control thresholds apply.

Example 3 - Portland, Oregon

The City of Portland's Sewer Development Services Administrative Rules require that the City's Bureau of Environmental Services (BES) review building permits during building plan reviews for compliance with the City's Stormwater Management Manual. Adopted in September 2004, the Stormwater Manual has the following performance criteria.

"The quality of stormwater leaving the site after development shall be equal to or better than the quality of stormwater leaving the site before development, as much as is practicable, based on the following criteria:

a. Water quality control facilities required for development shall be designed, installed and maintained in accordance with the Stormwater Management Manual, which is based on achieving at least 70 percent removal of the Total Suspended Solids from the flow entering the facility for the design storm specified in the Stormwater Management Manual.

b. Land use activities of particular concern as pollution sources shall be required to implement additional pollution controls, including, but not limited to, those management practices specified in the Stormwater Management Manual.

c. Development in a watershed that drains to streams with established Total Maximum Daily Load limitations, as provided under the Federal Clean Water Act, Oregon Law, Administrative Rules, and other legal mechanisms shall assure that water quality control facilities meet the requirements for pollutants of concern, as stated in the Stormwater Management Manual."

d. Note: additional criteria follow related to implementing these criteria onsite or on an offsite facility. Otherwise, there is an option for payment in lieu.

"The quantity of stormwater leaving the site after development shall be equal to or less than the quantity of stormwater leaving the site before development, as much as is practicable, based on the following criteria:

a. Development shall mitigate all project impervious surfaces through retention and onsite infiltration to the maximum extent practicable. Where onsite retention is not possible, development shall detain stormwater through a combination of provisions that prevent an increased rate of flow leaving the site during a range of storm frequencies as specified in the Stormwater Management Manual.

b. The Director may exempt areas of the City from the requirement a. above if flow control is not needed or desirable and if stormwater is discharged to a large waterbody directly through a private outfall or if stormwater is discharged to a waterbody directly through a separated public storm sewer having adequate capacity to convey the additional flow.

c. Any development that contributes discharge to a tributary to the Willamette River shall design facilities such that the rate of flow discharging from water quantity control facilities for up to the two-year storm does not lengthen the period of time the channel sustains erosion-causing flows, as determined by the Bureau. (Note: This criterion is required due to evidence of excessive stream bank erosion and channel erosion in most tributary streams in Portland.)

d. Facilities shall be designed to safely convey the less frequent, higher flows through or around facilities without damage.

"Note: additional criteria follow related to implementing these criteria onsite or on an offsite facility. Otherwise, there is an option for payment in lieu. The City also provided incentives for reduction of stormwater runoff and impervious area through stormwater discounts.

"Regulatory Exemptions:

"Developments less than 15,000 sq.ft. are exempted from detention (devices with orifices); development less than 500 sq.ft. is exempted from retention."

The City is currently revising its Stormwater Management Manual and will release the updated manual in late fall 2007. The revisions are intended to clarify the intent of the current standards.

Example 4 – Grand Rapids, Michigan

The city of Grand Rapids, Michigan is introducing an analytic method for calculating the amount of stormwater impacts prevented by installation of higher floor area ratios. The rationale for the policy is that, although higher density development will have a greater percentage of impervious area per acre of development, the total impervious area per residence actually will be less. This overall watershed benefit is typically not recognized in site level hydrology assessments.

The runoff reduction of a higher density project is estimated by subtracting from one, the ratio of the site's actual impervious area (AIsite) divided by the impervious area (AiLD) of a low density development having the same number of units, and converted to a percentage.

Percent Runoff Reduction = (1 – AIsite / AiLD) x 100%

The city established a performance standard of 80 percent reduction of runoff based on the performance of a vegetated roof. The city then used the same 80 percent (80%) runoff reduction as the threshold for the granting of a waiver for high density developments. The city evaluated the typical impervious surface coverage of lower density development, as shown in 0.

Table A-3. Typical Impervious Area Values for Low Density Development Types

Low Density Development Type	Average Impervious Area	Development Unit
Residential	4,700 square feet	Residence
Parking Lot	275 square feet	Park-Loading Space
Office/Commercial	1 square foot	Gross Floor Area

The analysis showed that the reduction rates allow a waiver when the follow intensity is met:

- Residential projects – 38 units/acre (compared to 5 units per acre as the low density complement)
- Parking – 744 spaces per acre or a 5-deck or higher parking structure
- Office/Commercial – Floor area ratio of 5 floors or higher

Note that the analysis did not take into account related offsite public impervious surfaces such as sidewalks, access lanes and street frontage. Because higher density development projects have smaller frontage lengths, the roadway length serving the site is less (Lemoine, to be published October 2007).

Example 5 - San Jose, California

In a 2001 Order to its co-permittees, the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) modified its C.3. regulatory requirements related to new and redevelopment. (The C.3 requirements are contained in the San Francisco Regional Water Quality Board's permit and deal with stormwater treatment).

The 2001 Order required changes to the Urban Runoff Management Plan, including some of the following elements:

- *Performance Standard Implementation*. Use planning and outreach programs to help implement the new requirements.
- *Development Project Approval Process.* Modify project review processes to incorporate new requirements. The order recommended incorporation of :
  - *Site design measures.* Address the generation of excess impervious surface coverage through site and neighborhood planning. Examples cited in the 2001 Order include minimizing land disturbance, minimizing impervious surfaces (e.g., roadway width, driveway area), minimum-impact street design (e.g., neo-traditional street design standards), and parking lot design standards.
  - *Source control measures.* Prevent stormwater pollution by mitigating pollutant loading from certain uses, such as restaurants, automobile services, and landscaping.
  - *Treatment measures.* Integrate measures into site and development plans to infiltrate or filter stormwater.
- *Limitation on Increase of Peak Stormwater Runoff Discharge Rates.* Hydrograph Modification Management Plans (HMMP) was introduced to limit discharge rates. The 2001 Order recognized that certain projects, such as transit villages, may not be able to meet all of the performance standards, but since most transit villages occur in already-developed areas, the redevelopment would be unlikely to change the stormwater characteristics of the site.
- *Waiver Based on Impracticability and Compensatory Mitigation.* The 2001 Order requires that the co-permittees establish a definition for impracticability or infeasibility, and a process to

decide which alternative compliance measures could be incorporated into the site design or decision-approval process for new development and significant redevelopment projects.

- *Update General Plans.* The order recommends looking at large scale plans for opportunities to minimize the impacts of stormwater runoff at the regional or watershed scale.

In response to the revised permit, the city of San Jose sought to incorporate the new guidance into a local stormwater ordinance that would work in concert with other rules and its long-term Visioning Plan (the 2020 Plan), as well as other smart growth initiatives.

San Jose developed rules specifying that all new and redevelopment projects had to implement Post-Construction Best Management Practices (BMPs) and Treatment Control Measures (TCMs) to the maximum extent practicable. San Jose structured its policy so that deviations from the standard requirements could be established through a finding of impracticality. San Jose's policy includes some of the more common challenges, such as soil type or legacy pollutants. The city echoed the regional policy of favoring landscape-based controls, such as biofiltering and swales. However, the city also recognized some urban areas with site constraints can make landscaped-based controls expensive or impossible for the types of projects that deliver a range of economic, housing and transportation benefits.

The San Jose policy allows flexibility and several alternative measures that complement smart growth projects. First, a project can participate in a regional or shared TCM. Instead of requiring each and every project to address its own stormwater onsite, a shared TCM can lower costs and make more efficient use of land in urban areas. The city also established a category of projects called "Water Quality Benefit Projects." According to the policy:

> "Water Quality Benefit Project – In its discretion, the City may find that Smart Growth Projects provide equivalent water quality benefit. For other projects the City may find equivalent stormwater benefits where the project sponsor provides project and/or environmental documentation showing the development of the site itself, the nature of the site design, its location in the watershed, and/or proposed change in use protects/enhances water quality."

Further, the city defined "Smart Growth Projects" as a project meeting one or more of the following criteria:

a. Significant Redevelopment Project within the Urban Core

b. Low-income, moderate income, or senior housing Development Project, meeting one of the criteria listed in other sections of the city's code

c. Brownfields Projects.

For more information, see the Santa Clara Valley Urban Runoff Pollution Prevention Program (http://www.scvurppp.org/). Also, in 2007, SCVURPPP issued an update of the Guidelines of Site Design Examples. The guidebook presents examples of built projects, BMPs and a description of BMP design. See http://www.scvurppp-w2k.com/pdfs/0607/SC_Site_Design_Manual_Final_0207.pdf . The San Jose 2020 General Plan can be found at http://www.sanjoseca.gov/planning/gp/2020_text/index_htm.htm.

Example 5 – Palo Alto, California

Within the Zoning Chapter related to Off Street Parking and Loading Regulations, the city has adopted the following language:

> "Automobile and bicycle parking requirements prescribed by this chapter may be adjusted by the director of planning and community environment in the following instances and in accord with the prescribed limitations, when in his/her opinion such adjustment will be in accord with the purposes of this chapter and will not create undue

> impact on existing or potential uses adjoining the site or in the general vicinity. (f) Transportation and Parking Alternatives. Upon demonstration to the director of planning and community environment that effective alternatives to automobile access are in effect, the director of planning and community environment may defer by not more than twenty percent the parking requirement otherwise prescribed for any use, or combination of uses on the same or adjoining sites, to an extent commensurate with the permanence, effectiveness, and the demonstrated reduction of off-street parking demand effectuated by such alternative programs. Land area required for provision of deferred parking stalls shall be maintained in reserve and shall be landscaped pursuant to a plan approved by the architectural review board demonstrating that ultimate provision of the deferred stalls will meet all requirements of this chapter. The director of planning and community environment shall set such conditions as necessary to guarantee provision of such deferred stalls whenever the building official determines the need to exist. Alternative programs which may be considered by the director of planning and community environment under this provision include, but are not limited to the following: (1) Immediate proximity to pubic transportation facilities serving a significant portion of residents, employees, and/or customers; (2) Operation of effective private or company carpool, vanpool, bus, or similar transportation programs; (3) Evidence that a proportion of residents, employees, and/or customers utilize, on a regular basis, bicycle transportation commensurate with reduced parking requirements."

(Source: Municipal Code Title 18. Zoning Chapter 18.83 Off Street Parking and Loading Regulations Section 18.83.120 www.smartcommunities.ncat.org/codes/paloalto3.shtml.)

In addition, the city allows permeable paving under the following parameters:

> "City of Palo Alto. Municipal Code. Title 18. Zoning Chapter 18-12 R-1 Single-Family Residence District Regulations Section 18.12.050 Site Development Regulations The following site development regulations shall apply in the R-1 single-family residence district. Modifications of some regulations may be applicable if the R-1 single-family residence district is combined with the special building site combining district. More restrictive regulations may be recommended by the architectural review board and approved by the director of planning and community environment, pursuant to Chapter 16.48: (r) Parking and driveway surfaces may have either permeable or impermeable paving. Gravel and similar loose materials shall not be used for driveway or parking surfaces within ten feet of the public right of way."

PROGRAM ADMINISTRATION

Stormwater management or water quality ordinances must also lay out the key elements of program administration. These include, but are not limited to, BMP operation, inspection, maintenance; enforcement; BMP design; methods for evaluating compliance with performance standards; administrative fees; etc. While detailed requirements for these elements are specified in administrative manuals which are referenced in the ordinance (e.g., BMP Design Manual), the ordinance must address program administration in order to provide enabling authority for staff and clarify overall program requirements. Below we have highlighted some of the key requirements for an effective stormwater ordinance as it relates to program administration.

BMP Operations, Inspection Maintenance and Local Enforcement

Regarding regular operations, inspections, and maintenance of BMPs, the first question that a local government needs to answer is, "Who will be required to carry out these duties?" Most local governments

have stipulated that property owners are required to carry out inspections/maintenance and ensure that the BMP is operating properly.

Concerned about whether residential homeowners and homeowners' associations will actually be able to conduct inspections and maintenance over the long-term, the City of Charlotte/Mecklenburg County has said that it will accept maintenance responsibilities from single family detached residential developments and town homes if the BMPs have been satisfactorily maintained during the two-year warranty period by the owner or designee; meet all requirements of the stormwater management ordinance and Design Manual; and include adequate and perpetual access for inspections, maintenance, repair, or reconstruction. For other residential and non-residential developments, the property owner will be required to operate and maintain the BMP facilities. The logic behind this public-private division of labor is that the commercial establishments with professional property managers are capable of carrying out inspections and maintenance duties. More and more jurisdictions with stormwater utilities are questioning whether in the future the utility should assume operations and maintenance of the stormwater BMPs and charge a stormwater utility fee to recoup the cost.

What is required of property owners when they are in charge of maintenance? Progressive ordinances require the following:

Operations and Maintenance Agreement. This legal instrument requires the property owner and its successors, heirs, and assigns to regularly inspect, maintain, and repair stormwater facilities; provides a timeframe for performing needed repairs after inspections; attaches a schedule of long-term maintenance activities to be performed; allows the local government rights of ingress and egress for inspections and monitoring; outlines the requirements for notice of violation; allows the local government to perform needed maintenance if the property owner fails to do so, and requires the property owner to reimburse the local government for all costs incurred. The inspections and maintenance requirements of the agreement depend on the BMPs onsite, but inspections are required at least annually. (Note: Such requirements are also usually outlined in the local government's Construction or Design Manual.)

Annual Inspections and Maintenance Report. This must be submitted to the jurisdiction from a qualified engineer or landscape architect.

Access Easement for Inspections of BMPs. This is a separate legal instrument which is recorded with the deed.

Performance Security for Installation and Maintenance. The local government may require submittal of a performance security or bond with surety, cash escrow, letter of credit, or other legal arrangement prior to issuance of a stormwater management permit. Typically, the local government requires such performance security for the period of BMP installation and a minimum performance bond to cover maintenance or replacement costs after construction has been completed for a certain period of time (e.g., 5 or 10 years). Durham County North Carolina requires that stormwater management permit holders maintain an approved plan and performance security for the life of the project.

What is required of the local government? Through the ordinance, the local government provides enabling authority for local staff (or the jurisdiction's designee) to carry out an inspections program including routine inspections, random inspections, and inspections based on complaints. These inspections may include reviewing maintenance and repair records; sampling discharges, surface water, water in BMPs, etc.; and evaluating the condition of the BMPs. The purpose of the inspection is to determine if the activity onsite is being conducted in accordance with the ordinance and design manual and whether the measures required in the stormwater management plan of the site are effective.

The Ordinance must also specify the consequences of noncompliance, including notice of violation, penalties (e.g., civil penalty), and remedies (e.g., withholding or disapproval of subsequent permits or certificates, injunctions, costs as lien, restoration of areas affected by failure to comply).

Design Manual for BMPs

An effective BMP design manual is a critical feature of a progressive stormwater ordinance. It is more than a set of instructions for constructing a practice to meet a regulation – it must bridge the gaps between the concepts of LID, the goals of the local stormwater management program, and the way the management practices are to be constructed. The manual should communicate the importance of the stormwater management goals, and provide education and detailed guidance to those that use it. Engineers may be accustomed to a cookie-cutter approach to design, and may not understand the reasons for a different approach, nor be familiar with LID goals of retaining stormwater onsite versus the standard approach of moving it off as quickly as possible. With these goals in mind, this section will discuss the following elements:

- How should the BMP design manual be linked to the ordinance?
- What are the important elements of the manual? What should it contain?
- What incentives can be used to encourage the use of innovative practices?

How should the BMP design manual be linked to the ordinance?

The BMP design manual and any other technical documents should be linked to the ordinance by reference. For example, the Town of Huntersville's Water Quality Ordinance says, "Specific requirements regarding the design, installation and maintenance of LID structures and a discussion of LID site planning is contained in the Huntersville Water Quality Design Manual."

It is critically important that the ordinance **does not** include details about design guidelines that achieve performance standards, nor specific assumptions about BMP performance. Current research may indicate that a particular practice achieves a certain level of pollutant removal, or that retention of a particular storm event runoff volume will prevent downstream channel erosion. However, the science of stormwater management is young and rapidly evolving. Current BMP designs may need to be updated. New research may show that a particular BMP does not remove as much of a pollutant as previously thought. Performance standards themselves may need to be changed, if over time they are not working as expected. For this reason, it is more important for the ordinance to refer to the goals of the performance standards (e.g., reduce nutrient runoff from development to protect downstream water resources, reduce impacts of stormwater volume to prevent stream channel erosion and protect biological resources). Separate documents can then be updated as needed to support the ultimate goals. If a specific design is cited in the ordinance as meeting performance standards, it will be much more difficult to change the ordinance itself.

What are the important elements of the manual? What should it contain?

BMP design manuals are quite common, and have typically grown out of a history of engineering requirements for stormwater management. Some are limited in nature. The most basic focus on design elements for peak flow control, and provide little or no context for their purpose. In locations where pollutant impacts from stormwater became an issue, practitioners began developing a larger toolbox of practices, and provided more robust design manuals with background and guidance. North Carolina's BMP manual published in 1999 (NCDENR, 1999) was produced to support recently enacted water supply watershed regulations, which required removal of 85 percent of post-construction sediment loads. The 1999 manual is 85 pages in length, covers eight separate BMPs (including bioretention areas, stormwater wetlands, and infiltration devices), and has detailed narrative about the practices, design calculations with examples, costs, and maintenance. Interest in innovative stormwater management has grown in NC, and the scope of regulation increased when a large portion of the state came under nutrient management regulations resulting from nitrogen TMDLs for large river basins. As a result, the 2007 manual (NCDENR, 2007) has grown to several hundred pages in length, covers 13 practices (including the addition of permeable pavement, green roofs, cisterns, and restored forest buffers), and has an in-depth

discussion of BMP design considerations. While the NC design manual does not promote LID per se, it does show the importance of providing a large toolbox of practices, and educating practitioners about their importance.

An LID stormwater manual should therefore provide the entire holistic framework, starting with a detailed discussion of LID, its goals, and how it represents a fundamentally different way of managing site hydrology. Performance standards specific to the managing authority should also be covered, including why they are needed and how they protect the intended resources. Finally, detailed design guidelines and examples should be provided for each BMP.

For example, Prince George's County (MD) provides two guidance documents, one with an overview of the approach (Prince George's County, 1999a) and one with details about hydrologic analysis (Prince George's County, 1999b). While it the guidance documents are not linked to any specific performance standards, they do discuss in detail the goal of mimicking pre-development site hydrology. The State of Georgia's stormwater management manual includes both a policy/overview document and a detailed design manual (Atlanta Regional Commission, 2001). The design manual provides details about the management goals, including performance standards related to storm event runoff volume, and design guidelines, specifications, and performance standard calculations for 19 BMPs.

What incentives can be used to encourage the use of innovative practices?

One of the fundamental principles of LID is to micromanage runoff and to prevent it from leaving the site. A site that uses a full suite of LID practices should have a greatly reduced volume of runoff, even during a large storm event. Performance standards often require storage and treatment of a significant volume of runoff. By receiving credit for using LID practices, developers can reduce the cost of other practices by reducing their size.

Knox County (TN) has a draft stormwater manual with good examples of how stormwater credits can be used to provide incentives for LID practices. The County's new ordinance (adopted September 2007) includes a performance standard of capturing and treating the runoff from the first 1.1 inches of rainfall, called the Water Quality Volume (WQv). The manual allows for a reduction of the WQv via six practices:

1. Natural area preservation
2. Managed area preservation (open space)
3. Routing runoff to stream and vegetated buffers
4. Using specially designed grass swales for treatment
5. Disconnection of impervious surfaces
6. Large lot neighborhoods

Each has very specific design guidelines and limitations, but used separately or together they may potentially reduce the volume of runoff that must be treated with structural practices, thus reducing the cost to the developer. The last option incorporates low housing densities requirements with other practices, and allows the developer to completely waive the WQv requirement.

Methods for Evaluating Performance Standards and Water Quality Objectives

Assessing performance standards adds a layer of complexity to the process of development review, both for the developer and the regulator. If the calculation of the site targets and how the site meets those practices is complicated, developers may find it difficult to test a variety of innovative designs, and may elect to choose a conventional design. Likewise, the reviewing authority must spend additional time reviewing the calculations and assumptions submitted by the developer for errors.

In some cases, simple calculations or spreadsheet tools may be sufficient. For instance, sediment loads could be estimated from proportions of the site under various land covers (i.e., forest, developed pervious, and impervious) using predetermined factors. A BMP or a set of BMPs treat a portion of the land covers, and the sediment they remove should be calculated using predetermined removal rates. From that, the final sediment load can be estimated.

However, when there are multiple performance standards, this can become difficult. Simple performance standard models can be used to reduce both administrative burden, and to allow the developer to explore a wider range of options. These models do not have to be complicated to learn or use. For example, the City of Huntersville uses the SET, a Microsoft Excel based spreadsheet that was developed to assess the impacts of development, including sediment and nutrient loading, on a site scale. It provides a better environment for testing multiple management practices and site configurations than do simple export calculations, and it incorporates several principles of hydraulic and water quality modeling for more realistic BMP response solutions. The tool lets the user define pre- and post-treated land use/land cover, allowing for multiple drainage areas and various combinations of practices. An important benefit of SET is that the user can test management practices in combination with each other, of a site or small catchment. In addition, both structural and nonstructural practices can be represented, offering a suite of options for evaluation. The Huntersville version of the SET calculates loads and removal for sediment, nutrients, and fecal coliform bacteria, as well as calculating a runoff volume performance standard linked to the location of the development. Other versions of the SET also calculate storm event peak flow. The SET also estimates pre- and post-development annual runoff, an important measure for LID.

LAND USE CODES ALLOWING EFFECTIVE SITE DESIGN

A strong stormwater ordinance is only half of the equation for effective stormwater management. A local government also needs to have a development ordinance that allows or even encourages effective site design for reducing or managing stormwater. While strong stormwater performance standards can provide an impetus for developers to minimize impervious area, maximize undisturbed area, and other good site design techniques, often local codes erect barriers and disincentives to implementing LID.

Local governments and developers practicing LID design over the last decade have developed some tools and methods for doing so. They have provided useful guidelines for low-impact site design, which include the following steps (Prince George's County, 1999a):

1. Identify applicable zoning, land use, subdivision, and other local regulations.
2. Define development envelope and protected areas (reduce limits of clearing and grading; use site fingerprinting).
3. Use drainage/hydrology as a design element.
4. Reduce/minimize total impervious area.
5. Develop integrated preliminary site plan.
6. Minimize directly connected impervious areas.
7. Modify/increase drainage flow paths.
8. Compare pre- and post-development hydrology (using hydrologic analysis).
9. Complete site plan.

Based on local governments' experience, USEPA, the Center for Watershed Protection, and others have developed a number of "how to" LID design documents. In taking the first step toward LID, i.e., identifying applicable zoning and land use regulations, the Center for Watershed Protection has developed *Better Site Design: A Handbook for Changing Development Rules in Your Community* (1998). The Guide

includes a Code and Ordinance Worksheet, which is a tool for reviewing the standards, ordinances, and codes that shape how development occurs in a community and how the local rules compare to the principles of better site design. In addition, the USEPA has produced a series of documents on LID. The first in the series is *Low-Impact Development Design Strategies, An Integrated Approach* (1999). This and other LID manuals are at: http://www.epa.gov/owow/nps/urban.html.

The Smart Growth Leadership Institute has conducted code audits for larger scale code and land development standards. These codes are based on concepts related to smart growth and comprehensive planning. To see their worksheet, go to http://www.epa.gov/smartgrowth/scorecards/sglicodeaudit.pdf. Also, the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) developed an audit procedure for code language for its 17 member cities, the Santa Clara Water District, and the County. Visit the "Summary of Findings" link at http://www.scvurppp-w2k.com/compare_contrast.htm (the worksheet begins on page II.14).

Tetra Tech recommends making the ordinance revisions highlighted above, either through a holistic "roundtable process" described in the *Better Site Design Handbook*, or incrementally through text amendments. However, as noted in conversations with staff of many local governments, many LID elements are currently allowed in the local ordinances, but are not encouraged and in some cases discouraged. Therefore, Tetra Tech recommends that each jurisdiction work interdepartmentally—with the Planning, Engineering and Public Works Departments—to resolve issues and remove barriers which are blocking use of the above LID practices.

Below is a checklist, Opportunities for Low-Impact Development Design Techniques, that can be used in the local ordinance review and roundtable discussion process. This checklist is adapted from *Low-Impact Development Design Strategies*, Prince George's County MD; *Better Site Design: A Handbook for Changing Development Rules in Your Community*, Center for Watershed Protection; and *State of North Carolina Model Ordinance for Water Supply Watershed Protection*. In reviewing summaries of roundtable discussions and recommendations for better site design, these are the types of issues that need to be addressed in local ordinances to remove barriers to LID.

Checklist: Opportunities for Low-Impact Development Design Techniques

Clearing and Grading

- Is disturbance of vegetated areas and riparian areas minimized?
- Do the building envelopes avoid sensitive environmental areas such as riparian areas, wetlands, high infiltration soils, steep slopes, etc.?
- Is total site disturbance minimized?

Minimizing Impervious or Built Upon Area

Streets

- For low volume residential roads and streets, are the street pavement widths between 18 to 22 feet?
- Do regulations promote or allow the most efficient street layout to reduce overall street length? This may include revising frontage requirements.
- Can the culs-de-sac radius be 35 feet or less?
- Are landscaped island or bioretention islands allowed or encouraged in culs de sac?
- Are grass swales or bioretention swales used instead of curb and gutter where slopes allow?

Parking/Driveways/Sidewalks

- For office buildings, is the parking ratio 3.0 spaces per 1000 sq.ft. of gross floor area or less?
- For commercial centers, is the parking ratio 2 to 4.5 spaces per 1,000 sq.ft. of gross floor area or less?
- Is a mass transit stop provided or nearby (if applicable)?
- Can a proposed development take advantage of opportunities for shared parking?
- Is the minimum stall width for a standard parking space 9 feet or less?
- Can parking medians (if required) have bioretention cells where feasible?
- Are driveways 9 feet or less in width?
- Are shared driveways used?
- Is on-street parking considered and imperviousness minimized (no on-street or single-side parking where allowed)?
- Are sidewalks (if required) designed to the narrowest allowable width?
- Can developments provide sidewalks on one side of street only?

Clustering Development

- To encourage clustering and open space design, are setbacks minimized (e.g., for residential lots that are ½ acre or less in size is the front setback 20 feet or less, the rear setback 25 feet or less, and the side setback 8 feet or less)?
- Does the design focus development on areas of lesser slopes and farther from watercourses?

Preserving Sensitive Areas

Wetlands

- Are existing wetlands preserved?
- Will the site design minimize hydrologic alteration to existing wetlands?

Steep Slopes

- Does the ordinance encourage or require that building footprints be concentrated on slopes 10 percent or less?
- Is disturbance minimized on slopes 15 percent to 25 percent and revegetation proposed where disturbance occurs?
- Does the ordinance promote preservation of areas with 25 percent or greater slope?

Soils

- Do the building footprints avoid highly erodible soils?
- Do the building footprints avoid soils with high permeability?

Stream Buffer

- Does the ordinance encourage or require that a 50 to 75 foot stream buffer be provided?
- Will the stream buffer remain in a natural state?

Managing Open Space

- Does the ordinance promote or require open space preservation?
- Will the preserved open space be managed in a natural condition?
- Will there be a Homeowners Association or other association that can effectively manage the open space?

After reviewing the summary of roundtable discussions and recommendations from a number of communities, it appears that some of the most challenging issues to reach consensus on include:

- *Residential street and roads widths*. The recommendation for 18 to 22 feet streets widths (for low volume traffic) often conflicts with state minimum road and street design requirements, which are in turn adopted and required by local governments before accepting a street for public maintenance. Fire departments also object to the narrower streets because they believe they are not wide enough for fire trucks to navigate.
- *Culs-de-sac.* The recommendation that a cul-de-sac have a radius of 35 feet or less can conflict with state DOT standards. For example PennDOT requires use of a circular turn around with a 40-foot minimum radius in order for municipalities to receive state funding. This standard is related to transport of liquid fuels.
- *Use of grass swales and bioretention areas rather than curb and gutter*. The major objection to this recommendation comes from local engineering and public works departments that are concerned about the maintenance of the swales and street edges and the use of swales on steeply sloped areas.
- *Use of one sidewalk rather than two.* Planning departments often object to this ordinance revision because they believe it conflicts with their goal of providing walkable communities.
- *Reducing residential setback and frontage requirements to encourage cluster development*. Planning Departments are concerned that the reduced setback/frontage requirements would be incompatible with exiting neighborhoods built under traditional subdivision requirements.

Clearly, in many cases, state DOT standards will need to be addressed in order for local governments to eliminate barriers in their ordinances related to street design. In most cases, the resistance to ordinances changes arises from competing local government departmental objectives and concerns. The planning, public works, and fire departments have to resolve these internal issues to determine the extent to which LID techniques can be incorporated into the subdivision and zoning ordinances and used in the community. For each issue, it will be important to show how other communities have overcome barriers through creative design, construction standards, approval process requirements, etc.

Appendix D: LID Grant Solicitation Draft Language and Evaluation Criteria

PURPOSE

This section includes language that could be used in a grant solicitation or request for proposals (RFP) to encourage implementation of LID at the local level. Two types of projects are envisioned: planning projects for municipalities to audit and update codes and ordinances that allow or encourage LID, and implementation projects in which communities would install LID features as part of capital improvements. Included in this grant solicitation language is a checklist for communities to quantify the extent to which codes and ordinances allow, encourage, or require LID and related measures. This checklist and other details of the grant solicitation language are intended to divide the grant applicants into categories based on progress achieved thus far. Ultimately, this solicitation language would reward communities that have already audited and updated codes and ordinances, while still providing an opportunity for financial support to communities who would like to implement code and ordinance changes but may not have had the impetus or resources in the past. Note that additional details, such as criteria and a ranking system to evaluate proposed implementation projects, would need to be included before a solicitation of this type is issued.

APPLICABLE PROJECTS

Grants under this type of solicitation would be for two types of projects: (1) planning projects that will bring about changes in codes and development of LID performance standards, and (2) implementation projects, namely capital improvement projects that have one or more LID components.

Planning Projects

These projects will involve performing a detailed audit (see Appendix A) of all zoning and development-related codes to identify conflicts with LID principles, or conducting studies to establish at the local level where barriers or long-standing practices have been identified and prevent adoption of LID (e.g., a parking utilization study). The result will be to revise code language and develop stormwater performance standards for new and redevelopment projects. Additional planning projects can include development of a performance standard for LID techniques or development of an active monitoring program for LID practices.

Implementation Projects

These projects will require that one or more LID practices be incorporated into a capital improvement project. Alternatively, the project may involve the retrofit of an existing municipal property with one or more LID practices. Examples of LID practices include porous pavement, ecoroofs, bioretention, downspout disconnection, conversion of impervious surfaces to pervious surfaces, regrading and amending soils for enhanced stormwater capture, and other integrated stormwater management techniques.

EVALUATION CRITERIA

To be evaluated for an award, applicants are required to perform a self-audit of local codes and standards using the checklist included in Appendix A. For each affirmative answer, applicants should provide a citation for the applicable development code or standard (page, section, or line number).

Eligibility

Applicants will be eligible for grant funding for planning or implementation projects based on the self-audit responses as follows:

Score of 0 to 10 points:

Applicants that score between 0 and 10 points on the self-audit are not eligible for implementation project grants. However, they are eligible for a grant to revise codes/ordinances and develop guidelines to increase their self-audit score to 15.

Score of 11 to 24 points:

Applicants that score between 11 and 24 points are eligible for implementation project grants with the condition that they revise codes/ordinances and develop guidelines to increase their self-audit score to 25.

Score of 25 or more points:

Applicants who score 25 or more points on the self-audit are eligible for an LID implementation project grant without conditions.

For planning assistance, applicants must submit a letter of good faith from the planning director or other municipal executive stating that they support code revision and standards development as proposed in the grant application.

Project Merit

Grant applications will be assessed based on project merit. In your grant application, please describe the following for each type of project:

Planning Projects:

Describe proposed changes to codes and standards to improve the self-audit score to the required minimum. List code/standard language that is in conflict with LID and discuss possible changes to remove conflicts. Describe studies that might be needed to obtain stakeholder buy-in, such as parking utilization studies or demonstration projects with emergency responders. Describe the administrative process to implement changes, including the process through which stakeholders (other municipal departments, citizen groups, developers, etc.) will be involved.

Implementation Projects:

Describe the capital improvement project and identify the LID component(s) to be incorporated. Identify the waterbody or waterbodies affected by stormwater runoff from the site and discuss how the LID features will address recognized pollutants of concern for the waterbody or waterbodies. Estimate reductions in directly connected impervious surfaces that result from LID practice implementation. Describe how the LID project fits into the larger watershed management system. Outline a plan to assess the performance of the project over the long term, and identify whether monitoring will be performed as part of this assessment. Describe how maintenance of the LID project will be assured over the long term.

Applicants proposing planning and implementation projects must submit descriptions for both project types as described above.

LOW IMPACT DEVELOPMENT CODE AND ORDINANCE SELF-AUDIT

To be evaluated for an award, applicants are required to perform a self-audit of local codes and standards using the following checklist. For each affirmative answer, applicants should provide a citation for the applicable development code or standard (page, section, or line number). Applicants will be eligible for grant funding for planning or implementation projects based on the self-audit responses as follows:

Score of 0 to 10 points:	Score of 11to 24 points:	Score of 25 or more points:
Applicants can apply for a grant to revise codes/ordinances and develop guidelines to increase the score to a minimum of 15.	Applicants can apply for a grant to revise codes/ordinances to increase the score to a minimum of 25 and propose an LID implementation project.	Applicants can apply for a grant for an LID implementation project.

A. GENERAL INFORMATION

Name of Applicant: _____

List Citations for Codes/Ordinances Relevant to Stormwater and Smart Growth: _____

_____

_____

_____

B. STORMWATER ORDINANCE

How have post-construction stormwater requirements been incorporated into local ordinances?

- ❑ A stand-alone post-construction stormwater ordinance has been developed (2 points)
- ❑ Post-construction stormwater requirements have been integrated into a development ordinance or another type of ordinance (2 points)
- ❑ Post-construction stormwater requirements were included in several different ordinances (2 points)

Attach copies of the official approval (e.g., letter, meeting minutes) showing adoption of the ordinance(s) by the municipal governing body.

- ❑ Post-construction stormwater requirements are not yet included in local ordinances (0 points)

C. GENERAL PLANS

How has post-construction stormwater management, natural drainage, or low impact development been incorporated into your General Plan?

- ❑ The General Plan has been reviewed and General Plan Elements have been amended to include natural drainage, low impact development, and post-construction stormwater management (2 points)
- ❑ The City/County is in the process of identifying where natural drainage, low impact development, and post-construction stormwater management should be included in the next update of the General Plan (1 point) Date of next General Plan update: _____
- ❑ The City/County has not yet initiated a review of the General Plan for inclusion of natural drainage, low impact development, and post-construction stormwater management (0 points)

D. CODE LANGUAGE

Please review the list of stormwater- and smart growth-related code language and check all that are included in existing codes or ordinances. If a change has been implemented already, provide a section, page, or line reference for the code change. Note this may include zoning codes, specific plans or standards issued by Transportation and Fire Protection Districts.

The items below are scored at 1 point each.

Clearing and Grading

- ❑ Do codes/ordinances regulate the disturbance of vegetated areas and riparian areas? Indicate the extent to which disturbance is limited: _____ (Reference: _____)
- ❑ Do codes/ordinances regulate the total amount of site disturbance? Indicate the extent to which disturbance is limited: _____ (Reference: _____)

Minimizing Impacts of Impervious or Built Area

Streets

- ❑ For low-volume residential roads and streets, are the street pavement widths required to be between 18 and 22 feet? (Reference: _____)
- ❑ Do codes/ordinances promote or allow the most efficient street layout to reduce overall street length? This may include revising frontage requirements. (Reference: _____)
- ❑ Do codes/ordinances allow a cul-de-sac radius to be 35 feet or less? (Reference: _____)
- ❑ Are landscaped islands or bioretention islands allowed or encouraged in culs-de-sac? (Reference: _____)
- ❑ Are LID techniques (e.g., grass swales, bioretention swales, tree planters, etc.) allowed, encouraged, or required to be used instead of curb and gutter where slopes allow? (Reference: _____)

Parking/Driveways

- ❑ Has a parking utilization study been performed and were results incorporated into codes/ordinances? (Reference: _____)
- ❑ Do codes/ordinances provide incentives for shared parking? (Reference: _____)
- ❑ Is the minimum stall width for a standard parking space allowed, encouraged, or required to be 9 feet or less? (Reference: _____)
- ❑ Can parking medians (if required) have bioretention cells where feasible? (Reference: _____)
- ❑ Is porous pavement allowed, encouraged, or required? (Reference: _____)
- ❑ Are driveways allowed, encouraged, or required to be 9 feet or less in width? (Reference: _____)
- ❑ Are shared driveways allowed, encouraged, or required? (Reference: _____)
- ❑ Is imperviousness associated with on-street parking required to be minimized (e.g., no on-street parking, or single-side parking where allowed)? (Reference: _____)

Buildings/Landscape

- ❑ Are green roofs allowed, encouraged, or required? (Reference: _____)
- ❑ Is roof runoff allowed, encouraged, or required to be directed to bioretention planter boxes, bioswales, bioretention cells, or other landscaped/pervious area? (Reference: _____)
- ❑ Are cisterns, rain barrels, or other methods for water reuse allowed, encouraged, or required? (Reference: _____)
- ❑ Has the master landscaping code been revised (or have revisions been initiated) to integrate water conservation, water reuse, and stormwater handling within landscaped areas? (Reference: _____)

Preserving Sensitive Areas

Wetlands/Floodplains

- ❑ Do codes/ordinances require prevention or mitigation of hydrologic impacts on existing wetlands and floodplains? (Reference: _____)
- ❑ Are site designs required to mitigate the impacts of hydrologic alteration to existing wetlands/floodplains by including such areas in stormwater management calculations? (Reference: _____)

Steep Slopes

- ❑ Do codes/ordinances encourage or require that building footprints be concentrated on slopes 10 percent or less? (Reference: _____)
- ❑ Do codes/ordinances require that disturbance be minimized on slopes 15 percent to 25 percent and revegetation proposed where disturbance occurs? (Reference: _____)
- ❑ Do codes/ordinances require preservation of areas with 25 percent or greater slope? (Reference: _____)

Soils

- ❑ Are building footprints required to avoid highly erodible soils? (Reference: _____)
- ❑ Are building footprints required to avoid soils with high permeability (e.g., Soil Conservation Service Soil Group A)?
  (Reference: _____)

Stream Buffers

- ❑ Do codes/ordinances encourage or require a scientifically defensible wetland/riparian buffer setback? (Reference: _____)
- ❑ Do codes/ordinances limit activities (e.g., material storage, mowing, etc.) in wetland/riparian buffer zones?
  (Reference: _____)

Managing Open Space

- ❑ Have local park and open space plans been revised to incorporate stormwater management features into pervious and landscaped areas?
  (Reference: _____)
- ❑ Have codes/ordinances governing open space for multi-family residential development been revised to include on-site water quality and quantity management of stormwater?
  (Reference: _____)
- ❑ Do codes/ordinances encourage or require open space preservation based on a regional or watershed-scale plan?
  (Reference: _____)
- ❑ To encourage clustering and open space design, are setbacks allowed, encouraged, or required to be minimized? (Reference: _____)
- ❑ Do codes/ordinances encourage or require that development be directed to already-developed areas (e.g., infill sites or corridor redevelopment areas)? (Reference: _____)

E. SCORING AND PROJECT CATEGORY

Applicants will be eligible for grant funding for planning or implementation projects as follows:

Score of 0 to 10 points:	Score of 11to 24 points:	Score of 25 or more points:
Applicants can apply for a grant to revise codes/ordinances and develop guidelines to increase the score to a minimum of 15.	Applicants can apply for a grant to revise codes/ordinances to increase the score to a minimum of 25 and propose an LID implementation project.	Applicants can apply for a grant for an LID implementation project.

Total Number of Points: _____

Please Mark the Appropriate Project Category:

❑ Planning (0-10 pts) ❑ Planning/Implementation (11-24 pts) ❑ Implementation (>25 pts)

We have reviewed the latest draft MS4 permit for the San Francisco Bay Region (NPDES permit No. CAS612008) public noticed on December 29, 2007 and we would like to offer the following comments primarily regarding the New Development and Redevelopment Component of the permit (Part C.3).

In April 2007, EPA entered into an agreement with several national organizations to promote green infrastructure (which is very similar to LID) to improve stormwater quality management for MS4s. In January 2008, EPA also published an action strategy for the new initiative which is available at http://cfpub.epa.gov/npdes/whatsnew.cfm?program_id=6). The strategy encourages green infrastructure/LID requirements (such as bioretention, green roofs) in MS4 permits and we are trying to ensure that MS4 permits in our Region 9 include appropriate requirements to promote green infrastructure/LID. We are particularly interested in ensuring that green infrastructure/LID is adequately required and implemented in new developments and redevelopments, as the effectiveness of vegetation-based treatment for stormwater is clearly superior* to conventional treatment (such as detention basins, drain inlet inserts) which is covered in Part C.3.d of the permit; landscape-based treatment also has greater capacity to reduce the impact of spills. A wide range of other benefits of green infrastructure/LID was identified in our action strategy, and again we believe it is important that this be emphasized in permits. One of the elements of the strategy is the development of appropriate requirements for MS4 permits, but this is still a work in progress at the moment.

We have reviewed the green infrastructure/LID requirements in the proposed permit and except as noted below we believe they are appropriate for now. While the requirements for green infrastructure/LID in Part C.3.c are narrative, the issue is clearly emphasized in the permit. Further, the permit includes specific (and stringent) requirements on applicability in that they would apply to all new projects creating 10,000 square feet or more of impervious surface and (in the future) certain special categories of projects which create 5,000 square feet of impervious surface. As our green infrastructure/LID strategy is implemented we may have additional more specific recommendations concerning permit requirements and we would like to work with the Board concerning incorporation of such requirements in future permits or in existing permits via permit modifications.

The one concern we have with the LID requirements of the proposed permit is Part C.3.c.i.(2)(d) which requires "a portion" of impervious areas to be drained to a pervious area, and Part C.3.c.i.(2)(e) which

similarly requires for walkways and trails, etc. that "a portion" of such areas be constructed with permeable surfaces. To ensure adequate enforceability and clarity of the permit, we believe the permit needs to include a numeric value for the quantity of runoff which would be directed to pervious areas. We would suggest a requirement such as proposed in the August 2007 draft Ventura County MS4 permit which limits the effective impervious area of new developments to 5% of the total area of a project (see Part E.III.1.(a) of the draft Ventura County permit). We are not wedded to any particular numeric value; this could be determined based on local considerations, but we believe the requirements should be expressed quantitatively to ensure clarity and enforceability.

Elsewhere in the proposed permit, we are pleased to see that the permit includes detailed BMP requirements in many areas such as municipal maintenance, illicit discharges and industrial/commercial site controls. These requirements clarify MEP and improve the enforceability of the permit. Our municipal audits of recent years have identified lack of detailed requirements as a frequent shortcoming in previously-issued MS4 permits in our Region.

We also noted one element which we would suggest be strengthened in the permit. With regards to construction sites, NPDES regulations at 40 CFR 122.26(d)(2)(iv)(D)(4) require an education program on the part of MS4s for construction site operators. The permit does include staff training for MS4 personnel in conducting construction site inspections (Part C.6.g), but education for the construction industry itself is limited to providing educational materials (in Part C.6.d) and education during inspections (in Part C.6.e). We would suggest adding a new Part to the permit following your format (Task Description, Implementation Level and Reporting) which would require that the MS4s provide training workshops in the Bay Area for the construction industry with a minimum frequency of once/every other year (as with staff training) in which MS4s would explain municipal requirements for construction sites.

Thank you for the opportunity to comment on the draft permit. I can be reached at (415) 972-3510.

*See for example the analysis prepared by Dr. Richard Horner entitled "Initial Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for the San Francisco Bay Area" submitted to the San Francisco Bay Regional Board by NRDC. A similar analysis was also submitted to the Los Angeles Regional Board by NRDC attached to comments on the proposed Ventura County MS4 permit of December 2006.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

February 13, 2009

Michael Adackapara
Division Chief
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Re: Draft MS4 Permit for Orange County and Incorporated Cities within Orange County (NPDES Permit No. CAS618030)

Dear Mr. Adackapara:

The following are EPA Region 9's comments on the November 10, 2008 "First Draft" of the renewed Areawide Urban Stormwater Permit for Orange County and incorporated cities within Orange County within the jurisdiction of the Santa Ana Regional Water Quality Control Board.

EPA is generally supportive of the approach taken by the Santa Ana Regional Board in the draft permit. The following comments are informed by our review of other Municipal Separate Storm Sewer System (MS4) permits throughout our Region, and our review of the implementation of these permits via audits of nearly 50 MS4 programs.

The renewed Orange County MS4 permit will be the fourth permit issued for these municipal stormwater discharges. It is appropriate for the permit provisions to evolve based on lessons learned from past permits. The renewed permit is an opportunity to include clear permit provisions that support water quality benefits. Our comments concern two aspects of the draft permit.

1. Implementation of Low Impact Development (LID) Requirements

EPA agrees with the draft permit's approach for incorporating LID techniques, also known as green infrastructure. On a national level, EPA is advocating LID as an approach to stormwater management that is cost-effective, sustainable, and environmentally-sound. Ongoing efforts to promote the use of these techniques are described in EPA's January 2008 Action Strategy for Managing Wet Weather with Green Infrastructure. Materials regarding EPA's policies in this area can be found at: http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy.

On page 20 of 89 of the draft permit, Finding #62 states, "The USEPA has determined that by limiting the effective impervious area of a development site to 5% or less, downstream impacts can be minimized." While it is true that EPA agrees that limiting effective impervious area (EIA) to 5% or less will have positive impacts on water quality,

EPA has not made a determination that the 5% EIA concept is necessarily the only or always the best method to implement LID. We recommend replacing Finding #62 with the following:

> "USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of stormwater pollution that will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits such as aesthetics, recreation, and wildlife areas. EPA has reviewed studies[1] that have evaluated the % EIA concept and we believe that it is a reasonable and effective metric for incorporating LID principles into stormwater permits."

EPA's primary objective for incorporating LID into renewed MS4 permits, especially for those representing the fourth generation of permits regulating these discharges, is that the permit must include clear, measurable, enforceable provisions for implementation of LID. In our review of MS4 programs in our Region, we have found it common for permits to rely on the development of plans to achieve certain permit controls, rather than including clearly prescriptive requirements in the permits. While the permittees generally make significant and sincere efforts in their development of these plans, the plans often result in a reliance on qualitative provisions rather than specific measurable criteria. As a result, we've often found uncertainty among both the MS4 permittees and the permitting agencies as to specific permit controls. The incorporation of LID techniques into MS4 permits provides an opportunity to establish clear, measurable performance measures for the implementation of LID.

Section XII of the draft permit, entitled "New Development (Including Significant Re-Development)," appropriately sets a 5% EIA limit as a means for measuring the utilization of site controls, including LID techniques, for limiting stormwater runoff. This section of the draft permit also appropriately includes measurable requirements for controlling hydromodification by comparing post-development runoff to pre-development flows. EPA is in agreement with these permit provisions. While these approaches are not the only means available for including measurable requirements for the implementation of LID and the control of hydromodification in municipal stormwater permits to promote water quality improvements, EPA is supportive of the approaches you've chosen. We understand there is an alternative proposal to include a specific, measurable design storm volume which must be managed using LID techniques. Conceptually, we are supportive of such an approach, although we would be

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[1] See for example the analysis prepared by Dr. Richard Horner entitled "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

interested in reviewing specific permit language. We would not support replacing these approaches with qualitative provisions that do not include measurable goals.

We support the concept of alternatives and in-lieu programs for LID outlined in section XII.E. However, this section should be restructured to require that these waiver programs be approved prior to their utilization. If a permittee intends to grant waivers, they should be required to first establish the water quality credit system described in section XII.E.3. Section XII.E.3 should be moved to the beginning of section XII.E (thus renumbered as XII.E.1). The permit should require that any credit system that the permittees establish must (not "should") be submitted to the Executive Officer for review and approval. Any approved alternative programs should include measurable requirements, consistent with our comments above regarding the need for clear, measurable and enforceable permit conditions. In the section which is currently section XII.E.1 (which would become XII.E.2) the first sentence should be revised to note that if a BMP is not feasible, the permittee may grant a waiver pursuant to their approved Credit System.

2. Incorporation of Total Maximum Daily Loads (TMDLs)

The permit appropriately includes the relevant TMDLs, but the permit should more explicitly state that the wasteload allocations (WLAs) established by these TMDLs are intended to be enforceable permit effluent limitations and that compliance is a permit requirement. As a general matter, it is also our view that the permit language should clarify what monitoring will be done to determine compliance with WLAs. We recognize that the permit includes several different sections which describe monitoring efforts. However, with respect to the specific TMDLs described in section XVIII, the requirements for monitoring receiving waters (and end-of-pipe monitoring for sediments) are not always clear. If required monitoring to determine compliance with WLAs is specified in existing, separate monitoring plans, these existing plans should be clearly identified. With respect to existing plans, there should be confirmation that the plans clearly identify what monitoring will be conducted, and that monitoring results will enable the Board to clearly determine compliance with WLAs. If these referenced plans have not yet been prepared, the permit should contain required plan submittal dates, along with the expectations for the content of the plans to enable the Board to determine compliance with WLAs.

To further support WLA requirements in the permit, we recommend that Finding #52 for the permit include the following statement: "NPDES regulations at 40 CFR 122.44(d)(1)(vii)(B) require that permits be consistent with Waste Load Allocations (WLAs) approved by EPA. In the case of this permit, where there are EPA-approved TMDLs for waters in Orange County, this permit must incorporate provisions consistent with the WLAs associated with municipal stormwater, aka "urban runoff," from these TMDLs."

Section XVIII.B (technical TMDLs with no implementation plans)

i. Please note that the parenthetical statement in section XVIII.B.1.c should refer to paragraph 2, not paragraphs 4 & 5.

ii. In section XVIII.B.2, the permit references the Newport Bay/San Diego Creek organochlorine (OC) compounds TMDLs adopted by the Regional Board in September 2007. Despite having been adopted by the Regional Board, these TMDLs and the implementation plan have not yet been submitted to the State Board for approval. Until they are submitted to the State Board, and in turn approved by the State Board, OAL, and EPA, they are not applicable. Rather, the permit should recognize that the EPA TMDLs adopted in June 2002 are the currently applicable TMDLs.

iii. Based on our review of the Newport Bay/San Diego Creek TMDLs, it appears that the concentrations in Tables 1A/1B do not accurately reflect the WLAs for urban runoff in EPA's 2002 TMDLs. In addition to correcting these Tables, the permit should clarify that the WLAs are intended to be enforceable effluent limits. Compliance with the WLAs could be required in accordance with the time frame envisioned by the Board's implementation plan since this would be consistent with the intent of the EPA TMDLs.

iv. This section currently requires activities (the Regional Monitoring Plan (RMP) and Toxicity Reduction and Investigation Program (TRIP)) geared toward compliance with the Regional Board's as-yet unapproved OC TMDLs. These activities are similar to those contemplated for compliance with EPA's OC TMDLs. However, it should be confirmed that the monitoring results will enable determinations regarding compliance with the approved and currently applicable EPA TMDLs. Monitoring plans must clearly identify monitoring locations, the frequency of required monitoring, and required submittal of monitoring results. As recommended by the EPA TMDL, the monitoring plan should include water column and sediment monitoring. In addition, fish tissue monitoring should be included (if not already in the existing plan) since this was identified as an important environmental indicator in EPA's TMDL.

v. The permit should include conditions consistent with the WLAs for metals and selenium established by EPA in June 2002 for Newport Bay, San Diego Creek and the Rhine Channel. The description of the selenium TMDL for Newport Bay on page 67 describes selenium as naturally occurring. However, the TMDL suggests that selenium loads are made up of both naturally occurring and anthropogenic sources. The permit's required monitoring of selenium should not be limited to sources of naturally occurring selenium. Section XVIII.B.3 of the permit mentions that revised TMDLs for selenium are being developed by the Regional Board, but until the revised TMDLs and implementation plan are approved, the WLAs from the existing TMDLs are applicable. The EPA TMDLs for selenium and metals do not include a compliance deadline, but rather suggest a phased, iterative approach for compliance with the WLAs. Consistent with the recommendations of the EPA TMDLs, we suggest the permit require the

development and submittal of a compliance plan (with an implementation schedule) to the Board by the permittees. Detailed requirements for a monitoring program to determine compliance with the WLAs, including monitoring locations, frequency of sampling, and reporting should also be required.

vi. Section XVIII.B.3 of the permit refers to the activities and plans underway for revised nutrient TMDLs. We understand that these ongoing activities are focused on revisions to the nutrient TMDL implementation plan, not the TMDLs themselves. The permit should be corrected accordingly.

vii. Section XVIII.B.3 of the permit lays out an open-ended approach to the development of a monitoring plan for selenium and nitrogen. A specific deadline for the submittal of the monitoring plan should be included in the permit.

viii. We support the approach provided for incorporating the Coyote Creek WLAs, by establishing a date certain for submittal of a source control plan and monitoring plan. The permit should clarify the monitoring plan must include the frequency of sampling, and any other details to be required in using the collected data to determine compliance with WLAs.

Section XVIII.C (TMDLs beyond the permit term)

Tables 5a and 5b (in section XVIII.C.1) contain errors in that the first two rows of each table both include, "Total Maximum Daily Load for Fecal Coliform." It appears that one of these rows should present the WLA for urban runoff. The permit should also clarify that the urban runoff WLAs are intended to be permit effluent limits; we suggest that language be added to the permit such as: "The permittees shall comply with the wasteload allocations for urban runoff in Tables 5a and 5b in accordance with the deadlines in Tables 5a and 5b."

Section XVIII.D (TMDLs with compliance schedules within the permit term)

i. The permit (section XVIII.D.1) should clarify that the diazinon and chlorpyrifos WLAs are intended to be permit effluent limits; we would suggest that language be added to the permit such as: "The permittees shall comply with the following wasteload allocations in Tables 6a and 6b." Immediate compliance should be required unless an alternate date is provided in the implementation plan. We would also recommend that the fact sheet discuss the current compliance status of the permittees with the WLAs; given the phase-out of these pesticides within urban areas, compliance may have already been achieved.

ii. Regarding the nutrient TMDLs, the fact sheet (page 9) indicates the current and future targets for nutrients are already being met. In contrast, the permit (page 71) indicates that

the *overall* allocations have been met, leaving questions about the urban runoff WLA. Recent monitoring reports submitted to the Regional Board show that the urban runoff allocations for both the total nitrogen and total phosphorus loads are not currently being met. This discrepancy should be clarified in the fact sheet. Further, the permit should be clarified to indicate that the urban runoff WLAs in the Tables 7, 8 and 9 are intended to be permit effluent limits.

iii. Regarding the Newport Bay sediment TMDL, the permit should include firm dates for the submittal of monitoring data presenting the 10-year running averages.

Section XVIII.E.2 refers to "numeric effluent limits." For clarity, and for consistency with the rest of section XVIII, we suggest this be revised to: "Based on the TMDLs, numeric effluent limits have been specified to ensure consistency with the wasteload allocations."

We appreciate the opportunity to provide our views on this draft permit. If you'd like to discuss these comments, please contact John Tinger of the NDPES Permits Office at (415) 972-3518, or Eugene Bromley of the NPDES Permits Office at (415) 972-3510.

Sincerely,

Douglas E. Eberhardt, Chief
NPDES Permits Office

INITIAL INVESTIGATION OF THE FEASIBILITY AND BENEFITS OF LOW-IMPACT SITE DESIGN PRACTICES ("LID") FOR THE SAN FRANCISCO BAY AREA

Richard R. Horner†

ABSTRACT

The Clean Water Act NPDES permit that regulates municipal separate storm sewer systems (MS4s) in the San Francisco Bay Area, California will be reissued in 2007. The draft permit includes general provisions related to low impact development practices (LID) for certain kinds of development and redevelopment projects. Using six representative development project case studies, based on California building records, the author investigated the practicability and relative benefits of LID options for the majority of the region having soils potentially suitable for infiltration either in their natural state or after amendment using well recognized LID techniques. The results showed that (1) LID site design and source control techniques are more effective than conventional best management practices (BMPs) in reducing runoff rates; and (2) in each of the case studies, LID methods would reduce site runoff volume and pollutant loading to zero in typical rainfall scenarios.

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INTRODUCTION

The Assessment in Relation to Municipal Permit Conditions

This purpose of this study is to investigate the relative water quality and water reuse benefits of three levels of storm water treatment best management practices (BMPs): (1) basic "treat-and-release" BMPs (e.g., drain inlet filters, CDS units), (2) commonly used BMPs that expose runoff to soils and vegetation (extended-detention basins and biofiltration swales and filter strips), and (3) low impact development (LID) practices. The factors considered in the investigation are runoff volume, pollutant loading, and the availability of water for infiltration or other reuse. In order to assess the differential impact of storm water reduction approaches on these factors, this study examines six case studies typical of development covered by the proposed Municipal Regional Urban Runoff Phase I NPDES Stormwater Permit (MRP).

This report covers locations in the Bay Area most amenable to soil infiltration of stormwater runoff, those areas having soils in Natural Resources Conservation Service (NRCS) Hydrologic Soil Groups A, B, or C as classified by the Natural Resources Conservation Service (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Depending on site-specific conditions, A and B soils would generally effectively infiltrate water without modification, whereas C soils could require organic amendments according to now standard LID methods. This report does not cover locations with group D soils, which are generally not amenable to infiltration, again depending on the specific conditions on-site. A subsequent report will examine options in these locations, which include other LID techniques (e.g., roof runoff harvesting for irrigation or gray water supply) and state-of-the-art conventional stormwater

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management practices. A minority but still substantial fraction of the Bay Area has group D soils (39.3, 68.0, 18.3, and 50.1 percent of the mapped areas of Alameda, Contra Costa, San Mateo, and Santa Clara Counties, respectively). Regarding any mapped soil type, it is important to keep in mind that soils vary considerably within small distances. Characteristics at specific locations can deviate greatly from those of the major mapped unit, making infiltration potential either more or less than may be expected from the mapping.

Low impact development methods reduce storm runoff and its contaminants by decreasing their generation at sources, infiltrating into the soil or evaporating storm flows before they can enter surface receiving waters, and treating flow remaining on the surface through contact with vegetation and soil, or a combination of these strategies. Soil-based LID practices often use soil enhancements such as compost, and thus improve upon the performance of more traditional basins and biofilters. The study encompassed vegetated swales (channels for conveyance at some depth and velocity), vegetated filter strips (surfaces for conveyance in thin sheet flow), and bioretention areas (shallow basins with a range of vegetation types in which runoff infiltrates through soil either to groundwater or a subdrain for eventual surface discharge). Application of these practices in a low impact site design mode requires either determination that existing site soils can support runoff reduction through infiltration or that soils will be amended using accepted LID techniques to attain this objective. Finally, the study further broadened implementation options to include water harvesting (collection and storage for use in, for example, irrigation or gray water systems), roof downspout infiltration trenches, and porous pavements.

The investigation also considered whether typical development patterns and local conditions in the Bay Area would enable LID implementation as required by a new standard proposed for the 2007 Ventura County Municipal Storm Water Permit. This standard requires management of effective impervious area (EIA), limiting it to 5%, as well as other impervious area (what might be termed Not-Connected Impervious Area, NCIA), and pervious areas.

Where treatment control BMPs are required to manage runoff from a site, Volume or Flow Hydraulic Design Bases commonly used in California were assumed to apply. The former basis applies to storage-type BMPs, like ponds, and requires capturing and treating either the runoff volume from the 85th percentile, 24-hour rainfall event for the location or the volume of annual runoff to achieve 80 percent or more volume treatment. The calculations in this analysis used the 85th percentile 24-hour rainfall event basis. The Flow basis applies to flow-through BMPs, like swales, and requires treating the runoff flow rate produced from a rain event equal to at least 0.2 inches per hour intensity (or one of two other approximately equivalent options).

Scope of the Assessment

With respect to each of the six development case studies, three assessments were undertaken: a baseline scenario incorporating no stormwater management controls; a second scenario employing conventional BMPs; and a third development scenario employing LID stormwater management strategies.

To establish a baseline for each case study, annual stormwater runoff volumes were estimated, as well as concentrations and mass loadings of four pollutants: (1) total suspended solids (TSS), (2) total recoverable copper (TCu), (3) total recoverable zinc (TZn), and (4) total phosphorus (TP). These baseline estimates were based on the anticipated land use and cover with no stormwater management efforts.

Two sets of calculations were then conducted using the parameters defined for the six case studies. The first group of calculations estimated the extent to which basic BMPs reduce runoff volumes and pollutant concentrations and loadings, and what impact, if any, such BMPs have on recharge rates or water retention on-site.

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The second group of calculations estimated the extent to which commonly used soil-based BMPs and LID site design strategies ameliorate runoff volumes and pollutant concentrations and loadings, and the effect such techniques have on recharge rates. When evaluating LID strategies in the context of the EIA concept employed in the draft Ventura County MS4 permit, it was presumed that EIA would be limited to three percent. It was also assumed that pervious surfaces on a site receiving runoff from other areas on the site would be sized and prepared to manage (through infiltration or storage) the volume directed there in addition to precipitation falling directly on those areas. The assessment of basins, biofiltration, and low impact design practices analyzed the expected infiltration capacity of the case study sites. It also considered related LID techniques and practices, such as source reduction strategies, that could work in concert with infiltration to serve the goals of: (1) preventing increase in annual runoff volume from the pre- to the post-developed state, (2) preventing increase in annual pollutant mass loadings between the two development states, and (3) avoiding exceedances of the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) criteria for copper and zinc.

The results of this analysis show that:

- A full-range of typical development categories common in the Bay Area, from single family residential to restaurants, housing developments, and commercial uses like office buildings, can feasibly implement standard LID techniques to achieve no stormwater discharge during rain events equal to, and in some cases greater than, design storm conditions. This conclusion is based on an analysis that used actual building records in California and annual rainfall records in two rainfall zones in the Bay Area to show that site conditions support this level of performance. In addition, site conditions typical at a wide range of development projects are more than sufficient to attain compliance with a three percent EIA limit, as is being contemplated in other MS4 re-issuance proceedings in California presently.

- Developments implementing no post-construction BMPs result in storm water runoff volume and pollutant loading that are substantially increased, and recharge rates that are substantially decreased, compared to pre-development conditions.

- Developments implementing basic post-construction treatment BMPs achieve reduced pollutant loading compared to developments with no BMPs, but stormwater runoff volume and recharge rates are similar to developments with no BMPs.

- Developments implementing traditional basins and biofilters, and even more so low impact post-construction BMPs, achieve significant reduction of pollutant loading and runoff volume as well as greatly enhanced recharge rates compared to both developments with no BMPs and developments with basic treatment BMPs.

This report covers the methods employed in the investigation, data sources, and references for both. It then presents the results, discusses their consequences, draws conclusions, and makes recommendations relative to the feasibility of utilizing low-impact development practices in Bay Area developments.

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CASE STUDIES

Six case studies were selected to represent a range of urban development types considered to be representative of the Bay Area. These case studies involved: a multi-family residential complex (MFR), a relatively small-scale (23 homes) single-family residential development (Sm-SFR), a restaurant (REST), an office building (OFF), a relatively large (1000 homes) single-family residential development (Lg-SFR), and a single home (SINGLE).[1]

Parking spaces were estimated to be 176 sq ft in area, which corresponds to 8 ft width by 22 ft length dimensions. Code requirements vary by jurisdiction, with the tendency now to drop below the traditional 200 sq ft average. About 180 sq ft is common, but various standards for full- and compact-car spaces, and for the mix of the two, can raise or lower the average.[2] The 176 sq ft size is considered to be a reasonable value for conventional practice.

Roadways and walkways assume a wide variety of patterns. Exclusive of the two SFR cases, simple, square parking lots with roadways around the four sides and square buildings with walkways also around the four sides were assumed. Roadways and walkways were taken to be 20 ft and 6 ft wide, respectively.

Single-family residences were assumed each to have a driveway 20 ft wide and 30 ft long. It was further assumed that each would have a sidewalk along the front of the lot, which was calculated to be 5749 sq ft in area. Assuming a square lot, the front dimension would be 76 ft. A 40-ft walkway was included within the property. Sidewalks and walkways were taken to be 4 ft wide. For each case study the total area for all of these impervious features was subtracted from the total site area to estimate the pervious area, which was assumed to have conventional landscaping cover (grass, small herbaceous decorative plants, bushes, and a few trees).

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[1] Building permit records from the City of San Marcos in San Diego County provided data on total site areas for the first four case studies, including numbers of buildings, building footprint areas (including porch and garage for Sm-SFR), and numbers of parking spaces associated with the development projects. While the building permit records made no reference to features such as roadways, walkways, and landscaping normally associated with development projects, these features were taken into account in the case studies using assumptions described herein. Larger developments and redevelopment were not represented in the sampling of building permits from the San Marcos database. To take these types of projects into account in the subsequent analysis, the Lg-SFR scenario scaled up all land use estimates from the Sm-SFR case in the ratio of 1000:23. The single home case (SINGLE) was derived from Bay Area records obtained at http://www.ppic.org/content/other/706EHEP_web_only_appendix.pdf, which showed 8000 ft^2 as a rough average for a single home lot in the region. As with the other cases, these hypothetical developments were assumed to have roadways, walkways, and landscaping, as described herein.

[2] J. Gibbons, *Parking Lots*, NONPOINT EDUCATION FOR MUNICIPAL OFFICERS, Technical Paper No. 5 (1999) (http://nemo.uconn.edu/tools/publications/tech_papers/tech_paper_5.pdf).

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Table 1 summarizes the characteristics of the six case studies. The table also provides the recorded or estimated areas in each land use and cover type.

Table 1. Case Study Characteristics and Land Use and Land Cover Areas

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
No. buildings	11	23	1	1	1000	1
Total area (ft^2)	476,982	132,227	33,669	92,612	5,749,000	8,000
Roof area (ft^2)	184,338	34,949	3,220	7,500	1,519,522	2114
No. parking spaces	438	-	33	37	-	-
Parking area (ft^2)	77,088	-	5808	6512	-	-
Access road area (ft^2)	22,212	-	6097	6456	-	-
Walkway area (ft^2)	33,960	10,656	1362	2078	463,289	518
Driveway area (ft^2)	-	13,800	-	-	600,000	835
Landscape area (ft^2)	159,384	72,822	17,182	70,066	3,166,190	4533

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single-family home

METHODS OF ANALYSIS

Annual Stormwater Runoff Volumes

Annual surface runoff volumes produced were estimated for both pre- and post-development conditions for each case study site. Runoff volume was computed as the product of annual precipitation, contributing drainage area, and a runoff coefficient (ratio of runoff produced to rainfall received). For impervious areas the following equation was used:

$$C = (0.009)\, I + 0.05$$

where I is the impervious percentage. This equation was derived by Schueler (1987) from Nationwide Urban Runoff Program data (U.S. Environmental Protection Agency 1983). With I = 100 percent for fully impervious surfaces, C is 0.95.

The basis for pervious area runoff coefficients was the Natural Resource Conservation Service's (NRCS) Urban Hydrology for Small Watersheds (NRCS 1986, as revised from the original 1975 edition). This model estimates storm event runoff as a function of precipitation and a variable representing land cover and soil, termed the curve number (CN). Larger events are forecast to produce a greater amount of runoff in relation to amount of rainfall because they more fully saturate the soil. Therefore, use of the model to estimate annual runoff requires selecting some event or group of events to represent the year. The 85th percentile, 24-hour rainfall event was used in the analysis here for the relative comparison between pre- and post-development and applied to deriving a runoff coefficient for annual estimates, recognizing that smaller storms would produce less and larger storms more runoff.

A memorandum titled Rainfall Data Analysis and Guidance for Sizing Treatment BMPs (http://www.cccleanwater.org/construction/Publications/CCCWPBasinSizingMemoFINAL_4-20-05.pdf) prepared for the Contra Costa Clean Water Program demonstrated a linear relationship between unit basin storage volume for 80 percent capture (which is related to the 85th

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percentile event) and mean annual precipitation. Rainfall for Bay Area 85th percentile, 24-hour events could thus be determined from locations where events have been established in direct proportion to mean annual rainfall.

In order to obtain appropriate regional estimates of annual precipitation, rainfall records were obtained from a number of sites in the four counties, plus the city of Vallejo, covered by the permit.[3] The mean annual range is from 13.73 to 24.30 inches, with quantities close to either 14 or 20 inches predominating. The study was performed for both of these rainfall totals. These figures were used in conjunction with 85th percentile, 24-hour event amounts of 0.75 for Los Angeles and 0.92 for Santa Rosa (http://ci.santa-rosa.ca.us/pworks/other/SW/SRSWManualFinalDraft.pdf), respectively, and mean annual totals of 12 and 31 inches for the respective cities to estimate 85 percentile, 24-hour event quantities of 0.77 and 0.82 inch for the 14 and 20-inch Bay Area rainfall zones, respectively.

Pre- and post-development runoff quantities were computed with selected CN values and the 0.77- and 0.82-inch rainfalls. The CN choices based on tabulated data in NRCS (1986) and professional judgment were 83 before development and 86 after land modification. Estimate runoff amounts were then divided by the rainfall totals to obtain runoff coefficients. The results were about the same for the two rainfall zones at 0.07 and 0.12 before and after development, respectively. Finally, total annual runoff volumes were estimated based on the two average annual precipitation figures.

Stormwater Runoff Pollutant Discharges

Annual pollutant mass discharges were estimated as the product of annual runoff volumes produced by the various land use and cover types and pollutant concentrations typical of those areas. Again, the 0.75-inch precipitation event was used as a basis for volumes. Stormwater pollutant data have typically been measured and reported for general land use types (e.g., single-family residential, commercial). However, an investigation of low impact development practices of the type this study sought to conduct demands data on specific land coverages. The literature offers few data on this basis. Those available and used herein were assembled by a consultant to the City of Seattle for a project in which the author participated. They appear in Attachment A (Herrera Environmental Consultants, Inc. undated).

Pollutant concentrations expected to occur typically in the mixed runoff from the several land use and cover types making up a development were estimated by mass balance; i.e., the concentrations from the different areas of the sites were combined in proportion to their contribution to the total runoff.

The Effect of Conventional Treatment BMPs on Runoff Volume, Pollutant Discharges, and Recharge Rates

The first question in analyzing how BMPs reduce runoff volumes and pollutant discharges was, What BMPs are being employed in Bay Area developments under the permit now in force? These county permits provide regulated entities with a large number of choices and few fixed requirements regarding the selection of stormwater BMPs. (See Contra Costa County NPDES Municipal Stormwater Permit, Order No. 99-058; see also Santa Clara County NPDES Municipal Stormwater Permit, Order No. 01-024, at C.3.a.). Clean Water Program Available options presumably include manufactured BMPs, such as drain inlet inserts (DIIs) and continuous deflective separation (CDS) units. Developments may also select such non-

[3] http://www.census.gov/stab/ccdb/cit7140a.txt, http://www.acwd.org/dms_docs/76d0b026b60d97830492079a48b1cb88.pdf, http://www.ci.berkely.ca.us/aboutberkeley/weather.html, http://www.usbr.gov/dataweb/dams/ca10168.htm, http://www.redwoodcity.org/about/weather.html.

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proprietary devices as extended-detention basins (EDBs) and biofiltration swales and filter strips. EDBs hold water for two to three days for solids settlement before releasing whatever does not infiltrate or evaporate. Biofiltration treats runoff through various processes mediated by vegetation and soil. In a swale, runoff flows at some depth in a channel, whereas a filter strip is a broad surface over which water sheet flows. Each of these BMP types was applied to each case study, although it is not clear that these BMPs, in actuality, have been implemented consistently within the Bay Area to date.

The principal basis for the analysis of BMP performance was the California Department of Transportation's (CalTrans, 2004) BMP Retrofit Pilot Program, performed in San Diego and Los Angeles Counties. One important result of the program was that BMPs with a natural surface infiltrate and evaporate (probably, mostly infiltrate) a substantial amount of runoff, even if conditions do not appear to be favorable for an infiltration basin. On average, the EDBs, swales, and filter strips lost 40, 50 and 30 percent, respectively, of the entering flow before the discharge point. DIIs and CDS units do not contact runoff with a natural surface, and therefore do not reduce runoff volume.

The CalTrans program further determined that BMP effluent concentrations were usually a function of the influent concentrations, and equations were developed for the functional relationships in these cases. BMPs generally reduced influent concentrations proportionately more when they were high. In relatively few situations influent concentrations were constant at an "irreducible minimum" level regardless of inflow concentrations.

In analyzing the effects of BMPs on the case study runoff, the first step was to reduce the runoff volumes estimated with no BMPs by the fractions observed to be lost in the pilot study. The next task was estimating the effluent concentrations from the relationships in the CalTrans report. The final step was calculating discharge pollutant loadings as the product of the reduced volumes and predicted effluent concentrations. As before, typical pollutant concentrations in the mixed runoff were established by mass balance.

Estimating Infiltration Capacity of the Case Study Sites

Infiltrating sufficient runoff to maintain pre-development hydrologic characteristics and prevent pollutant transport is the most effective way to protect surface receiving waters. Successfully applying infiltration requires soils and hydrogeological conditions that will pass water sufficiently rapidly to avoid overly-lengthy ponding, while not allowing percolating water to reach ground-water before the soil column captures pollutants.

The study assumed that infiltration would occur in surface facilities and not in below-ground trenches. The use of trenches is certainly possible, and was judged to be an approved BMP by CalTrans after the pilot study. However, the intent of this investigation was to determine the ability of pervious areas to manage the site runoff. This was accomplished by determining the infiltration capability of the pervious areas in their original condition for each development case study, and further assessing the pervious areas' infiltration capabilities if soils were modified according to low impact development practices.

The chief basis for this aspect of the work was an assessment of infiltration capacity and benefits for Los Angeles' San Fernando Valley (Chralowicz et al. 2001). The Chralowicz study posited providing 0.1-0.5 acre for infiltration basins to serve each 5 acres of contributing drainage area. At 2-3 ft deep, it was estimated that such basins could infiltrate 0.90-1.87 acre-ft/year of runoff in San Fernando Valley conditions. Soils there are generally various loam textures with infiltration rates of approximately 0.5-2.0 inches/hour. Loams are also common formations in the portion of the Bay Area covered by this report, those areas with Hydrologic

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Soil Groups A, B, and C,[4] thus making the conclusions of the San Fernando Valley study applicable for these purposes. This information was used to estimate how much of each case study site's annual runoff would be infiltratable, and if the pervious portion would provide sufficient area for infiltration. For instance, if sufficient area were available, the infiltration configuration would not have to be in basin form but could be shallower and larger in surface area. This study's analyses assumed the use of bioretention areas rather than traditional infiltration basins.

Volume and Pollutant Source Reduction Strategies

As mentioned above, the essence of low impact development is reducing runoff problems before they can develop, at their sources, or exploiting the infiltration and treatment abilities of soils and vegetation. If a site's existing infiltration and treatment capabilities are inadequate to preserve pre-development hydrology and prevent runoff from causing or contributing to violations of water quality standards, then LID-based source reduction strategies can be implemented, infiltration and treatment capabilities can be upgraded, or both.

Source reduction can be accomplished through various LID techniques. Soil can be upgraded to store runoff until it can infiltrate, evaporate, or transpire from plants through compost addition. Soil amendment, as this practice is known, is a standard LID technique.

Upgraded soils are used in bioretention cells that hold runoff and effect its transfer to the subsurface zone. This standard LID tool can be used where sufficient space is available. This study analyzed whether the six development case study sites would have sufficient space to effectively reduce runoff using bioretention cells, assuming the soils and vegetation could be amended and enhanced where necessary.

Conventional pavements can be converted to porous asphalt or concrete or replaced with concrete or plastic unit pavers or grid systems. For such approaches to be most effective, the soils must be capable of infiltrating the runoff passing through, and may require renovation.

Source reduction can be enhanced by the LID practice of water harvesting, in which water from impervious surfaces is captured and stored for reuse in irrigation or gray water systems. For example, runoff from roofs and parking lots can be harvested, with the former being somewhat easier because of the possibility of avoiding pumping to use the water and fewer pollutants. Harvesting is a standard technique for Leadership in Energy and Environmental Design (LEED) buildings.[5] Many successful systems of this type are in operation, such as the Natural Resources Defense Council office (Santa Monica, CA), the King County Administration Building (Seattle, WA), and two buildings on the Portland State University campus (Portland, OR). This investigation examined how water harvesting could contribute to stormwater management for case study sites where infiltration capacity, available space, or both appeared to be limited.

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[4] http://gis.ca.gov/catalog/BrowseCatalog.epl?id=108, http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

[5] New Buildings Institute, Inc., *Advanced Buildings* (2005) (http://www.poweryourdesign.com/LEEDGuide.pdf).

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RESULTS OF THE ANALYSIS

1. "Base Case" Analysis: Development without Stormwater Controls

Comparison of Pre- and Post-Development Runoff Volumes

Table 2 presents a comparison between the estimated runoff volumes generated by the respective case study sites in the pre- and post-development conditions, assuming implementation of no stormwater controls on the developed sites. On sites dominated by impervious land cover, most of the infiltration that would recharge groundwater in the undeveloped state is expected to be lost to surface runoff after development. This greatly increased surface flow would raise peak flow rates and volumes in receiving water courses, raise flooding risk, and transport pollutants. Only the office building, the plan for which retained substantial pervious area, would lose less than 40 percent of the site's pre-development recharge.

Table 2. Pre- and Post-Development without BMPs: Distribution of Surface Runoff Versus Recharge to Groundwater (annual volume in acre-ft)

Distribution	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall:						
Precipitation[b]	12.8	3.54	0.90	2.47	154	0.21
Pre-development runoff[c]	0.89	0.25	0.07	0.17	10	0.02
Pre-development recharge[d]	11.9	3.29	0.83	2.30	144	0.19
Post-development impervious runoff[c]	8.07	1.51	0.42	0.57	66	0.09
Post-development pervious runoff[c]	0.51	0.24	0.06	0.23	10	0.01
Post-development total runoff[c]	8.58	1.75	0.48	0.80	76	0.10
Post-development recharge[d]	4.22	1.79	0.42	1.67	78	0.11
Post-development recharge loss (% of pre-development)	7.68 (65%)	1.50 (46%)	0.41 (49%)	0.65 (27%)	66 (45%)	0.08 (41%)
20 Inches/Year Rainfall:						
Precipitation[b]	18.2	5.06	1.29	3.54	220	0.30
Pre-development runoff[c]	1.28	0.35	0.10	0.24	15	0.03
Pre-development recharge[d]	16.9	4.71	1.19	3.30	205	0.27
Post-development impervious runoff[c]	11.5	2.16	0.60	0.82	94	0.13
Post-development pervious runoff[c]	0.73	0.34	0.08	0.33	15	0.01
Post-development total runoff[c]	12.2	2.50	0.68	1.15	109	0.14
Post-development recharge[d]	6.0	2.56	0.61	2.39	111	0.16
Post-development recharge loss (% of pre-development)	10.9 (65%)	2.15 (46%)	0.58 (49%)	0.91 (27%)	94 (45%)	0.11 (41%)

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single family home
[b] Volume of precipitation on total project area
[c] Quantity of water discharged from the site on the surface
[d] Quantity of water infiltrating the soil; the difference between precipitation and runoff

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Pollutant Concentrations and Loadings

Table 3 presents the pollutant concentrations from the literature and loadings calculated as described for the various land use and cover types represented by the case studies. Landscaped areas are expected to release the highest TSS concentration, although relatively low TSS mass loading because of the low runoff coefficient. The highest copper concentrations and loadings are expected from parking lots. Roofs, especially commercial roofs, top the list for both zinc concentrations and loadings. Landscaping would issue by far the highest phosphorus, although access roads and driveways would contribute the highest mass loadings. With expected concentrations being equal in the two rainfall zones, mass loadings in the 20 inches/year zone would be higher than those in the 14 inches/year zone in the same proportion as the ratio of rainfall quantities.

Table 3. Pollutant Concentrations and Loadings for Case Study Land Use and Cover Types

Land Use	Concentrations				Loadings			
	TSS (mg/L)	TCu (mg/L)	TZn (mg/L)	TP (mg/L)	Lbs. TSS/ acre-year	Lbs. TCu/ acre-year	Lbs. TZn/ acre-year	Lbs. TP/ acre-year
14 Inches/Year Rainfall:								
Residential roof	25	0.013	0.159	0.11	75	0.039	0.477	0.330
Commercial roof	18	0.014	0.281	0.14	54	0.042	0.844	0.420
Access road/driveway	120	0.022	0.118	0.66	360	0.066	0.354	1.981
Parking	75	0.036	0.097	0.14	225	0.108	0.291	0.420
Walkway	25	0.013	0.059	0.11	75	0.039	0.177	0.330
Landscaping	213	0.013	0.059	2.04	81	0.005	0.022	0.774
20 Inches/Year Rainfall:								
Residential roof	25	0.013	0.159	0.11	107	0.056	0.683	0.472
Commercial roof	18	0.014	0.281	0.14	77	0.060	1.207	0.601
Access road/driveway	120	0.022	0.118	0.66	515	0.094	0.507	2.834
Parking	75	0.036	0.097	0.14	322	0.155	0.417	0.601
Walkway	25	0.013	0.059	0.11	107	0.056	0.253	0.472
Landscaping	213	0.013	0.059	2.04	135	0.008	0.037	1.291

The Basin Plan freshwater acute criteria for copper and zinc are 0.013 mg/L and 0.120 mg/L, respectively (http://www.swrcb.ca.gov/rwqcb2/basinplan/web/BP_CH3.html). All developed land uses are expected to discharge copper at or above the criterion, based on the mass balance calculations using concentrations from Table 3. Any surface release from the case study sites would just meet or violate the criterion at the point of discharge, although dilution by the receiving water would lower the concentration below the criterion at some point. Even if copper mass loadings are reduced by BMPs, any surface discharge would equal or exceed the criterion initially, but it would be easier to dilute below that level. In contrast, runoff from land covers other than roofs would not violate the acute zinc criterion. Because of this difference, the evaluation considered whether or not the zinc criterion would be exceeded in each analysis, whereas there was no point in this analysis for copper. There are no equivalent water quality criteria for TSS and TP; hence, their concentrations were not further analyzed in the different scenarios.

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Table 4 shows the overall loadings, as well as zinc concentrations, expected to be delivered from the case study developments should they not be fitted with any BMPs. As Table 4 shows, all cases are forecast to exceed the 0.120 mg/L acute zinc criterion. Because of its size, the large residential development dominates the mass loading emissions.

Table 4. Case Study Pollutant Concentration and Loading Estimates without BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/ Year Rainfall:						
TZn (mg/L)	0.127	0.123	0.128	0.133	0.123	0.121
Lbs. TSS/year	1254	328	119	230	14249	20
Lbs. TCu/year	0:44	0.070	0.030	0.043	3.04	0.004
Lbs. TZn/year	2.94	0.576	0.165	0.286	25.04	0.034
Lbs. TP/year	6.24	2.27	0.68	1.69	98.55	0.14
20 Inches/ Year Rainfall:						
TZn (mg/L)	0.127	0.123	0.128	0.133	0.123	0.121
Lbs. TSS/year	1864	501	180	360	21781	30
Lbs. TCu/year	0.63	0.102	0.043	0.063	4.44	0.006
Lbs. TZn/year	4.22	0.833	0.238	0.417	36.2	0.050
Lbs. TP/year	9.60	3.55	1.05	2.71	154	0.22

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single-family home

2. *"Conventional BMP" Analysis: Effect of Basic Treatment BMPs*

Effect of Basic Treatment BMPs on Post-Development Runoff Volumes

The current set of regional permits allows regulated parties to select from a range of BMPs in order to treat or infiltrate a given quantity of annual rainfall. The administrative draft of the proposed MRP is also non-specific regarding the role of LID in satisfying permit conditions. The range of BMPs includes drain inlet inserts, CDS units, and other manufactured BMPs, detention vaults, and sand filters, all of which isolate runoff from the soil; as well as basins and biofiltration BMPs built in soil and generally having vegetation. Treatment BMPs that do not permit any runoff contact with soils discharge as much stormwater runoff as equivalent sites with no BMPs, and hence yield zero savings in recharge. As mentioned above, the CalTrans (2004) study found that BMPs with a natural surface can reduce runoff by substantial margins (30-50 percent for extended-detention basins and biofiltration).

With such a wide range of BMPs in use, runoff reduction ranging from 0 to 50 percent, and a lack of clearly ascertainable requirements, it is not possible to make a single estimate of how much recharge savings are afforded by maximal implementation of the current permits or the Municipal Regional Permit (MRP), if issued as now proposed. We made the following assumptions regarding implementation of BMPs. Assuming natural-surface BMPs perform at the average of the three types tested by CalTrans (2004), i.e., 40 percent runoff reduction, the estimate can be bounded as shown in Table 5. The table demonstrates that allowing free choice of BMPs without regard to their ability to direct water into the ground forfeits substantial groundwater recharge benefits when hardened-surface BMPs are selected. Use of soil-based conventional BMPs could cut recharge losses from half or more of the full potential to about one-quarter to one-third or less, except with the highly impervious commercial development. This analysis shows the wisdom of draining impervious to pervious surfaces, even if those surfaces are not prepared in any special way. But as subsequent analyses showed, soil amendment can gain considerably greater benefits.

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Table 5. Pre- and Post-Development with Conventional BMPs: Distribution of Surface Runoff Versus Recharge to Groundwater (annual volume in acre-ft)

Distribution	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall:						
Precipitation[b]	12.8	3.54	0.90	2.47	154	0.21
Pre-development runoff[c]	0.89	0.25	0.07	0.17	10	0.02
Pre-development recharge[d]	11.9	3.29	0.83	2.30	144	0.19
Post-development impervious runoff[e]	4.84-8.07	0.90-1.51	0.25-0.42	0.34-0.57	39-66	0.05-0.09
Post-development pervious runoff[e]	0.30-0.51	0.14-0.24	0.04-0.06	0.13-0.23	6.3-10	0.006-0.01
Post-development total runoff[e]	5.15-8.58	1.05-1.75	0.29-0.48	0.48-0.80	46-76	0.06-0.10
Post-development recharge[d, e]	4.22-7.60	1.79-2.49	0.42-0.62	1.67-2.00	78-108	0.11-0.15
Post-development recharge loss (% of pre-development)[e]	4.29-7.68 (36-65%)	0.80-1.50 (24-46%)	0.80-0.41 (26-49%)	0.30-0.65 (13-27%)	34-66 (24-45%)	0.05-0.08 (24-41%)
20 Inches/Year Rainfall:						
Precipitation[b]	18.2	5.06	1.29	3.54	220	0.30
Pre-development runoff[c]	1.28	0.35	0.10	0.24	15	0.03
Pre-development recharge[d]	16.9	4.71	1.19	3.30	205	0.27
Post-development impervious runoff[e]	6.92-11.5	1.29-2.16	0.35-0.60	0.49-0.82	56-94	0.08-0.13
Post-development pervious runoff[e]	0.44-0.73	0.20-0.34	0.05-0.08	0.19-0.33	9.0-15	0.006-0.01
Post-development total runoff[e]	7.36-12.2	1.50-2.50	0.41-0.68	0.68-1.15	65-109	0.08-0.14
Post-development recharge[d, e]	6.0-10.8	2.56-3.56	0.61-0.88	2.39-2.86	111-155	0.16-0.22
Post-development recharge loss (% of pre-development)[e]	6.1-10.9 (36-65%)	1.14-2.15 (24-46%)	0.31-0.58 (26-49%)	0.44-0.91 (13-27%)	49-94 (24-45%)	0.07-0.11 (24-41%)

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single-family home. Ranges represent 40 percent runoff volume reduction, with full site coverage by BMPs having a natural surface, to no reduction, with BMPs isolating runoff from soil.

[b] Volume of precipitation on total project area

[c] Quantity of water discharged from the site on the surface

[d] Quantity of water infiltrating the soil; the difference between precipitation and runoff [e] Ranging from the quantity with hardened bed BMPs to the quantity with soil-based BMPs

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Effect of Basic Treatment BMPs on Pollutant Discharges

Table 6 presents estimates of zinc effluent concentrations and mass loadings of the various pollutants discharged from four types of conventional treatment BMPs. The loading reduction results show the CDS units always performing below 50 percent reduction for all pollutants analyzed, and most often in the vicinity of 20 percent, with zero copper reduction.

Table 6. Pollutant Concentration and Mass Loading Reduction Estimates with Conventional BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
Effluent Concentrations:						
CDS TZn (mg/L)[a]	0.095	0.095	0.098	0.102	0.095	0.094
EDB TZn (mg/L)[a]	0.085	0.086	0.084	0.084	0.086	0.084
Swale TZn (mg/L)	0.055	0.054	0.055	0.056	0.054	0.053
Filter strip TZn (mg/L)	0.039	0.039	0.039	0.041	0.039	0.038
Mass Loading Reductions—14 Inches/Year Rainfall:						
CDS TSS reduction	15.7%	19.9%	22.0%	24.0%	19.9%	20.2%
CDS TCu reduction	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CDS TZn reduction	22.7%	22.4%	22.9%	23.1%	22.4%	22.5%
CDS TP reduction	30.6%	41.5%	40.7%	45.9%	41.5%	42.0%
EDB TSS reduction	68.1%	73.7%	79.0%	81.1%	73.7%	74.3%
EDB TCu reduction	61.9%	55.7%	66.2%	63.0%	55.7%	55.8%
EDB TZn reduction	59.7%	59.6%	60.4%	61.9%	59.6%	59.8%
EDB TP reduction	61.9%	69.7%	69.1%	72.9%	69.7%	70.1%
Swale TSS reduction	68.8%	71.1%	73.1%	73.9%	71.1%	71.3%
Swale TCu reduction	72.5%	68.5%	78.2%	73.3%	68.5%	68.5%
Swale TZn reduction	78.4%	78.1%	84.3%	78.8%	78.1%	78.2%
Swale TP reduction	66.3%	70.7%	67.2%	76.2%	70.7%	71.1%
Filter strip TSS reduction	69.9%	75.4%	80.6%	82.6%	75.4%	76.0%
Filter strip TCu reduction	74.4%	69.1%	78.2%	75.4%	69.1%	69.1%
Filter strip TZn reduction	78.3%	77.9%	78.4%	78.7%	77.9%	78.1%
Filter strip TP reduction	48.4%	53.1%	63.7%	59.8%	53.1%	53.5%

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Table 6 continued

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
Mass Loading Reductions—20 Inches/Year Rainfall:						
CDS TSS reduction	18.8%	25.0%	26.3%	30.5%	25.0%	25.4%
CDS TCu reduction	0.7%	1.9%	1.1%	3.0%	1.9%	2.0%
CDS TZn reduction	23.1%	23.3%	23.6%	24.7%	23.3%	23.4%
CDS TP reduction	35.4%	46.6%	44.8%	51.8%	46.6%	47.1%
EDB TSS reduction	68.8%	74.6%	79.6%	81.6%	74.6%	75.1%
EDB TCu reduction	61.8%	55.6%	66.0%	62.7%	55.6%	55.7%
EDB TZn reduction	59.6%	59.3%	60.2%	61.5%	59.3%	59.6%
EDB TP reduction	63.0%	70.4%	69.7%	73.4%	70.4%	70.7%
Swale TSS reduction	69.1%	71.4%	73.6%	74.1%	71.4%	71.6%
Swale TCu reduction	72.5%	68.4%	77.9%	73.1%	68.4%	68.5%
Swale TZn reduction	78.3%	78.0%	84.1%	78.6%	78.0%	78.1%
Swale TP reduction	67.6%	71.9%	68.2%	77.1%	71.9%	72.3%
Filter strip TSS reduction	70.6%	76.3%	81.2%	83.1%	76.3%	76.8%
Filter strip TCu reduction	74.4%	69.0%	78.0%	75.1%	69.0%	69.1%
Filter strip TZn reduction	78.2%	77.8%	78.3%	78.5%	77.8%	77.9%
Filter strip TP reduction	49.9%	54.6%	66.3%	61.0%	54.6%	55.0%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single family home; CDS— continuous deflective separation unit; EDB—extended-detention basin

When treated with extended-detention basins, swales, or filter strips, effluents from each development case study site are expected to fall below the Basin Plan acute zinc criterion. These natural-surface BMPs, if fully implemented and well maintained, are predicted to prevent the pollutant masses generated on the six case study development sites from reaching a receiving water in both rainfall zones, which do not differ appreciably. Only total phosphorus reduction falls below 50 percent for three case studies. Otherwise, mass loading reductions range from about 60 to above 80 percent for the EDB, swale, and filter strip. These data indicate that draining impervious to pervious surfaces, even if those surfaces are not prepared in any special way, pays water quality as well as hydrologic dividends.

3. LID Analysis

(a) Hydrologic Analysis

The LID analysis repeats the analysis above, focusing here on the performance of LID techniques in reducing or eliminating runoff from the six development case studies. In addition to assessing the total runoff that would be expected, the analysis also considered whether LID techniques would be sufficient to attain compliance with a performance standard being

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considered by the Los Angeles Regional Water Quality Control Board for Ventura County, California. This standard limits EIA (Effective Impervious Area) to five percent (but our analysis further assumed EIA would be ultimately reduced to three percent). All runoff from NCIA (Not-Connected Impervious Area) was assumed to drain to vegetated surfaces.

One goal of this exercise was to identify methods that reduce runoff production in the first place. It was hypothesized that implementation of source reduction techniques could allow all of the case study sites to infiltrate substantial proportions, or all, of the developed site runoff, advancing the hydromodification mitigation objective of the Draft Permit. When runoff is dispersed into the soil instead of being rapidly collected and conveyed away, it recharges groundwater, supplementing a resource that maintains dry season stream flow and wetlands. An increased water balance can be tapped by humans for potable, irrigation, and process water supply. Additionally, runoff volume reduction would commensurately decrease pollutant mass loadings.

Accordingly, the analysis considered the practicability of more than one scenario. In one option, all roof runoff is harvested and stored for some beneficial use. A second option disperses runoff into the soil via roof downspout infiltration trenches. The former option is probably best suited to cases like large commercial and office buildings, while distribution in the soil would fit best with residences and relatively small commercial developments. The analysis was repeated with the assumptions of harvesting OFF roof runoff for some beneficial use and dispersing roof runoff from the remaining four cases in roof downspout infiltration systems.

Expected Infiltration Capacities of the Case Study Sites

The first inquiry on this subject sought to determine how much of the total annual runoff each property is expected to infiltrate, since infiltration is a basic (although not exclusive) LID technique. Based on the findings of Chralowicz et al. (2001), it was assumed that an infiltration zone of 0.1-0.5 acres in area and 2-3 ft deep would serve a drainage catchment area in the size range 0-5 acres and infiltrate 0.9-1.9 acre-ft/year. The conclusions of Chralowicz et al. (2001) were extrapolated to conservatively assume that 0.5 acre would be required to serve each additional five acres of catchment, and would infiltrate an incremental 1.4 acre-ft/year (the midpoint of the 0.9-1.9 acre-ft/year range). According to these assumptions, the following schedule of estimates applies:

Pervious Area Available for Infiltration	Catchment Served acres	Infiltration Capacity
0.5 acres	0-5 acres	1.4 acre-ft/year
1.0 acres	5-10 acres	2.8 acre-ft/year
1.5 acres	10-15 acres	4.2 acre-ft/year
(Etc.)	...	...

As a formula, infiltration capacity ≈ 2.8 x available pervious area. To apply the formula conservatively, the available area was reduced to the next lower 0.5-acre increment before multiplying by 2.8.

As shown in Table 7, in both rainfall zones all six of the sites have adequate or greater capacity to infiltrate the full annual runoff volume expected from NCIA and pervious areas where EIA is limited to three percent of the total site area. Indeed, five of the six development types have sufficient pervious area to infiltrate *all* runoff, including runoff from EIA areas. These results are based on infiltrating in the native soils with no soil amendment. For any development project at which infiltration-oriented BMPs are considered, it is important that infiltration potential be carefully assessed using site-specific soils and hydrogeologic data. In the event such an investigation reveals a marginal condition (e.g., hydraulic conductivity, spacing to groundwater) for infiltration basins, soils could be enhanced to produce bioretention zones to assist infiltration. Notably, the five case studies with far greater than necessary infiltration capacity would offer substantial flexibility in designing infiltration, allowing ponding at less than 2-3 ft depth.

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Table 7. Infiltration and Runoff Volume (With 3 Percent EIA and All NCIA Draining to Pervious Areas)

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall:						
EIA runoff (acre-ft/year)	0.36	0.10	0.03	0.07	4.4	0.01
NCIA + pervious area runoff (acre-ft/year)	**8.20**	**1.64**	**0.45**	**0.73**	**71.3**	**0.08**
Total runoff (acre-ft/year)	8.56	1.74	0.48	0.80	75.7	0.09
Pervious area available for infiltration (acres)	3.66	1.67	0.39	1.61	72.7	0.10
Estimated infiltration capacity (acre-ft/year)[b]	**9.8**	**4.2**	**1.4**	**4.2**	**203**	**0.28**
Infiltration potential[c]	>100%	>100%	>100%	>100%	>100%	>100%
20 Inches/Year Rainfall:						
EIA runoff (acre-ft/year)	0.52	0.14	0.04	0.10	6.2	0.01
NCIA + pervious area runoff (acre-ft/year)	**11.7**	**2.34**	**0.64**	**1.04**	**101.7**	**0.14**
Total runoff (acre-ft/year)	12.2	2.48	0.68	1.14	108.0	0.15
Pervious area available for infiltration (acres)	3.66	1.67	0.39	1.61	72.7	0.10
Estimated infiltration capacity (acre-ft/year)[b]	**9.8**	**4.2**	**1.4**	**4.2**	**203**	**0.28**
Infiltration potential[c]	84%	>100%	>100%	>100%	>100%	>100%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single family home;
[b] Based on Chralowicz et al. (2001) according to the schedule described above
[c] Compare runoff production from NCIA + pervious area (**row 3**) with estimated infiltration capacity (**row 6**)

As Table 7 shows, each of the six case study sites have the capacity to infiltrate *all* or substantially all of the runoff produced onsite annually by draining impervious surfaces to pervious areas on native soils or, in some soil regimes, soils amended with organic matter. If these sites were designed as envisioned in this analysis, no runoff discharge is expected in storms as large as, and probably larger than, the design storm event—using infiltration only. Discharge would be anticipated only with exceptionally intense, large, or prolonged rainfall that saturates the ground at a faster rate than water can infiltrate or evaporate. Even runoff from the area assumed to be EIA could be infiltrated in most cases based on the amount of pervious area available in typical development projects. Therefore, this analysis shows that the EIA performance standard being considered for Ventura County, California, or one more stringent, can be met readily in development projects occurring on A, B, and C soils in the San Francisco Bay Area.

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Additional Source Reduction Capabilities of the Case Study Sites: Water Harvesting Example

As noted, infiltration is one of a wide variety of LID-based source reduction techniques. Where site conditions such as soil quality or available area limit a site's infiltration capacity, other source LID measures can enhance a site's runoff retention capability. For example, soil amendment, which improves infiltration, is a standard LID technique. Water harvesting is another. Such practices can also be used where infiltration capacity is adequate, but the developer desires greater flexibility for land use on-site. Table 8 shows the added LID implementation flexibility created by subtracting roof runoff by harvesting it or efficiently directing it into the soil through downspout dispersion systems, further demonstrating the feasibility and robust performance of LID options for reducing or eliminating runoff in most expected conditions. Specifically, all development types studied could readily infiltrate and/or retain all expected annual precipitation.

Table 8. Infiltration and Runoff Volume Reduction Analysis Including Roof Runoff Harvesting or Disposal in Infiltration Trenches (Assuming 3 Percent EIA and All NCIA Draining to Pervious Areas)

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall:						
EIA runoff (acre-ft/year)	0.36	0.10	0.03	0.07	4.4	0.01
Roof runoff (acre-ft/year)	4.68	0.89	0.08	0.19	38.5	0.05
Other NCIA + pervious area runoff (acre-ft/year)	**3.52**	**0.75**	**0.37**	**0.54**	**32.7**	**0.04**
Total runoff (acre-ft/year)	8.56	1.74	0.48	0.80	75.6	0.10
Pervious area available for infiltration (acres)	3.66	1.67	0.39	1.61	72.7	0.10
Estimated infiltration capacity (acre-ft/year)[b]	**9.8**	**4.2**	**1.4**	**4.2**	**203**	**0.28**
Infiltration capacity[c]	>100%	>100%	>100%	>100%	>100%	>100%
20 Inches/Year Rainfall:						
EIA runoff (acre-ft/year)	0.52	0.14	0.04	0.10	6.2	0.01
Roof runoff (acre-ft/year)	6.67	1.27	0.12	0.28	55.1	0.08
Other NCIA + pervious area runoff (acre-ft/year)	**5.03**	**1.07**	**0.52**	**0.76**	**46.7**	**0.06**
Total runoff (acre-ft/year)	12.2	2.48	0.68	1.14	108.0	0.15
Pervious area available for infiltration (acres)	3.66	1.67	0.39	1.61	72.7	0.10

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Table 8 continued

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
Estimated infiltration capacity (acre-ft/year)[b]	**9.8**	**4.2**	**1.4**	**4.2**	**203**	**0.28**
Infiltration capacity[c]	>100%	>100%	>100%	>100%	>100%	>100%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—single family home;
[b] Based on Chralowicz et al. (2001) according to the schedule described above
[c] Comparison of runoff production from NCIA + pervious area (**row 3**) with estimated infiltration capacity (**row 6**)

Effect of Full LID Approach on Recharge

Table 9 shows the recharge benefits of preventing roofs from generating runoff and infiltrating as much as possible of the runoff from the remainder of the case study sites. The data show that LID methods offer significant benefits relative to the baseline (no stormwater controls) in all cases. These benefits are particularly impressive in developments with relatively high site imperviousness, such as in the MFR case.

Table 9. Comparison of Water Captured Annually (in acre-ft) from Development Sites for Beneficial Use with a Full LID Approach Compared to Development With No BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall:						
Pre-development recharge[b] (acre-ft)	11.9	3.29	0.83	2.30	144	0.19
No BMPs—						
Post-development recharge[b] (acre-ft)	4.22	1.79	0.42	1.67	78	0.11
Post-development recharge lost (acre-ft)	7.68	1.50	0.41	0.65	66	0.08
Post-development % recharge lost	65%	46%	49%	27%	45%	41%
Full LID approach—						
Post-development runoff capture (acre-ft)[c]	11.9	3.29	0.83	2.30	144	0.19
Post-development recharge lost (acre-ft)	0	0	0	0	0	0
Post-development % recharge lost	0%	0%	0%	0%	0%	0%

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Table 9 continued

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
20 Inches/Year Rainfall:						
Pre-development recharge[b] (acre-ft)	16.9	4.71	1.19	3.30	205	0.27
No BMPs—						
Post-development recharge[b] (acre-ft)	6.0	2.56	0.61	2.39	111	0.16
Post-development recharge lost (acre-ft)	10.9	2.15	0.58	0.91	94	0.11
Post-development % recharge lost	65%	46%	49%	27%	45%	41%
Full LID approach—						
Post-development runoff capture (acre-ft)[c]	16.9	4.71	1.19	3.30	205	0.27
Post-development recharge lost (acre-ft)	0	0	0	0	0	0
Post-development % recharge lost	0%	0%	0%	0%	0%	0%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—Single family home
[b] Quantity of water infiltrating the soil; the difference between precipitation and runoff
[c] Water either entirely infiltrated in BMPs and recharged to groundwater or partially harvested from roofs and partially infiltrated in BMPs. EIA was not distinguished from the remainder of the development, because these sites have the potential to capture all runoff.

(b) Water Quality Analysis

It was assumed that any site discharges would be subject to treatment control. For purposes of the analysis, treatment control was assumed to be provided by conventional sand filtration. This choice is appropriate for study purposes for two reasons. First, sand filters can be installed below grade, and land above can be put to other uses. Pervious area should be reserved for receiving NCIA drainage, and using sand filters would not draw land away from that service or other site uses. A second reason for the choice is that sand filter performance data equivalent to the data used in analyzing other conventional BMPs are available from the CalTrans (2004) work. Sand filters may or may not expose water to soil, depending on whether or not they have a hard bed. This analysis assumed a hard bed, meaning that no infiltration would occur and thus there would be no additional recharge in sand filters. Performance would be even better than shown in the analytical results if sand filters were built in earth.

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Pollutant Discharge Reduction Through LID Techniques

The preceding analyses demonstrated that in each of the six case studies, *all* stormwater discharges could be eliminated at least under most meteorological conditions by dispersing runoff from impervious surfaces to pervious areas. Therefore, pollutant additions to receiving waters would also be eliminated.

SUMMARY AND CONCLUSIONS

This paper demonstrated that common Bay Area residential and commercial development types subject to the Municipal NPDES Permit are likely, without stormwater management, to reduce groundwater recharge from the pre-development state by approximately half in most cases to a much higher fraction with a large ratio of impervious to pervious area. With no treatment, runoff from these developments is expected to exceed Basin Plan acute copper and zinc criteria at the point of discharge and to deliver large pollutant mass loadings to receiving waters.

Conventional soil-based BMP solutions that promote and are component parts of low impact development approaches, by contrast, regain about 30-50 percent of the recharge lost in development without stormwater management in Bay Area locations having NRCS Hydrologic Soil Groups A, B, and C. It is expected the soil-based BMPs generally would release effluent that meets the acute zinc criterion at the point of discharge, although it would still exceed or just barely meet the copper limit. Excepting phosphorus, it was found that these BMPs would capture and prevent the movement to receiving waters of the majority of the pollutant loadings considered in the analysis.

It was found that by draining all site runoff to pervious areas with A, B, or C soil types, runoff can be eliminated entirely in most development categories. It follows that a three percent Effective Impervious Area standard can be met in typical developments, as well. This result was reached assuming the use of native soils or well recognized soil enhancement techniques (typically, with compost). Draining impervious surfaces onto these soils, in connection with limiting directly connected impervious area to three percent of the site total area, should eliminate storm runoff from some development types and greatly reduce it from more highly impervious types. Adding roof runoff elimination to the LID approach (by harvesting or directing it to downspout infiltration trenches) provides an additional tool, increasing flexibility and confidence that no discharge in most meteorological conditions is a feasible performance expectation. Even in the development scenarios involving the highest relative proportion of impervious surface, losses of rainfall capture for beneficial uses could be reduced from the untreated scenario when draining to pervious areas was supplemented with water harvesting. These results demonstrate the basic soundness of the concept of using LID techniques to reduce stormwater pollution in the Bay Area, and further show that limiting directly connected impervious area and draining the remainder over pervious surfaces, as contemplated by some Regional Water Boards in California, is also feasible.

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ATTACHMENT A

POLLUTANT CONCENTRATIONS FOR URBAN SOURCE AREAS (HERRERA ENVIRONMENTAL CONSULTANTS, INC. UNDATED)

Source Area	Study	Location	Sample Size (n)	TSS (mg/L)	TCu (ug/L)	TPb (ug/L)	TZn (ug/L)	TP (mg/L)	Notes
Roofs									
Residential	Steuer, et al. 1997	MI	12	36	7	25	201	0.06	2
Residential	Bannerman, et al. 1993	WI	~48	27	15	21	149	0.15	3
Residential	Waschbusch, et al. 2000	WI	25	15	n.a.	n.a.	n.a.	0.07	3
Residential	FAR 2003	NY		*19*	*20*	*21*	*312*	*0.11*	4
Residential	Gromaire, et al. 2001	France		*29*	*37*	*493*	*3422*	*n.a.*	5
Representative Residential Roof Values				**25**	**13**	**22**	**159**	**0.11**	
Commercial	Steuer, et al. 1997	MI	12	24	20	48	215	0.09	2
Commercial	Bannerman, et al. 1993	WI	~16	15	9	9	330	0.20	3
Commercial	Waschbusch, et al. 2000	WI	25	18	n.a.	n.a.	n.a.	0.13	3
Representative Commercial Roof Values				**18**	**14**	**26**	**281**	**0.14**	
Parking Areas									
Res. Driveways	Steuer, et al. 1997	MI	12	157	34	52	148	0.35	2
Res. Driveways	Bannerman, et al. 1993	WI	~32	173	17	17	107	1.16	3
Res. Driveways	Waschbusch, et al. 2000	WI	25	34	n.a.	n.a.	n.a.	0.18	3
Driveway	FAR 2003	NY		*173*	*17*		*107*	*0.56*	4
Representative Residential Driveway Values				**120**	**22**	**27**	**118**	**0.66**	
Comm./ Inst. Park. Areas	Pitt, et al. 1995	AL	16	110	116	46	110	n.a.	1
Comm. Park. Areas	Steuer, et al. 1997	MI	12	110	22	40	178	0.2	2
Com. Park. Lot	Bannerman, et al. 1993	WI	5	58	15	22	178	0.19	3
Parking Lot	Waschbusch, et al. 2000	WI	25	51	n.a.	n.a.	n.a.	0.1	3
Parking Lot	Tiefenthaler, et al. 2001	CA	5	36	28	45	293	n.a.	6
Loading Docks	Pitt, et al. 1995	AL	3	40	22	55	55	n.a.	1
Highway Rest Areas	CalTrans 2003	CA	53	*63*	*16*	*8*	*142*	*0.47*	7
Park and Ride Facilities	CalTrans 2003	CA	179	*69*	*17*	*10*	*154*	*0.33*	7
Comm./ Res. Parking	FAR 2003	NY		*27*	*51*	*28*	*139*	*0.15*	4
Representative Parking Area/Lot Values				**75**	**36**	**26**	**97**	**0.14**	

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Landscaping/Lawns									
Landscaped Areas	Pitt, et al. 1995	AL	6	33	81	24	230	n.a.	1
Landscaping	FAR 2003	NY		*37*	*94*	*29*	*263*	n.a.	4
Representative Landscaping Values				**33**	**81**	**24**	**230**	**n.a.**	
Lawns - Residential	Steuer, et al. 1997	MI	12	262	n.a.	n.a.	n.a.	2.33	2
Lawns - Residential	Bannerman, et al. 1993	WI	~30	397	13	n.a.	59	2.67	3
Lawns	Waschbusch, et al. 2000	WI	25	59	n.a.	n.a.	n.a.	0.79	3
Lawns	Waschbusch, et al. 2000	WI	25	122	n.a.	n.a.	n.a.	1.61	3
Lawns - Fertilized	USGS 2002	WI	58	n.a.	n.a.	n.a.	n.a.	2.57	3
Lawns - Non-P Fertilized	USGS 2002	WI	38	n.a.	n.a.	n.a.	n.a.	1.89	3
Lawns - Unfertilized	USGS 2002	WI	19	n.a.	n.a.	n.a.	n.a.	1.73	3
Lawns	FAR 2003	NY	3	*602*	*17*	*17*	*50*	*2.1*	4
Representative Lawn Values				**213**	**13**	**n.a.**	**59**	**2.04**	

Notes:

Representative values are weighted means of collected data. Italicized values were omitted from these calculations.

1 - Grab samples from residential, commercial/institutional, and industrial rooftops. Values represent mean of DETECTED concentrations

2 - Flow-weighted composite samples, geometric mean concentrations

3 - Geometric mean concentrations

4 - Citation appears to be erroneous - original source of data is unknown. Not used to calculate representative value

5 - Median concentrations. Not used to calculate representative values due to site location and variation from other values.

6 - Mean concentrations from simulated rainfall study

7 - Mean concentrations. Not used to calculate representative values due to transportation nature of land use.

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SUPPLEMENTARY INVESTIGATION OF THE FEASIBILITY AND BENEFITS OF LOW-IMPACT SITE DESIGN PRACTICES ("LID") FOR THE SAN FRANCISCO BAY AREA

Richard R. Horner[†]

ABSTRACT

The Clean Water Act NPDES permit that regulates municipal separate storm sewer systems (MS4s) in the San Francisco Bay Area, California will be reissued in 2007. The draft permit includes general provisions related to low impact development practices (LID) for certain kinds of development and redevelopment projects. Using eight representative development project case studies, based on California building records, the author investigated the practicability and relative benefits of LID options for the portion of the region having soils potentially limiting to infiltration. The principal LID option applicable in this situation is roof runoff harvesting, supplement by dispersion of the roof water in single-home sites. Other site runoff would be treated by conventional stormwater best management practices (BMPs), as specified in the permit. The results showed that effectively managing roof runoff and treating the remainder with conventional BMPS can: (1) reduce annual runoff volumes by almost half to more than 3/4, depending on land use characteristics, with much of the water saved available for a beneficial use; and (2) decrease mass loadings of pollutants to receiving waters by 63 to over 90 percent, depending on pollutant and land use.

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INTRODUCTION

Background

A report titled Initial Investigation of the Feasibility and Benefits of Low-Impact Development Practices ("LID") for the San Francisco Bay Area used six representative development project case studies, based on California building records, to investigate the practicability and relative benefits of LID options for the majority of the region having soils potentially suitable for infiltration either in their natural state or after amendment using well recognized LID techniques. The results demonstrated that: (1) LID site design and source control techniques are more effective than conventional best management practices (BMPs) in reducing runoff rates; and (2) in each of the case studies, LID methods would reduce site runoff volume and pollutant loading to zero in typical rainfall scenarios.

For a broad regional assessment of relatively large scale use of soil-based, infiltrative LID practices, the initial report covered areas having soils in Natural Resources Conservation Service (NRCS) Hydrologic Soil Groups A, B, or C as classified by the Natural Resources Conservation Service (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Depending on site-specific conditions, A and B soils would generally effectively infiltrate water without modification, whereas C soils could require organic amendments according to now standard LID methods. This supplementary report covers locations with group D soils, which are generally not amenable to infiltration, again depending on the specific conditions on-site. A minority but still substantial fraction of the Bay Area has group D soils (39.3, 68.0, 18.3, and 50.1 percent of the mapped areas of Alameda, Contra Costa, San Mateo, and Santa Clara Counties, respectively). Regarding any mapped soil type, it is important to keep in mind that soils vary considerably within small distances. Characteristics at specific locations can deviate greatly from

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those of the major mapped unit, making infiltration potential either more or less than may be expected from the mapping. The soil survey data are regarded as appropriate for use in broad-scale assessments such as underlie this and the initial report, but once site-specific implementation begins, it is important to verify site conditions.

General Assessment Methods

The assessment for group D soils reported herein emphasizes the use of LID practices appropriate in areas with relatively restrictive soils to the greatest possible extent, supplemented by conventional stormwater management practices implemented at fully practicable, high levels of effectiveness. The assessment was performed in a manner analogous to the analysis for the other soil groups and as described in the initial report. To recap briefly, with respect to each of several development case studies, three assessments were undertaken: a baseline scenario incorporating no stormwater management controls; a second scenario employing conventional BMPs; and a third development scenario employing LID stormwater management strategies. In each assessment, annual stormwater runoff volumes were estimated, as well as concentrations and mass loadings (the products of concentrations times flow volumes) of four pollutants: (1) total suspended solids (TSS), (2) total recoverable copper (TCu), (3) total recoverable zinc (TZn), and (4) total phosphorus (TP). The results of the second and third assessments were expressed in terms of the extent to which the management practices would reduce pollutant concentrations and loadings and runoff volumes, converting stormwater discharge a potential beneficial use (direct consumption or, in the case of group A, B, C soil areas, groundwater recharge).

Six case studies were selected to represent a range of urban development types considered to be representative of the Bay Area. These case studies involved: a multi-family residential complex (MFR), a relatively small-scale (23 homes) single-family residential development (Sm-SFR), a restaurant (REST), an office building (OFF), a relatively large (1000 homes) single-family residential development (Lg-SFR), and a single home (SINGLE). The land cover types for these various land uses were derived from building permit and other public records from the Bay Area or elsewhere in California.

Adaptation of Methods for Areas with Group D Soils

A key LID technique in a setting with soils relatively restrictive to infiltration is water harvesting, which can be applied at larger scales in commercial and light industrial developments and at smaller residential scales using cisterns or rain barrels. Harvesting has been successful in reducing runoff discharged to the storm drain system and conserving water in applications at all scales. For example, in downtown Seattle the King County Government Center collects enough roof runoff to supply over 60 percent of the toilet flushing and plant irrigation water requirements, saving approximately 1.4 million gallons of potable water per year (http://www.psat.wa.gov/Publications/LID_studies/rooftop_rainwater.htm, http://dnr.metrokc.gov/dnrp/ksc_tour/features/features.htm). A much smaller public building in Seattle, the Carkeek Environmental Learning Center, drains roof runoff into a 3500-gallon cistern to supply toilets (http://www.harvesth2o.com/seattle.shtml). Collecting drainage from individual dwellings for household use is a standard technique around the world, particularly in areas deficient in rainfall and without affordable alternative sources.

An additional general category of LID practices for poorly infiltrating locations, applicable especially at single homes and other relatively small-scale developments, is runoff dispersion for storage in vegetation and soil until evapotranspiration and some infiltration occurs. Section C.3.c of the California Regional Water Quality Control Board San Francisco Bay Region "Administrative Draft" NPDES Municipal Regional Stormwater Permit (“the Permit”) requires all single-family home projects that create and/or replace 5,000 square feet or more of impervious surface to implement one or more stormwater lot-scale BMPs from a selection of: (1) diverting roof runoff to vegetated areas; (2) directing paved surface runoff flow to vegetated areas; and/or (3) installing driveways, patios, and walkways with pervious material such as pervious concrete or pavers. Another way of distributing and dissipating roof runoff used successfully in varied soils in the state of Washington is the downspout dispersion system, consisting of a splash block or gravel-filled trench serving to spread roof runoff over a vegetated area (Washington Department of Ecology 2005 [Volume III, Section 3.1.2]).

The basis of the group D soils assessment was harvesting roof runoff to the maximum possible degree, supplemented in smaller-scale developments by runoff dispersion methods. The report asserts that, through these LID BMPs, it is practicable to prevent the entrance of any roof runoff into the municipal storm drain system in any soils setting in the Bay Area. In group D soils, infiltration likely cannot be relied upon to reduce runoff from other portions of developments, such as walkways, driveways, parking lots, access roads, and landscaping. Some water loss would undoubtedly occur, especially through evapotranspiration and at least some infiltration of runoff generated on or directed to landscaping. The analysis presented in this report does not take account of these losses and hence is somewhat conservative in estimating benefits.

As required by the Permit, any runoff not attenuated by harvest, evapotranspiration, or infiltration would be subject to quantity and quality controls. The analysis assumes that extended-detention basins (EDBs) with water residence times up to 72 hours would provide this control. EDBs are one of several general-purpose, conventional stormwater BMPs available for this service, others being wet ponds, constructed wetlands, sand or other media filters, and biofiltration swales and filter strips. The California Department of Transportation (Caltrans, 2004) tested the performance of all of these practices in its BMP Retrofit Pilot Program, conducted in San Diego and Los Angeles Counties. The initial report investigating LID for A, B, and C soils presented estimates of benefits for EDBs, swales, and filter strips, along with continuous deflective separation (CDS) units, a practice that effectively captures only large particulate pollutants. For brevity, this follow-up report focuses on just EDBs as the supplement to LID. In performance, EDBs tend to fall between swales and filter strips for total suspended solids, slightly lower than the other two BMP types for metals, and either between the two or comparable to swales for total phosphorus.

These practices were applied to the same six case studies used in the initial analysis and described in Table 1 of the first report. Two additional case studies were defined for the assessment reported here: a sizeable commercial retail installation (COMM) and an urban redevelopment (REDEV). The hypothetical COMM scenario consists of a building with a 2-acre footprint and 500 parking spaces. Parking spaces were estimated to be 176 sq ft in area, which corresponds to 8 ft width by 22 ft length dimensions. A simple, square parking lot with roadways around the four sides and a square building with walkways also around the four sides were assumed. Roadways and walkways were taken to be 20 ft and 6 ft wide, respectively. The REDEV case was taken from an actual project in Berkeley involving a remodel of an existing structure, built originally as a corner grocery store with apartments above and a large side yard, and the addition of a new building on the same site to create a nine-unit, mixed-use, urban infill project. Table 1 summarizes the characteristics of these two case studies. The table also provides the recorded or estimated areas in each land use and cover type.

Table 1. Characteristics and Land Use and Land Cover Areas of Added Case Studies

	COMM[a]	REDEV[a]
No. buildings	1	1
Total area (ft^2)	226,529	5,451
Roof area (ft^2)	87,120	3,435
No. parking spaces	500	2 uncovered
Parking area (ft^2)	88,000	316 uncovered
Access road area (ft^2)	23,732	-
Walkway area (ft^2)	7,084	350
Driveway area (ft^2)	-	650
Landscape area (ft^2)	20,594	700

[a] COMM—retail commercial; REDEV—commercial/residential infill

The assessment for group D soils employed the same methods as the earlier analysis to estimate annual stormwater runoff volumes and pollutant discharges. Please refer to the initial report for details on those

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methods. The Natural Resource Conservation Service (NRCS, 1986) methodology cited in that report was applied to estimate that infiltration in group D soils would be roughly 60 percent of the amount through landscaping or the bed of a conventional BMP in C soils, which were the basis for establishing runoff coefficients in the first analysis. While that initial analysis was performed for both 14- and 20-inch average annual runoff zones, typical of different Bay Area locations, this supplementary work covered only the former condition. This simplification was made in the interest of brevity in this report, given that the first analysis showed almost no difference in conclusions between the two situations.

RESULTS OF THE ANALYSIS

Table 2 provides a comprehensive summary of the results. Rows shaded in gray compare runoff and pollutant discharges with and without treatment by CDS units, which can capture relatively large solids but have no mechanisms for dissolved substances and the finer particles. Having no soil contact and very limited residence time for evaporation, this BMP cannot reduce runoff volume at all. It can achieve some substantial reductions in TSS and TP for land uses relatively high in landscaped area but little removal of metals, especially copper.

The blue-shaded rows show the performance of conventional EDBs. In the group D soils considered in this analysis, they were estimated to reduce annual runoff volumes by 13-23 percent, the higher values for land uses with relatively small impervious footprints (OFF and REST). These BMPs can capture the majority of the long-term mass loading of most pollutants from most land uses in these soils, falling below 50 percent in reducing metals in stormwater flowing from residential developments.

Rows shaded in green present the results of applying LID BMPs appropriate for group D soils, roof runoff harvesting supplemented by dispersion in single-home land uses, plus treating the remaining runoff with EDBs. Comparing annual runoff volumes with and without LID, it can be seen that removing roof runoff from the storm drain system affords very significant benefits in reducing surface discharge and putting much of that water to productive use. Compared to directing all site runoff to EDBs, LID is expected to reduce volume by almost 10 times in the REDEV case, by about five times for the various residential land uses, 3.6 times for the large commercial development, and around twice for the OFF and REST cases. This management strategy can recover over 3/4 of the stormwater that would otherwise go down the drain in the intense redevelopment case, approximately 2/3 for the multi- and single-family residential cases, over half in the COMM development, and almost half in the office and restaurant cases with relatively small roof footprints.

Reduction of volume translates to decreases in pollutant loadings also. The combination of LID and EDB treatment is estimated to raise copper and zinc reductions to about 70 to over 90 percent in all except the developments with relatively low roof proportions (60-65 percent in these cases). TSS predictions come in at a quite consistent 75-82 percent across land uses. Total phosphorus estimates are a similarly consistent 63-71 percent, a bit higher in the highly impervious REDEV case.

Effectively managing roof runoff gives a way out of the dilemma posed by group D soils in the Bay Area. The analysis has demonstrated that harvesting this runoff stream, supplemented by ground dispersion techniques with sufficient space, shows strong promise to reduce the majority of flow inputs to municipal storm drain systems while conserving water. Moreover, this strategy can also stem the majority of solids, copper, zinc, and phosphorus transport to receiving waters.

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Table 2. Runoff Volume and Pollutant Loading Reductions with Conventional and Low-Impact Development (LID) Best Management Practices (BMPs) for Eight Land Use Case Studies in Hydrologic Group D Soils

	COMM[a]	OFF[a]	REST[a]	REDEV[a]	MFR[a]	Lg-SFR[a]	Sm-SFR[a]	SINGLE
Total annual runoff with no BMPs (ac-ft)	5.29	0.80	0.47	0.12	8.57	75.66	1.74	0.10
Total annual runoff with CDS units[b] (reduction)	5.29 (0.0%)	0.80 (0.0%)	0.47 (0.0%)	0.12 (0.0%)	8.57 (0.0%)	75.66 (0.0%)	1.74 (0.0%)	0.10 (0.0%)
Total annual runoff with EDBs[b] (reduction)	4.43 (16.3%)	0.63 (21.3%)	0.36 (23.2%)	0.11 (8.1%)	7.48 (12.7%)	65.27 (13.7%)	1.50 (13.7%)	0.09 (13.3%)
Total annual runoff with LID[b] (reduction)	2.22 (58.0%)	0.44 (45.0%)	0.28 (40.4%)	0.03 (78.9%)	2.80 (67.3%)	26.72 (64.8%)	0.61 (64.8%)	0.04 (65.7%)
CDS TSS reduction[b, c]	19.4%	44.8%	33.9%	22.1%	27.1%	37.1%	37.1%	37.7%
CDS TCu reduction[b, c]	0.4%	11.0%	4.2%	0.9%	2.7%	7.3%	7.3%	7.6%
CDS TZn reduction[b, c]	25.3%	29.1%	25.5%	25.5%	24.1%	25.6%	25.6%	25.9%
CDS TP reduction[b, c]	25.9%	63.7%	54.3%	35.7%	46.7%	57.6%	57.6%	58.2%
EDB TSS reduction[b, c]	64.7%	78.1%	74.9%	66.5%	62.8%	70.3%	70.3%	70.9%
EDB TCu reduction[b, c]	57.9%	51.6%	56.4%	53.2%	51.4%	43.5%	43.5%	43.6%
EDB TZn reduction[b, c]	57.6%	49.6%	48.9%	58.1%	48.5%	47.7%	47.7%	48.0%
EDB TP reduction[b, c]	44.4%	67.6%	63.3%	52.8%	56.3%	64.4%	64.4%	64.7%
LID + EDB TSS reduction[b, c, d]	74.6%	80.3%	77.0%	81.5%	79.4%	81.3%	81.3%	81.8%
LID + EDB TCu reduction[b, c, d]	71.9%	60.3%	62.2%	82.3%	73.8%	68.9%	68.9%	69.5%
LID + EDB TZn reduction[b, c, d]	79.7%	65.1%	60.9%	92.3%	78.9%	76.4%	76.4%	77.0%
LID + EDB TP reduction[b, c, d]	63.1%	69.8%	66.0%	75.2%	69.4%	70.8%	70.8%	71.1%

[a] COMM—retail commercial; OFF—office building; REST—restaurant; REDEV—commercial/residential redevelopment; MFR—multi-family residential; Lg-SFR—large-scale single-family residential; Sm-SFR—small-scale single-family residential; SINGLE—single family home

[b] CDS— continuous deflective separation; EDBs—extended-detention basins; reduction—comparison with no BMPs

[c] TSS—total suspended solids; TCu—total recoverable copper; TZn—total recoverable zinc; TP—total phosphorus

[d] LID + EDB—roof runoff harvesting for COMM, OFF, REST, REDEV, AND MFR; harvesting supplemented by dispersion of roof runoff for Lg-SFR, Sm-SFR, and SINGLE; treatment of remaining runoff by EDBs

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SARB_014452

The Economics of Low-Impact Development: A Literature Review

November 2007

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This work was supported in part by funding provided by the Waterkeeper Alliance.

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EXECUTIVE SUMMARY

Low-impact development (LID) methods can cost less to install, have lower operations and maintenance (O&M) costs, and provide more cost-effective stormwater management and water-quality services than conventional stormwater controls. LID also provides ecosystem services and associated economic benefits that conventional stormwater controls do not.

The available economic research on some of these conclusions is preliminary or limited in scope. For example, most economic studies of LID describe the costs of installing LID, or compare the costs of installing LID with the costs of installing conventional controls. Few reports quantify the economic benefits that LID can provide in addition to managing stormwater. Fewer researchers report results of studies that measure at least some costs *and* at least some benefits of LID vs. conventional controls.

The costs and benefits of LID controls can be site specific and will vary depending on the LID technology (e.g., green roof vs. bioswale), and local biophysical conditions such as topography, soil types, and precipitation. Including developers, engineers, architects and landscape architects early in the design process can help minimize the LID-specific construction costs.

Despite the fact the LID technologies have been promoted and studied since the early 1990s, for many stormwater managers and developers, LID is still a new and emerging technology. As with most new technologies, installation and other costs of LID are highest during the early phases of development and adoption. Over time, as practitioners learn more about the technology, as the number of suppliers of inputs expands, and as regulations adapt to the new technology, costs will likely decline.

Combined sewer overflows (CSO), and the resulting biophysical and economic consequences, are major concerns for municipal stormwater managers. LID can help minimize the number of CSO events and the volume of contaminated flows by managing more stormwater on site and keeping flows out of combined sewer pipes. Some preliminary evidence exists that LID can help control CSO volumes at lower cost than conventional controls.

Many municipalities have zoning and building-inspection standards in place that were adopted many years ago, long before LID was an option. Municipalities with outdated stormwater regulations typically require that builders file variances if they want to use LID controls. This can increase a builder's design and regulatory costs, which delays construction and can increase a builder's financing costs. Updating building regulations to accommodate LID can help reduce the regulatory risk and expense that builders face.

The large majority of the economic studies on LID focus on the costs of including LID in new construction. Replacing curbs, gutters and stormwater pipes with bioswales, pervious pavers and other LID controls can reduce construction costs. Protecting a site's existing drainage patterns can reduce the need for pipe infrastructure and a developer may be able to do away with surface stormwater ponds, which also increases the number of developable lots. Some researchers report that developments that emphasize LID controls and protected natural grass and forest drainage areas cost less to develop and sell for more than traditionally-developed lots with conventional stormwater controls.

Few studies considered the economic outcomes of including LID in urban redevelopment projects. Some evidence exists that LID controls cost more than conventional controls under these conditions, however, these studies excluded O&M costs of the two alternatives and the economic benefits that the LID controls can provide.

I. INTRODUCTION

Conventional stormwater controls collect stormwater from impervious surfaces, including roads, parking lots and rooftops, and transport the flow off site through buried pipes to treatment facilities or directly to receiving bodies of water. This approach efficiently collects and transports stormwater, but also can create high-velocity flows polluted with urban contaminants, including sediment, oil, fertilizers, heavy metals, and pet wastes. Such flows can erode stream banks and natural channels, and deposit pollutants that pose ecosystem and public health risks (Kloss and Calarusse 2006).The resulting ecosystem and public health consequences can create significant economic costs.

A study of the biophysical and public health damages and associated economic costs of stormwater runoff in the Puget Sound estimates these costs at over $1 billion during the next decade (Booth et al. 2006). These costs include flood-related property damage and financial losses, capital costs of new stormwater infrastructure, cleaning up stormwater-polluted water resources, and habitat restoration and protection efforts. The Natural Resources Defense Council (Kloss and Calarusse 2006) describes similar impacts attributed to conventional controls across the U.S.: stormwater sewers collect and discharge untreated stormwater to water bodies, while combined sewer and stormwater systems overflow during heavy rains, discharging both untreated sewage and stormwater into the nation's rivers and lakes. Both contribute to impaired water quality, flooding, habitat degradation, and stream bank erosion. The U.S. Environmental Protection Agency (EPA) estimates the costs of controlling combined sewer overflows (CSO) throughout the U.S. at approximately $56 billion. Developing and implementing stormwater-management programs and urban-runoff controls will cost an additional $11 to $22 billion (Kloss and Calarusse 2006).

In contrast to conventional stormwater controls, low-impact development (LID) techniques emphasize on-site treatment and infiltration of stormwater. The term low-impact development encompasses a variety of stormwater-management techniques. Examples include bioswales, rain gardens, green streets, and pervious pavers (U.S. EPA 2000). The name LID came into use around the late 1990s, however stormwater managers employed LID techniques prior to this. Technicians in Prince George's County, Maryland were some of the first to install what eventually became known as LID techniques in the early 1990s as an alternative to conventional stormwater controls. Soon after, a few communities in the Chesapeake Bay area followed, experimenting with a number of LID demonstration projects. Over time, interest in LID as an alternative or complement to conventional controls grew, and so did the number of LID demonstration projects and case studies across the United States. The EPA reviewed the early literature on LID and described their assessment of this literature in a report released in 2000 (U.S. EPA and Low Impact Development Center 2000). Their review assessed the availability and reliability of data on LID projects and the effectiveness of LID at managing stormwater. While this report focused primarily on the potential stormwater-management benefits of LID, it concluded that LID controls can be more cost effective and have lower maintenance costs than conventional stormwater controls. In December of the following year, the Center for Watershed Protection published one of the earliest studies that focused primarily on the economic aspects of "better site design," which included many LID principles (Center for Watershed Protection 2001).

The amount of information available on the economics of managing stormwater using LID has grown since the publication of these first reports. Most studies describe the costs of installing LID, or compare the costs of installing LID with the costs of installing conventional controls. Other reports focus on the economic benefits that LID can provide in addition to managing stormwater. These benefits include mitigating flooding, improving water-quality, and providing amenity values for properties adjacent to LID, such as green streets. A few—very few—researchers report results of studies that attempt to characterize at least some costs *and* at least some benefits of LID vs. conventional controls in a *single* study. In this report we summarize our review of the literature on the economic costs and benefits of managing stormwater by LID.

This literature review has three objectives. First, to describe briefly, and in plain language, the methods economists use when measuring the costs and benefits of LID and conventional stormwater controls. This information provides the reader with a context for the economic descriptions of costs and benefits that follow. Second, to summarize the literature that identifies and measures the economic costs and benefits of managing stormwater using LID, or that compares costs or benefits, or both, between LID and conventional controls. Third, to organize and present this information in a way that non-economist municipal officials, stormwater managers, ratepayer stakeholders and others can use as they consider and deliberate stormwater-management plans.

This literature review differs from literature reviews that accompany academic studies. Typically, academic literature reviews provide an introduction and a context for an analysis of a specific economic issue, e.g., a new analytical technique that measures economic benefits. In this case, the literature review is a stand-alone document that summarizes information on the broad issue of economic costs and benefits of LID. Academic literature reviews also target academic and professional economists. This literature review targets non-economist readers.

The technical effectiveness of LID stormwater controls is outside the scope of our review. Our analysis assumes that the LID techniques described in the economic studies that we reviewed provide the necessary or expected stormwater controls. As we understand, there is a growing body of literature on LID effectiveness, and we include some of these references in the Appendix to this report. Also, the more general topic of the economic values of ecosystem services, while somewhat related, was outside the scope of our review. Our analysis focused on the values of ecosystem services as affected by LID techniques.

We began our search for relevant literature by developing a list of key words with which to find reports or articles that contained relevant information. After a cursory search of LID literature, we identified LID- and economics-related key words that researchers and practitioners use when describing LID projects and analyses. The list includes words often used synonymously with LID (i.e., source control, natural drainage systems, sustainable stormwater management), or that describe a set of conservation-design strategies that include LID techniques (i.e., green infrastructure and conservation development). We also searched the literature using economics-related terms (i.e., costs, benefits, and savings). Table 1-1 lists the LID- and economics-related search terms we used in our search of the literature.

Using the terms listed in Table 1-1, we searched databases that contained the widest-possible range of sources including academic literature, reports produced by government

agencies and non-profit organizations, news coverage, and articles in the popular press. These databases include information published in peer-reviewed articles, books, reports, conference papers and presentations, and web pages. Table 1-2 lists the databases included in our search.

Table 1-1: Search Terms

LID-Related Search Terms	Economics-Related Search Terms
Low-impact development	Economics
Source control	Benefits, economic benefits
Green infrastructure	Costs, economic costs
Natural drainage systems	Cost comparison
Sustainable stormwater management	Savings
Conservation development	Benefit cost analysis, cost benefit analysis
Alternative stormwater management	Cost effectiveness
Better site design	
Low-impact urban design and development	

Source: ECONorthwest

Table 1-2: Databases

Database	Description
Academic Search Premier	Index of 8,000 academic journals in the social sciences, humanities, and general science, back to 1965.
Article First	Index of 16,000 journal titles in business, humanities, popular culture, science, social science, and technology, back to 1990.
Econlit	American Economic Association's index of economic research, back to 1969.
Environmental Protection Agency (EPA) website	Database of studies, reports, educational material, and newsletters authored or supported by the EPA.
Environmental Valuation Reference Inventory (EVRI)	Database of empirical studies conducted internationally on the economic values of ecosystem services.
Google	Source for non-peer reviewed reports, articles, websites and other publications.
Journal Storage (JSTOR)	Index of over 100 major research journals in a variety of academic disciplines, some back to 1870.
Web of Science	Index of science and social science journals, back to 1975.
WorldCat	Index of bibliographic records of books, journals, manuscripts, etc. archived in university, public and private library catalogs around the world.

Source: ECONorthwest

We reviewed potential sources for relevance. If a source contained LID-related cost or benefit information, we indexed it in our own database, summarized the information on costs or benefits, and reviewed its bibliography for additional sources of information.

This report of our review of the literature is organized as follows. The next two sections provide background information to the discussion of the economic costs and benefits of managing stormwater. This background information provides a context or economic frame-of-reference that will help the reader consider the descriptions of costs and benefits that follow.

In **Section II** we list the range of benefits associated with LID, as identified in the LID literature, along with illustrations of the values of these benefits as reported in the economic literature. We found that many more reports simply list these benefits rather than quantify them.

In **Section III** we describe two of the more common methods of measuring the economic costs and benefits of stormwater controls: the cost-effectiveness and benefit-cost methods. As the names imply, cost-effectiveness studies compare alternatives looking exclusively at the alternatives' costs. This method assumes away benefits or holds them constant across alternatives. A benefit-cost analysis considers the range of costs and benefits for each alternative. The benefit-cost method has greater data demands and can be more expensive than the cost-effectiveness approach—primarily because it adds benefits into the analysis—but it can also yield a more accurate economic picture of the full range of economic consequences of implementing the alternatives.

In **Section IV** we summarize the literature that considers the costs and benefits of LID. The large majority of these studies focus exclusively on the costs of installing LID, or compare the costs of installing LID with the costs of installing conventional controls. Some studies look beyond installation costs to include operations and maintenance costs. Few studies consider both the costs and benefits of LID or compare costs and benefits of LID with conventional controls.[1] When the literature allowed, we described the economic aspects of adopting LID from the perspective of municipal decisionmakers, ratepayer stakeholders, and private developers.

In **Section V** we describe LID from the perspective of property developers. As with other new technologies, adopting LID includes opportunities and risks. We describe the risks and challenges that developers face when they include LID controls in their projects and the successes developers have had adopting LID.

In **Section VI** we discuss areas of future research that would increase our understanding of the economics of LID. For example, limited information exists on the life-cycle costs of LID, the economic benefits of LID beyond stormwater control, and the economic impacts of installing LID in urban-redevelopment settings.

The **Bibliography** lists the references we cite in this report. During our search for information on the economic aspects of LID, we encountered non-economic information that supports the use of LID. We list this information in the **Appendix** to this report.

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[1] We list the reported dollar amounts of costs and benefits without converting to current, 2007-year, dollars because in most cases, the available information prevented such a conversion.

II. ECOSYSTEM SERVICES PROVIDED OR ENHANCED BY LOW-IMPACT DEVELOPMENT

Conventional controls and LID techniques both manage stormwater flows. By promoting stormwater management on site using a variety of techniques, LID controls can provide a range of ecosystem services beyond stormwater management. Braden and Johnston (2004), Coffman (2002), and the Natural Resources Defense Council (Lehner et al. 2001) list and describe the kinds of ecosystem services that LID can provide or enhance. Taken together, these researchers describe the following ecosystem services: reduced flooding, improved water quality, increased groundwater recharge, reduced public expenditures on stormwater infrastructure, reduced ambient air temperatures and reduced energy demand, improved air quality, and enhanced aesthetics and property values. We briefly describe each of these services below.

Reduced Flooding

Braden and Johnston (2004) studied the flood-mitigation benefits of managing stormwater on site, including reduced frequency, area, and impact of flooding events. In a follow-up study, Johnston, Braden, and Price (2006) focus on the downstream benefits accrued from flood reduction accomplished by greater upstream on-site retention of stormwater. These benefits include reduce expenditures on bridges, culverts and other water-related infrastructure.

Improved Water Quality

Brown and Schueler (1997), Center for Watershed Protection (1998), U.S. EPA and Low Impact Development Center (2000), and Braden and Johnston (2004) describe the water-quality benefits that LID stormwater controls can provide. These benefits include effectively capturing oil and sediment, animal waste, landscaping chemicals, and other common urban pollutants that typically wash into sewers and receiving water bodies during storm events. Plumb and Seggos (2007) report that LID controls that include vegetation and soil infiltration, e.g., bioswales, can prevent more stormwater pollutants from entering New York City's harbor than conventional controls.

Increased Ground Water Recharge

On-site infiltration of stormwater helps recharge groundwater aquifers. According to a report by American Rivers, the Natural Resources Defense Council, and Smart Growth America (Otto et al. 2002), areas of impervious cover can significantly reduce ground water recharge and associated water supplies. The study found that impervious surfaces in Atlanta reduced groundwater infiltration by up to 132 billion gallons each year—enough water to serve the household needs of up to 3.6 million people per year.

Braden and Johnston (2004) distinguish between two services associated with increased groundwater recharge: the increased volume of water available for withdrawal and consumption, and maintaining a higher water table, which reduces pumping costs and increases well pressure.

Reduced Public Expenditures on Stormwater Infrastructure

The Center for Watershed Protection (1998), Lehner et al. (2001), and U.S. EPA (2005) report that LID techniques, such as bioswales, rain gardens, and permeable surfaces, can help reduce the demand for conventional stormwater controls, such as curb-and-gutter, and pipe-and-pond infrastructure. Braden and Johnston (2004) report that retaining stormwater runoff on site reduces the size requirements for downstream pipes and culverts, and reduces the need to protect stream channels against erosion.

Two recent studies by the Natural Resources Defense Council (Kloss and Calarusse 2006) and Riverkeeper (Plumb and Seggos 2007) report that by managing stormwater on site, LID techniques can help reduce combined sewer overflows. Combined sewer systems transport both sewage and stormwater flows. Depending on the capacity of the pipes and the amount of rainfall, the volume of combined sewer and stormwater flows can exceed the capacity of the pipes when it rains. When this happens, overflows of sewage and stormwater go directly to receiving bodies of water untreated. LID helps to keep stormwater out of the combined system, which reduces CSO events. Thurston (2003) found that decentralized stormwater controls, such as LID, can control CSO events at a lower cost than conventional controls.

Reduced Energy Use

LID techniques, such as green roofs and shade trees incorporated into bioswales and other controls can provide natural temperature regulation, which can help reduce energy demand and costs in urban areas. Plumb and Seggos (2007) estimate that covering a significant amount of the roof area in New York City with green roofs could lower ambient air temperatures in summer by an estimated 1.4 degrees Fahrenheit. The U.S. EPA and Low Impact Development Center (2000) report that the insulation properties of vegetated roof covers can help reduce a building's energy demand, and notes that green roofs in Europe have successfully reduced energy use in buildings.

Improved Air Quality

Trees and vegetation incorporated into LID help improve air quality by sequestering pollutants from the air, including nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and particulate matter (American Forests 2000-2006). In a study by Trees New York and Trees New Jersey, Bisco Werner et al. (2001) report similar air-quality benefits of trees and vegetation in urban areas. Plumb and Seggos (2007) cite one study that found that a single tree can remove 0.44 pounds of air pollution per year.

Enhanced Aesthetics and Property Values

Several studies including Lacy (1990), Mohamed (2006), U.S. Department of Defense (2004), and Bisco Werner et al. (2001) report that the natural features and vegetative cover of LID can enhance an area's aesthetics, and increase adjacent property values. The U.S. Department of Defense (2004) highlights how LID can improve the aesthetics of the landscape and increase adjacent property values by providing architectural interest to otherwise open spaces. On commercial sites, Bisco Werner et al. (2001) found that LID on commercial sites provided amenities for people living and working in the area and complemented the site's economic vitality, which improved its competitive advantage over similar establishments for customers and tenants.

III. Economic Framework: Measuring Costs and Benefits of Low-Impact Development

Researchers and practitioners assess the economic aspects of LID using several methodologies. These methodologies range from rough cost evaluations, that compare a subset of costs of LID against the same costs for conventional management techniques, to benefit-cost analyses, that compare a range of costs and benefits of LID to the same for conventional stormwater controls. This section examines the differences in these methodologies.

Most economic evaluations of LID reported in the literature emphasize costs. The overwhelming majority of these studies confined their analyses to measuring installation costs. Evaluators prefer this method perhaps because from a developer's perspective, installation cost is one of the most important considerations when choosing between LID or conventional controls. LID can compare favorably with conventional controls in a side-by-side analysis of installation costs (*see for example* Foss 2005; Conservation Research Institute 2005; U.S. EPA 2005; Zickler 2004), however, focusing on installation costs misses other relevant economic information. For example, such a focus excludes operation and maintenance (O & M) costs, differences in the effectiveness of LID versus conventional systems, and the environmental and economic benefits that LID can provide, but which conventional controls cannot.

Evaluating projects based on installation costs has advantages of costing less than studies that include other economic factors, e.g., O & M costs, taking less time than more extensive analyses, and relying on readily available construction-cost data. The tradeoff for stormwater managers is an incomplete and possibly biased description of economic consequences, especially over the long term.

Some researchers look beyond comparisons of installation costs and evaluate LID and conventional controls using a method know as a life-cycle cost analysis (LCCA) (Powell et al. 2005; Sample et al. 2003; Vesely et al. 2005). This approach considers a comprehensive range of stormwater-management costs including planning and design costs, installation costs, O & M costs, and end-of-life decommissioning costs. An LCCA method requires more data than a comparison of installation costs, and this data, particularly data on lifetime O & M costs, may not exist or is difficult and costly to obtain. The tradeoff for policy makers is more accurate information on the cost implications of alternative stormwater-management options. However, LCCA, like more limited cost comparisons, excludes measures of economic benefits.

Another limitation of cost comparisons is that they ignore differences in effectiveness between LID and conventional controls. For this reason, researchers recommend that LCCA should compare projects that provide the similar levels of services (Powell et al. 2005). Brewer and Fisher (2004), Horner, Lim, and Burges (2004), and Zielinski (2000) found, however, that LID approaches can manage stormwater quantity and quality more effectively than the conventional approaches, either controlling more flow, or filtering more pollutants, or both. In these cases, an LCCA study could conclude that an LID option costs more than the conventional control, without accounting for the fact that the LID option can manage a larger volume of stormwater.

The benefit-cost approach overcomes the limitations of simple cost comparisons or LCCA by considering the full range of costs and benefits of alternative management options. The tradeoff is that the benefit-cost approach requires more data than cost comparison, which increases the time and costs of conducting the economic analysis.

The benefit-cost approach evaluates the net economic benefits of a project, or compares outcomes among projects, by comparing relevant costs with relevant economic benefits (Boardman et al. 2005; Field and Field 2006; Gramlich 1990; Kolstad 2000). Economic researchers in academic, business, and public-policy sectors have for many years conducted benefit-cost analyses in a wide variety of applications. Since at least the middle of the twentieth century, economic evaluations of large-scale public projects included some type of benefit-cost analysis, and since 1981, the federal government required that new programs and regulations include a benefit cost analysis (Freeman 2003). The U.S. Office of Management and Budget (OMB) considers the benefit-cost method the "recommended" technique when conducting formal economic analyses of government programs or projects (U.S. OMB 1992). Over the years, the technique has grown more sophisticated, especially with respect to measuring and incorporating non-market goods and services, such as the values of ecosystem services (Croote 1999).

The economic literature on benefit-cost analysis is voluminous and growing, but the basic process can be broken into four steps (Field and Field 2006).[2]

1. The first step defines the scope of the analysis, including the population that will experience the benefits and costs, and the elements of the project, including location, timing, and characteristics of the work to be done.

2. The second step determines a project's full range of inputs and effects, from the planning and design phase through the end of the project's lifespan.

3. The third step identifies and, where possible, quantifies the costs and benefits resulting from the project's inputs and effects. Where quantification is not possible, qualitatively describe the cost or benefit in as much detail as possible, including degree of uncertainty and expected timing of impacts (long-term or short-term).

4. The final step compares the benefits and costs of the project, either in terms of net benefits (the total benefits minus the total costs) or in terms of a benefit-cost ratio (the amount of benefits produced per unit of cost). If relevant, compare results among alternative projects.

We found few benefit-cost evaluations of LID projects. The large majority of studies estimate installation costs, a few consider additional costs, such as O & M costs, and a handful compared some measures of costs against some measures of benefits. The reported benefit-cost studies of LID include Bachand (2002) and Fine (2002),[3] Devinny

[2] For a more complete discussion of benefit-cost analysis, see Field and Field (2006), Gramlich (1990) and Harberger and Jenkins (2002).

[3] We reviewed summaries of Bachand (2002) and Fine (2002) because we were unable to acquire copies of the full articles.

et al. (2005), and Doran and Cannon (2006). Data limitations may explain part of the reason for the limited number of benefit-cost analyses of LID. This is especially true for lifetime O & M costs and the economic importance of LID benefits. Sample et al. (2003), Powell et al. (2005), Johnston, Braden, and Price (2006), and Conservation Research Institute (2005), among others, describe the need for more research quantifying the benefits of LID practices.

Another reason may be that economic benefits or lifetime O & M costs have no relevance to a given economic study. For example, property developers pay installation costs of stormwater controls, but not lifetime O & M costs. Nor do they benefit directly from the ecosystem services that LID can enhance or provide. Economic results reported by developers will therefore likely focus exclusively on installation costs of LID or compare installation costs for LID and conventional controls.

Using the benefit-cost approach has challenges that the other analytical methods do not. However, benefit-cost analysis has advantages in that it can provide decisionmakers, ratepayers and other stakeholders with a more complete picture of the economic consequences of stormwater-management alternatives than other analytical methods. This is especially true for costs and benefits of alternatives over the long term. In situations in which time, budget, or other information constraints limit quantifying economic benefits or costs, the next best alternative is identifying the range of costs and benefits, quantifying what can be measured and describing the remaining impacts qualitatively. The federal government takes this approach in that the OMB recommends that when benefits and costs cannot be quantified, agencies should provide qualitative descriptions of the benefits and costs. These qualitative descriptions should include the nature, timing, likelihood, location, and distribution of the unquantified benefits and costs (U.S. OMB 2000).

IV. Costs and Benefits of Low-Impact Development

The large majority of literature that describe economic assessments of LID focus on the costs of installing the technology. Most studies report the costs of building LID stormwater controls, or compare the costs of installing LID to the costs of conventional controls. The organization of this section reflects this emphasis in the literature. We begin by summarizing studies that list the costs of installing various LID techniques. Most of these reports describe the outcomes of case studies of LID installed as new or developing stormwater-management technologies. We then discuss studies that compare the costs of building LID controls with the costs of building conventional controls.

A number of researchers looked beyond installation costs and considered the impacts that operations and maintenance costs can have on economic evaluations of LID. Analysts sometimes refer to these as life-cycle studies because they consider the relevant costs throughout the useful life of a technology. We summarize three studies that took this approach with LID evaluations.

Combined sewer overflows, and the resulting biophysical and economic consequences, are major concerns for municipal stormwater managers. LID can help minimize the number of CSO events and the volume of contaminated flows by managing more stormwater on site and keeping flows out of combined sewer pipes. We summarize five studies that evaluated the costs of managing CSO events using LID.

A relatively small percentage of the economic evaluations of LID reported in the literature include assessments of the economic benefits of the technology. We summarize a number of these reports at the end of this section.

A. Cost of Low-Impact Development

Brown and Schueler (1997) surveyed construction costs for different methods of managing stormwater in urban areas. Their survey emphasized conventional controls but also included a number of LID techniques. At the time of their study, LID techniques were considered "next generation" best-management practices (BMPs). The report lists construction costs for sixty-four BMPs including wet and dry stormwater ponds, bioretention areas, sand filters and infiltration trenches. The authors' major conclusion is that a BMP's construction cost increases with the volume of stormwater the BMP stores. The report's construction costs may be out-of-date, however they provide insights into relative cost differences between LID and other controls listed in the report.

In a more recent study, Tilley (2003) reports construction costs for LID case studies implemented in Puget Sound and Vancouver, B.C. The report describes a range of case studies from small-scale projects implemented by homeowners to large installations completed by universities, developers and municipal governments. The LID techniques studied include rain gardens, permeable pavement and green roofs. The amount of cost information varies by case study. In some cases the report lists per-unit costs to install an LID, e.g., a pervious concrete project cost $1.50 per square foot for materials (excluding labor). Other descriptions report costs generally, but not costs specific to the case study described, e.g., the cost for pervious concrete is typically $6 to $9 per square foot. Some descriptions have no cost information, and others list total construction costs without a detailed breakdown of cost components.

The U.S. Department of Defense (DoD) (2004) developed a manual of design guidelines to incorporate LID into DoD facilities. The manual describes 13 stormwater-management techniques and their most appropriate uses, maintenance issues, and cost information. The list of LID techniques includes bioretention, grassed swales, and permeable pavers. The manual describes costs in some detail but also notes the site-specific nature of construction costs and factors that can influence construction costs for certain LIDs.

Liptan and Brown (1996) describe one of the earliest comparisons of construction costs for LID with that for conventional controls.[4] They focus on two projects in Portland, Oregon, which they refer to as the OMSI and FlexAlloy projects, and the Village Homes development in Davis, California. In all cases, the LID option cost less. The LID design implemented at the OMSI project saved the developer $78,000 in construction costs by reducing manholes, piping, trenching, and catch basins. At the FlexAlloy site, the City of Portland conducted a retrospective study of LID vs. conventional development, after the builder installed conventional controls. The City calculated that the developer could have saved $10,000 by implementing the LID option. The description of the FlexAlloy case study includes a detailed comparison of construction costs for the two options. The Village Homes case study concluded that by using vegetated swales, narrow streets, and a cluster layout of building lots, the developer saved $800 per lot, or $192,000 for the development. The Village Homes description includes no additional details on construction costs for the two options. The report also includes brief descriptions of other LID case studies, some with cost comparisons for LID vs. conventional controls. The authors conclude that involving developers, engineers, architects and landscape architects early in the design of a development that includes LID can help minimizing the LID-specific construction costs.

Hume and Comfort (2004) compared the costs of constructing conventional roads and stormwater controls with the costs of building LID options, such as bioretention cells and pervious pavement. The researchers added complexity to some of their comparisons by paring the same conventional and LID controls, e.g., infiltration trench (conventional) vs. bioretention cell (LID) on a different soil types and with different sources of stormwater runoff (e.g., driveway vs. roof top) to see how this affected construction costs. In some comparisons the LID option cost more than the conventional option, in other cases the results were opposite. These comparisons illustrate the site-specific nature of LID construction costs. Local conditions, e.g., less pervious soils, can influence the costs of LID controls.

In some cases, LID can help lower construction costs by making use of a site's existing or undisturbed drainage conditions in ways that conventional controls cannot. Planners of a 44-acre, 80-lot residential development in Florida took advantage of the site's natural drainage patters to help lower stormwater-management costs (PATH 2005). The site's low-lying areas convey the large majority of stormwater runoff to forested basins. The developer minimized disturbing natural drainage patterns by clustering building sites and connecting sites with narrow roads. Relying on natural infiltration and drainage patterns help the developer save $40,000 in construction costs by avoiding the costs of constructing stormwater ponds.

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[4] In this Section we describe some of the developments associated with costs comparisons reported in the LID literature. The next Section focuses on LID from the perspective of property developers and contractors. In that Section we list results for a larger number of cost comparisons

Comparing construction costs between LID and conventional options, while informative, provides no information on the relationship between the cost and effectiveness. For example, in cases where the LID option costs more to build, it may also control a larger volume of stormwater relative to the conventional option. LID that keeps stormwater out of pipes and treatment facilities help lower operations and maintenance (O & M) costs, and help extend the useful life of the infrastructure, which can reduce future construction costs. The relative importance of construction or O & M costs depends on who pays for them. Builders likely focus exclusively on construction costs, however, cost and effectiveness information would help stormwater managers better evaluate control options and plan for future demands on stormwater infrastructure.

Brewer and Fisher (2004) report the results of four case studies that compared the cost and effectiveness of LID to that of conventional controls. The case studies modeled stormwater costs and conditions on four developments: high- and medium-density residential, an elementary school, and a commercial development. In both residential developments LID controls cost less than conventional controls. LID cost more for the school and commercial development. However, in all four cases, the LID option managed a larger volume of stormwater than the conventional option. We reproduce Brewer and Fisher's results in Table 4-1.

Table 4-1: Comparison of Runoff Controlled and Cost Savings for Conventional and LID Design.

Site Example	Runoff Storage (acre-feet)		LID Net Cost or Savings
	Conventional	LID	
Medium Density Residential	1.3	2.5	$476,406
Elementary School	0.6	1.6	$(48,478)
High Density Residential	0.25	0.45	$25,094
Commercial	0.98	2.9	$(9,772)

Source: Brewer and Fisher 2004

We calculated the economic value of the additional storage provided by the LID designs reported in Brewer and Fisher (2004), using data on the national average of construction costs as reported by American Forests. American Forests' CITYgreen analyses calculate the national-average cost of storing 1 acre-foot of runoff at $87,120.[5] American Forests uses a value of $2.00 per cubic foot of storage, obtained from national estimates of stormwater construction costs. This amount represents the avoided costs of not building stormwater detention ponds. This value may vary, depending on a project's location. In some of its analyses, American Forests uses local estimates of construction costs, which can be lower or higher than the national average. For example, American Forests uses

[5] *See, for example,* American Forests. 2003. *Urban Ecosystem Analysis: San Diego, California*. July. Retrieved August 2, 2007, from http://www.americanforests.org/downloads/rea/AF_SanDiego.pdf, American Forests. 2003. *Urban Ecosystem Analysis: Buffalo-Lackawanna Area, Erie County, New York*. June. Retrieved August 2, 2007, from http://www.americanforests.org/downloads/rea/AF_Buffalo.pdf.

$0.66 per cubic foot of storage in Houston, TX,[6] $5.00 per cubic foot of storage in the Washington D.C. Metro Area,[7] and $6.00 per cubic foot of storage in Portland, OR.[8] Table 4-2 shows the results of our calculation.

Table 4-2: Value of the Difference in Runoff Storage Provided by LID Designs.

Site Example	Runoff Storage (acre-feet)			Runoff Storage Difference (cubic-feet)[a]	Value of Difference in Runoff Storage ($2/cf)
	Conventional	LID	Difference		
Medium Density Residential	1.3	2.5	1.2	52,272	$104,544
Elementary School	0.6	1.6	1	43,560	$87,120
High Density Residential	0.25	0.45	0.2	8,712	$17,424
Commercial	0.98	2.9	1.92	83,635	$167,270

Source: ECONorthwest
Notes: [a] To convert from an acre foot to cubic feet, multiply by 43,560 (the number of cubic feet in an acre-foot).

Based on the results reported in Table 4-1, and taking the perspective of a builder, LID is the higher-cost alternative for the school and commercial development. Including the results from Table 4-2, and taking the perspective of a municipal stormwater manager—that is, considering construction costs and the cost savings associated with reductions in stormwater volume in our example calculation above—the LID option dominates the conventional choice in all four cases. The LID options control a larger volume of stormwater, which helps avoid municipal expenditures on stormwater management.

Doran and Cannon (2006) studied the relationship between construction costs of LID and conventional controls and effectiveness as measured by improvements in water quality. They studied the impacts of incorporating LID into a downtown redevelopment project in Caldwell, Idaho. The analysis modeled construction costs and improvements to water quality as measured by reduced concentrations of sediment and phosphorus in stormwater runoff. The LID techniques used in the project included permeable pavers, bioretention swales, riparian wetlands, and plantings of restored native vegetation. The study evaluated the LID and conventional controls using the cost of a 1-percent reduction in sediment and phosphorus concentrations. Conventional stormwater controls had lower

[6] American Forests. 2000. *Urban Ecosystem Analysis for the Houston Gulf Coast Region*. December. Retrieved August 2, 2007, from http://www.americanforests.org/downloads/rea/AF_Houston.pdf.

[7] American Forests. 2002. *Urban Ecosystem Analysis: The District of Columbia*. February. Retrieved August 2, 2007, from http://www.americanforests.org/downloads/rea/AF_WashingtonDC2.pdf.

[8] American Forests. 2001. *Regional Ecosystem Analysis for the Willamette/Lower Columbia Region of Northwestern Oregon and Southwestern Washington State*. October. Retrieved August 2, 2007, from http://www.americanforests.org/downloads/rea/AF_Portland.pdf.

installation costs, but also had a lesser impact on water quality. Conventional controls cost $8,500 and reduced sediment and phosphorus concentrations by 5 percent, or $1,700 per percent reduction. LID stormwater controls cost more, $20,648, but had a greater impact on water quality, reducing sediment by 32 percent and phosphorus by 30 percent. The authors calculated a cost of $645 per percent reduction for the LID option. The LID option produced a better return on initial investment, as measured by improvements to water quality, than did investments in conventional controls.

As the previous two studies illustrate, comparing LID and conventional controls based on costs may bias the assessment against the most effective management option, and the option that yields the greatest return on investment. LID may cost more to build, but from an investment perspective, it may also control more stormwater and better improve water quality. The studies above considered separately LID effectiveness as measured by volume of stormwater managed and improvements in water quality of stormwater runoff. A more complete and accurate assessment of effectiveness and costs would consider the impacts on both in a single study. That is, compare LID and conventional controls based on costs and effectiveness as measured by volume of stormwater *and* water quality. We found no such studies in the literature.

Looking beyond construction costs to O & M and other costs gives a more complete description of the economic consequences of adopting LID or conventional controls. Sample et al. (2003) promotes evaluating stormwater BMPs using life-cycle-cost (LCC) analysis. LCC analysis includes the initial capital expenditures for construction, planning, etc., and the present value of lifetime O & M costs, and the salvage value at the end of the BMP's useful life. In addition, the authors suggest including the opportunity cost of land in the cost analysis. BMPs that occupy more land area have a higher opportunity cost valued at the next-best use for the land, e.g., residential value.

Vesely et al. (2005) compared the LCC for LID controls in the Glencourt Place residential development in Auckland, New Zealand with LCC results for conventional controls. The LID option had the added benefit of reusing stormwater collected on site as grey water for laundry, flushing toilets and irrigation. The LID option had LCCs that were 4 to 8 percent higher than the conventional option, depending on the discount rate and number of years in the analysis. These results do not account for the value of recycled stormwater. Including the avoided cost associated with water saved by recycling stormwater as household gray water, the LCC for the LID option were 0 to 6 percent higher, again, depending on the discount rate and number of future years in the analysis. The authors conclude that accounting for the value of water saved, the LID option was cost competitive with the conventional approach, as measured by the LCC method.

Data constraints on this study included difficulty estimating current and future maintenance costs and future decommissioning costs. Accounting for the opportunity cost of land also proved challenging give the available data. Data limitations also prevented the authors from considering the economic aspects of environmental externalities associated with the LID and conventional options.

LCC evaluations are an improvement over comparisons of construction costs in that they provide a more comprehensive assessment of relevant costs. On the other hand, LCC analyses require more data and results are sensitive to the discount rate applied to future values and the number of years of the analysis. Powell et al. (2005) underscore these advantages and challenges associated with LCC analysis. They recommend a checklist of

factors to consider when conducting a LCC for LID and conventional controls. The checklist includes *quantitative* assessments of the components of LCC costs including acquisition, construction, O & M, and salvage value. Also included are *qualitative* assessments of the effectiveness of managing stormwater and the benefits attributed to the management option. The authors note that effectively and accurately implementing LCC analyses for LID will require more research into the costs of LID design, construction and O & M. Further research is also need in assessing the monetary benefits of LID controls.

Despite the fact that LID technologies have been promoted and studied since the early 1990s, in many ways, and to many stormwater managers, LID is still a new and emerging technology (Coffman 2002). As with most new technologies, installation and other costs for LID are highest during the early phases of development and adoption. Over time, as practitioners learn more about the technology, as the number of suppliers of inputs increases, and as regulations adapt to the new technology, costs will likely decline.

Foss (2005) describes this relationship between a learning curve and construction costs for greenstreet technology in Seattle. The city spent $850,000 implementing a greenstreet pilot project, known as the "Street Edge Alternative" (SEA) street. The City's street planners expect that based on their experience with the pilot project, building greenstreets in the future will cost substantially less. Foss quotes the manager of the City's surface water program on this point:

> *"You could take $200,000 off the price just from what we didn't know. … The pilot phases that we are currently in are more expensive, but as the project becomes institutionalized, all the costs will come down. Even still, these projects are less expensive than standard projects." (p. 7)*

B. Costs of Managing Combined Sewer Overflows By Low-Impact Development

One of the earliest studies of the economic aspects of managing combined sewer overflows by LID evaluated a project that disconnected downspouts as a means of reducing the number of CSO events and costs (Kaufman and Wurtz 1997). In 1994, the Beecher Water District (BWD) near Flint, Michigan, provided free downspout diversions from home sites to sanitary-sewer pipes for the 6,020 residential customers in their service area. The purpose of the program was to reduce the volume of sewer flows from the BWD to the City of Flint's stormwater facility—and reduce the fees that BWD paid the city to manage these flows—and reduce the number and volume of CSO events in the BWD.

The program was a success on many levels and is an example of a small-scale and inexpensive approach that effectively managed CSO events. Disconnecting downspouts cost the BWD just over $15,000. After the diversions, the mean volume of sewer flows measured across all precipitation events decreased 26 percent. The program saved the BWD over $8,000 per month in reduced fees to the City of Flint's stormwater facility, and in reduced costs of managing CSO events. The program paid for itself in two months. Other benefits included reduced CSO-related customer complaints, improved recharge of groundwater and reduced pollution of the Great Lakes, the receiving waters for CSO from the District.

In another study looking at controlling CSO events on a smaller scale, Thurston et al. (2003) modeled the costs of CSO controls for a small watershed in Cincinnati, Ohio. The modeling exercise was part of a study that evaluated the theoretical considerations of developing a market for tradable stormwater credits as a means of reducing CSO events and costs. One part of the study compared the construction costs of controlling CSO events by building tunnels and storage vaults with the costs of building LID controls on each of the 420 mostly-residential lots in the study area.

They calculated that building the tunnel and vault option would cost between $8.93 to $11.90 per cubic foot of storage capacity. Building LID controls on individual lots would cost $5.40 per cubic foot of capacity. Based on these results the researchers suggest that the costs of managing CSOs by implementing LID throughout the watershed would cost less than building a large centralized tunnel and vault system to store excess flows. They also note, however that their analysis does not include the opportunity cost of land that the LID controls would occupy, and so the cost of the LID option would be higher than they report. Their analysis also excludes O & M costs for both options, as well as the costs of education and outreach to property owners, and managing the construction of a large number of dispersed LID projects as components of the LID option. The project also excludes the economic benefits of the LID option.

Kloss and Calarusse (2006) developed a set of policy guidelines for decisionmakers interested in implement LID controls as a means of reducing CSO events in their jurisdictions. Regarding the costs of LID controls, the authors distinguish between new and retrofit construction projects. In new developments, they conclude, LID typically cost less than conventional stormwater controls. They note, however, that retrofit developments in urban areas that include LID typically cost more than conventional controls. This is especially true for individual, small-scale retrofit projects. The relative costs of LID controls can be reduced when they are incorporated into larger-scale redevelopment projects. The report provides conclusions with limited details on cost information. The report also describes the experiences of nine municipalities across the country that include LID in their policies to control CSO events and related costs.

Montalto et al. (2007) described the relationship between public agencies tasked with controlling CSO events, and private land owners on whose property the large majority of LID controls would be sited. The public agencies benefit from the reduced stormwater flows and CSO events that LID provides. The land owner, however, pays the LID installation and O & M costs, but may see little benefit beyond reduced stormwater fees or increased property values from LID such as greenstreets. These benefits may not outweigh the costs to the land owner, and so they may choose not to install LID controls. Given this disconnect, the authors note the benefits of public policies, incentives and subsidies to promote LID adoptions by private-property owners.

In an effort, in part, to measure the amount of subsidy that may be required, the authors developed a model to assess the cost-effectiveness of mitigating CSO events in urban areas using LID. They applied their model to a case study in the Gowanus Canal area of Brooklyn, NY. The case study compared the costs of installing porous pavement, green roofs, wetland developments and other LID throughout the study area to the costs of installing storage tanks to catch excess stormwater flows. As part of their analysis they collected and report installation and O & M costs for a range of LID techniques.

They conclude that under a range of cost and performance assumptions, LID installed throughout the study area could potentially reduce the number of CSO events and volume at a cost that would be competitive or less than the costs of the conventional storage-tank option. They note that they could improve the performance of their model if more data were available on LID performance, costs and public acceptance.

Plumb and Seggos (2007) studied the impacts of diverting monies currently designated to building storage tanks and other conventional CSO controls for New York City to building LID controls throughout the city. They compared the effectiveness of storage tanks and LID controls based on gallons of stormwater managed per $1,000 invested. We reproduce their results in Table 4-3 below. Except for greenroofs, the LID options control more stormwater per $1,000 invested than the conventional storage-tank option.

Table 4-3: Gallons of Stormwater Managed per $1,000 Invested.

Stormwater Control	Gallons per $1,000 Invested
Conventional Storage Tanks	2,400
Greenstreet	14,800
Street Trees	13,170
Greenroof	810
Rain Barrel	9,000

Source: Plumb and Seggos 2007

They describe their analysis as a simple and preliminary cost comparison and conclude that their results demonstrate that LID controls can be cost competitive with conventional controls, if not more so. The authors recommended further detailed study of the issue. Their analysis focused on the costs of LID vs. conventional controls and did not consider economic benefits of the LID techniques.

C. Economic Benefits of Low-Impact Development

Many reports and articles describe the potential benefits that LID stormwater controls can provide—benefits that conventional controls can not offer.[9] Very few studies, however, quantify these benefits, either in biophysical measures or in dollar amounts. A study by CH2MHill (2001) is a typical example. The analysis compared the costs and benefits of managing stormwater in two residential developments using LID or conventional controls. The cost analysis included detailed information for the LID and conventional controls. In this case, results of the cost analysis were mixed. In one development the LID option cost less to build and in the other development the conventional control cost less. In both cases the LID option had higher maintenance costs but homeowners would benefit from lower stormwater and water fees.

[9] We list a number of these sources in Section II of this report.

The analysis of benefits included much less detailed information. The study lists the benefits that the LID option would provide, benefits that the conventional approach would not. These benefits include reduced auto traffic, increased open space, improved downstream water quality, and increased groundwater recharge. However, the benefits were not quantified in dollar amounts.

In another example, Bachand (2002) studied the costs and benefits of developing wetlands as a stormwater management option. The analysis described the construction and O & M costs associated with the wetlands option, and the benefits including adding new recreational opportunities, increased wildlife habitat and increase property values for near-by homeowners. However, they did not measure the benefits in economic terms. An accompanying study by Fine (2002) quantified some of the recreational benefits that derive from wildlife watching in the wetlands, but left unquantified the benefits of other direct uses of the wetlands, as well as the value of habitat improvements and other non-use benefits.[10]

When researchers cite the needs for further research into LID-related topics, quantifying benefits and measuring their economic importance invariably makes the list. For example, Sample et al. (2003) cites the need for more research into measuring the technical and economic benefits of LID, including benefits to downstream receiving waters. Powell et al. (2005) note the need for more research into monetary measures of the benefits of LID, e.g., the impact that a greenstreet can have on adjacent property values. Vesely et al. (2005) state that future studies should include not only the economic benefits of LID but also the negative economic impacts of conventional controls. Failing to do so will continue biasing management decisions in favor of conventional controls:

> *"Exclusive reliance on profitability and market value will favour [sic] the conventional approach to stormwater management by disregarding both the negative environmental externalities associated with this approach, and the positive environmental externalities associated with the low impact approach." (page 12)*

A number of studies do measure some of the economic benefits of on-site stormwater controls. For example, Braden and Johnson (2004) studied the economic benefits that on-site stormwater management could have on properties downstream. The researchers first estimated the impacts that on-site stormwater controls could have on the frequency and extent of downstream flooding. Using information reported in the literature on the extent to which property markets discount the value of properties in a floodplain, they approximated the economic value of reduced flooding attributed to on-site management of stormwater. They then calculated the value of avoided flood damage as a percentage of property values. They estimate that a marginal reduction in flooding would increase property values 0 to 5 percent for properties in a floodplain, depending on the extent to which the on-site controls reduce stormwater runoff.

They then took a similar approach to valuing improvements in water quality. Based on values reported in the literature, they estimate that the benefits of improved water quality could reach 15 percent of market value for properties that border the water body at issue

[10] We were unable to obtain a copy of the full report. We base our description on a summary of the analysis.

if water quality improves significantly. The increase is much less for smaller improvements in water quality, for undeveloped properties, and for properties not adjacent to the water body.

They conclude with a best-guess estimate of a 2 to 5 percent increase in property values for properties in a floodplain from on-site management of stormwater. Other benefits that could not be quantified or valued given available information include reduced infrastructure expenditures for culverts, bridges and other drainage infrastructure.

In a follow-up case study, Johnston, Braden, and Price (2006) applied the analytical method developed in the previous study to properties in the one-hundred-year floodplain portion of a watershed in the Chicago area. They estimate the economic benefit of avoided flooding two ways and extend the analysis to approximate reduced municipal expenditures on culverts.

Applying the 0 to 5 percent impact on property values calculated in the previous study to properties in the case study, the researchers estimated an economic benefit of $0 to $7,800 per acre of increased property value attributed to reduced flooding. They also calculated the economic benefit of reduced flooding based on the avoided flood damage to structures and contents for properties in the floodplain. This analytical method included data compiled by the U.S. Army Corps of Engineers on the relationship between flooding and damages to properties in floodplains. This approach yields an economic benefit of avoided flooding of $6,700 to $9,700 per acre for properties in the floodplain.

The researchers approximate that for the case-study portion of the watershed, conservation-design practices such as LID techniques that retain more stormwater on site and reduce flooding could generate $3.3 million in avoided costs for road culverts.

The estimated economic benefit of increased on-site management of stormwater for properties in the case study for both avoided flooding and reduced municipal expenditures on culverts is $380 to $590 per acre.

A series of analyses by American Forests (2000-2006) report the economic benefits of stormwater services provided by trees in various cities and regions throughout the United States. These reports describe results from American Forests' CITYgreen model, which calculates the volume of stormwater absorbed by existing tree canopies and estimates the avoided costs in stormwater management that the trees provide. The model includes city-specific per-unit stormwater-management costs when available. The model substitutes national per-unit costs when city-specific data are not available. In Table 4-4 below we report the results for some of American Forests' city and regional analyses. The dollar amounts represent the costs of expanding stormwater infrastructure to manage the stormwater that existing trees otherwise absorb and transpire.

Table 4-4: Avoided stormwater-construction costs attributed to trees, as measured by the American Forests' CITYgreen model.

Urban Area	Amount that trees save in one-time stormwater-construction costs
Houston, Texas	$1.33 billion
Atlanta, Georgia	$2.36 billion
Vancouver, Washington/ Portland-Eugene, Oregon	$20.2 billion
Washington D.C. Metro Area	$4.74 billion
New Orleans, Louisiana	$0.74 billion
San Antonio, Texas	$1.35 billion
San Diego, California	$0.16 billion
Puget Sound Metro Area, Washington	$5.90 billion
Detroit, Michigan	$0.38 billion
Chesapeake Bay Region	$1.08 billion

Source: American Forests 2000-2006

The Bisco Werner et al. (2001) analysis of the economic benefits of trees attributed to stormwater management also employed the CITYgreen model. Researchers applied the CITYgreen model to a case study that included the commercial corridor along a major highway through central New Jersey. The analysis modeled the change in tree canopy between 1975 and 1995, and calculated the value of lost stormwater services. During this time, the value of services declined from $1.1 million to $896,000, a 19-percent reduction. If existing trends continue, the expected value in 2015 will be $715,000, a 35-percent reduction relative to the value of services available in 1975. As services supplied by street trees declines, demand on municipal stormwater controls, and associated costs, increase.

The researchers extended their study to include the economic benefits of tree cover attributed to removing air pollutants. This portion of their analysis studied the tree cover at a number of commercial properties in the New York and New Jersey area. In this case the CITYgreen model calculated avoided stormwater-construction costs associated with stormwater services provided by trees on site and, using values reported in the literature, the amounts of air pollutants absorbed by trees, and the per-unit value for each pollutant.

In one case study of a shopping mall, the analysis estimated that the trees currently on the site manage approximately 53,000 cubic feet of stormwater. The CITYgreen model estimated the value of the associated avoided infrastructure costs at just over $33,000. The value of air-pollutant removed is estimated at $1,441 per year. The report lists results for fifteen such case studies.

Wetlands that absorb stormwater runoff can help minimize stormwater-related management and infrastructure costs. Depending on their location and makeup, wetlands

may provide other benefits, such as wildlife habitat and recreational opportunities. Fine (2002)[11] studied the recreational benefits provided by wetlands proposed as part of the Treasure Island redevelopment in San Francisco Bay. The analysis assumes that the wetlands will attract visitors year round, with the winter months providing the best opportunity to view migratory birds. Based on recreational expenditures for similar sites in the San Francisco Bay area, Fine calculates that area visitors will spend $4 to $8 million annually. Other benefits that Fine was unable to quantify and value include fisheries enhancement and water-quality services.

Devinny et al. (2005) developed a first-approximation of a benefit-cost analysis of complying with water-quality requirements throughout Los Angeles County using LID and other stormwater BMPs. They present their analysis as an alternative to the approach described by Gordon et al. (2002), which relies on collecting and treating the county's stormwater using conventional controls. The Devinny et al. approach assumes widespread adoption of LID and other on-site stormwater BMPs.

The Devinny et al. analysis accounts for the fact that the density of existing development will limit the extent to which LID and other BMPs can be retrofitted into developments. As an alternative they propose a combination of LID and BMPs along with directing stormwater to regional wetlands and other infiltration systems. As the density of development increases, so does the size and costs of developing regional wetlands.

This study differs from other benefit-cost analyses of stormwater-management options in that the researchers quantify a range of potential benefits associated with the approach that emphasizes on-site treatment of stormwater. They estimate the cost of their approach at $2.8 billion if disbursed LID and other on-site BMPs sufficiently control stormwater quality. Costs increase to $5.7 to $7.4 billion if regional wetlands and other infiltration systems are needed. This approach costs less than the estimated cost of $44 billion to implement the option that emphasizes conventional controls (California Department of Transportation 2005).

The estimated value of the economic benefits of implementing LID, other on-site BMPs and regional wetlands range from $5.6 to $18 billion. Benefits include the economic aspects of reduced flood control, increased property values adjacent to new greenspaces and wetlands, additional groundwater supplies, improved beach tourism, and reduced sedimentation of area harbors. The conventional approach would provide none of these economic benefits.

[11] We were unable to obtain a copy of the full report. We base our description on a summary of the analysis.

V. Developers' Experiences With Low-Impact Development

Baring regulations that mandate LID controls, developers adopt LID because they help reduce construction costs, increase sales, boost profits, or some combination of the three. These deliberations focus primarily on the extent to which local property markets account for the direct costs and benefits that LID can provide. Typically these deliberations do not include indirect costs and benefits and the potential non-market impacts of LID that may be important to others such as municipal stormwater managers and area residents. These non-market impacts may include reduced downstream flooding, improved water quality and habitat of water bodies that receive stormwater, reduced CSO events, or impacts on the costs of operating municipal-stormwater infrastructure.

In this section we summarize developers' experiences installing LID. As with other new technologies, adopting LID includes opportunities and risks. We begin by describing the risks and challenges that developers face by including LID in their projects. These risks include uncertain construction delays as the developer applies for variances to local zoning codes because the codes do not explicitly recognize LID as an accepted stormwater control.

Next, we describe some of the efforts by municipal governments to reduce the developers' regulatory risk and uncertainty of using LID. Finally, we list some of the successes developers have had adopting LID and the resulting impacts on construction costs, sales, and profits.

A. Challenges Developers Face Using LID

Much of the general public is still unaware of LID attributes, the benefits they can provide, or their O & M costs. As such, they may not understand or appreciate why a developer included LID in a project. This may give developers pause because they supply products that they believe their customers—homebuyers—want and will purchase. Potential buyers may shy away from homes that include an unfamiliar technology.

A general lack of understanding of LID may concern developers in part because including on-site treatment of stormwater will also require on-site management of stormwater facilities, the LID technologies. Homeowners unfamiliar with LID likely will have no understanding of their maintenance requirements (Lewis 2006; England 2002; Foss 2005). For example, a bioswale clogged with sediment may not control stormwater volume or quality, which could negatively reflect on the builder. Another concern has to do with the lack of understanding as to the life-expectancy of LID controls (Lewis 2006). A builder may be concerned that an untimely failure of stormwater controls could negatively affect their reputation.

Similar to the public's general lack of understanding of LID, many builders are also unfamiliar with the technology. A builder may not be able to identify the most effective and least-cost LID technology for a given development from the wide variety of possible LID controls (Foss 2005; Lewis 2006). A related point is that construction costs for LID technologies are site specific. For example, not all soils can support LID technologies that emphasize stormwater infiltration. Assessing a site and designing LID technologies that will function on the site may also increase a builder's design costs (Coffman 2002; Strassler et al. 1999).

A much-mentioned impediment to builders' adoption of LID is building codes that do not account for LID as stormwater controls. Many municipalities have zoning and building-inspection standards in place that were adopted many years ago, long before LID was an option (Coffman 2002; NAHB Research Center Inc. 2003; Foss 2005; Lewis 2006). These standards emphasize conventional stormwater controls that collect stormwater and transport it off site to a receiving body of water or to a treatment facility. Municipalities with outdated stormwater regulations typically require that builders file variances if they want to use LID controls. Filing variances for LID increases design and regulatory costs, which delays construction and can increase a builder's financing costs (Clar 2004; Coffman 2002; Lewis 2006; NAHB Research Center Inc. 2003).

A related constraint in some jurisdictions with outdated regulations is a lack of technical expertise or understanding by regulators regarding LID stormwater controls. In some cases, regulators unfamiliar with LID technology must be convinced of their effectiveness, which also increases a builder's design and regulatory costs (Coffman 2002; NAHB 2003; Lewis 2006).

B. Municipal Actions To Increase LID Adoption On Private Developments

Some jurisdictions help promote LID adoption on private lands and take steps that reduce the regulatory uncertainty and risk that builders face when including LID in private developments. These jurisdictions may have CSO problems, or are trying to extend the useful life of their stormwater infrastructure in the face of increasing population and economic activity. In any case, they recognize the importance of managing as much stormwater on site as possible and keeping it out of the jurisdiction's stormwater pipes.

One way that jurisdictions promote LID adoption on private lands is by updating their zoning codes and building-inspection standards to explicitly address LID stormwater controls (Coffman 2002; NAHB Research Center Inc. 2003; Foss 2005; Lewis 2006). This helps reduce a builder's regulatory risk because it eliminates the need to file variances. Rather than spending time convincing regulators as to the desirable stormwater attributes or effectiveness of LID controls, builders can instead proceed with their development.

Granting density bonuses for developments that install LID stormwater controls is another way jurisdictions encourage the proliferation of LID techniques. In this case, the jurisdiction grants the developer a greater number of individual building lots than would have been allowed if the development relied on conventional stormwater controls (Coffman 2002; NAHB Research Center Inc. 2003). This type of incentive not only reduces a builder's regulatory risk, and associated costs, but also increases the number of lots that can be sold, which can increase the builder's revenue and profits. Jurisdictions also promote LID installation on private lands by reducing development-related fees, such as inspection fees (Coffman 2002; NAHB Research Center Inc. 2003).

C. Benefits To Developers of Including LID Controls in Their Projects

Developers who accept the regulatory uncertainty and other challenges of adopting LID do so with the expectation that controlling stormwater on site can have economic

advantages. These advantages include increasing the number of developable lots and reducing expenditures associated with stormwater infrastructure. Managing stormwater on site using LID controls can mean doing away with stormwater ponds, thus increasing a site's developable area (Coffman 2002; NAHB Research Center Inc. 2003). Selling additional lots can increase a builder's revenues and profits. Replacing curbs, gutters and stormwater pipes with bioswales, pervious pavers and other LID controls reduces construction costs for some developers (Coffman 2002; NAHB Research Center Inc. 2003; Center for Watershed Protection 2001).

An analysis of a development in Prince George's County, Maryland, documented the impacts that controlling stormwater on site with LID can have on the site's buildable area and construction costs. The Somerset Community development installed rain gardens, grass swales along streets, and other LID controls. Substituting LID for conventional controls saved the developer approximately $900,000. Doing away with the site's stormwater ponds gave the developer six additional lots (Foss 2005).

A study of the Pembroke Woods Subdivision in Frederick County, Maryland found similar results (Clar 2004). The developer substituted LID for conventional controls, doing away with curbs, gutters, sidewalks, and eliminated two stormwater ponds. Eliminating the curbs and gutters saved the developer $60,000. Installing narrower streets eliminated impervious area and reduced paving costs by 17 percent. Excluding the stormwater ponds saved $200,000 in construction costs and added two developable lots, valued at $45,000 each. Other economic benefits to the developer include reduced costs of clearing land for development of $160,000, and adding 2.5 additional acres of open space, which reduced the developer's wetland-mitigation requirements.

Conservation subdivisions take a comprehensive approach to stormwater management by combining LID controls with a site design that takes advantage of existing drainage patterns. Narrow streets and clustered building lots make maximum use of natural stormwater controls, thus reducing construction costs (Center for Watershed Protection 2001). A study of ten subdivisions found that conservation subdivisions that emphasized LID and protected natural drainage patterns cost, on average, thirty-six percent less than subdivisions that relied on conventional stormwater controls (Conservation Research Institute 2005).

Researchers note that some conservation subdivisions have an additional benefit in that there's greater demand for lots in these subdivisions compared with the demand for lots in conventional subdivisions. Greater demand for lots means the developer can charge more for the lot and lots may sell faster (Center for Watershed Protection 2001).

A case study of conservation and conventional subdivisions in South Kingstown, Rhode Island quantified the market benefits of conservation developments. The study compared the costs of developing the lots and the market value of the lots (Mohamed 2006). Results show that conservation lots cost less to develop and sell for a higher price. On average, conservation lots cost $7,400 less to produce than lots in conventional subdivisions, and sold for 12 to 16 percent more, per acre, than conventional lots. Lots in the conservation subdivision also sold in approximately half the time as lots in conventional subdivisions.

Another study of cluster developments in New England found that houses in these types of developments appreciate faster than houses in conventional developments (Lacy 1990). Lacy identified developments in Concord and Amherst, Massachusetts that were

characterized by smaller individual lots surrounded by natural open space, limited lot clearing, and narrower streets. He compared these with nearby conventional developments. The Concord cluster development appreciated 26 percent more than conventional developments over an eight-year study period. The Amherst cluster development also yielded a higher rate of return on investment over a 21-year study period, compared to nearby conventional development.

In Tables 5-1 and 5-2 below we summarize the results of studies that compared construction costs using LID vs. conventional stormwater controls for residential and commercial developments (respectively). We included information in the tables if a study described the source of the cost difference, e.g., substituting a bioswale for curbs and gutters saved $Z. We excluded studies that reported a cost difference, but did not describe the details of the cost comparison. We found many studies in the literature that did not provide details of cost comparisons.

We distinguish between study results for built developments from results for proposed or modeled developments. In some cases the studies report total cost savings for a development but not savings per lot in the development. In these cases we calculated the per-lot cost savings. We recognize that the cost savings values reported below are in dollars from different years, and so comparisons of cost savings between examples may not be appropriate. We found insufficient data in most case studies to convert all values to the same-year dollars.

The large majority of studies listed in Tables 5-1 and 5-2 describe LID installed or proposed to be installed in new developments. We found very few studies that measured the economic outcomes of including LID stormwater controls in urban, redevelopment projects. We identified these studies as “retrofits” in the tables.

Table 5-1: Cost savings attributed to installing LID stormwater controls in residential developments.

Location	Description	LID Cost Savings[a]
Meadow on the Hylebos Residential Subdivision Pierce County, WA	9-acre development reduced street width, added swale drainage system, rain gardens, and a sloped bio-terrace to slowly release stormwater to a creek. Stormwater pond reduced by 2/3, compared to conventional plan. (Zickler 2004)	LID cost 9% less than conventional
Somerset Community Residential Subdivision Prince George's Co., MD	80-acre development included rain gardens on each lot and a swale drainage system. Eliminated a stormwater pond and gained six extra lots. (NAHB Research Center Inc. 2003)	$916,382 $4,604 per lot
Pembroke Woods Residential Subdivision Frederick County, MD	43-acre, 70-lot development reduced street width, eliminated sidewalks, curb and gutter, and 2 stormwater ponds, and added swale drainage system, natural buffers, and filter strips. (Clar 2004; Lehner et al. 2001)	$420,000 $6,000 per lot[b]
Madera Community Residential Subdivision Gainesville, FL	44-acre, 80-lot development used natural drainage depressions in forested areas for infiltration instead of new stormwater ponds. (PATH 2005)	$40,000 $500 per lot[b]
Prairie Crossing Residential Subdivision Grayslake, IL	667-acre, 362-lot development clustered houses reducing infrastructure needs, and eliminated the need for a conventional stormwater system by building a natural drainage system using swales, constructed wetlands, and a central lake. (Lehner et al. 2001; Conservation Research Institute 2005)	$1,375,000-$2,700,000 $3,798-$7,458 per lot[b]
SEA Street Retrofit Residential street retrofit Seattle, WA	1-block retrofit narrowed street width, installed swales and rain gardens. (Tilley 2003)	$40,000
Gap Creek Residential Subdivision Sherwood, AK	130-acre, 72-lot development reduced street width, and preserved natural topography and drainage networks. (U.S. EPA 2005; Lehner et al. 2001; NAHB Research Center Inc. 2003)	$200,021 $4,819 per lot
Poplar Street Apartments Residential complex Aberdeen, NC	270-unit apartment complex eliminated curb and gutter stormwater system, replacing it with bioretention areas and swales. (U.S. EPA 2005)	$175,000
Kensington Estates* Residential Subdivision Pierce County, WA	24-acre, 103-lot hypothetical development reduced street width, used porous pavement, vegetated depressions on each lot, reduced stormwater pond size. (CH2MHill 2001; U.S. EPA 2005)	$86,800 $843 per lot[b]
Garden Valley* Residential Subdivision Pierce County, WA	10-acre, 34-lot hypothetical development reduced street width, used porous paving techniques, added swales between lots, and a central infiltration depression. (CH2MHill 2001)	$60,000 $1,765 per lot[b]
Circle C Ranch Residential Subdivision Austin, TX	Development employed filter strips and bioretention strips to slow and filter runoff before it reached a natural stream. (EPA 2005)	$185,000 $1,250 per lot

Location	Description	LID Cost Savings[a]
Woodland Reserve* Residential Development Lexana, KS	Reduced land clearing, reduced impervious surfaces, and added native plantings. (Beezhold 2006)	$118,420
The Trails* Multi-Family Residential Lexana, KS	Reduced land clearing, reduced impervious surfaces, and added native plantings. (Beezhold 2006)	$89,043
Medium Density Residential* Stafford County, VA	45-acre, 108-lot clustered development, reduced curb and gutter, storm sewer, paving, and stormwater pond size. (Center for Watershed Protection 1998b)	$300,547 $2,783 per lot[b]
Low Density Residential* Wicomico County, MD	24-acre, 8-lot development eliminated curb and gutter, reduced paving, storm drain, and reforestation needs. Eliminated stormwater pond and replaced with bioretention and bioswales. (Center for Watershed Protection 1998b)	$17,123 $2,140 per lot[b]

Source: ECONorthwest, with data from listed sources.
Notes: * indicates hypothetical or modeled project, not actually constructed.
[a] Dollar amounts as reported at the time of study.
[b] Per-lot cost savings calculated by ECONorthwest.

Table 5-2: Cost savings attributed to installing LID stormwater controls in commercial developments.

Location	Description	LID Cost Savings[a]
Parking Lot Retrofit Largo, MD	One-half acre of impervious surface. Stormwater directed to central bioretention island. (U.S. EPA 2005)	$10,500-$15,000
Old Farm Shopping Center* Frederick, MD	9.3-acre site redesigned to reduce impervious surfaces, added bioretention islands, filter strips, and infiltration trenches. (Zielinski 2000)	$36,230 $3,986 per acre[b]
270 Corporate Office Park* Germantown, MD	12.8-acre site redesigned to eliminate pipe and pond stormwater system, reduce impervious surface, added bioretention islands, swales, and grid pavers. (Zielinski 2000)	$27,900 $2,180 per acre[b]
OMSI Parking Lot Portland, OR	6-acre parking lot incorporated bioswales into the design, and reduced piping and catch basin infrastructure. (Liptan and Brown 1996)	$78,000 $13,000 per acre[b]
Light Industrial Parking Lot* Portland, OR	2-acre site incorporated bioswales into the design, and reduced piping and catch basin infrastructure. (Liptan and Brown 1996)	$11,247 $5,623 per acre[b]
Point West Shopping Center* Lexana, KS	Reduced curb and gutter, reduced storm sewer and inlets, reduced grading, and reduced land cost used porous pavers, added bioretention cells, and native plantings. (Beezhold 2006)	$168,898
Office Warehouse* Lexana, KS	Reduced impervious surfaces, reduced storm sewer and catch basins, reduced land cost, added bioswales and native plantings. (Beezhold 2006)	$317,483
Retail Shopping Center*	9-acre shopping development reduced parking lot area, added porous pavers, clustered retail spaces, added infiltration trench, bioretention and a sand filter, reduced curb and gutter and stormwater system, and eliminated infiltration basin. (Center for Watershed Protection 1998b)	$36,182 $4,020 per acre[b]
Commercial Office Park*	13-acre development reduced impervious surfaces, reduced stormwater ponds and added bioretention and swales. (Center for Watershed Protection 1998b)	$160,468 $12,344 per acre[b]
Tellabs Corporate Campus Naperville, IL	55-acre site developed into office space minimized site grading and preserved natural topography, eliminated storm sewer pipe and added bioswales. (Conservation Research Institute 2005)	$564,473 $10,263 per acre[b]
Vancouver Island Technology Park Redevelopment Saanich, British Columbia	Constructed wetlands, grassy swales and open channels, rather than piping to control stormwater. Also used amended soils, native plantings, shallow stormwater ponds within forested areas, and permeable surfaces on parking lots. (Tilley 2003)	$530,000

Source: ECONorthwest, with data from listed sources.
Notes: * indicates hypothetical or modeled project, not actually constructed.
[a] Dollar amounts as reported at the time of study.
[b] Per-acre cost savings calculated by ECONorthwest.

VI. DIRECTIONS FOR FUTURE RESEARCH

Despite the increasing use of LID stormwater controls, and the growing number of economic studies of this technique, our literature review found areas for further research. These areas include:

- Additional research that quantifies the costs and benefits of stormwater management. This includes economic research on the lifetime O & M costs for LID and conventional controls, as well as, studies that quantify the economic benefits of LID methods.

- More detailed information on costs associated with LID. Specifically, information on the factors that contribute to cost savings or cost increases of LID relative to conventional controls.

- Economic studies of LID and conventional methods that control for the effectiveness of the techniques regarding managing stormwater volumes and improving water quality. Comparing LID techniques that cost more to install than conventional methods, but control larger amounts of stormwater, is an apples-to-oranges comparison.

- The large majority of economic studies of LID methods apply to new construction. More research is needed on the economic outcomes of including LID methods in urban redevelopment projects.

- Some preliminary evidence exists that LID can help control CSO volumes at a lower cost than conventional controls. Stormwater managers and public-policy decisionmakers would benefit from additional economic research on this topic.

- Economic studies that model theoretical LID and conventional controls, while informative, may be less convincing to some stormwater managers, decisionmakers and ratepayer stakeholders than retrospective studies of installed controls.

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APPENDIX: ADDITIONAL LOW-IMPACT DEVELOPMENT RESOURCES

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Linda S. Adams
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California Regional Water Quality Control Board

Central Coast Region

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February 15, 2008

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Notification to Traditional, Small MS4s on Process for Enrolling under the State's General NPDES Permit for Storm Water Discharges

Introduction

As Executive Officer of the Regional Water Quality Control Board, Central Coast Region (Water Board), I am writing to notify you of the Water Board's revised process for enrolling traditional, small Municipal Separate Storm Sewer Systems (MS4s) under the State's General Permit No. CAS000004 (General Permit). Water Board staff have identified you as an entity that owns or operates an MS4, so you must enroll in the General Permit and develop and implement a Storm Water Management Program (SWMP). This letter describes the SWMP approval process and our expectations regarding the content of your SWMP to comply with the General Permit, and provides you with the schedule Water Board staff intend to follow for review of your SWMP and enrollment of your MS4 under the General Permit. Staff will communicate further with you as your enrollment cycles begin, to establish specific schedules for the five phases leading to enrollment.

Water Board staff will evaluate your SWMP for compliance with the General Permit requirements, including the Maximum Extent Practicable standard, and as appropriate will approve the SWMP and enroll you in the General Permit. If requested, Water Board staff will schedule a public hearing before the Central Coast Water Board for consideration of an individual SWMP.

The Water Board's revised enrollment process is a fundamental shift from the way we have reviewed and approved SWMPs to date. The revised enrollment process eliminates the multiple SWMP review/edit iterations and negotiations that characterized our previous approach. For SWMPs that do not meet the schedule and content described here for General Permit compliance, staff will draft specific resolutions or individual permits for Water Board consideration that will protect water quality, beneficial uses, and the biological and physical integrity of watersheds.

Enrollment Process and Schedule

Water Board staff grouped the 24 remaining un-enrolled traditional MS4s into eight enrollment cycles (Table 1). Each cycle spans a period of 33 to 38 weeks and concludes, on the projected date, with Water Board approval of individual SWMPs and enrollment of the MS4s under the General Permit.

Each enrollment cycle includes five time-limited phases requiring specific actions by both Water Board staff and the MS4 (Table 2). The precise timing and duration of each phase is subject to

change; Water Board staff will develop specific schedules at the commencement of each enrollment cycle.

Table 1: Enrollment Cycles for Attachment 1 and 2 MS4s

Cycle	MS4 Group	Group Members	Projected Start Date for Enrollment Cycle	Projected Executive Officer SWMP Approval	Projected Board SWMP Approval [1]
1	Santa Maria/Lompoc	Santa Maria Lompoc	Jan. 22, 2008	July 28, 2008	Sept. 5, 2008 San Luis Obispo
2	Coastal Santa Barbara County	Goleta Carpinteria Santa Barbara UC Santa Barbara	Jan. 29, 2008	September 2, 2008	Oct. 17, 2008 Santa Barbara
3	Santa Cruz Mountains and Coast	Santa Cruz County Capitola Soquel Aptos Ben Lomond Boulder Creek Live Oak Felton Coralitos Watsonville City of Santa Cruz Scotts Valley UC Santa Cruz	Mid February 2008	October 20, 2008	Dec. 5, 2008 San Luis Obispo
4	Coastal San Luis Obispo County	Arroyo Grande Grover Beach Pismo Beach Oceano Morro Bay Baywood – Los Osos	Mid April 2008	January 2009	2009 – 1st Quarter San Luis Obispo
5	Upper Salinas	King City Templeton Atascadero	Early June 2008	February 2009	2009 – 1st Quarter Salinas
6	City of San Luis Obispo	City of San Luis Obispo	Early September 2008	April 2009	2009 – 2nd Quarter San Luis Obispo
7	Upper Pajaro	Gilroy San Martin Santa Clara	Early November 2008	August 2009	2009 – 3rd Quarter Watsonville
8	Santa Ynez	Buellton Solvang Vandenberg AFB	Mid November 2008	August 2009	2009 – 3rd Quarter San Luis Obispo

1. Board approval only required if a hearing is requested by stakeholder

Table 2: Phases of MS4 Enrollment Cycle

	Duration (weeks)
Phase I: Water Board Staff Assessment of Water Quality Challenges	
Water Board staff: Assess available water quality information Accept input from stakeholders on water quality conditions Prepare and transmit to MS4 staff a statement of current knowledge of water quality challenges that must be addressed by SWMP	3 – 4
Phase II: Water Board Staff SWMP Review	
Water Board staff: Review SWMP and "red-lines" text Send red-lined SWMP and letter explaining requirements to MS4	3 – 4
Phase III: MS4 SWMP Redraft	
MS4 staff re-draft SWMP and post for Public Review	6
Phase IV: Water Board Staff Final Review and Posting of SWMP	
Water Board staff review SWMP	2 – 4
Water Board staff post SWMP and table of required revisions for Public Review	8
Water Board staff respond to public comment and EO approves SWMP	3 – 4
Phase V: Water Board Action (if hearing requested)	
Water Board staff prepare Staff Report with recommendation and resolution for SWMP approval	2
Water Board Staff: Post Staff Report with Board Agenda for Public Review Respond to additional public comment Prepares Presentation for Hearing Conduct internal review up to Board Meeting	6
Total	**33 to 38**

Communication

Clear and open communication between Water Board staff, MS4 staff, and stakeholders is vital to the success of this enrollment process. Also, the Phase II General Permit requires public participation as a component of developing and implementing successful stormwater management programs for MS4s. To comply with the General Permit, you must verify that you have achieved broad and timely distribution of announcements of scoping meetings, draft stormwater program documents, and local agency actions on stormwater program activities when you submit your SWMP for Water Board staff review.

Water Board staff are committed to ensuring that the enrollment process proceeds with open communication. Staff will employ a list-serve (email notification) for notifying all interested parties of important milestones in each enrollment cycle. Water Board staff will also maintain an MS4 enrollment tracking webpage where staff will post relevant documents and indicate the status of each MS4 in the enrollment process. Additionally, an individual Water Board staff person will be assigned to each enrollment cycle. We request that you also identify an individual to serve as point of contact representing your MS4 with whom we will communicate during the enrollment process. You must identify your point of contact when Water Board staff contact you to initiate your enrollment cycle.

Central Coast Water Board Expected SWMP Content

The federal Clean Water Act (CWA) provides that National Pollutant Discharge Elimination System (NPDES) permits for MS4s must require municipalities to reduce pollutants in their stormwater discharges to the Maximum Extent Practicable (MEP) (CWA §402(p)(3)(B)). The California Water Boards have established the meaning and application of this standard through several adopted stormwater permits (the MEP standard is the same for Phase I and Phase II municipalities)[1]. The Water Board implements the General Permit to be consistent with its Water Quality Control Plan (Basin Plan) to ensure protection of water quality, beneficial uses, and the biological and physical integrity of watersheds according to the issues in the Regions.

Your SWMP must include an array of Best Management Practices (BMPs), including the six Minimum Control Measures listed in the General Permit, to achieve the following conditions:

I. Maximize infiltration of clean stormwater, and minimize runoff volume and rate
II. Protect riparian areas, wetlands, and their buffer zones
III. Minimize pollutant loading; and
IV. Provide long-term watershed protection

I. Maximize Infiltration of clean stormwater, and minimize runoff volume and rate.
Water Board staff expect your SWMP to present a schedule for development and adoption of control standards for hydromodification. For SWMP adoption, staff will recommend to the Water Board the following interim requirements, which would apply until such time that you develop acceptable control standards for hydromodification:

- For new and re-development projects, Effective Impervious Area[2] shall be maintained at less than five percent (5%) of total project area.
- For new and redevelopment projects that create and/or replace 5,000 square feet or more of impervious surface, the post-construction runoff hydrographs shall match within one percent (1%) the pre-construction[3] runoff hydrographs, for a range of events with return periods from 1-year to 10-years.
- For projects whose disturbed project area exceeds two acres, preserve the pre-construction drainage density (miles of stream length per square mile of watershed) for all drainage areas serving a first order stream[4] or larger, and ensure that post-project time of concentration is equal or greater than pre-project time of concentration.

These interim requirements must be implemented for all applicable projects subject to your discretionary approvals within six (6) months of your enrollment in the Phase II permit. Your schedule for development and adoption of your own control standards for hydromodification must include:

- Numeric criteria for controlling stormwater runoff volume and rates from new and redevelopment.

[1] Several stormwater permits adopted by different Regional Boards have been legally challenged. All have been upheld by the State Water Resources Control Board and the courts. The Water Boards have broad authority to regulate stormwater and land use activities that result in discharges to waters of the State. Urbanization is one the most important land use activities affecting water quality, beneficial uses, and the physical and biological integrity of watersheds in the Central Coast Region.

[2] Effective Impervious Area is that portion of the impervious area that drains directly to a receiving surface waterbody via a hardened storm drain conveyance without first draining to a pervious area. In other words, impervious surfaces tributary to pervious areas are not considered Effective Impervious Area.

[3] Pre-construction condition is defined as undeveloped soil type and vegetation.

[4] A first order stream is defined as a stream with no tributaries.

- Numeric criteria for stream stability required to protect downstream beneficial uses and prevent physical changes to downstream stream channels that would adversely affect the physical structure, biologic condition, and water quality of streams.
- Specific applicability criteria, land disturbance acreage thresholds, and exemptions.
- Performance criteria for control BMPs and an inspection program to ensure proper long term functioning over.
- Education requirements for appropriate municipal staff on hydromodification and Low Impact Development.

You must include an effective strategy to control hydromodification, or Water Board staff will recommend to the Water Board requirements in the resolution approving your SWMP and enrolling you in the Phase II permit.

II. Protect riparian areas, wetlands, and their buffer zones:
Your SWMP must include BMPs and/or other control measures to establish and maintain a minimum 30-foot buffer zone for riparian areas and wetlands[5]. The buffer zone is a protective area that is undisturbed to the maximum extent practicable. Your SWMP must include consideration and prioritization of local conditions, such as habitat degradation, water quality, and land management practices, and apply more substantial buffer zones where necessary to protect riparian areas and wetlands.

You must include an effective strategy to adopt and implement protection of riparian areas, wetlands, and their buffer zones, or Water Board staff will recommend to the Water Board requirements in the resolution approving your SWMP and enrolling you in the Phase II permit.

III. Minimize pollutant loading
Your SWMP must include BMPs and/or other control measures to minimize pollutant loading, including volume- and/or flow-based treatment criteria. Your SWMP must include consideration and prioritization of local conditions, such as existing pollutant loading, water quality, 303(d) listed impaired waters, pollutants of concern, habitat degradation, and land management practices, and apply more stringent control measures where necessary to minimize pollutant loading.

You must include an effective strategy to reduce pollutant loading, or Water Board staff will recommend to the Water Board requirements in the resolution approving your SWMP and enrolling you in the Phase II permit.

IV. Provide long-term watershed protection
You must include in your SWMP a strategy to develop watershed based hydromodification management plans. These plans should incorporate Low Impact Development strategies with the goal of Post Construction Storm Water Management to achieve an Effective Impervious Area of no more than three to ten percent (3 – 10%) of watershed area within your jurisdiction, depending on local conditions.

The requirements listed above are often characterized as hydromodification controls, or Low Impact Development. These terms are related and their meanings overlap. These requirements are necessary to ensure protection of water quality, beneficial uses, and the biological and physical integrity of watersheds and aquatic habitat. You can reference information on hydromodification controls and Low Impact Development principles on the Central Coast Water Board's website:

[5] The Central Coast Water Quality Control Plan (Basin Plan) requires protection of riparian and wetland habitat and their buffer zones (Basin Plan, Section V.G. 4).

http://www.waterboards.ca.gov/centralcoast/stormwater/low%20impact%20devel/lid_index.htm.

Evaluation of Program Effectiveness and Progress toward Water Quality Goals

Because MEP is a dynamic performance standard which evolves over time as stormwater management knowledge increases, MS4 managers must continually assess and modify their programs to incorporate improvements in control measures and BMPs to achieve MEP. Therefore, your SWMP should contain a detailed plan for evaluating its effectiveness and progress toward complying with the General Permit. Your SWMP must also explain how you will communicate evaluation results with stakeholders. Your evaluation plan should include quantifiable measures for evaluating the effectiveness of the program and be based on the following objectives:

- Assess compliance with requirements of the General Permit , including:
  - Inspection Programs
  - Construction Site Controls
  - Elimination of unlawful discharges
  - New development and redevelopment requirements
- Verify that BMPs are being implemented (e.g., all new applicable developments meet hydromodification control requirements described above and as further described in your SWMP);
- Assess the chemical, physical, and biological impacts on beneficial uses caused by pollutants of concern in stormwater discharges;
- Characterize watersheds and stormwater discharges;
- Identify sources of pollutants; and
- Evaluate long-term trends in receiving water quality.

Conclusion

Please become familiar with the schedule for the enrollment cycle for your MS4, and the steps in the enrollment process. When Water Board staff contact you to initiate your enrollment cycle, please provide us with contact information for the individual that will be representing your MS4.

Please begin updating or preparing your SWMP to include the following as explained in this letter:

- Hydromodification controls for new and redevelopment;
- Protection of riparian and wetland habitat and their buffer zones;
- Minimization of pollutant loading;
- Provision of long-term watershed protection; and
- Evaluation of program effectiveness.

Your SWMP must be specific and must include: well-defined BMPs and other actions that you will implement, schedules, measurable goals, and measures to determine the effectiveness of your program. If your SWMP is not comprehensive or lacks specificity, I will not approve it, and Water Board staff will draft a resolution or an individual permit for consideration by the Water Board at a hearing.

I am clarifying the Water Board's revised enrollment process and SWMP content and requirements to speed up approval of SWMPs for MS4s in the Central Coast Region that will protect water quality, beneficial uses, and the biological and physical integrity of watersheds. I am also committing staff time to regulate MS4s and provide technical and financial assistance to municipalities for stormwater management programs.

The Proposition 84 Storm Water Grant Program funds may be used to provide matching grants to local public agencies for the reduction and prevention of stormwater pollution of rivers, lakes, and streams. A total of approximately $82 million will be available for matching grants. A scoping meeting to answer questions and to solicit input will be held at our office in San Luis Obispo on Monday, March 3, 2008, from 1:00 – 4:00 PM. For more information on the Proposition 84 Storm Water Grant Program and workshops, visit the State Water Board's website at: http://www.waterboards.ca.gov/funding/prop84.html.

I anticipate you will have questions about this letter and the expected content of your SWMP. Please contact us. Our lead staff for this enrollment process is **Dominic Roques**, **droques@waterboards.ca.gov** or at **(805) 542-4780.**

Sincerely,

Roger W. Briggs
Executive Officer

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600.0 STORMWATER MANAGEMENT

The Water Department, as authorized by Section 14-1603.1 of the Philadelphia Code, requires the following specifications for stormwater detention and retention systems as of January 1, 2006.

600.1 Definitions

For the purposes of these Regulations, the following words and phrases shall mean and be interpreted pursuant to the below definitions. Whenever any of these words appear in these Regulations in the singular or plural form, the opposite shall also hold as applicable.

(a) Buffer: The area of land immediately adjacent to any surface water body measured perpendicular to and horizontally from the top-of-bank on both sides of a stream that must remain or be restored to native plants, trees, and shrubs.

(b) Design Professional: A licensed professional engineer registered in the Commonwealth of Pennsylvania.

(c) Design Storm: The magnitude and temporal distribution of precipitation from a storm event defined by probability of occurrence (e.g., five-year storm) and duration (e.g., 24-hours), used in the design and evaluation of stormwater management systems.

(d) Developer: Any landowner, agent of such landowner, or tenant with the permission of such landowner, who makes or causes to be made a subdivision of land or land development project prior to issuance of the Certificate of Occupancy.

(e) Development: Any human-induced change to improved or unimproved real estate, whether public or private, including but not limited to land development, construction, installation, or expansion of a building or other structure, land division, street construction, and site alteration such as embankments, dredging, grubbing, grading, paving, parking or storage facilities, excavation, filling, stockpiling, or clearing. As used in these Regulations, development encompasses both new development and redevelopment. It includes the entire development site, even when the project is performed in stages.

(f) Development Site: The specific tract of land where any Earth Disturbance activities are planned, conducted, or maintained.

(g) Diffused Drainage Discharge: Drainage discharge not confined to a single point location or channel, such as sheet flow or shallow concentrated flow.

(h) Directly Connected Impervious Area (DCIA): An impervious or impermeable surface, which is directly connected to the drainage system as defined in the Manual.

(i) Earth Disturbance: Any human activity which moves or changes the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling, or storing of soil, rock or earth materials.

(j) Erosion and Sediment Control Plan: A plan for a project site that identifies stormwater detention and retention structures that will minimize accelerated erosion and sedimentation during the construction phase.

(k) Groundwater Recharge: The replenishment of existing natural underground water supplies without degrading groundwater quality.

(l) Management District: Sub-area delineations that determine peak rate attenuation requirements, as defined in the Manual. Sites located in more than one management district shall conform to the requirements of the district into which the site discharges.

(m) Manual: The most recent version of the Philadelphia Stormwater Management Guidance Manual.

(n) New Development: Any development project that does not meet the definition of redevelopment as defined in these Regulations or any development project at a site where structures or impervious surfaces were removed before January 1, 1970.

(o) Post Construction Stormwater Management Plan (PCSMP): A complete stormwater management plan as described in these regulations and in the Manual.

(p) Predevelopment Condition: For new development, the predevelopment condition shall be the existing condition of the site, and for redevelopment, predevelopment shall be defined according to the procedures found in the Manual.

(q) Redevelopment: Any development on a site that requires demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970, with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered redevelopment. Interior remodeling projects are also not considered redevelopment.

(r) Stormwater Management Practice (SMP): Any man-made structure that is designed or constructed to convey, store, or otherwise control stormwater runoff quality, rate, or quantity. Typical SMPs include, but are not limited to, detention and retention basins, swales, storm sewers, pipes, and infiltration structures.

(s) Stormwater Pretreatment: Techniques employed to remove pollutants before they enter the SMP, limited to techniques defined and listed as pretreatment in the Manual.

600.2 Regulated Activities

(a) Regulated activities under these Regulations include any development, including new development and redevelopment, that results in an area of earth disturbance greater than or equal to 15,000 square feet. The area of Earth Disturbance during the construction phase determines requirements for both the erosion and sediment controls and the post-construction stormwater management.

(b) The applicability of these Regulations is summarized in the Table of Applicable Stormwater Regulations in Philadelphia.

(c) These Regulations shall apply to the entire development site even if development on that site is to take place in phases.

(d) Existing SMPs may be used on sites where development occurs as long as they meet all of the requirements of these Regulations.

600.3 Exemptions

(a) General Exemptions

The following cases are exempt from the specified requirements of these Regulations.

(1) Development, including new development and redevelopment, that results in an area of Earth Disturbance less than fifteen thousand (15,000) square feet is exempt from all requirements of these Regulations;

(2) Redevelopment that results in an area of Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet, but less than one (1) acre, is exempt from the requirements of Section 600.5(b), Channel Protection Requirement.

(3) Redevelopment that results in an area of Earth Disturbance greater than or equal to one (1) acre and reduces the predevelopment DCIA on the site by at least twenty percent (20%) is exempt from the Channel Protection and Flood Control Requirements of this Regulation.

(b) Exemption Responsibilities

An exemption shall not relieve the Developer from implementing such measures as are necessary to protect public health and safety.

(c) Emergency Exemption

Emergency maintenance work performed for the protection of public health and safety is exempt from the requirements of these Regulations. A written description of the scope and extent of any emergency work performed shall be submitted to the Water Department within two (2) calendar days of the commencement of the activity. If the Water Department finds that the work is not an emergency, then the work shall cease immediately and the requirements of these Regulations shall be addressed as applicable.

(d) Special Circumstances

If conditions exist that prevent the reasonable implementation of water quality and /or quantity control practices on site, upon written request by the owner, the Philadelphia Water Department may at its sole discretion accept off-site stormwater management practices, retrofitting, stream restorations, or other practices that provide water quality and /or quantity control equal or greater than onsite practices for the volume which the owner has demonstrated to be infeasible to manage and treat on site.

Table of Applicable Stormwater Regulations in Philadelphia				
		Earth Disturbance Associated with Development		
		0-15,000 sq. ft.	15,000 sq. ft.-1 acre	> 1 acre
Section 600.5(a) Water Quality Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes
Section 600.5(b) Channel Protection Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Exempt	Yes (Alternate Criteria)
Section 600.5(c) Flood Control Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes (Alternate Criteria)	Yes (Alternate Criteria)
Section 600.6 Nonstructural Project Design Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes
Section 600.8 Post-Construction Stormwater Management Plan Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes

Yes (Alternate Criteria) – requirements of section may be waived depending on post-development site conditions (See Sections 600.3(a)(3), 600.5(b) and 600.5(c) for further details).

N/A - Not Applicable, development project is not subject to requirements of indicated Regulations section. Voluntary controls are encouraged.

Exempt – Development project is not subject to requirements of indicated Regulations section.

**– If the proposed development results in stormwater discharge that exceeds stormwater system capacity, causes a combined sewer overflow, or degrades receiving waters, the design specifications presented in these Regulations may be applied to proposed development activities as warranted to protect public health, safety, or property.

600.4 Erosion and Sediment Control during Earth Disturbance

(a) All Earth Disturbance must comply with the Erosion and Sediment Control requirements of the Pennsylvania Department of Environmental Protection (PADEP) as specified in 25 Pa. Code § 102.4(b).

(b) No Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet and less than 1 acre shall commence until the Water Department approves an Erosion and Sediment Control Plan conforming to the regulations of the PADEP.

600.5 Post-Construction Stormwater Management Criteria

(a) Water Quality Requirement: The Water Quality Requirement is designed to recharge the groundwater table and to provide water quality treatment for stormwater runoff.

(1) The following formula shall be used to determine the water quality volume, (WQv), in cubic feet of storage for the development site.

$$WQ_v = \left(\frac{P}{12}\right) * (I) \qquad \text{Eqn: 600.1}$$

Where:

WQv = Water Quality Volume (cubic feet)

P = 1.0 inch

I = DCIA within the limits of earth disturbance (square feet)

(2) Groundwater Recharge Requirement: In order to preserve or restore a more natural water balance on new development and redevelopment sites, the water quality volume shall be infiltrated on site. A list of acceptable practices for infiltration is provided in the Manual.

(A) The infiltration volume shall be equal to one (1.0) inch of rainfall over all DCIA within the limits of Earth Disturbance.

(B) The Design Professional is required to follow the Hotspot Investigation, Subsurface Stability, and Suitability of Infiltration procedures in the Manual to determine whether the proposed infiltration on the Development Site is appropriate.

(C) If soil investigation reports demonstrate that the soil is unsuitable for infiltration, the Design Professional shall be responsible for providing written documentation to the Water Department showing that the required volume cannot physically be infiltrated within the required time period.

(3) Water Quality Treatment Requirement.

(A) Where it has been demonstrated, in accordance with section 600.5(a)(2) of these Regulations, that a portion or all of the water quality volume cannot be infiltrated on site, the water quality volume which cannot be infiltrated on site must be treated for water quality.

(B) Water quality treatment is attained differently in separate sewer areas than in combined sewer areas. Separate sewer areas achieve water quality treatment through approved stormwater management practices. Combined sewer areas achieve water

quality treatment by detaining and releasing stormwater at a specified maximum rate as stated in the Manual.

(b) Channel Protection Requirement: The Channel Protection Requirement is designed to minimize accelerated channel erosion resulting from stormwater runoff from Development Sites.

(1) To meet the Channel Protection Requirement, SMPs shall retain or detain the runoff from all DCIA within the limits of Earth Disturbance from a one-year, 24-hour Natural Resources Conservation Service (NRCS) Type II design storm in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours to drain from the facility.

(2) Redevelopment sites with less than one (1) acre of Earth Disturbance or redevelopment sites that demonstrate a twenty percent (20%) reduction in DCIA from predevelopment conditions as described in the Manual are exempt from this requirement.

(3) The infiltration and water quality volumes may be incorporated into the channel protection portion of the design provided the design meets all requirements concurrently.

(4) Design criteria and a list of SMPs for channel protection are included in the Manual.

(c) Flood Control Requirement

(1) To prevent flooding caused by extreme events, the City of Philadelphia is divided into Management Districts that require different levels of stormwater attenuation depending on their location. Design Professionals shall determine the appropriate Management District for the development site using the maps provided in the Manual.

(A) The Table of Peak Runoff Rates for Management Districts lists the attenuation requirements for each Management District.

(B) Sites located in more than one Management District shall conform to the requirements of the district where the discharge point is located.

(2) Redevelopment sites that can demonstrate a twenty percent (20%) reduction in DCIA from predevelopment conditions as described in the Manual are exempt from this requirement.

(3) Predevelopment Conditions for Redevelopment are specified in the Manual.

Table of Peak Runoff Rates for Management Districts

District	Column A NRCS Type II 24-hour Design Storm applied to Proposed Condition	Column B NRCS Type II 24 –hour Design Storm applied to Predevelopment Condition
A	2 – year	1 - year
A	5 – year	5 - year
A	10 – year	10 - year
A	25 – year	25 - year
A	100-year	100-year
B-1	2 – year	1- year
B-1	10 – year	5 - year
B-1	25 – year	10 - year
B-1	50- year	25- year
B-1	100-year	100-year
B-2	2 – year	1- year
B-2	5 – year	2 - year
B-2	25 – year	5 - year
B-2	50- year	10- year
B-2	100 – year	100 - year
C*	Conditional Direct Discharge District	

SMPs shall be designed such that peak rates from Column B are less than or equal to Peak Rates from Column A.

* In District C, development sites that can discharge directly to the Delaware River main channel or Tidal Schuylkill River major tributary without use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms.

The Predevelopment Condition for new development is the existing condition. For redevelopment purposes, the Predevelopment Condition is determined according to the procedures found in the Manual.

600.6 Nonstructural Project Design and Sequencing to Minimize Stormwater Impacts

(a) A Developer is required to find practicable alternatives to the surface discharge of stormwater, the creation of impervious surfaces, and the degradation of Waters of the Commonwealth.

(b) All development shall include the following steps in sequence to comply with water quality requirements of §14.1603.1 of the Philadelphia Code. The goal of the sequence is to minimize the increases in stormwater runoff and impacts to water quality resulting from the proposed regulated activity.

(1) Prepare an Existing Resource and Site Analysis (ERSA) map and worksheet, showing environmentally sensitive areas including, but not limited to: steep slopes, ponds, lakes, streams, suspected wetlands, hydric soils, vernal pools, land development, any existing recharge areas, and any other requirements of the worksheet available in the Manual;

(2) establish a Buffer by preserving or restoring native plants, trees, and shrubs to the area of land immediately adjacent to any surface water body.

(A) The Buffer shall be a minimum of ten (10) feet on both sides of the stream, measured perpendicular to and horizontally from the top-of-bank.

(B) In the Wissahickon Watershed, there shall be no new impervious ground cover constructed or erected within 200 feet of the bank of a surface water body or within 50 feet of the centerline of a swale.

(3) prepare a draft project layout avoiding the sensitive areas identified in ERSA;

(4) evaluate nonstructural stormwater management alternatives as described in the Manual;

(5) minimize Earth Disturbance during the construction phase;

(6) use site design techniques described in the Manual to minimize the impervious surfaces within the limits of Earth Disturbance;

(7) use techniques in the Manual to minimize DCIA within the limits of Earth Disturbance;

(8) design appropriate detention and retention structures according to the Manual;

(A) meet Water Quality Requirement and provide for Stormwater Pretreatment prior to infiltration or water quality treatment in accordance with the Manual

(B) meet Channel Protection Requirement in accordance with Section 600.5(b) of these Regulations;

(C) meet Flood Control Requirement for the appropriate Management District in accordance with Section 600.5(c) of these Regulations; and

(9) adjust the site design as needed to meet all requirements of the Regulations concurrently.

600.7 Requirements for the Design of SMPs

(a) General Requirements

(1) In order to provide for the protection of public health and safety and to more effectively manage stormwater in Philadelphia, all SMPs shall meet the requirements of these Regulations.

(2) The existing points of concentrated drainage that discharge onto adjacent land shall not be altered in any manner that could cause property damage without written permission of the owner of the adjacent land.

(3) The design of all SMPs shall incorporate sound engineering principles and practices as detailed in the Manual. The Water Department reserves the right to disapprove any design that would result in the creation or continuation of a stormwater problem area.

(4) All stormwater runoff in excess of any volume infiltrated on site must be routed through a dedicated stormwater pipe and conveyed up to the approved connection or point of discharge.

(5) When the Development Site is located within a combined sewer area and adjacent to a receiving water body, stormwater shall be discharged directly to receiving waters after requirements of these Regulations and any applicable state or federal requirements are met.

(6) Areas of existing diffused drainage discharge shall be subject to any applicable discharge criteria in the general direction of existing discharge, whether proposed to be concentrated or maintained as diffused drainage areas, except as otherwise provided by these Regulations. If diffused drainage discharge is proposed to be concentrated and discharged onto adjacent land, the Developer must document that adequate downstream conveyance facilities exist to safely transport the concentrated discharge, or otherwise prove that no erosion, sedimentation, flooding or other impacts will result from the concentrated discharge.

(7) All SMPs shall incorporate maximum ponding and/or draw down requirements consistent with the Manual.

(8) Calculation Methodology: Acceptable calculation methods for the design of SMPs are provided in the Manual.

600.8. PCSMP Requirements

(a) General Requirements

For any activities regulated by these Regulations and the Philadelphia Code Section §14.1603.1:

(1) No zoning permit may be applied for until the Water Department has approved a conceptual site plan.

(2) No Earth Disturbance may commence or Zoning Permit be issued until the Water Department has approved a PCSMP.

(b) Preliminary Approval

In order to obtain preliminary approval from the Water Department, the owner must complete the ERSA worksheet and map and Site Plan Review Meeting with the City as described in the Manual.

(c) PCSMP Approval

(1) The PCSMP shall include a general description of the project, project sequence, calculations, maps and plans as described in Section 600.6(b) of these Regulations. A list of required contents of the PCSMP is located in the Manual.

(2) For any activities that require one or more state or federal permits, proof of application for said permit(s) or approvals shall be part of the plan.

(3) All PCSMP materials shall be submitted to the Water Department in a format that is clear, concise, legible, neat, and well organized; otherwise, the PCSMP shall not be accepted for review and shall be returned to the Developer for revision.

600.9 Permit Requirements by Other Government Entities

(a) Other government entities may require permits for certain regulated Earth Disturbance activities.

(b) Requirements for these permits must be met prior to commencement of Earth Disturbance.

600.10 Inspections

(a) The Water Department or its designee may inspect any phase of the installation of the SMPs.

(b) During any stage of the work, if the Water Department or its designee determines that the SMPs are not being installed in accordance with the approved PCSMP, the Water Department shall issue a "Stop Work Order" until a revised PCSMP is submitted and approved and the deficiencies are corrected.

(c) As-built drawings for all SMPs must be submitted to the Water Department prior to final inspection.

(d) A final inspection of all SMPs shall be conducted by the Water Department or its designee to confirm compliance with the approved PCSMP prior to the issuance of any Certificate of Occupancy.

600.11 Responsibilities for Operations and Maintenance of SMPs

(a) No regulated Earth Disturbance activities shall commence until the Water Department has approved a PCSMP and SMP Operations and Maintenance Plan (O & M Plan), prepared in accordance with the requirements set forth in the Manual, which describes how the post-construction SMPs will be properly operated and maintained.

(b) The O & M Plan must include a signed agreement between the owner and the City to maintain the SMPs in accordance with the O & M Plan.

(c) There shall be no alteration or removal of any SMP required by an approved PCSMP and O & M Plan, and the owner must not allow the property to remain in a condition which does not conform to an approved PCSMP and O & M Plan.

(d) The Water Department reserves the right to accept or reject the operations and maintenance responsibility for any or all of the stormwater controls and SMPs.

600.12 Stormwater Management Easements

(a) Stormwater management easements or right-of-ways are required for all areas used for off-site SMPs or stormwater conveyance, unless a waiver is granted by the Water Department.

(b) Stormwater management easements shall be provided by the owner if necessary for access for inspections and maintenance, or for the preservation of stormwater runoff conveyance, infiltration, detention areas and/or other stormwater controls and SMPs, by persons other than the property owner.

(c) The stormwater management easement and its purpose shall be specified when recorded in accordance with section 600.13 of these Regulations.

600.13 Recording of O& M Plans

(a) The owner of any land upon which SMPs will be placed, constructed or implemented as described in the PCSMP and Operation and Maintenance Plan (O & M Plan), shall record the following documents with the Philadelphia Department of Records, within fifteen (15) calendar days of approval of the PCSMP by the Water Department:

(1) The O & M Plan, or a summary thereof, and

(2) Operations and Maintenance Agreements as included as part of the PCSMP submitted under Section 600.8 and Easements under Section 600.12 of these Regulations.

(b) The Water Department may suspend or revoke any approvals granted for the project site upon discovery of the failure of the owner to comply with these Regulations.

600.14. Prohibited Discharges

(a) No person shall allow, or cause to allow, stormwater discharges into the City's separate storm sewer system which are not composed entirely of stormwater.

(b) In the event that the Water Department determines that any discharge to a storm sewer is not composed entirely of stormwater, the Water Department will notify the responsible person to immediately cease the discharge.

(c) Nothing in this Section shall affect a discharger's responsibilities under state law.

600.15 Prohibited Connections

(a) The following connections are prohibited, except as provided in Section 600.14(a)(1) of these Regulations.

(1) Any drain or conveyance, whether on the surface or subsurface, which allows any non-stormwater discharge including sewage, groundwater, process wastewater, and wash water, to enter the separate storm sewer system.

(2) Any connections to the storm drain system from indoor drains and sinks.

(3) Any drain or conveyance connected from a commercial or industrial land use to the separate storm sewer system that has not been documented in plans, maps, or equivalent records, and approved by the City.

_____
Bernard Brunwasser
Water Commissioner

Approved as to Form,
Romulo L. Diaz, Jr., City Solicitor

Per:_____
Keith J. Jones
Deputy City Solicitor

PENNSYLVANIA

Stormwater BMP Manual

December 30, 2006

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Watershed Management

DOCUMENT NUMBER:	363-0300-002
TITLE:	Pennsylvania Stormwater Best Management Practices Manual
EFFECTIVE DATE:	December 30, 2006
AUTHORITY:	Pennsylvania Clean Streams Law (35 P.S. §§ 691.1-691.1001); Pennsylvania Stormwater Act (32 P.S. §§ 680.1-680.17); Federal Clean Water Act (33 U.S.C.A. § 1342), 40 CFR Part 122 and 25 Pa Code Chapters 92, 93, 102, 105 and 111.
POLICY:	The Department will ensure that activities and plans approved under its authority will employ stormwater management plans utilizing best management practices to control the volume, rate and water quality of post construction stormwater runoff so as to protect and maintain the chemical, physical and biological properties of waters of the Commonwealth. These best management practices must, at a minimum, protect and maintain water resources, preserve water supplies, maintain stream base flows, preserve and restore the flood carrying capacity of waters, preserve to the maximum extent practicable the natural stormwater runoff regimes and natural course, current and cross section of waters of the Commonwealth, and protect and conserve ground waters and ground-water recharge areas.
PURPOSE:	Clean, reliable water resources are critical for sustaining the environmental health of our natural resources, protecting the public's health and safety, and maintaining the economic vitality of the Commonwealth. The purpose of this guidance manual is to ensure effective stormwater management to minimize the adverse impacts of stormwater on ground water and surface water resources to support and sustain the social, economic and environmental quality of the Commonwealth.
APPLICABILITY:	This guidance applies to all persons conducting or planning to conduct activities that require a written post-construction stormwater management plan.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The guidelines herein are not an adjudication or a regulation. The Department reserves the discretion to vary from this guidance as circumstances warrant.

SARB_014514

PAGE LENGTH:	642
LOCATION:	Volume 34, Tab 20
DEFINITIONS:	See Title 25 Pa. Code, Chapters 92, 93, 102, 105 and 111.

Pennsylvania Stormwater Best Management Practices Manual

December 2006



363-0300-002 / December 30, 2006

SARB_014516

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FOREWORD

Stormwater runoff and flooding are natural events that, over the millennia, have helped shape the world around us. Our activities on the landscape routinely alter these natural drainage patterns by intensifying and redirecting runoff, potentially leading to stream pollution, property damage and, in extreme cases, loss of life.

Localized flash flooding, stream bank scour and destabilization, siltation, loss of ground water recharge, declining dry-weather stream flows and habitat destruction are all the results of unmanaged or poorly managed stormwater. In addition to its physical impact on the environment, stormwater may carry a variety of pollutants into our waters including metals, bacteria, oil and grease, pesticides, nutrients and sediment. The Department's stream assessment efforts have documented that urban runoff is the third leading source of stream impairment in Pennsylvania. Moving forward, these historic problems can be avoided or minimized through a combination of forethought and planning, and properly constructed and maintained best management practices (BMPs). By managing stormwater runoff as a valuable and reusable resource rather than as a waste that must be quickly moved away, a host of opportunities are opened that promote environmental protection and enhancement while complementing new growth and development.

This manual is based on the following set of principles:

1. Managing stormwater as a resource;
2. Preserving and utilizing existing natural features and systems;
3. Managing stormwater as close to the source as possible;
4. Sustaining the hydrologic balance of surface and ground water;
5. Disconnecting, decentralizing and distributing sources and discharges;
6. Slowing runoff down, and not speeding it up;
7. Preventing potential water quality and quantity problems;
8. Minimizing problems that cannot be avoided;
9. Integrating stormwater management into the initial site design process; and
10. Inspecting and maintaining all BMPs.

The manual supplements federal and state regulations, and the Department's Comprehensive Stormwater Management Policy, by emphasizing effective site planning as the preferred method of managing runoff while also providing numerous examples of BMPs that can be employed in Pennsylvania to further avoid and minimize flooding and water resource problems. This manual has no independent regulatory authority. The manual is intended to be a technical reference of planning concepts and design standards that will satisfy Pennsylvania's regulatory requirements and stormwater management policies when properly tailored and applied to local site conditions. Alternate BMPs not listed in the manual may also be used to satisfy regulatory requirements if they provide the same or greater level of protection. No predetermined set of practices will be applicable to every building site. Specific considerations such as soil type, underlying geology, slope, project size and building density will determine which practices are applicable and feasible for a given project.

SARB_014529

Acknowledgements

The following individuals and organizations participated in developing this manual. Participation does not infer concurrence or endorsement of the manual or it's contents.

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Special thanks are expressed to the members of the Stormwater Manual Oversight Committee who assisted in providing direction, guidance and expertise in the preparation of this manual. Committee members include:

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Pennsylvania Stormwater Best Management Practices Manual

Chapter 1

Introduction and Purpose



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Chapter 1 Introduction and Purpose

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1.2 How to Use this Manual……1

1.3 Overview of Pennsylvania's Existing Stormwater Management Program….3

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1.1 Purpose of this Manual

The purpose of the Pennsylvania Stormwater Best Management Practices (BMP) Manual is to provide guidance, options and tools that can be used to protect water quality, enhance water availability and reduce flooding potential through effective stormwater management. This manual presents design standards and planning concepts for use by local authorities, planners, land developers, engineers, contractors, and others involved with planning, designing, reviewing, approving, and constructing land development projects.

This manual describes a stormwater management approach to the land development process that strives to:

- First, prevent or minimize stormwater problems through comprehensive planning and development techniques, and
- Second, to mitigate any remaining potential problems by employing structural and non-structural BMPs.

Manual users are strongly encouraged to follow the progression of prevention first and mitigation second. Throughout the chapters of this manual the concept of an integrated stormwater management program, based on a broad understanding of the natural land and water systems, is a key and recurring theme. Such a thorough understanding of the natural systems demands an integrated approach to stormwater management, so critical to "doing it better, doing it smarter."

This manual provides guidance on managing all aspects of stormwater: rate, volume, quality, and groundwater recharge. Controlling the peak rate of flow during extreme rainfall events is important, but it is not sufficient to protect the quality and integrity of Pennsylvania streams. Reducing the overall volume of runoff during large and small rainfall events, improving water quality, and maintaining groundwater recharge for wells and stream flow are all vital elements of protecting and improving the quality of Pennsylvania's streams and waterways.

It is important to note that The Pennsylvania Stormwater Best Management Practice Manual has no independent regulatory authority. The strategies, practices, recommendations and control guidelines presented in the manual can become binding requirements only through the following means:

1. Ordinances and rules established by local municipalities, or
2. Permits and other authorizations issued by local, state, and federal agencies.

1.2 How to Use this Manual

The following provides a guide to the various chapters of the Manual.

***Chapter 1* – Introduction and Purpose**

***Chapter 2* – Stormwater and the Impacts of Development and Impervious Surfaces**

This section provides an overview of the impacts of development on Pennsylvania's natural systems and natural resources, including discussions about the effect of increased runoff volumes, water quality, stream channel erosion, flooding, and lost groundwater recharge and stream baseflow.

***Chapter 3* – Stormwater Management Principles and Recommended Control Guidelines**

This section discusses stormwater management principles to protect water resources and provides recommended control guidelines for stormwater management. This chapter also discusses how the recommended guidelines relate to diverse conditions, such as urban areas rural settings, brownfield sites and karst topography.

***Chapter 4* –Integrating Site Design and Stormwater Management**

This section discusses the *process* of comprehensive stormwater management, which begins with better site design and protection of important natural features first, and the use of structural Best Management Practices to manage stormwater second. An approach to site design and stormwater management for Pennsylvania is outlined in flowchart and checklist formats.

***Chapter 5* – Non-Structural BMPs**

This section describes in detail 13 design and development techniques (non-structural BMPs) that reduce the impact of stormwater. It includes both specific design practices and recommendations that may be required or encouraged by municipal officials within the context of zoning and land development ordinances. Use of these "non-structural" BMPs is considered to be the primary means of stormwater management.

***Chapter 6* – Structural BMPs**

This section describes in detail 21 specific engineering measures that reduce and mitigate the impacts of development. The use of the "structural BMPs" is considered the second step in stormwater design. Chapter 6 includes recommendations (protocols) for the design of infiltration systems and for soil investigation for infiltration systems.

***Chapter 7* – Special Management Areas**

This chapter discusses issues and stormwater management implications unique to some special management areas such as brownfields, highways and roads, karst areas, mined lands, water supply well areas, surface water supplies, special protection waters, and highly urbanized areas.

***Chapter 8* – Stormwater Calculations and Methodology**

This chapter discusses engineering techniques and methods used to perform stormwater calculations. Improved sources for rainfall estimates (NOAA Atlas 14, 2004) are suggested. This chapter also provides guidance on developing stormwater calculations based on the recommended control guidelines in Chapter 3 of the manual. In addition, this chapter includes optional flowcharts and worksheets to assist stormwater designers and reviewers organize and conduct their calculations.

***Chapter 9* - Case Studies**

This chapter presents case studies of projects that have been implemented throughout Pennsylvania that incorporate innovative techniques and approaches to stormwater management. This chapter identifies sites in various regions of the state that users of the manual may visit to observe innovative stormwater management techniques in a range of development settings.

***Appendix A* – Water Quality**

***Appendix B* – Pennsylvania Native Plant List**

***Appendix C* – Protocols for Structural BMPs**

Protocol 1 – Site Evaluation and Soil Infiltration Testing
Protocol 2 – Infiltration Systems Design and Construction Guideline

***Appendix D* – Storm water Calculations and Methodology – Case Study**

Glossary

1.3 Overview of Pennsylvania's Existing Stormwater Management Program

The Clean Stream Law of 1937 provides the legal foundation for water quality protection and restoration, and water resources management in Pennsylvania. The Department of Environmental Protection is primarily responsible for administering the provisions of the act. The Clean Streams Law has been affected by passage of a series of federal laws, such as the Clean Water Act (CWA) of 1972, which has also been amended over time. Local government implements specific regulations for land development and stormwater management. Pennsylvania has 2566 municipalities and 376 designated stormwater management watersheds, with diverse natural, social, and cultural features. The Pennsylvania Municipalities Planning Code (MPC) law enables, but does not require, comprehensive planning, zoning, and subdivision/land development regulation on the municipal, county, and regional levels. To achieve regulatory status, the recommendations and guidelines in this manual must be implemented by ordinances and zoning at the municipal level.

The Pennsylvania Storm Water Management Act of 1978 (Act 167) provides the legislative basis for statewide stormwater management. The Act 167 stormwater management program is mandated, administered, and funded at a 75 percent level by the state. However, stormwater management plans must be developed by the respective counties in a given watershed, and be implemented by the effected municipalities through the adoption of stormwater ordinances. This is a rather uniquely structured "sharing" of authority and powers by all levels of Pennsylvania government.
In addition to the requirements under local zoning and ordinances, federal regulations require individual land development projects to obtain National Pollutant Discharge Elimination System (NPDES) permits. These permits are required for all land development projects that disturb one acre or more. The permits authorize discharges from erosion and sediment control facilities and approve post-construction stormwater management plans. The 1999 update to the federal stormwater regulations also required 923 small municipalities and numerous institutions throughout Pennsylvania to obtain NPDES permits for their stormwater discharges. Each permit holder must implement and enforce a stormwater management program that reduces the discharge of pollutants to the maximum extent practicable. More detailed discussions of individual and municipal NPDES construction and stormwater management permits can be found on the DEP web site under the keyword "Stormwater Management".

SARB_014539

Pennsylvania Stormwater Best Management Practices Manual

Chapter 2

Making the Case for Stormwater Management



363-0300-002 / December 30, 2006

SARB_014541

Chapter 2 Making the Case for Stormwater Management

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2.1 A Brief Review of Stormwater Problems in Pennsylvania

Pennsylvania is the most flood prone state in the country. It has experienced several serious and sometimes devastating floods during the past century, often as a result of tropical storms and hurricanes, and heavy rainfall on an existing snow pack. To a large extent, the flooding that results from such extreme storms and hurricanes occurs naturally and will continue to occur. Stormwater management cannot eliminate flooding during such severe rainfall events (Figure 2-1).



Figure 2-1. Flooding impacts are devastating communities, even with conventional stormwater management programs (F. Thorton).

In many watersheds throughout the state, flooding problems from rain events, including the smaller storms, have increased over time due to changes in land use and ineffective stormwater management. This additional flooding is a result of an increased volume of stormwater runoff being discharged throughout the watershed. This increase in stormwater volume is the direct result of more extensive impervious surface areas (Figure 2-2), combined with substantial tracts of natural landscape being converted to lawns on highly compacted soil or agricultural activities.



Figure 2-2. Parking lots are common impervious surfaces that affect stormwater runoff.

The problems are not limited to flooding. Stormwater runoff carries significant quantities of pollutants washed from the impervious and altered land surfaces (Figure 2-3). The mix of potential pollutants ranges from sediment to varying quantities of nutrients, organic chemicals, petroleum hydrocarbons, and other constituents that cause water quality degradation.



Figure 2-3. Pollutant laden runoff degrades water quality.

Increased stormwater runoff volume can turn small meandering streams into highly eroded and deeply incised stream channels (Figure 2-4). Stream meander and the resulting erosion and sedimentation is a natural process, and all channels are in a constant process of alteration. However, as the volume of runoff from each storm event is increased, natural stream channels experience more frequent bank full or near bankfull conditions. As a result, streams change their natural shape and form. Pools and riffles that support aquatic life are disrupted as channels erode to an unnatural level, and the eroded bank material contributes to sediment in the stream and degrades it's health by smothering stream bottom habitat. The majority of this stream channel devastation is intensified during the frequently occurring small-to-moderate precipitation events, not during major flooding events.



Figure 2-4.Stormwater influenced stream bank morphology in Valley Creek.

Rainfall is an important resource to replenish the groundwater and maintain stream flow (Figure 2-5). When the stormwater runoff during a storm event is allowed to drain away rather than recharge the groundwater, it alters the hydrologic balance of the watershed. As a consequence, stream base flow is deprived of the constant groundwater discharge and may diminish or even cease. During a drought, reduced stream base flow may also significantly affect the water quality in a stream.

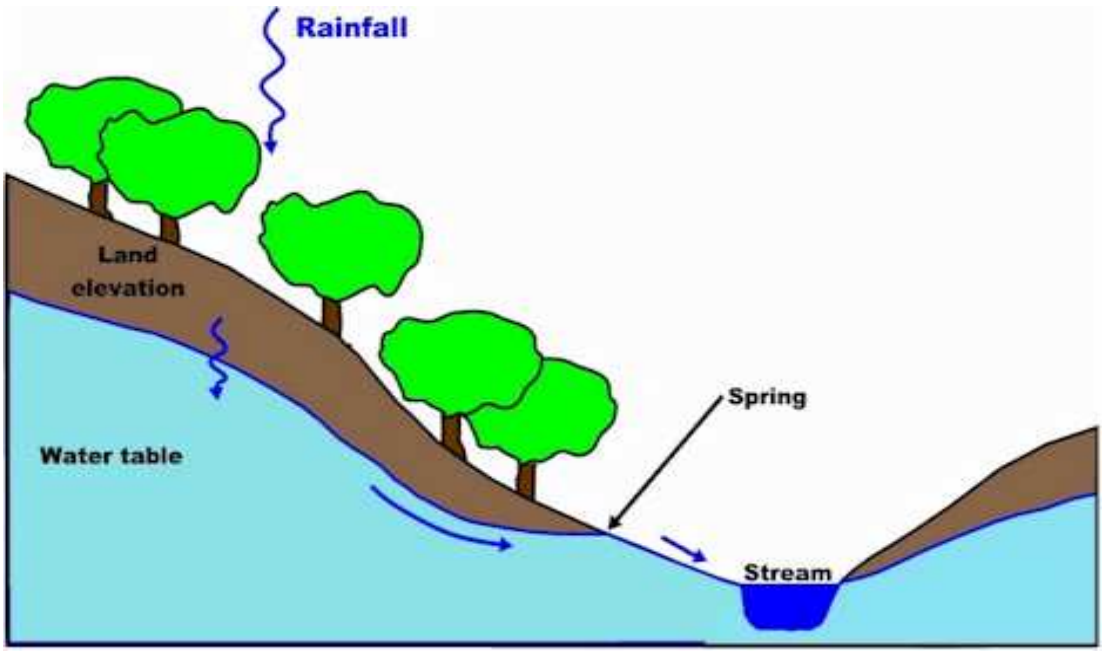

Figure 2-5. Rainfall replenishes the groundwater, which in turn provides stream base flow.

The groundwater discharge to a stream is at a relatively constant temperature, whereas stormwater runoff from impervious surfaces may be very hot in the summer months and extremely cold in the winter months. These temperature extremes can have a devastating effect on aquatic organisms, from bacteria and fungi to larger species. Many fish, especially native trout, can be harmed by acute temperature changes of only a few degrees.

Improperly managed stormwater causes increased flooding, water quality degradation, stream channel erosion, reduced groundwater recharge, and loss of aquatic species. But these and other impacts can be effectively avoided or minimized through better site design. This chapter discusses the potential problems associated with stormwater and explains the need for better stormwater management. The problems caused by impervious and altered surfaces can be avoided or minimized, but only through stormwater management techniques that include runoff volume reduction, pollutant reduction, groundwater recharge and runoff rate control for all storms.

2.2 The Hydrologic Cycle and The Effects of Development

The movement of water from the atmosphere to the land surface and then back to the atmosphere is a continuous process, with water constantly in motion. This balanced water cycle of precipitation, runoff, evapotranspiration, infiltration, groundwater recharge, and stream base flow sustains Pennsylvania's water resources. This representation of the hydrologic cycle, while depicting the general concept, over-simplifies the complex interactions that define the surface and subsurface flow processes of humid regions in the United States.

Changes to the land surface, along with inappropriate stormwater management, can significantly alter the natural hydrologic cycle. In a natural Pennsylvania woodland or meadow, very little of the annual rainfall leaves the site as runoff. More than half of the annual amount of rainfall returns to the atmosphere through evapotranspiration. Surface vegetation, especially trees, transpires water to the atmosphere (with seasonal variations). Water is also stored in puddles, ponds and lakes on the earth's surface, where some of it will evaporate. Water that percolates through the soil either moves vertically and eventually reaches the zone of saturation or water table, moves laterally through the soil and often emerges as springs or seeps down gradient or is stored in the soil.

Soils are influenced and formed by vegetation, climate, parent material, topography and time. All of these factors have some effect on how water will move through the soil. Restrictive soil horizons may impede the vertical movement of water and cause it to move laterally. It is important to understand these factors when designing an appropriate stormwater system at a particular location. Under natural woodland and meadow conditions, only a small portion of the annual rainfall becomes stormwater runoff. Although the total amount of rainfall varies in different regions of the state, the basic average hydrologic cycle shown below holds true (Figure 2-6).



Figure 2-6. Annual hydrologic cycle for an undisturbed acre in the Pennsylvania Piedmont region.

Changing the land surface causes varying changes to the hydrologic cycle (Figure 2-7). Altering one component of the water cycle invariably causes changes in other elements of the cycle. Roads, buildings, parking areas and other impervious surfaces prevent rainfall from soaking into the soil and significantly increase the amount of runoff. As natural vegetation is removed, the amount of evapotranspiration decreases.

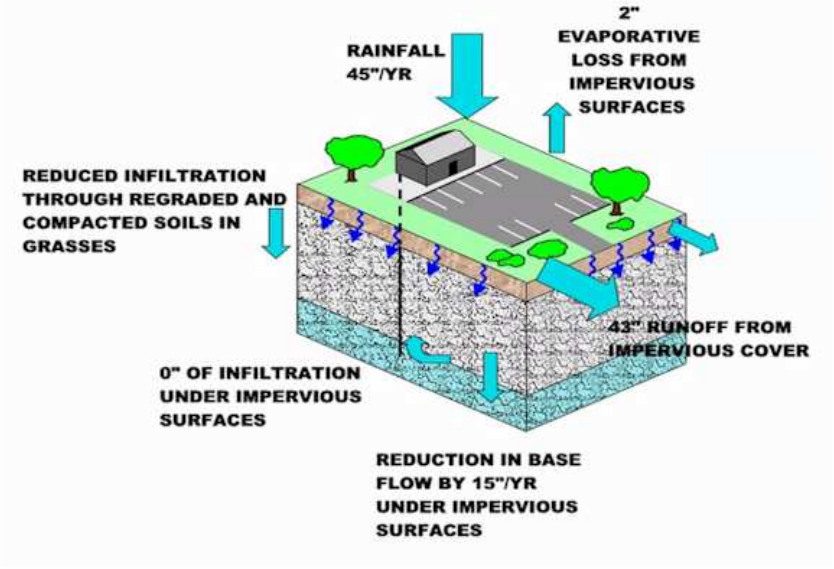

Figure 2-7. Representative altered hydrologic cycle for a developed acre in the Piedmont region.

These changes in the hydrologic cycle have a dramatic effect on streams and water resources. Annual stormwater runoff volumes increase from inches to feet per acre, groundwater recharge decreases, stream channels erode, and populations of fish and other aquatic species decline. Past practices focused on detaining the peak flows for larger storms. While detention is helpful in reducing peak flows for the immediate downstream neighbor, it does not address most of the other problems discussed earlier.

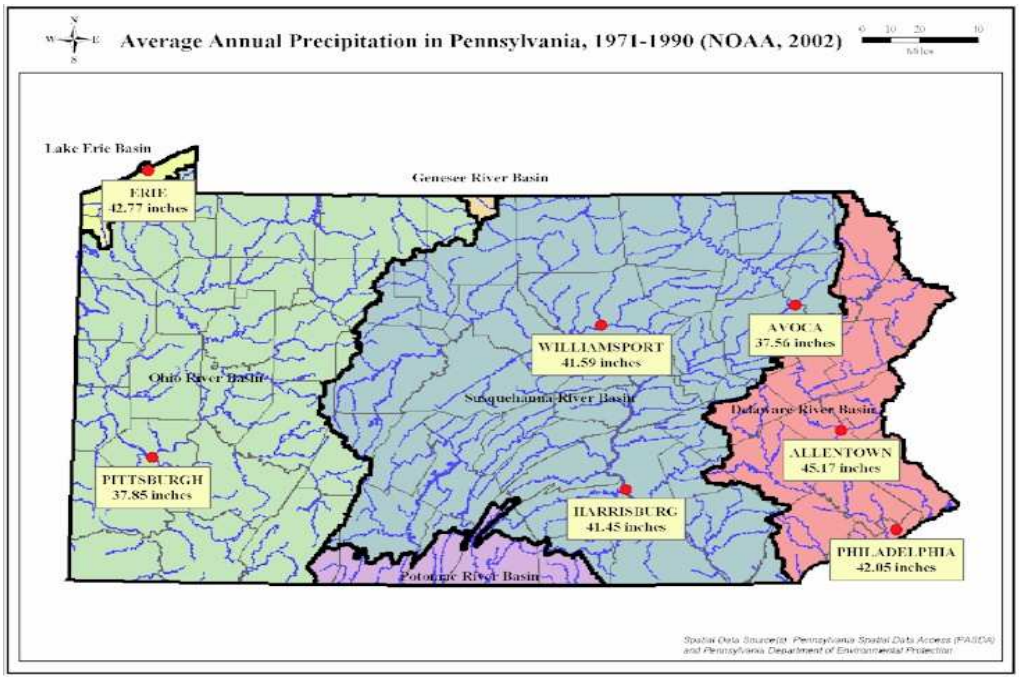

Figure 2-8. Average annual precipitation in Pennsylvania.

2.2.1 Rainfall, Runoff, and Flooding

In Pennsylvania, average annual precipitation ranges from 37 inches to more than 45 inches per year (Figure 2-8), and reflects a humid pattern. Nearly all of the annual rainfall occurs in small storm events (Figure 2-9**)**. Precipitation of an inch or less is frequent and well distributed throughout the year. However, large storms, hurricanes, and periods of intense rainfall can occur at any time.

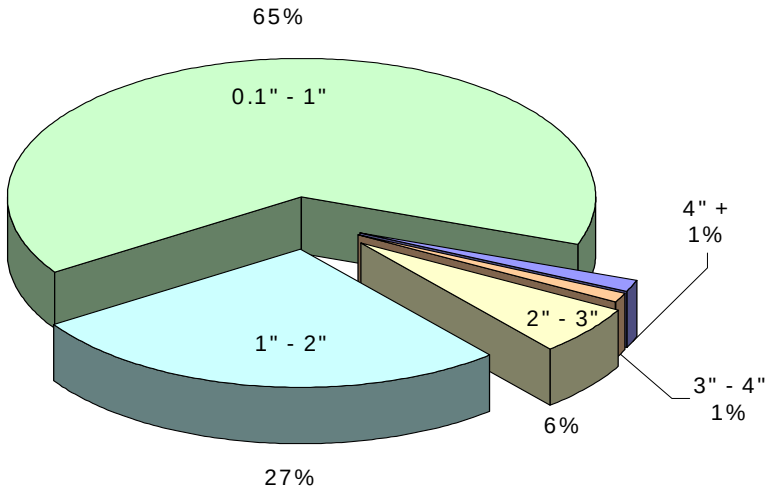

Figure 2-9. Distribution of precipitation by storm magnitude for Harrisburg, PA (Original Data from Penn State Climatological Office, 1926-2003)

Stormwater management has historically focused on managing flooding from the larger but less frequent extreme event storms (Table 2-1). Traditional site design has focused on the **peak rate** of runoff during such events; that is, how fast the stormwater runoff is leaving the site after development. Detention facilities are built to slow down the rate of runoff leaving a site during large storms so that the rate of runoff after development is not greater than the rate before development. Regulatory criteria is often based on controlling the "release" rate of runoff from the 2-year through 100-year storm events. Storm frequency is based on the statistical probability of a storm being exceeded in any year. That is, a 2-year storm has a 50% probability of being exceeded in any single year, and a 100-year storm, a 1% probability.

Table 2-1. Statistical Storm Frequency Events for locations in PA (24 hour duration) (Source: NOAA National Weather Service Precipitation Frequency Data Server, 2004).

Location	Frequency of Occurrence (Years)				
	2-year	5-year	10-year	50-year	100-year
Philadelphia	3.3	4.1	4.8	6.7	7.6
Pittsburgh	2.4	2.9	3.3	4.4	4.9
Scranton	2.6	3.2	3.7	5.4	6.4
State College	2.7	3.3	3.8	5.2	5.9
Williamsport	2.8	3.5	4.1	6.0	7.0
Erie	2.6	3.2	3.7	5.1	5.8

Preventing increased runoff rates from large storm events is extremely important but it does not do enough to protect streams and water quality. With a change in land surface, not only does the peak **rate** of runoff increase, the **volume of** runoff also increases. While a stormwater detention facility may slow the rate of runoff leaving a site, there may still be an increased volume of runoff. This is shown graphically in Figure 2-10. Detention controls the peak runoff rate by extending the hydrograph. So while the rate of runoff may not increase, the duration of runoff will be longer than before development because of the increased volume.

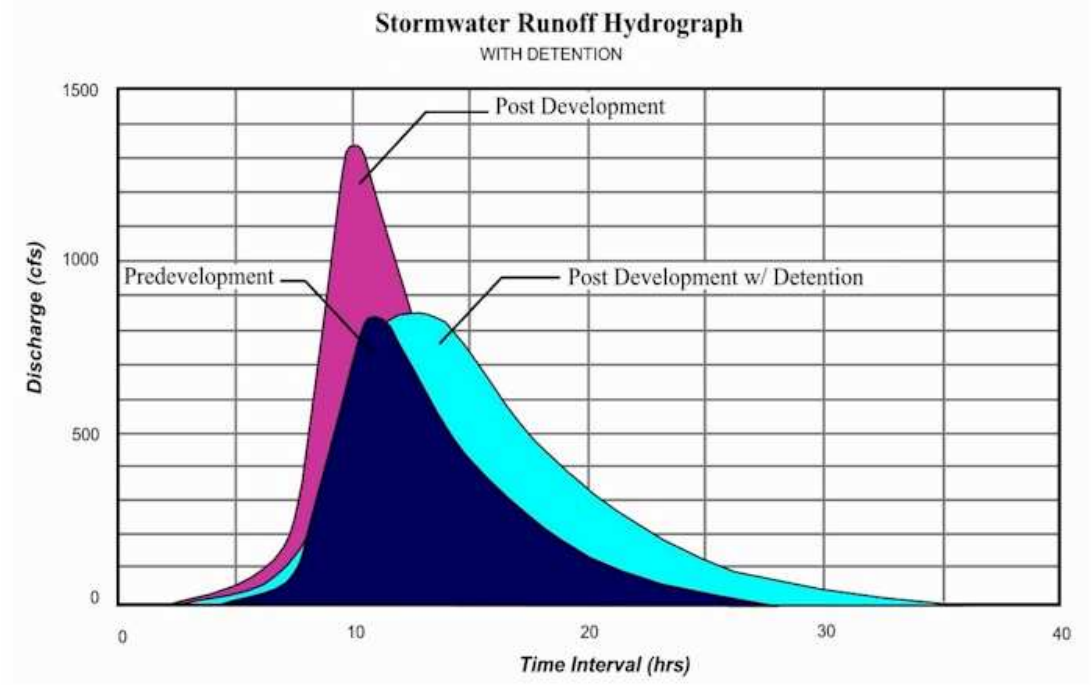

Figure 2-10. The hydrograph is an important tool used for understanding the hydrologic response of a given rainfall event. The area beneath the hydrograph curve represents the total volume of runoff being discharged.

On a watershed basis, detention becomes ineffective downstream as the sole management strategy for stormwater control due to the extended hydrograph and increased volume. There is even a possibility that the peak flows may **increase** downstream flooding. The combination of more runoff volume over a longer time period will result in downstream flow rates that are higher than before development, as indicated in Figure 2-11.

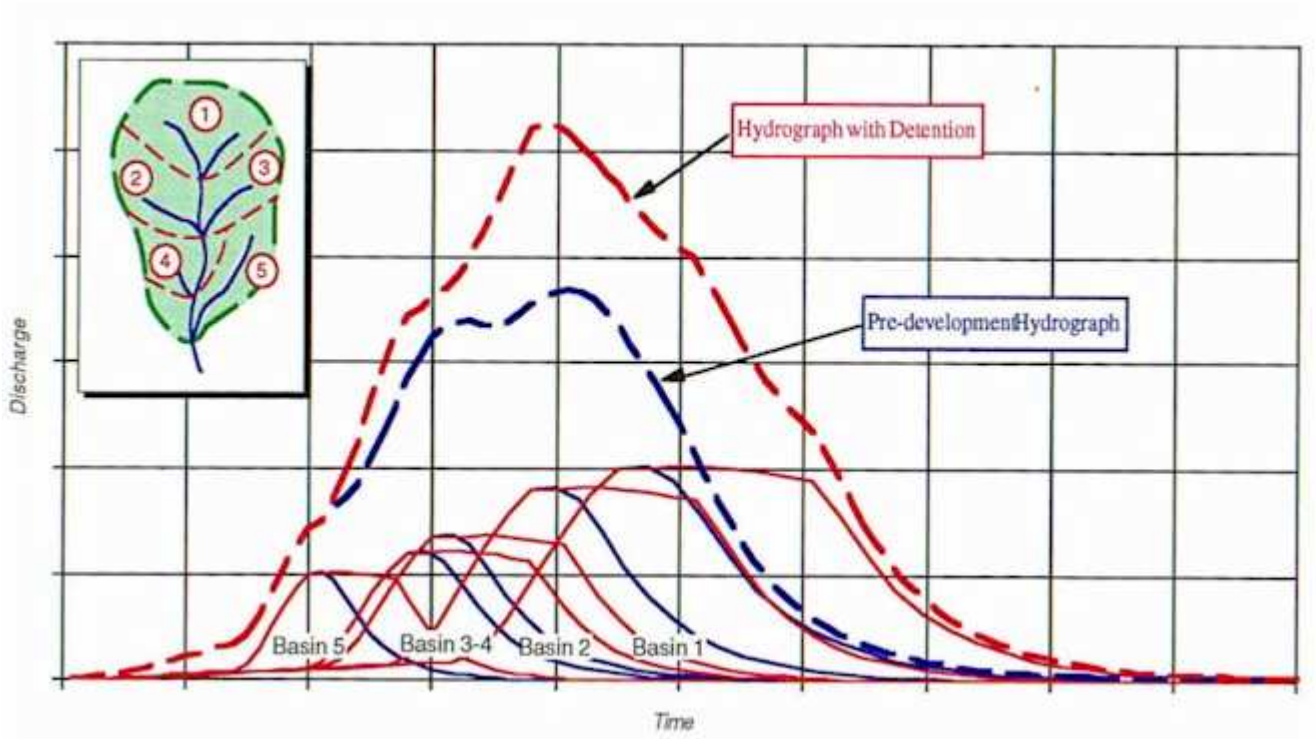

Figure 2-11. This figure illustrates a small watershed comprised of five hypothetical Subbasin development sites, 1 through 5, each of which undergoes development and relies on a separate peak rate control detention basin. As the storm occurs, five different hydrographs result for each sub-area and combine to create a resultant pre-development hydrograph for the overall watershed. The net result of the combined hydrographs is that the watershed peak rate increases considerably, because of the way in which these increased volumes are routed through the watershed system and combine downstream. Flooding increases considerably in peak and duration, even though these detention facilities have been installed at each individual development.

The second reason that detention alone is not sufficient for stormwater management is that it does not address the frequent small storm events in Pennsylvania. Most of the rainfall in Pennsylvania occurs in relatively small storm events, as indicated for the Harrisburg area (Figure 2-9). In Harrisburg, over half of the average annual rainfall occurs in storms of less than 1 inch (in 24 hours). Over 90 percent of the average annual rainfall occurs in storms of 2 inches or less, and over 95 percent of average annual rainfall occurs in storms of 3 inches or less. This pattern is typical of the entire state.

Detention facilities that are designed to control the peak flow rate for large storm events often allow frequent small storm events to “pass through” the detention facility. These small frequent rainfall events discharge from the site at a higher rate and a greater volume of runoff than before development. There is also an increase in the **frequency** of runoff events because of the change

in land surface. For example, little runoff will occur from most wooded sites until over an inch of rainfall has fallen. In contrast, a paved site will generate runoff almost immediately (Figure 2-12). After development, runoff will occur with greater frequency than before development, and runoff may be observed with every rainfall. The design of stormwater systems that collect, convey and concentrate runoff may further degrade conditions.

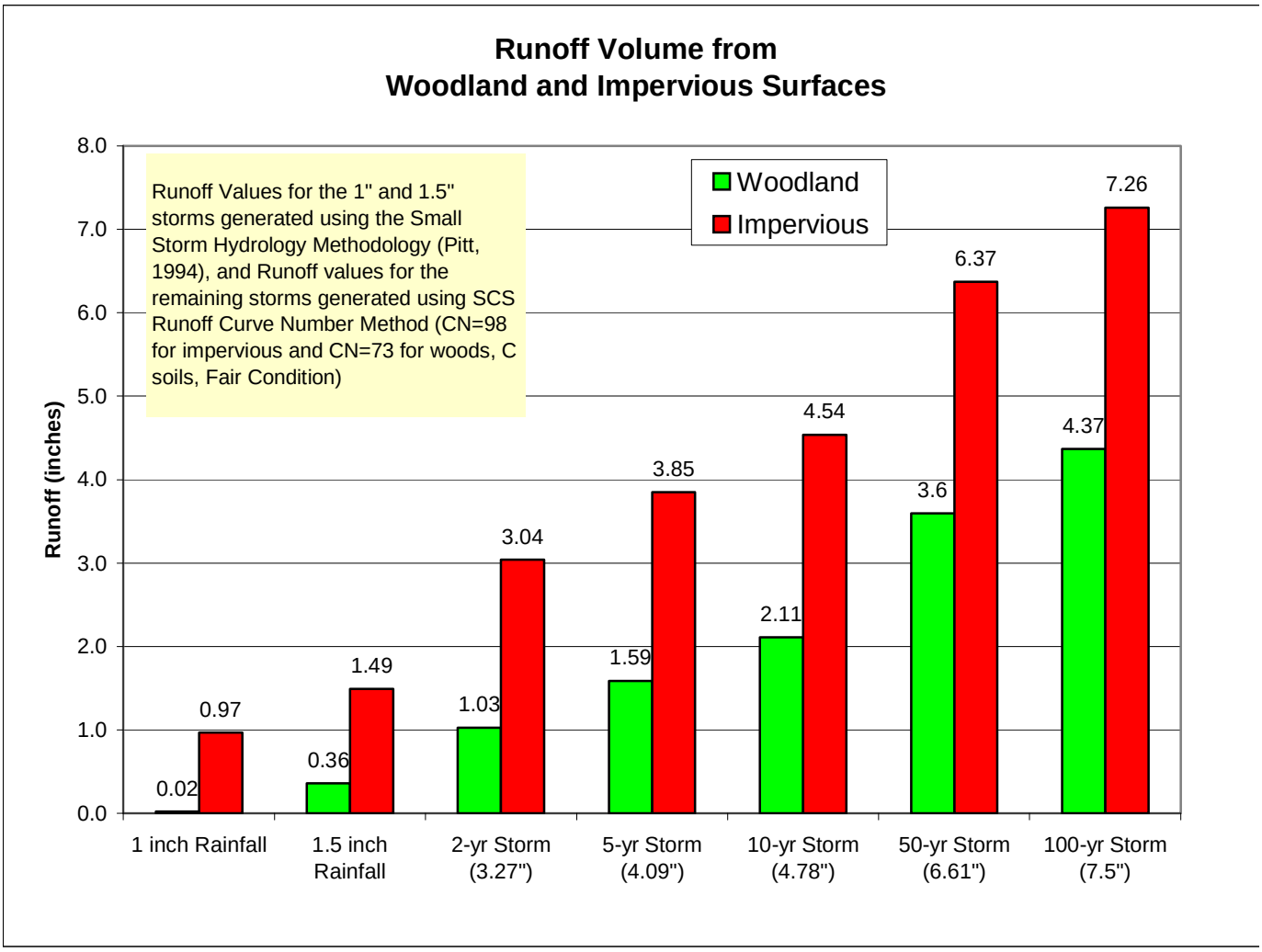

Figure 2-12. This graph generally compares the volume of runoff generated from a woodland site with the volume of runoff generated by impervious area for different rainfall amounts. Note that the volume increase for small storms is significant.

The combination of more runoff, more often and at higher rates will create localized flooding and damage even in small storm events. Throughout the state, over 95 percent of the annual rainfall volume occurs in storm events that are less than the 2-year storm event. The net effect is that during most rainfall events, stormwater discharges are not managed or controlled, even with numerous detention basins in place.

2.2.2 The Impacts of Vegetation Loss and Soil Changes

On woodland and meadow areas, over half of the average annual rainfall returns to the atmosphere through evaporation and transpiration (Figure 2-6). The vegetation itself also intercepts and slows the rainfall, reducing its erosive energy, reducing overland flow of runoff, and allowing infiltration to occur. The root systems of plants also provide pathways for downward water movement into the soil mantle.

Evapotranspiration (ET) varies tremendously with season and with type of vegetative cover. Trees can effectively evapotranspire most, if not all, of the precipitation, that falls in summer rain showers. Evapotranspiration dramatically declines during the winter season. During these periods, more precipitation infiltrates and moves through the root zone, and the groundwater level rises. Removing vegetation or changing the land type from woods and meadow to residential lawnscapes reduces evapotranspiration and increases the amount of stormwater runoff.

Soil disturbance and compaction also increases stormwater runoff. Soils contain many small openings called "macropores" that provide a mechanism for water to move through the soil, especially under saturated conditions. When soil is disturbed (grading, stockpiling, heavy equipment traffic, etc.) the soil is compacted, macropores are smashed and the natural soil structure is altered. Soil permeability characteristics are substantially reduced.

Compaction can be measured by determining the bulk density of the soil. The more compacted the soil is, the heavier it is by volume. Heavy construction equipment can compact soil so significantly that the soil bulk density of lawn soil approaches the bulk density of concrete (Table 2-2 Ocean County, New Jersey Soil Conservation District, 2001; Hanks and Lewandowski, 2003). The result is a surface that is functionally impervious because the water absorbing capacity of the soil is so altered and reduced.

Table 2-2. Common Bulk Density Measurements

Undisturbed Lands Forest & Woodlands 1.03 g/cc	**Residential Neighborhoods 1.69 to 1.97 g/cc**
Golf Courses - Parks Athletic Fields 1.69 to 1.97 g/cc	**CONCRETE 2.2 g/cc**

As discussed in Chapters 5 and 6, comprehensive stormwater management focuses on preventing an increase in stormwater runoff volume by protecting vegetation and soils, or minimizing stormwater impacts by restoring vegetation and soils to reduce runoff volumes and the velocity of runoff. Vegetation and soils are a critical component of the "water balance" and are an essential part of better stormwater management.

2.2.3 Groundwater Recharge, Stream Base Flow, and First-Order Streams

Water moves through the soil until it is evapotranspired or reaches the groundwater table and replenishes the aquifer. The actual movement of water through the sub-surface pathways is complex, and less permeable soils, clay layers, and rock strata are often encountered. The water moving through the soil is generally referred to as gravitational water or drainage water. Other types of water in soil include capillary water and hygroscopic water. Capillary water is that water held in soil pores by surface attraction (sometimes referred to as capillary action); this is the water that is typically available to plants for uptake. Hygroscopic water is water that is tightly held by the

soil particles and can only be removed by physical drying. Although capillary water does play an important role in evaporation processes, gravitational water is of primary concern from a stormwater management prospective.

The movement of gravitational water through the soil is influenced by a soils texture, structure, layering and the presence of preferential flow pathways (macropores). Soil textures are defined by the percentage of sand, silt and clay present in the soil. In general, the permeability and hydraulic conductivity of a soil will decrease with decreasing textural grain size (i.e., gravitational water moves more easily through sands than silts and clays). Soil texture also influences the shape of the wetting front as water moves through a soil.

It has also been observed that there is a discontinuity of soil-water movement at the interface between soils of different textures. This layering causes percolating water to concentrate at certain points along the layer interface and then break into the layer interface in finger-like protrusions. The significance is that even a change in soil texture within a vertical profile will cause a disruption in the soil-water movement. This disruption often causes water to "back up" at the interface, which can cause water to move laterally.

Soil structure also influences the movement of water through a soil. A disruption in the movement of soil water will occur at the interface between soil layers of differing structures. While texture and structure are certainly important to how water moves through soils, soil layering and the presence of dominant flow paths (macropores) play the most significant role in defining how water moves through the subsurface.

Soils form over time in response to their landscape position, climate, presence of organisms and parent material. Soils that have formed in place from the weathering of their parent material, usually form a typical profile with A, B and C horizons above bedrock. However, many soils form from a combination of the weathering of parent materials and the deposition of transported soils creating a more complex layering effect. In general, any interface between soil layers can slow the downward movements of water through a soil profile and promote lateral flow. This is especially true in sloping landscapes typical of most of Pennsylvania.

Restrictive soil layers within a soil profile also disrupt the vertical movement of soil-water and promote the lateral movement of water through the soil. Restrictive soil layers include clay lenses, fragipans or plow pans, for example. Fragipans are layers within a soil profile that have been compressed as a result of some external influence (glaciation for example). This compressed layer often causes water to perch above the fragipan and promotes lateral flow. Fragipans are commonly found in colluvial and glacial soils. In addition, many soils in agricultural regions of Pennsylvania contain "plow-pans" which are compressed layers of soil formed by the repeated traversing by moldboard plows.

Soil water also follows preferential flow paths through the soil. Preferential flow paths include pathways created by plant roots, worm or rodent burrows, cracks or voids in the soil resulting from piping action caused by the lateral movement of soil-water. Preferential flow paths also form at the soil rock interface and within rock structures.

The groundwater level rises and falls depending on the amount of rainfall/snowmelt and the time of year. The water cycle illustration of Figure 2-6 estimates that approximately 12 inches of the 45 inches of average annual precipitation in this natural watershed system finds its way into the groundwater table.

A variety of processes can occur when precipitation falls on a natural soil surface. Hillslope hydrology processes have been identified by Chorley (1978) and are systematically illustrated in Figure 2-12. The flow processes illustrated here are only representative examples of the complex interactions that occur in nature. Simplified descriptions of these processes follow:

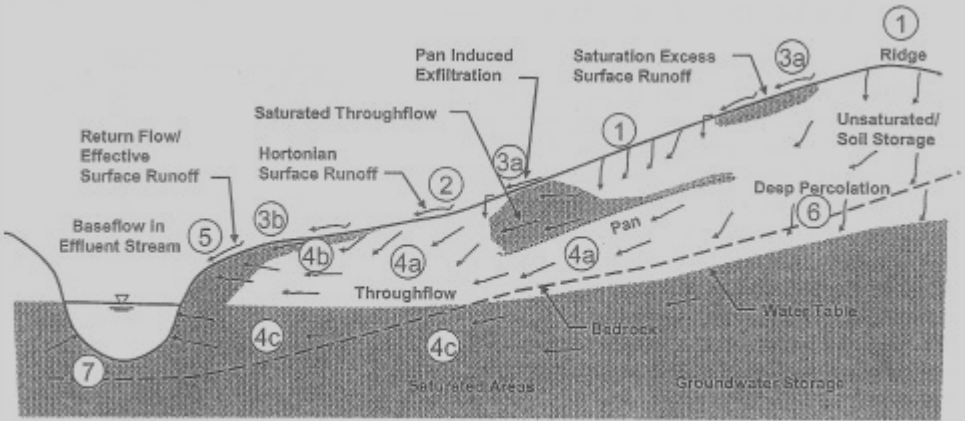

Figure 2-12 Components of hillslope hydrology (Adapted from Chorley [1978])

1. Areas marked with a “1” are areas where the infiltration capacity of the soils exceeds the rainfall rate. All rain falling on these areas infiltrates into the ground.
2. Areas labeled with a “2” identifies an area where the rainfall rate exceeds the surface infiltration rate, and the excess rainfall becomes surface runoff (Hortonian surface runoff).
3. Areas marked with a “3” represents areas where the soil has become saturated and cannot hold additional moisture; all rain falling on these areas immediately becomes surface runoff. Saturation can occur as a result of various subsurface conditions. Areas marked “3a” illustrates where a restricting layer (fragipans, clay lenses, etc.) limits the downward movement of soil water creating a perched water table that reaches the ground surface. Area “3b” identifies an area where water moving through the soil (through-flow) reaches the surface as a spring or seep (return-flow); in these cases the surface in the vicinity of the seep or spring becomes saturated.
4. The areas marked with a “4” represent areas of through-flow. Through-flow is the lateral movement of water through the soil. Area “4a” illustrates through-flow along preferential flow paths in unsaturated soils; area “4b” shows shallow surface flow (a common occurrence in PA); and area “4c” illustrates through-flow in saturated areas.
5. Areas marked with a “5” represents an area of return-flow. Return-flow is water that has moved through unsaturated or saturated subsurface areas and re-appears as surface flow through springs or seeps.
6. The area labeled as “6” represents an area of deep percolation or groundwater recharge.
7. Area “7” points to a location where groundwater discharges to the stream (influent streams). For effluent streams, water moves from the stream into the ground water table in these areas. In some streams, both processes may occur during different times of the year. (Brown/Fennessey/Petersen)

Most of these flow processes occur within natural watersheds in Pennsylvania. The extent to which one or more of these processes are active within a particular area is influenced by soil characteristics, geology and topography or landscape position.



Figure 2-13 Leaves and organic matter are initially broken down by bacteria and processed into food for higher organisms downstream.

Eventually the groundwater table intersects the land surface and forms springs, first order streams and wetlands (Figure 2-5). This groundwater discharge becomes stream base flow and occurs continuously, during both wet and dry periods. Much of the time, all of the natural flow in a stream is from groundwater discharge. In this sense, groundwater discharge can be seen as the "life" of streams, supporting all water-dependent uses and aquatic habitat. First-order streams are defined as "that stream where the smallest continuous surface flow occurs" (Horton, 1945), and are the beginning of the aquatic food chain that evolves and progresses downstream (Figure 2-13). As the link between groundwater and surface water, headwaters represent the critical intersection between terrestrial and aquatic ecosystems. During periods of wet weather, the water table may rise to near the ground surface in the vicinity of the stream. This higher ground water table coupled with through-flow, return-flow and shallow subsurface flow result in an area of saturation in the vicinity of the stream channel. As a result, this area saturates quickly during rain events; and the larger the rain event, the more extensive the area of saturation may be. It is understood by researchers that a significant amount of the surface runoff observed in streams during precipitation events is generated from the saturated areas surrounding streams (Chorley, 1978; Hewlett and Hibbert, 1967). The runoff generated from rainfall on saturated land areas is referred to as saturation overland flow. Hydrologists understand that the watershed runoff process is a complex integration of saturation overland flow and infiltration excess (Hortonian) overland flow (Troendle, 1985). Areas that generate surface runoff pulsate, shrink and expand in response to rainfall. This concept on a watershed scale is consistent with the hillslope hydrologic processes.

Changes in land use cause runoff volumes to increase and groundwater recharge to decrease. Wetlands and first order streams reflect changes in groundwater levels most profoundly, and this reduced flow can stress or even eliminate the aquatic community. As the most hydrologically and biologically sensitive elements of the drainage network, headwaters and first order streams warrant special consideration and protection in stormwater management.

2.2.4 Stream Channel Changes

The shape of a stream channel, its width, depth, slope, and how it moves through the landscape, is influenced by the amount of flow the stream channel is expected to carry. The stream channel morphology is determined by the energy of stream flows that range from "low flow" to "bank full". The flow depths determine the energy in the stream channel, and this energy shapes the channel itself. In an undeveloped watershed, bank full flow occurs with a frequency of approximately once every 18 months. During larger flood events, the flow overtops the stream banks and flows into the floodplain with much less impact on the shape of the stream channel itself.

In a developing watershed, the volume and rate of stormwater runoff increase during small storm events and the stream channel changes to accommodate the greater flows. Because the stream is conveying greater flows more often and for longer periods of time, the stream will try to accommodate these larger flows by eroding stream banks or cutting down the channel bottom. Since traditional detention basins do not manage small storms, these impacts are often most pronounced downstream of detention basins.

Numerous studies have documented the link between altered stream channels and land development. The Center for Watershed Protection (Article 19, Technical Note 115, Watershed Protection Techniques 3(3): 729-734) states that land development influences both the geometry (morphology) and stability of stream channels, causing downstream channels to enlarge through widening and stream bank erosion. These physical changes, in turn, degrade stream habitat and produce substantial increases in sediment loads resulting from accelerated channel erosion.

As the shape of the stream channel changes to accommodate more runoff, aquatic habitat is often lost or altered, and aquatic species decline. Studies, such as US EPA's *Urbanization and Streams: Studies of Hydrologic Impacts* (1997), conclude that land development is likely to be responsible for dramatic declines in aquatic life observed in developing watersheds. These stream channel impacts have been observed even where conventional stormwater management is applied.

The effects occur at many levels in the aquatic community. As the gravel stream bottom is covered in sediment, the amount and types of microorganisms that live along the stream bottom decline. The stream receives sediment from runoff, but additional sediment is generated as the stream banks are eroded and this material is deposited along the stream bottom. Pools and riffles important to fish and other aquatic life are lost, and the number and types of fish and aquatic insects diminishes. Trees and shrubs along the banks are undercut and lost, removing important habitat and decreasing natural shading and cooling for the stream.

The runoff from impervious surfaces is usually warmer than the stream flow, and can harm the aquatic community. When the stream flow is comprised primarily of groundwater discharge, the constant, cool temperature of the groundwater buffers the stream temperature. As the flow of groundwater decreases and the amount of surface runoff increases, the temperature regime of the stream changes. Runoff from impervious surfaces in the summer months can be much hotter than the stream temperature, and in the winter months this same runoff can be colder. These changes in temperature dramatically affect the aquatic habitat in the stream, ranging from the fish community that the stream can support to the microorganisms that form the foundation of the food chain. Important fungal communities can be lost altogether. It is apparent that increasing impervious areas can lead to significant degradation of surface water by altering the entire aquatic ecosystem.

2.2.5 Water Quality

Impervious surfaces and maintained landscapes generate pollutants that are conveyed in runoff and discharged to surface waters. Many studies of pollutant transport in stormwater have documented that pollutant concentrations show a distinct increase at the beginning of a flow hydrograph referred to as the "first flush". In fact, the particulate associated pollutants that are initially scoured from the land surface and suspended in the runoff are observed in a stream or river before the runoff peak occurs. These pollutants include sediment, phosphorus that is moving with colloids (clay particles), metals, and organic particles and litter. Dissolved pollutants, however,

may actually decrease in concentration during heavy runoff. These include nitrate, salts and some synthetic organic compounds applied to the land for a variety of purposes.

Managing stormwater to minimize pollutant loading includes reducing the sources of these pollutants as well as restoring and protecting the natural systems that are able to remove pollutants. These include stream buffers, vegetated systems, and the natural soil mantle, all of which can be put to use to remove pollutants from stormwater runoff.

Stormwater quantity and quality are inextricably linked and need to be managed together. Although the most obvious impact of land development is the increased rate and volume of surface runoff, the pollutants transported with this runoff comprise an equally significant impact. Management strategies that address quantity will in most cases address quality.

Stormwater runoff pollutants include sediment, organic detritus, phosphorus and nitrogen forms, metals, hydrocarbons, and synthetic organics. The increased stormwater runoff brought on by land development scours both impervious and pervious land surfaces. Stormwater runoff transports suspended and dissolved pollutants that were initially deposited on the land surface. Hot spot impervious areas such as fueling islands, trash dumpsters, industrial sites, fast food parking lots, and heavily traveled roadways contribute heavy pollutant loads to stormwater.

Many so-called pervious surfaces, such as the chemically maintained lawns and landscaped areas, also add significantly to the pollutant load, especially where these pervious areas drain to impervious surfaces, gutters and storm sewers. The soil compaction process applied to many land development sites results in a vegetated surface that is close to impervious in many instances, and produces far more runoff than the pre-development soil did. These new lawn surfaces are often loaded with fertilizers that result in polluted runoff that degrades all downstream ponds and lakes.

The two physical forms of stormwater pollutants are particulates and solutes. One very important distinction for stormwater pollutants is the extent to which pollutants are particulate in form, or dissolved in the runoff as solutes. The best example of this comparison is the two common fertilizers: Total phosphorus (TP) and nitrate (NO3-N). Phosphorus typically occurs in particulate form, usually bound to colloidal soil particles. Because of this physical form, stormwater management practices that rely on physical filtering and/or settling out of sediment particles can be quite successful for phosphorus removal. In stark contrast, nitrate tends to occur in highly soluble forms, and is unaffected by many of the structural BMPs designed to eliminate suspended pollutants. As a consequence, stormwater management BMPs for nitrate may be quite different than those used for phosphorous removal. Non-Structural BMPs (Chapter 5) may in fact be the best approach for nitrate reduction in runoff.

Particulates: Stormwater pollutants that move in association with or attached to particles include total suspended solids (TSS), total phosphorus (TP), most organic matter (as estimated by COD), metals, and some herbicides and pesticides. Kinetic energy keeps particulates in suspension and some do not settle out as easily. For example, an extended detention basin offers a good method to reduce total suspended solids, but is less successful with TP, because much of the TP load is attached to fine clay particles that may take longer to settle out.

If the concentration of particulate-associated pollutants in stormwater runoff, such as TSS and TP, is measured in the field during a storm event, a significant increase in pollutant concentration corresponding to but not synchronous with the surface runoff hydrograph is usually observed (Figure 2-14). This change in pollutant concentration is referred to as a “chemograph”, and has contributed to the concept of a “first flush” of stormwater pollutants. In fact, the actual transport

process of stormwater pollutants is somewhat more complex than “first flush” would indicate, and has been the subject of numerous technical papers (Cahill et al, 1974: 1975; 1976; 1980; Pitt, 1985, 2002). To accurately measure the total mass of stormwater pollution transported during a given storm event, both volume and concentration must be measured simultaneously, and a double integration performed to estimate the mass conveyed in a given event. To fully develop a stormwater pollutant load for a watershed, a number of storm events must be measured over several years. The dry weather chemistry is seldom indicative of the expected wet weather concentrations, which can be two or three orders of magnitude greater.

Because a major fraction of particulate associated pollutants is transported with the smallest particles, or colloids, their removal by BMPs is especially difficult. These colloids are so small that they do not settle out in a quiescent pool or basin, and remain in suspension for days at a time, passing through a detention basin with the outlet discharge. It is possible to add chemicals to a detention basin to coagulate these colloids to promote settling, but this chemical use turns a natural stream channel or pond into a treatment unit, and subsequent removal of sludge is required. A variety of BMPs have been developed that serve as runoff filters, and are designed for installation in storm sewer elements, such as inlets, manholes or boxes. The potential problem with all measures that attempt to filter stormwater is that they quickly become clogged, especially during a major event. Of course, one could argue that if the filter systems become clogged, they are performing efficiently, and removing this particulate material from the runoff. The major problem then with all filtering (and to some extent settling) measures is that they require substantial maintenance. The more numerous and distributed within the built conveyance system that these BMPs are situated, the greater the removal efficiency, but also the greater the cost for operation and maintenance.

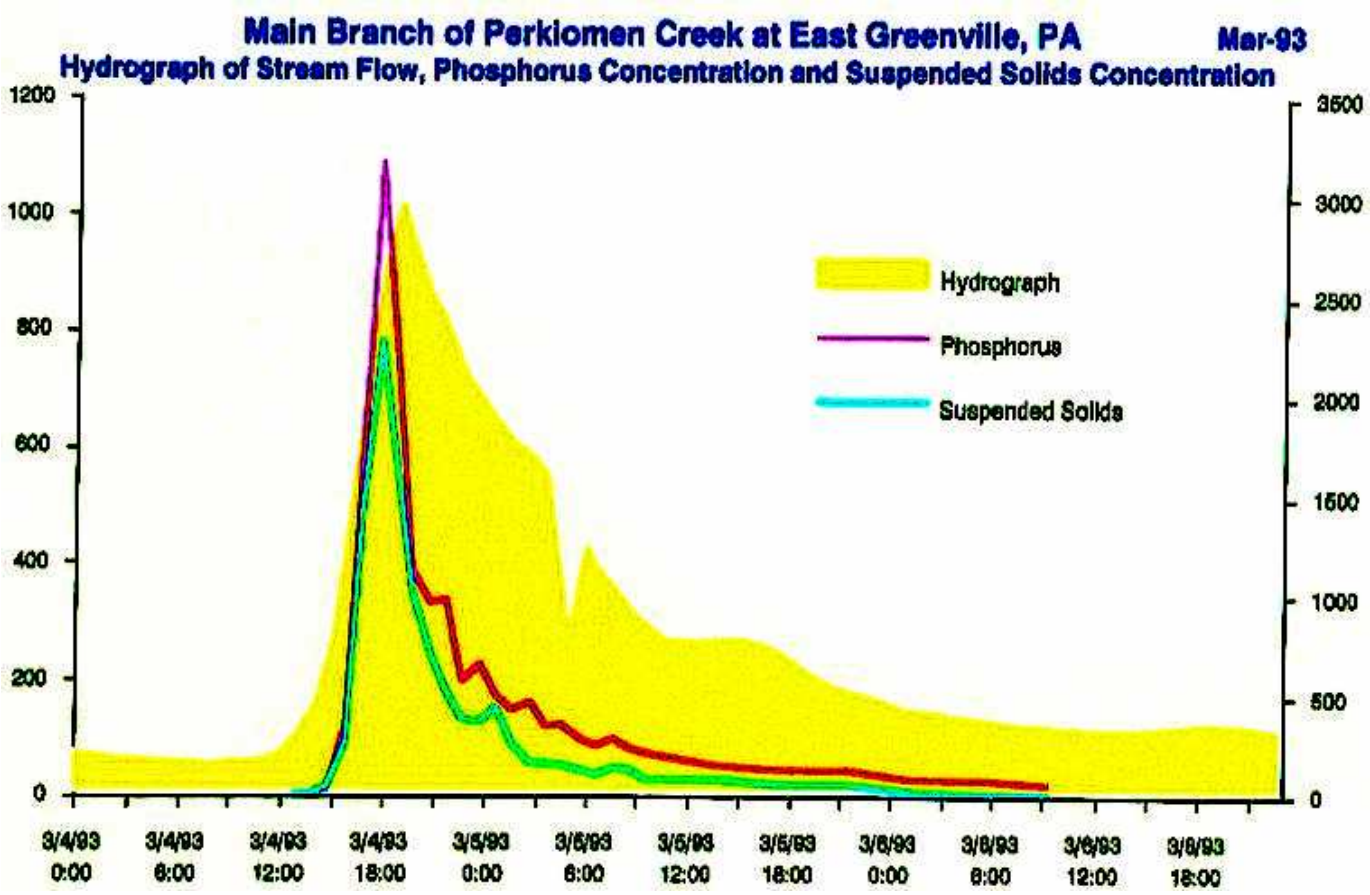

Figure 2-14. Chemograph of phosphorus and suspended solids in Perkiomen Creek (Cahill, 1993).

Solutes: Dissolved stormwater pollutants generally do not exhibit any increase during storm event runoff, and in fact may exhibit a slight dilution over a given storm hydrograph. Dissolved stormwater pollutants include nitrate, ammonia, salts, organic chemicals, many pesticides and herbicides, and petroleum hydrocarbons (although portions of the hydrocarbons may bind to particulates and be transported with TSS). Regardless, the total mass transport of soluble pollutants is dramatically greater during runoff because of the volume increase. In some watersheds, the stormwater transport of soluble pollutants can represent a major portion of the total annual discharge for a given pollutant, even though the absolute concentration remains relatively constant. For these soluble pollutants, dry weather sampling can be very useful, and often reflects a steady concentration of soluble pollutants that will be representative of high flow periods.

Some dissolved stormwater pollutants can be found in the initial rainfall, especially in regions with significant emissions from fossil fuel plants. Precipitation serves as a “scrubber” for the atmosphere, removing both fine particulates and gases (NOX and SOX). Chesapeake Bay scientists have measured rainfall with NO_3 concentrations of 1 to 2 mg/l, which could comprise a significant fraction of the total input to the Bay. Other rainfall studies by NOAA and USGS have resulted in similar conclusions. Impervious pavements can transport nitrate load, reflecting a mix of deposited sediment, vegetation, animal wastes, and human detritus of many different forms.

Pollution prevention through use of Non-Structural BMPs is very effective. A variety of Structural BMPs, including settling, filtration, biological transformation and uptake, and chemical processes

can also be used. Stormwater related pollution can be reduced if not eliminated through preventive Non-Structural BMPs (Chapter 5), but not all stormwater pollution can be avoided. Many of the Structural BMPs (Chapter 6) employ natural pollutant removal processes as essential elements. These "natural" processes tend to be associated with and rely upon both the existing vegetation and soil mantle. Thus preventing and minimizing disturbance of site vegetation and soils is essential to successful stormwater management.

Settling: Particles remain suspended in stormwater as long as the energy of the moving water is greater than the pull of gravity. In a natural stream, the stormwater that overflows the banks slows and is temporarily stored in the floodplain, which allows for sediment settling, and the building of the alluvium soils that comprise this floodplain. As runoff passes through any type of man-made structure, such as a detention basin, the same process takes place, although not as efficiently as in a natural floodplain. Where it is possible to create micro versions of runoff ponds (rain gardens), distributed throughout a site, the same settling effect will result. The major issue with settling processes is that the dissolved pollutant load is not subject to gravitational settling.

Filtration: Another natural process is physical filtration. Filtration through vegetation and soil is by far the most efficient way to remove suspended stormwater pollutants. Suspended particles are physically filtered from stormwater as it flows through vegetation and percolates into the soil. Runoff that is concentrated in swales, however, can exceed the ability of the vegetation to remove particles. Therefore, it is important to avoid concentrated flows by slowing and distributing the runoff over a broad vegetated area.

Stormwater flow through a relatively narrow natural riparian buffer of trees and herbaceous understory growth has been demonstrated to physically filter surprisingly large proportions of larger particulate-form stormwater pollutants. Both filter strip and grassed swale BMPs rely very much on this surface filtration process as discussed in Chapter 6.

Biological Transformation and Uptake/Utilization: This category includes an array of different processes that reflect the remarkable complexity of different surface vegetative types, their varying root systems, and their different needs and rates of transformation and utilization of different "pollutants," especially nutrients. An equally vast and complex community of microorganisms exists below the surface within the soil mantle, and though more micro in scale, the myriad of natural processes occurring within this soil realm is just as remarkable.

Phosphorus and nitrate are essential to plant growth and therefore are taken up through the root systems of grasses, shrubs and trees. Nitrogen transformations are quite complex, but the muck bottom of wetlands allows the important process of denitrification to occur and convert nitrates for release in gaseous form. Nitrates in stormwater runoff passing through wetlands is removed and used by wetland plants to build biomass. The caution in terms of a wetland or similar surface BMP is that if the vegetation dies at the end of a growing season and the detritus is discharged from the wetland, the net removal of nitrate is maybe less than expected. The guidance for BMP applications is that if biological transformation processes are considered, care must be taken to remove and dispose of the biomass produced in the process.

Chemical Processes: Various chemical processes occur in the soil to remove pollutants from stormwater. These include adsorption through ion exchange and chemical precipitation. Cation Exchange Capacity (CEC) is a rating given to soil, that relates the soil organic content to its ability to remove pollutants as stormwater infiltrates through the soil. Adsorption will increase as the total surface area of soil particles and/or the amount of decomposed organic material increases. Clay soils have better pollutant reduction performance than sandy soils, and their slower permeability

rate has a positive effect. CEC values typically range from 2 to 60 milli-equivalents (meq) per 100 grams of soil. Coarse sandy soils have low CEC values and therefore are not especially good stormwater pollutant removers. The addition of compost will greatly increase the CEC of sandy soils. A value of 10 meq. is often considered necessary to accomplish a reasonable degree of pollutant removal.

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Pennsylvania Stormwater Best Management Practices Manual

Chapter 3

Stormwater Management Principles and Recommended Control Guidelines



363-0300-002 / December 30, 2006

SARB_014568

Chapter 3 Stormwater Management Principles and Recommended Control Guidelines

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3.1 Introduction

This Chapter provides guidance for municipalities striving to improve their stormwater management programs. It presents stormwater management principles and recommends site control guidelines to address volume, water quality and flow rate. These guidelines can serve as the basis for municipal stormwater regulation. Pennsylvania laws and regulations do not directly manage stormwater at the state level, although some state level management occurs through the Stormwater Management Act and the NPDES permitting program. All municipalities, regardless of their specific setting, are encouraged to enact the most comprehensive stormwater management ordinances possible. They should also work with their watershed neighbors to integrate their individual municipal actions within the watershed as a whole.

The guidelines established in this chapter reflect the ten basic principles of stormwater management presented in the forward. The principles are listed below once more to emphasize their fundamental importance as the foundation for the control guidelines that will follow.

1. Managing stormwater as a resource;
2. Preserving and utilizing existing natural features and systems;
3. Managing stormwater as close to the source as possible;
4. Sustaining the hydrologic balance of surface and ground water;
5. Disconnecting, decentralizing and distributing sources and discharges;
6. Slowing runoff down, and not speeding it up;
7. Preventing potential water quality and quantity problems;
8. Minimizing problems that cannot be avoided;
9. Integrating stormwater management into the initial site design process; and
10. Inspecting and maintaining all BMPs.

3.2 Recommended Site Control Guidelines

Site control guidelines are designed to meet water volume and water quality requirements and to follow the ten principles previously listed. The control guidelines presented in this Chapter are comprehensive are consistent with the Pennsylvania Comprehensive Stormwater Management Policy, and are recommended to restore natural hydrology including velocity, current, cross-section, runoff volume, infiltration volume, and aquifer recharge volume. Following the guidelines will help sustain stream base flow and prevent increased frequency of damaging bank full flows. The guidelines also will help prevent increases in peak runoff rates for larger events (2-year through 100-year) on both a site-by-site and watershed basis. When applicable, Act 167 watershed plans may require additional rate controls to reduce cumulative flooding impacts downstream.

The site control guidelines are:

- **Effective** — The morphologic impacts on streams from increased volumes of runoff during smaller storms are prevented. The guidelines will be effective on a site-by-site basis, as well as on a broader watershed-wide scale;

- **Proportional** — The stormwater controls will produce approximately the same post-development stormwater discharge for all types of development in almost any location;

- **Equitable** — The requirements are based on project characteristics rather than project location so that physically similar projects will have similar storm water controls;

- **Flexible** — The diversity among Pennsylvania's 2,566 municipalities is accommodated by the guidelines. This diversity in physical conditions presents a major challenge that requires flexibility to achieve a uniform stormwater management program across the state.

3.3 Recommended Volume Control Guidelines

Regardless of where land development occurs, the impervious surfaces, the changes in vegetation, and the soil compaction associated with that development result in significant increases in runoff volume. When the balance of a developed site is cleared of existing vegetation, graded, and re-compacted, it produces an increase in runoff volume. While traditionally, if the original vegetation were replaced with natural vegetation, the runoff characteristics would be considered to be equivalent to the original natural vegetation. The disturbance and the compaction destroy the permeability of the natural soil.

The relative increase in runoff volume varies with event magnitude (return period). For example, the two-year rainfall of 3.27 inches/24 hours (SE PA) will result in an increase in runoff volume of 2.6 inches from every square foot of impervious surface placed on well-drained HSG B soil in woodland cover (Figure 3-1). For larger events, as the total rainfall increases, the net runoff also increases, but less than proportionately. For example, total rainfall for the 100-year storm is twice the rainfall for the 2-year storm (7.5 inches vs. 3.27 inches); however, the increase in runoff for the 100-year storm is only 1.7 inches more than the runoff for the 2-year storm (4.3 – 2.6 inches). This pattern holds true throughout the state.

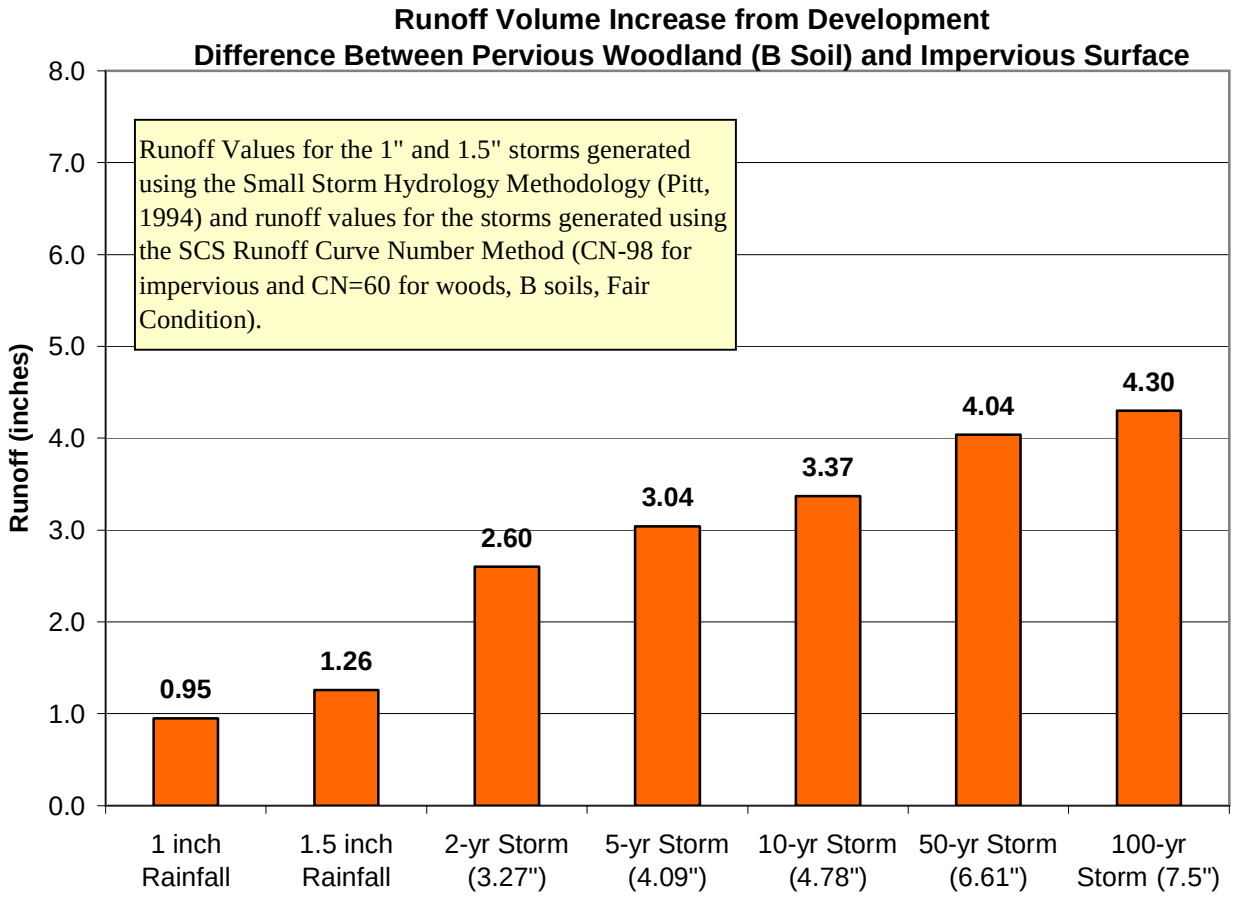

Figure 3-1. **Runoff Volume Increase from Impervious Surfaces - B Soils.**

For a specific site, the net increase in runoff volume during a given storm depends on both the pre-development permeability of the natural soil and the vegetative cover. Poorly drained soils result in a smaller increase of runoff volume because the volume of pre-development runoff is already high. Therefore, the amount of runoff resulting from development does not represent a large net increase. Using the same rainfall values, Figure 3-2 illustrates that the two-year rainfall of 3.27 inches/24 hours produces an increase of only 2.01 inches on a HSG C soil, while the better drained (B) soil in Figure 3-1 produces a 2.60-inch runoff volume increase. Thus a volume control guideline must be based on the net change in runoff volume for a given frequency rainfall to be equitable throughout the state on any given development site.

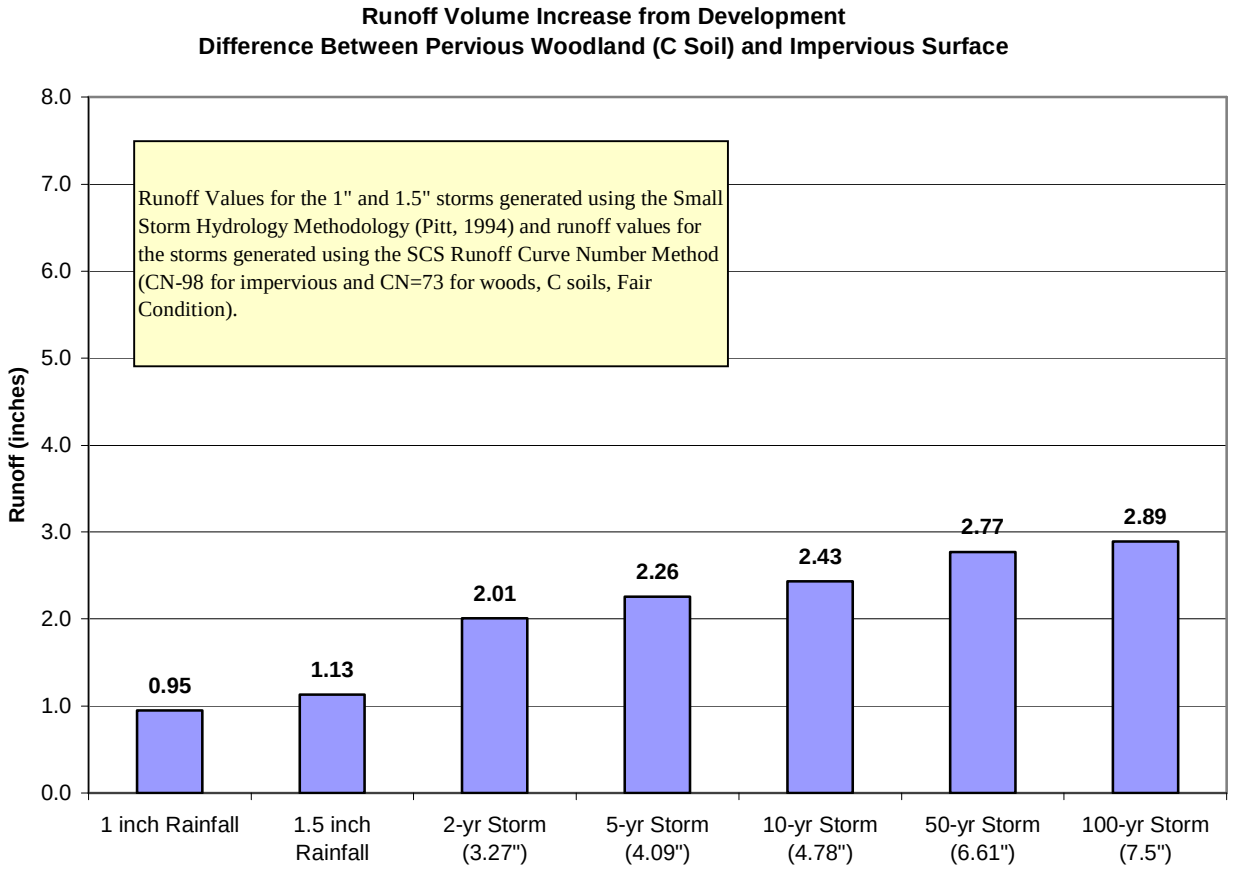

***Figure 3-2*. Runoff Volume Increase from Impervious Surfaces - C Soils**

Consideration of a volume control guideline has focused on providing stream channel protection and water quality protection from the frequent rainfalls that comprise a major portion of runoff events in any part of the state. On the basis of these factors, the 2-year event has been chosen as the stormwater management design storm for Volume Control Guideline 1.

Regardless of the volume reduction goal desired, it is considered unreasonable to design any stormwater BMP for greater than a 2-year event. The increase in runoff volume from the 100-year rainfall after site development is so large that it is impractical to require management of the total increase in volume. During such extreme events, the runoff simply overwhelms the natural and human-made conveyance elements of pipes and stream channels. In practice, a BMP sized for the increase in the 100-year runoff volume would be empty most of the time and would have a 1% probability of functioning at capacity in any one year. Of course, large storms need to be managed in terms of flooding and peak rate control, to the extent practicable.

3.3.1 Volume Control Criteria

A volume control guideline is essential to mitigate the consequences of increased runoff. To do this, the volume reduction BMP must:

1. Protect stream channel morphology;
2. Maintain groundwater recharge;
3. Prevent downstream increases in flooding; and
4. Replicate the natural hydrology on site before development to the greatest extent possible.

Protect Stream Channel Morphology: Increased volume of runoff results in an increase in the frequency of bank full or near bank full flow conditions in stream channels. The increased presence of high flow conditions in riparian sections has a detrimental effect on stream shaping, including stream channel and overall stream morphology. Stream bank erosion is greatly accelerated. As banks are eroded and undercut and as stream channels are gouged and straightened; meanders, pools, riffles, and other essential elements of habitat are lost or diminished. Research has demonstrated that bank-full stream flow typically occurs between the 1-year and the 2-year storm event (often around the 1.5-year storm). Urbanization can cause the natural bankfull stream flows to occur far more often. Strategies employed by the CG's include a combination of volume reduction and extended detention to reduce the bankfull flow occurances.

Maintain Groundwater Recharge: Over 80 percent of the annual precipitation infiltrates into the soil mantle in Pennsylvania's watersheds under natural conditions. More than half of this is taken up by vegetation and transpired. Part of this infiltrated water moves down gradient to emerge as springs and seeps, feeding local wetlands and surface streams. The rest enters deep groundwater aquifers that supply drinking water wells. Without groundwater recharge, surface stream flows and supplies of groundwater for wells will diminish or disappear during drought periods. Certain land areas recharge more groundwater than others; therefore, protecting the critical recharge areas is important in maintaining the water cycle's balance. In round numbers, an estimate of the annual water balance is: surface water runoff, 20%; evapotranspiration (ET), 45%; groundwater recharge, 35%.

Prevent Downstream Increases in Runoff Volume and Flooding: Although site-based rate control measures may help protect the area immediately downstream from a development site, the increased volume of runoff and the prolonged duration of runoff from multiple development sites can increase peak flow rates and duration of flooding from runoff caused by relatively small rain events. Replicating pre-development runoff volumes for small storms will usually substantially reduce the problem of frequent flooding that plague many communities. Although control of runoff volumes from small storms almost always helps to reduce flooding during large storms, additional measures are necessary to provide adequate relief from the serious flooding that occurs during such events.

Replicate the Surface Water Hydrology On-site Before Development: The objective for stormwater management is to develop a program that replicates the natural hydrologic conditions of watersheds to the maximum extent practicable. However, the very process of clearing the existing vegetation from the site removes the single largest component of the natural hydrologic regime, evapotranspiration (ET). Unless the ET component is replaced, the runoff increase will be substantial. Several of the BMPs described in this manual, such as infiltration, tree planting, vegetated roof systems and rain gardens, can help replace a portion of the ET function.

3.3.2 Volume Control Alternatives

While the volume control guideline alternatives are quite specific concerning the volume of runoff to be controlled from a development site, they do not specify the methods by which this can be accomplished. The selection of a BMP, or combination of BMPs, is left to the design process. But in all instances, minimizing the volume increase from existing and future development is the goal. The BMPs

described in this manual place emphasis on infiltration of precipitation as an important solution; however, three methods are provided to reduce the volume of runoff from land development:

1. Infiltration;
2. Capture and Reuse; and
3. Vegetation systems that provide ET, returning rainfall to the atmosphere.

It is anticipated that many of the stormwater management systems used in Pennsylvania will include one or more of these methods, depending on specific site conditions that constrain stormwater management opportunities**.** Inherent in these guidelines is the assumption that all soils allow some infiltration. Where this is not possible, a vegetated roof, or bioretention combined with capture-and-reuse systems, or other forms of runoff volume control will be necessary to achieve the required capture and removal volumes.

For Regulated Activities equal or less than one acre that do not require design of stormwater storage facilities, the applicant may select either Control Guideline 1 or Control Guideline 2 on the basis of economic considerations, applicability and limitations of the analytic procedures and other factors. Control Guideline 1 may require more complex and detailed analyses while providing a greater opportunity to select stormwater controls that require fewer resources to construct and operate. For all Regulated Activities larger than one acre and for all projects that require design of stormwater storage facilities, Control Guideline 2 may not be used.

3.3.3 Volume Control Guideline 1

The Control Guideline 1 is applicable to any size of the Regulated Activity. Use of Control Guideline 1 (CG-1) is recommended where site conditions offer the opportunity to reduce the increase in runoff volume as follows:

Do not increase the post-development total runoff volume for all storms equal to or less than the 2-year/24-hour event.

Existing (pre-development) non-forested pervious areas must be considered meadow (good condition) or its equivalent.

Twenty (20) percent of existing impervious area, when present, shall be considered meadow (good condition) in the model for existing conditions for redevelopment.

The scientific basis for Volume Control Guideline 1 is as follows:

- The 2-year event provides stream channel protection and water quality protection for the relatively frequent runoff events across the state;
- Volume reduction BMPs based on this standard will provide a storage capacity to help reduce the increase in peak flow rates for larger runoff events;
- In a natural stream system in Mid-Atlantic States, the bank full stream flow occurs with a period of approximately 1.5 years. If the runoff volume from storms less than the 2-year event are not increased, the fluvial impacts on streams will be reduced;
- The 2-year storm is well defined and data are readily accessible for use in stormwater management calculations.

3.3.4 Volume Control Guideline 2

Control Guideline 2 (CG-2) is independent of site constraints and should be used if CG-1 is not followed. This method is not applicable to Regulated Activities greater than one (1) acre or for projects that require design of stormwater storage facilities. For new impervious surfaces:

> **Stormwater facilities shall be sized to capture at least the first two inches (2") of runoff from all contributing impervious surfaces.**
>
> **At least the first one inch (1.0") of runoff from new impervious surfaces shall be permanently removed from the runoff flow — i.e. it shall not be released into the surface Waters of this Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.**
>
> **Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first one-half inch (0.5") of the permanently removed runoff should be infiltrated.**

The scientific basis for Volume Control Guideline 2 is as follows:

- Groundwater recharge will be maintained;
- The permanently removed volume will reduce the runoff;
- The combined permanently removed volume and extended detention volume will provide water quality protection by:
    - Capture / treatment of 95+/-% of the yearly water budget, and a higher volume of pollutants (first flush);
    - Capture / treatment of 99+/-% of the yearly storm events from paved areas. Example: for over 50 years of data on the Brandywine, 2.6 storms per year on average exceed 2";
- Volume reduction BMPs based on this standard will provide a storage capacity to reduce the increase in peak flow rates;
- In many of Pennsylvania's natural streams, the bank full stream flow occurs with a period of approximately 1.5 years. The combination of volume reduction and extended detention will reduce the depth and frequency of flows for all events less than the 2-year event, therefore, the fluvial impacts on streams will be reduced.

3.3.5 Retention and Detention Considerations

Infiltration areas should be spread out and located in the sections of the site that are most suitable for infiltration.

In all cases, retention and detention facilities should be designed to completely drain water quality volumes including both the permanently removed volume and the extended detention volume over a period of time not less than 24 hours and not more than 72 hours from the end of the design storm.

3.4 Recommended Peak Rate Control Guideline

Peak rate control for large storms, up to the 100-year event, is essential to protect against immediate downstream erosion and flooding. Most designs achieve peak rate control through the use of detention structures. Peak rate control can also be integrated into volume control BMPs in ways that eliminate the need for additional peak rate control detention systems. Non-Structural BMPs also can contribute to rate control, as discussed in Chapters 5 and 8.

The recommended control guideline for peak rate control is:

Do not increase the peak rate of discharge for the 1-year through 100-year events (at minimum); as necessary, provide additional peak rate control as required by applicable and approved Act 167 plans.

Where Act 167 plans apply, hydrologic modeling may have been performed to provide the basis for establishing more stringent release rate controls on sub-districts within the watershed. As volume reduction BMPs are incorporated into stormwater management on a watershed basis, release rate values will require re-evaluation. Use of the control guidelines will reduce or perhaps even eliminate the increase in peak rate and runoff volume for some storms.

3.5 Recommended Water Quality Control Guideline

The volume control achieved through applying CG-1 and CG-2 may also remove a major fraction of particulate associated pollutants from impervious surfaces during most storms. Pervious surfaces such as “lawnscapes” subject to continuing fertilization may generate NPS pollutants throughout a major storm, as may stream banks subjected to severe flows. While infiltration BMPs and landscape BMPs are very effective in NPS reduction, if the volume control measures simply overflow during severe storms then they will not achieve the control anticipated. Solutes will continue to be transported in runoff throughout the storm, regardless of magnitude.

CG-1 will provide water quality control and stream channel protection as well as flood control protection for most storms if the BMPs drain reasonably well and are adequately sized and distributed. CG-2 will not fully mitigate the peak rate for larger storms, and will require the addition of secondary BMPs for peak rate control. These secondary BMPs could also provide water quality control. In the event that this secondary BMP is added to assure rate mitigation during severe storms, the incorporation of vegetation could provide effective water quality controls.

The recommended control guideline for *total water quality control* is:

> Achieve an 85 percent reduction in post-development particulate associated pollutant load (as represented by Total Suspended Solids), an 85 percent reduction in post-development total phosphorus loads, and a 50 percent reduction in post-development solute loads (as represented by NO3-N), all based on post-development land use.

The recommended water quality control guideline is a set of performance-based goals. The guideline does not represent specific effluent limitations but presents composite efficiency expectations that can be used to select appropriate BMPs.

These reductions may be estimated based on the pollutant load for each land use type and the pollutant removal effectiveness of the proposed BMPs, as shown in Chapters 5 and 6 and discussed in Chapter 8. The inclusion of total phosphorus as a parameter is in recognition of the fact that much of

the phosphorus in transit with stormwater is attached to the small (colloidal) particles, which are not subject to gravity settlement in conventional detention structures, except over extended periods. With infiltration or vegetative treatment, however, the removal of both suspended solids and total phosphorus should be very high.

New impervious surfaces, such as rooftops, that produce relatively little additional pollutants can be left out of the water quality impact site evaluation under most circumstances. Rainfall has some latent concentration of nitrate (1 to 2 mg/l) as the result of air pollution, but it would be unreasonable to require the removal of this pollutant load from stormwater runoff. The control of nitrate from new development should focus on reduction of fertilizer applications rather than removal from runoff.

When the proposed development plan for a site is measured by type of surface (roof, parking lot, driveway, lawn, etc.), an estimate of potential pollutant load can be made based on the volume of runoff from those surfaces, with a flow-weighted pollutant concentration applied. The total potential non-point source load can then be estimated for the parcel, and the various BMPs, both Structural and Non-Structural, can be considered for their effectiveness. This method is described in detail in Chapter 8. In general, the Non-Structural BMPs are most beneficial for the reduction of solutes, with Structural BMPs most useful for particulate reduction. Because soluble pollutants are extremely difficult to remove, prevention or reduction on the land surface, as achieved through Non-Structural BMPs described in Chapter 5, are the most effective methods for reducing them.

3.6 Stormwater Standards for Special Management Areas

CG-1 and CG-2 may require modification, on a case-by-case basis, before they are applied to Special Management Areas around the Commonwealth. Special Areas include highways and roads, existing urban or developed sites, contaminated or brownfield sites, sites situated in karst topography, sites located in public water supply protection areas, sites situated in High Quality or Exceptional Value watersheds, sites situated on old mining lands, etc. These are areas where BMP application of any type may be limited. Stormwater management for these Special Management Areas is discussed in more detail in Chapter 7.

Pennsylvania Stormwater Best Management Practices Manual

Chapter 4

Integrating Site Design and Stormwater Management



363-0300-002 / December 30, 2006

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Chapter 4 Integrating Site Design and Stormwater Management

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4.1 A Recommended Site Design Procedure for Comprehensive Stormwater Management

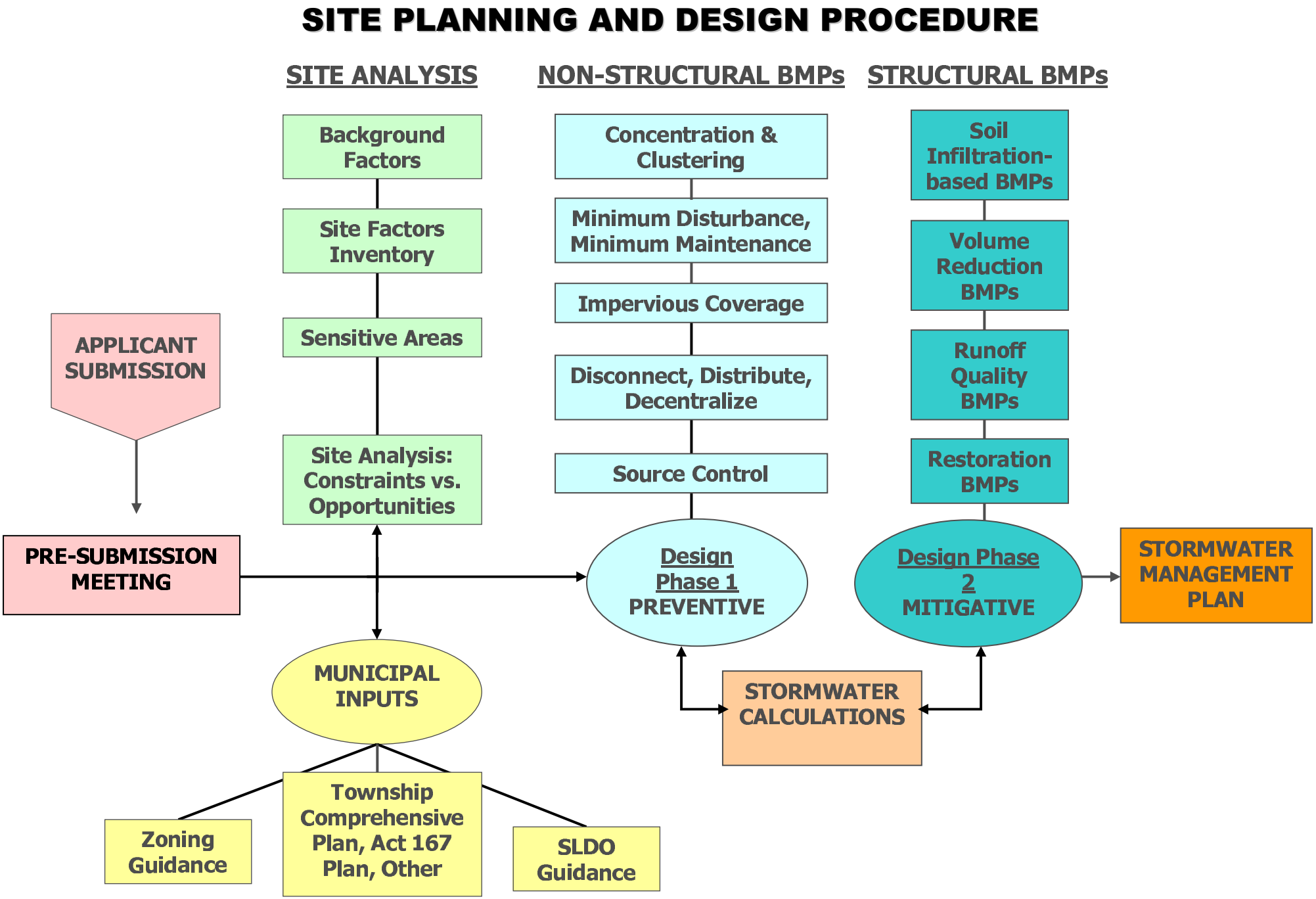
Chapters 5 and 6 describe multiple Non-Structural and Structural BMPs that can be used to achieve the Recommended Site Control Guidelines for comprehensive stormwater management described in Chapter 3. Obviously, not all of these BMPs are appropriate for all land development activities or every site. How can BMPs be selected to maximize their performance? What is the optimal blend between Non-Structural and Structural BMPs? How can stormwater management be best integrated into the site planning process?

A flow chart depicting a Site Design Procedure For Comprehensive Stormwater Management (Procedure) is set forth in Figure 4-1 (also referenced to the Checklist Summary in Figure 4-2 which is discussed in Section 4.2 below). This procedure begins with an assessment of the site and its natural systems and then proceeds to integrate both Non-Structural and Structural BMPs in the formulation of a comprehensive stormwater management plan. The intent of the planning process is to promote development of stormwater management "solutions" which achieve the rigorous quantity and quality standards set forth in Chapter 3. Some aspects of the procedure will not be fully applicable in all land development cases. For example, Non-Structural BMPs may be challenging to apply in those cases where higher densities/intensities are proposed on the smallest of sites in already developed areas.

An essential objective of the Procedure is to maximize stormwater "prevention" through use of Non-Structural BMPs (Chapter 5). Once prevention has been maximized, some amount of stormwater peaking and volume control will likely remain to be managed. These stormwater management needs should be met with an array of natural-system based Best Management Practices (Vegetated Swales, Vegetated Filter Strips, etc.), with the remaining stormwater management needs met with structural Best Management Practices such as infiltration basins, trenches, porous pavement, wet basins, retention ponds, constructed wetlands, and others presented in Chapter 6.

This Procedure, or a process similar to it, is an integral part of comprehensive stormwater management and transcends the bounds of conventional stormwater management that has existed in most Pennsylvania municipalities. Perhaps most importantly, the Procedure involves the total site design process. Conventional stormwater management has usually been relegated to the final stages of the site design and overall land development process, after most other building program issues have been determined and accommodated. To the contrary, the Procedure places stormwater management in the initial stages of site planning process, when the building program is being fitted and tested on the site. In this way, comprehensive stormwater management can be integrated effectively into the site design process.

Figure 4-1 Recommended procedures for comprehensive stormwater management.



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Much of the information relied on for the Procedure is information already required to satisfy other aspects of existing municipal land development ordinances. The Procedure is intended to more effectively utilize this already-collected site data to generate better stormwater management in the context of a markedly improved site plan. To the extent that this information is not already being collected and assessed, the information needs to be collected as part of the site design process.

4.2 The Site Design Checklist for Comprehensive Stormwater Management

Coordinated with the Recommended Site Design Procedure for Comprehensive Stormwater Management is a series of questions structured to facilitate and guide an assessment of the site's natural features and stormwater management needs. The Site Design Checklist for Comprehensive Stormwater Management (Figure 4-2) is intended to help facilitate the Procedure. The initial questions in the Checklist focus on Site Analysis, including Background Site Features, a Site Factors Inventory, Site Factors Analysis and Constraints and Opportunities. The checklist relates directly to the first Non-Structural BMP category: Protect Sensitive and Special Value Features, which include:

BMP 5.4.1 Protect Sensitive/Special Value features
BMP 5.4.2 Protect/conserve/enhance utilize riparian areas
BMP 5.4.3 Protect/utilize natural flow pathways in overall stormwater planning and design

Because these first steps in the Procedure are so important, they are further discussed below in Section 4.3 – "Importance of Site Assessment".

The Procedure continues with potentially multiple cycles of "testing" and "fitting" preventive Non-Structural BMPs at the site. The Checklist provides questions designed to identify the potential application of additional Non-Structural BMPs. Once Non-Structural BMPs have been "maximized," the Recommend Procedure then continues with the testing/fitting of Structural BMPs, again facilitated by the Checklist questions. This testing/fitting of Non-Structural and Structural BMPs can continue through several cycles. At the completion of the Procedure, a comprehensive stormwater management plan emerges, satisfying the Chapter 3 Recommended Site Control Guidelines. If the Checklist questions are addressed thoroughly and the Procedure is fully and effectively applied, the critical objective of managing stormwater comprehensively will be achieved in a cost effective manner. The Procedure, though largely common sense, constitutes a change from conventional engineering practice in many Pennsylvania municipalities.

(Figure 4-2) Checklist summary for use with Site Planning and Design Procedure

SITE ANALYSIS

Background Site Factors

Describe hydrologic context and other natural elements

- Chapter 93 stream use designation?
  - Special Protection Waters (EV, HQ)?
  - Fishery / Aquatic Life Use (WWF, CWF, TSF)?
- Any Chapter 303d/impaired stream listing classifications?
- Aquatic biota sampling?
- Existing water quality sensitivities downstream (water supply source?)?
- Location of any known downstream flooding?
- Includes any Special Areas?
  - Such as Previously Mined AMD/AML areas?
  - Brownfields?
  - Source Water Protection areas
  - Urban Areas?
  - Carbonate/Limestone?
  - Slide Prone Areas
  - Other

Site Factors Inventory

Describe the size and shape of the site

- Special constraints/opportunities?
- Special site border conditions and adjacent uses?

Describe the existing developed features of the site, if any

- Existing structures/improvements, structures to be preserved?
- Existing cover/uses?
- Existing impervious areas?
- Existing pervious maintained areas?
- Existing public sewer and water?
- Existing storm drainage systems at/adjacent to site?
- Existing wastewater, water systems onsite?

Describe important natural features of site

- Existing hydrology (drainage swales, intermittent, perennial)?
- Existing topography, contours, subbasins?
- Soil series found on site and their Hydrologic Soil Group ratings?
- Areas of vegetation (trees, scrub, shrub)?
- Special Value Areas?
  - Wetlands, hydric soils?
  - Floodplains/alluvial soils?
  - High quality woodlands, other woodlands and vegetation?
  - Riparian buffers?
  - Naturally vegetated swales/drainageways?
- Sensitive Areas?
  - Steep slopes?
  - Special geologic conditions (limestone?)?
  - Shallow bedrock (less than 2ft)?
  - High water table (less than 2ft)?
- PNDI areas or species?

Site Factors Analysis

Characterize the constraint-zones at site

- Avoid development on or near special and sensitive natural features

Characterize the opportunity-zones at site

- Location of well-draining soils
- Location and quality of existing vegetation
- Has a Potential Development Area been defined?
- Does building program fit the constraints and opportunities of natural features?

BACKGROUND SITE CONDITIONS

MUNICIPAL INPUTS	
Township Comprehensive Plan and Zoning guidance	BACKGROUND SITE CONDITIONS
Guidance in Comprehensive Plan?	
Existing Zoning District?	
Total number of units allowed?	
Type of units?	
Density of units?	
Any allowable options?	
Township SLDO guidance and options	
Performance standards for neo-traditional, village, hamlet planning?	
Reduce building setbacks?	
Curbs required?	
Street width, parking requirements, other impervious requirements?	
Cut requirements?	
Grading requirements?	
Landscaping requirements?	
Township SLDO/stormwater requirements	
Peak rate and design storms?	
Total runoff volume?	
Water quality provisions?	
Methodological requirements?	
Maintenance requirements?	
Is applicant submission complete? Fully responsive to municipal zoning/ SLDO requirements?	
Are municipal zoning/SLDO requirements inadequate?	
Is useful interaction at sketch plan or even pre-sketch plan phases occurring?	
SITE DESIGN: NON-STRUCTURAL BMPs	DESIGN PHASE 1: PREVENTIVE
Lot Concentration and Clustering	
Reduce individual lot size?	
Concentrate/cluster uses and lots?	
Configure lots to avoid critical natural areas ?	
Configure lots to take advantage of effective mitigative stormwater practices?	
Orient built structures to fit natural topography?	
Minimize site disturbance (excavation / grading) at site?	
Minimize site disturbance (excavation / grading) for each lot?	
Minimum Disturbance/Maintenance	
Define disturbance zones for site?	
Protect maximum total site area from development disturbance?	
Protect naturally sensitive and special areas from disturbance?	
Minimize total site compaction?	
Maximize zones of open space and greenways?	
Consider re-forestation and re-vegetation opportunities?	
Impervious Coverage Reduction	
Reduce road widths? Lengths?	
Utilize turnarounds? Cul-de-sacs with vegetated islands?	
Reduce driveway length and width?	
Reduce parking ratios?	
Reduce parking sizes?	
Examine potential for shared parking?	
Utilize porous surfaces for applicable parking features (overflow)?	
Design sidewalks for single-side street movement?	
Disconnect/Distribute/Decentralize	
Rooftop disconnection?	
Existing downgradient yard area opportunities?	
Existing downgradient vegetated areas/woods?	
Disconnection from storm sewers/street gutters?	
Front/side yard opportunities?	
Space for vegetated swales, rain gardens, etc.?	
Source Control	
Provisions for street sweeping? Other?	

SITE DESIGN: STRUCTURAL BMPs	DESIGN PHASE 1: MITIGATIVE
Volume/Peak Rate Through Infiltration	
Porous Pavement with Infiltration Beds?	
Infiltration Basins?	
Infiltration Trenches?	
Rain Garden/Bioretention?	
Dry Wells/Seepage Pits?	
Vegetated Swales?	
Vegetated Filter Strips?	
Infiltration Berm/Retentive Grading?	
Volume/Peak Rate Reduction	
Vegetated Rooftops?	
Capture & Reuse:	
Cisterns?	
Rain Barrels?	
Other?	
Runoff Quality/Peak Rate Reduction	
Constructed wetland?	
Wet pond/retention basin?	
Dry extended detention basin?	
Water quality filters: Constructed and Other	
Sand and sand/peat?	
Multi-chamber catch basins and inlets?	
Other types?	
Other	
Level Spreaders?	
Special Detention Storage: Parking Lots, Other	
Site Restoration for Stormwater	
Riparian Buffer Restoration?	
Landscape Restoration	
Soil Amendment/Restoration	
Protocols	
Soil Testing	
Site Infiltration	
STORMWATER METHODOLOGY AND CALCULATIONS	**SOTRMWATER CALCULATIONS**
Iterative Process Occurring Throughout Planning and Design Practices to Max out Non-Structural and Structural Practices	
Use acceptable methods, such as Soil Cover Complex Method (TR-55) for calculations	
Do not use Weighted Curve Numbers!	
Strive to:	
Minimize the pre to post development increase in Curve Numbers	
Maximize post-development Time of Concentration	
Assume "conservative" pre-development cover conditions (i.e., Curve Numbers) such as "Meadow Good" or "Woods" for all pre-development pervious areas?	
Respect natural sub-areas in the design and engineering calculations	
Strive To Achieve Standards of Comprehensive Stormwater Management	
No increase in volume of runoff, pre to post development, for up to the 2-yr storm	
No reduction in total volume of recharge, for up to the 2-yr storm	
No increase in peak rate of runoff, small to large storms	
No increase in pollutant loading	
DEVELOP COMPREHENSIVE STORMWATER MANAGEMENT PLAN	**PLAN**
Has There Been Thorough Approach To Use of Both Non-Structural and Structural BMP's?	
If not, what non-structurals and structurals might be used?	
Should the building program be modified?	
What Related Benefits Are Being Achieved Through The Use of BMPs?	

4.3 Importance of Site Assessment

Comprehensive stormwater management begins with a thorough assessment of the site and its natural systems. Site assessment includes inventorying and evaluating the various natural resource systems which define each site and pose both problems and opportunities for stormwater management. Resources include the full range of natural systems such as water quantity, water quality, floodplains and riparian areas, wetlands, soils, geology, vegetation, and more. Natural systems range in scale from resources of areawide importance on a macro scale, down to micro- and site-specific detail.

4.3.1 Background Site Factors

Broader system characteristics should be described, including State Chapter 93 stream classifications, presence of Special Protection Waters, stream order (i.e., 1st order, 2nd order, etc.), source water supply designations, 303d/TMDL/Impaired Stream designations, flooding history, and other information that provides an understanding of how a particular site is functioning within its watershed context. More specific questions would include:

- Does the site drain to special waterbodies with special water quality needs?
- Determine if the site ultimately flows into a reservoir or other water body where special water quality sensitivities exist, such as use as a water supply source.
- Determine if a special fishery exists.
- Determine if the site is linked to a special habitat system, such as delineated in the Pennsylvania Natural Diversity Inventory. For both water quality and temperature reasons, approaches and practices that achieve a higher order of protection may become especially important.

Are there known downstream flooding problems?
Determine if a stream system to which the site discharge is currently experiencing flooding problems. This is especially important where urbanization already has occurred and where hydrology already has been altered. Unfortunately, the existing FEMA mapping and related studies do not adequately assess this issue. County agencies and municipal offices may be able to indicate anecdotally the extent to which downstream flooding is already a problem or has the potential to become a problem if substantial additional development is projected. Greater care should be taken in both floodplain management as well as stormwater management if problems exist or are anticipated.

Does the site discharge to 1st, 2nd, 3rd order streams?
Another important question relates to the site's location within its watershed. Sites located near the base of watersheds pose less of a threat to the hydrologic characteristics of the watershed system. Sites located farther up the watershed are potentially more problematic when additional stormwater is generated. Perhaps even more critical, sites located within headwaters must be managed most carefully in terms of stormwater to maintain pre-development infiltration and groundwater recharge rates.

4.3.2 Site Factors Inventory

Site-specific factors that influence comprehensive stormwater management include the following items:

How does site size and shape affect stormwater management?
As site size increases, the ability to use a variety of Non-Structural and Structural BMPs increases. Comprehensive stormwater management, especially through site planning and the use of Non-Structural BMPs, can reduce space requirements at a site and offer greater BMP flexibility. Oddly shaped sites can also be better adapted with BMPs set forth here, given their wide variety of shapes and sizes.

What are the important natural features characterizing the site?
At the heart of the comprehensive stormwater management procedure is an understanding of the natural systems characterizing each site. Existing vegetation and soil have tremendous importance and are the key to understanding land development impacts on natural systems. Careful accounting of existing vegetation is an important prerequisite for comprehensive stormwater management, followed closely by soils mapping for permeability ratings, and natural pre-development surface flow patterns. Critical site features, such as wetlands, floodplains, riparian areas, natural drainage ways, special habitat areas, special geological formations (e.g., carbonate), steep slopes, shallow depth to water table, shallow depth to bedrock, and other factors should be inventoried and understood. Critical areas include those with special positive functions that can be translated into real economic value or benefit. Elimination or reduction of these functions through the land development process leads to real economic losses. These special value areas, including wetlands and floodplains and riparian areas, should be conserved and protected during land development. Critical natural areas also include sensitive areas, such as steep slopes, shallow bedrock, high water table areas, and other constraining features, where encroachment by land development typically creates unnecessary or unanticipated problems. Care must be taken to avoid these potential pitfalls.

4.3.3 Site Factors Analysis

Identify site factors that constrain comprehensive stormwater management, and identify site factors that can be viewed as opportunities.

How is the site constrained?
Determine where buildings, roads, and other disturbance should be avoided and why.

Where are the zones of site "opportunity," in terms of stormwater management?
Determine where most infiltration occurs in terms of vegetation and in terms of soils. Both constraints and opportunities are grounded in the natural systems present at the site. Constraints and opportunities are not necessarily simple opposites of one another. For example, certain types of critical natural areas should be viewed as constraints in terms of direct land disturbance and building construction, yet also provide significant opportunity in terms of stormwater management, quantity and quality. Woodlands, which should be protected from direct land development, provide excellent opportunity for stormwater management, provided that the correct approaches and practices are

used. Vegetated riparian buffers should not be disturbed for building and road construction yet they can be used carefully with level spreading devices to receive diffuse stormwater runoff. Soils with maximum permeabilities at the site should not be made impervious with buildings and roads, but used for stormwater management where feasible. Conversely, buildings and other impervious areas should be located on those portions of a site with least permeable soils. Site opportunities for volume control can typically be defined in terms of vegetation types that minimize runoff, as well as soil types with maximum permeabilities.

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Chapter 5

Non-Structural BMPs



363-0300-002 / December 30, 2006

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Chapter 5 Comprehensive Stormwater Management: Non-Structural BMPs

5.1 Introduction

The terms “Low Impact Development” and “Conservation Design” refer to an environmentally sensitive approach to site development and stormwater management that minimizes the effect of development on water, land and air. This chapter emphasizes the integration of site design and planning techniques that preserve natural systems and hydrologic functions on a site through the use of Non-Structural BMPs. Non-Structural BMP deployment is not a singular, prescriptive design standard but a combination of practices that can result in a variety of environmental and financial benefits. Reliance on Non-Structural BMPs encourages the treatment, infiltration, evaporation, and transpiration of precipitation close to where it falls while helping to maintain a more natural and functional landscape. The BMPs described in this chapter preserve open space and working lands, protect natural systems, and incorporate existing site features such as wetlands and stream corridors to manage stormwater at its source. Some BMPs also focus on clustering and concentrating development, minimizing disturbed areas, and reducing the size of impervious areas. Appropriate use of Non-Structural BMPs will reflect the ten “Principles” presented in the Foreword to this manual, and will be an outcome of applying the procedures described in Chapter 4.

From a developer’s perspective, these practices can reduce land clearing and grading costs, reduce infrastructure costs, reduce stormwater management costs, and increase community marketability and property values. Blending these BMPs into development plans can contribute to desirability of a community, environmental health and quality of life for its residents. Longer term, they sustain their stormwater management capacity with reduced operation and maintenance demands.

Conventional land development frequently results in extensive site clearing, where existing vegetation is destroyed, and the existing soil is disturbed, manipulated, and compacted. All of this activity significantly affects stormwater quantity and quality. These conventional land development practices often fail to recognize that the natural vegetative cover, the soil mantle, and the topographic form of the land are integral parts of the water resources system that need to be conserved and kept in balance, even as land development continues to occur.

As described in Chapter 4, identifying a site’s natural resources and evaluating their values and functional importance is the first step in addressing the impact of stormwater generated from land development. Where they already exist on a proposed development site, these natural resources should be conserved and utilized as a part of the stormwater management solution. The term “green infrastructure” is often used to characterize the role of these natural system elements in preventing stormwater generation, infiltrating stormwater once it’s created, and then conveying and removing pollutants from stormwater flows. Many vegetation and soil-based structural BMPs are in fact “natural structures” that perform the functions of more “structural” systems (e.g., porous pavement with recharge beds). Because some of these “natural structures” can be designed and engineered, they are discussed in Chapter 6 as structural BMPs.

5.2 Non-Structural Best Management Practices

This Manual differentiates BMPs based on Non-Structural (Chapter 5) and Structural (Chapter 6) designations. Non-Structural BMPs take the form of broader planning and design approaches – even principles and policies – which are less “structural” in their form, although non-structural BMPs do have

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very important physical ramifications. An excellent example would be "reducing imperviousness" (see BMPs 5.9 and 5.10 below) by reducing road width and/or reducing parking ratios. In this way, a proposed building program can be accommodated but with reduced stormwater generation. These non-structural BMPs can be applied over an entire site and are not fixed and designed at one location. Virtually all of the Non-Structural BMPs set forth in this Chapter of the manual share this kind of site-wide policy characteristic. Structural BMPs, on the other hand, are decidedly more locationally specific and explicit in their physical form.

Sometimes called Low Impact Development or Conservation Design techniques, Non-Structural BMPs are not always markedly different from Structural BMPs. In fact, some of the BMPs described in Chapter 6, such as Vegetated Swales and Vegetated Filter Strips, are largely based in natural systems and are intended to function as they would have prior to disturbance. Nevertheless, such BMPs can be thought of as natural structures, which are designed to mitigate any number of stormwater impacts: peak rates, total runoff volumes, infiltration and recharge volumes, non-point source water quality loadings and temperature increases.

Perhaps the most defining distinction for the Non-Structural BMPs set forth in this chapter is their ability to prevent stormwater generation and not just mitigate stormwater-related impacts once these problems have been generated. Prevention can be achieved by developing land in ways other than through use of standard or conventional development practices. Prevention and Non-Structural BMPs go hand in hand and can be contrasted with Structural BMPs that provide mitigation of those stormwater impacts, which cannot be prevented and/or avoided.

Several major "areas" of preventive Non-Structural BMPs have been identified in this manual:

Protect Sensitive and Special Value Features
Cluster and Concentrate
Minimize Disturbance and Minimize Maintenance
Reduce Impervious Cover
Disconnect/Distribute/Decentralize
Source Control

More specific Non-Structural BMPs have been identified for each of these generalized areas to better define and improve implementation of each of these areas. This list of specific BMPs will be refined and expanded as these stormwater management practices become more common throughout Pennsylvania.

A uniform format has been developed for the BMPs presented in Chapters 5 and 6 of this manual. It provides as many engineering details as possible, facilitated through diagrams, graphics and pictures. There are constant tradeoffs that must be made between providing a more complete explanation for the countless variations which can be expected to emerge across the state versus the need to be concise and user friendly.
The uniform format has been applied to all of the Non-Structural BMPs included in Chapter 5, to encourage recognition that these Non-Structural techniques are every bit as essential as the techniques presented in Chapter 6 Structural BMPs.

One of the most challenging technical issues considered in this manual involves the selection of BMPs that have a high degree of NPS reduction or removal efficiency. In the ideal, a BMP should be selected that has a proven NPS pollutant removal efficiency for all pollutants of importance, especially those that are critical in a specific watershed (as defined by a TMDL or

other process). Both Non-Structural BMPs in Chapter 5 and Structural BMPs in Chapter 6 are rated in terms of their anticipated pollutant removal performance or effectiveness. The initial BMP selection process analyzes the final site plan and estimates the potential NPS load, using Appendix A. The targeted reduction percentage for representative pollutants (such as 85% reduction in TSS and TP load and 50% reduction in the solute load) is achieved by a suitable combination of Non-Structural and Structural BMPs. This process is described in more detail in Chapter 8.

5.3 Non-Structural BMPs and Stormwater Methodological Issues

The methodological approach set forth in Chapter 8 provides a variety of straightforward and conservative ways to take credit for applying Non-Structural BMPs, provided that the "specifications" defined for each BMP in Chapter 5 are properly followed.

Because so many of the Non-Structural BMPs seem so removed from the conventional practice of stormwater engineering, putting these BMPs into play may be a challenge. Many of these Non-Structural BMPs ultimately require a more sophisticated approach to total site design. Some of the Non-Structural BMPs don't easily lend themselves to stormwater calculations as conventionally performed. How do we get stormwater credit for applying any of these techniques? Taking BMPs 5.6.1 and 5.6.2 again as examples, minimizing impervious cover by reducing road width or impervious parking area directly translates into reduced stormwater volumes and reduced stormwater rates of runoff. Site planners and designers will also recognize that many of the other Non-Structural BMPs, such as clustering of uses, conserving existing woodlands and other vegetative cover, and disconnecting impervious area runoff flows, all translate into reduced stormwater volume and rate calculations. As such, these BMPs are self-crediting.

5.4 Protect Sensitive and Special Value Resources

BMP 5.4.1: Protect Sensitive and Special Value Features



To minimize stormwater impacts, land development should avoid affecting and encroaching upon areas with important natural stormwater functional values (floodplains, wetlands, riparian areas, drainageways, others) and with stormwater impact sensitivities (steep slopes, adjoining properties, others) wherever practicable. This avoidance should occur site-by-site and on an area wide basis. Development should not occur in areas where sensitive/special value resources exist so that their valuable natural functions are not lost, thereby doubling or tripling stormwater impacts. Resources may be weighted according to their functional values specific to their municipality and watershed context.

Key Design Elements

- Identify and map floodplains and riparian area
- Identify and map wetlands
- Identify and map woodlands
- Identify and map natural flow pathways/drainage ways
- Identify and map steep slopes
- Identify and map other sensitive resources
- Combine for Sensitive Resources Map (including all of the above)
- Distinguish between including Highest Priority Avoidance Areas and Avoidance Areas
- Identify and Map Potential Development Areas (all those areas not identified on the Sensitive Resources Map)
- Make the development program and overall site plan conform to the Development Areas Map to the maximum; minimize encroachment on Sensitive Resources.

Potential Applications

Residential:
Commercial: Ultra Yes Yes
Urban: Industrial: Yes Yes
Retrofit: Yes Yes
Highway/Road:

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Description

A major objective for stormwater-sensitive site planning and design is to avoid encroachment upon, disturbance of, and alteration to those natural features which provide valuable stormwater functions (floodplains, wetlands, natural flow pathways/drainage ways) or with stormwater impact sensitivity (steep slopes, historic and natural resources, adjoining properties, etc.) Sensitive Resources also include those resources of special value (e.g., designated habitat of threatened and endangered species that are known to exist and have been identified through the Pennsylvania Natural Diversity Inventory or PNDI). The objective of this BMP is to avoid harming Sensitive/Special Value Resources by carefully identifying and mapping these resources from the initiation of the site planning process and striving to protect them while defining areas free of these sensitivities and special values (Potential Development Areas). BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas and BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas build on recommendations included in this BMP.

Variations

- BMP 5.4.1 calls for actions both on the parts of the municipality as well as the individual landowner and/or developer. Pennsylvania municipalities may adopt subdivision/land development ordinances which require that the above steps be integrated into their respective land development processes. A variety of models are available for municipalities to facilitate this adoption process, such as through the PADCNR *Growing Greener* program.

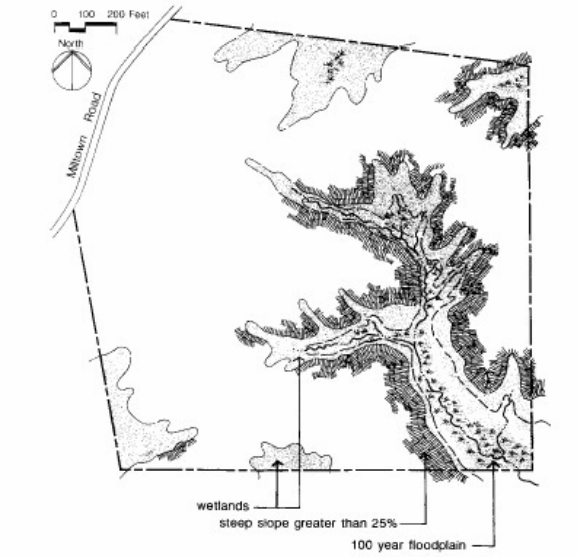


Figure 5.1-1. Growing Greener's Conservation Subdivision Design: Step One, Part One – Identify primary conservation areas.

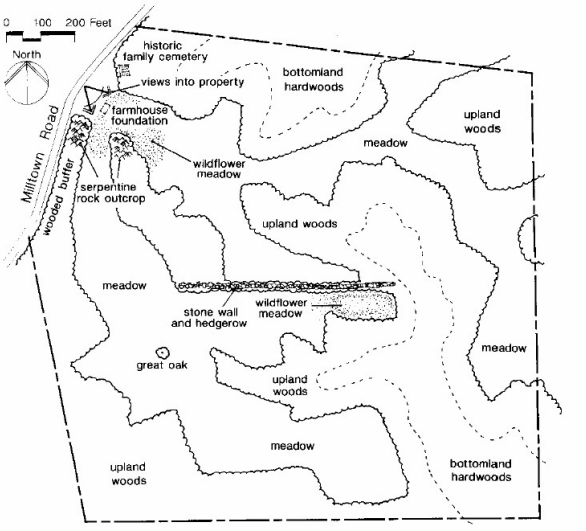


Figure 5.1-2. Growing Greener's Conservation Subdivision Design: Step One, Part Two – Identify secondary conservation areas.

Source: Growing Greener: Putting Conservation Into Local Codes; Natural Land Trusts, Inc. 1997

- The above steps use the *Growing Greener* Primary Conservation Areas and Secondary Conservation Areas designations and groupings. Identify and map the essential natural resources, including those having special functional value and sensitivity from a stormwater perspective, and then avoid developing (destroying, reducing, encroaching upon, and/or impacting) these areas during the land development process. Additionally, it is possible that Primary and Secondary can be defined in different ways so as to include different resources.

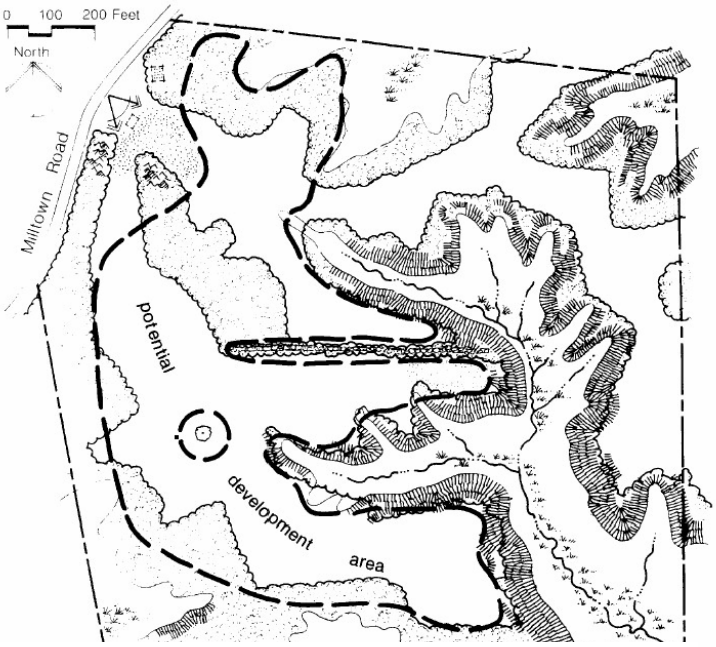


Figure 5.1-3. Growing Greener's Conservation Subdivision Design: Step One, Part Three – potential development areas.

Source: Growing Greener: Putting Conservation Into Local Codes; Natural Land Trusts, Inc. 1997

- Definition of the natural resources themselves can be varied. The definition of Riparian Buffer Area varies. Woodlands may be defined in several ways, possibly based on previous delineation/definition by the municipality or by another public agency. It is important to note here that Wooded Areas, which may not rank well in terms of conventional woodland definitions, maintain important stormwater management functions and should be included in the delineation/definition. Intermittent streams/swales/natural flow pathways are especially given to variability. Municipalities may not only integrate the above steps within their subdivision/land development ordinances, but also define these natural resource values as carefully as possible in order to minimize uncertainty.

- The level of rigor granted to Priority Avoidance and Avoidance Areas may be made to vary in a regulatory manner by the municipality and functionally by the owner and/or developer. A municipal ordinance may prohibit and/or otherwise restrict development in Priority Avoidance Areas and even Avoidance Areas. All else being equal, the larger the site, the more restrictive these requirements may be.

Applications

A number of communities across Pennsylvania have adopted ordinances that require natural resources to be identified, mapped, and taken into account in a multi-step process similar to the Growing Greener program. These include:

BUCKS COUNTY
Milford Township SLDO (Sep. 2002)

CHESTER COUNTY
London Britain Township (1999)
London Grove Township (2001)
Newlin Township (1999)
North Coventry Township (Dec. 2002)
Wallace Township (1994)
West Vincent Township (1998)

MONTGOMERY COUNTY
Upper Salford Township (1999)

MONROE COUNTY
Chestnuthill Township (2003)
Stroud Township SLDO (2003)

YORK COUNTY
Carroll Township (2003)



Figure 5.1-4. Steep slope development with woodland removal.

BMP 5.4.1 applies to all types of development in all types of municipalities across Pennsylvania, although variations as discussed above allow for tailoring according to different development density/intensity contexts.

Design Considerations

Not applicable.

Detailed Stormwater Functions

Impervious cover and altered pervious covers translate into water quantity and water quality impacts as discussed in Chapter 2 of this manual. Additional impervious area may further eliminate or in some way reduce other natural resources that were having especially beneficial functions.

Water quality concerns include all stormwater pollutant loads from impervious areas, as well as all pollutant loads from the newly created maintained landscape (i.e., lawns and other). Much of this load is soluble in form (especially fertilizer-linked nitrogen forms). Clustering as defined here, and combined with other Chapter 5 Non-Structural BMPs, minimizes impervious areas and the pollutant loads related to these impervious areas. After Chapter 5 BMPs are optimized, "unavoidable" stormwater is then directed into BMPs as set forth in Chapter 5, to be properly treated. Similarly, for all stormwater pollutant load generated from the newly-created maintained landscape, clustering as defined here, and

combined with other Chapter 5 Non-Structural BMPs, minimizes pervious areas and the pollutant loads related to these pervious areas, thereby reducing the opportunity for fertilization and other chemical application. Water quality prevention accomplished through Non-Structural BMPs in Chapter 5 is especially important because Chapter 6 Structural BMPs remain poor performers in terms of mitigating/removing soluble pollutants that are especially problematic in terms of this pervious maintained landscape. See Appendix A for additional documentation of the water quality benefits of clustering.

See Chapter 8 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

Construction Issues

Clearly, application of this BMP is required from the start of the site planning and development process. In fact, not only must the site developer embrace BMP 5.4.1 from the start of the process, the BMP assumes that the respective municipal officials have worked to include clustering in municipal codes and ordinances, as is the case with so many of these Chapter 5 Non-Structural BMPs.



Figure 5.1-5. Example of steep slope development.

Maintenance Issues

As with all Chapter 5 Non-Structural BMPs, maintenance issues are of a different nature and extent, when contrasted with the more specific Chapter 6 Structural BMPs. Typically, the designated open space may be conveyed to the municipality, although most municipalities prefer not to receive these open space portions, including all of the maintenance and other legal responsibilities associated with open space ownership. In the ideal, open space reserves ultimately will merge to form a unified open space system, integrating important conservation areas throughout the municipality. These open space segments may exist dispersed and unconnected. For those Pennsylvania municipalities that allow for and enable creation of homeowners associations or HOA's, the HOA may assume ownership of the open space. The HOA is usually the simplest solution to the issue.

In contrast to some of the other long-term maintenance responsibilities of a new subdivision and/or land development (such as maintenance of streets, water and sewers, play and recreation areas, and so forth), the maintenance requirements of "undisturbed open space" by definition should be minimal. The objective is conservation of the natural systems, including the natural or native vegetation, with little intervention and disturbance. Nevertheless, some legal responsibilities must be assumed and need to be covered.

Cost Issues

Clustering is beneficial from a cost perspective in several ways. Development costs are decreased because of less land clearing and grading, less road construction (including curbing), less sidewalk construction, less lighting and street landscaping, potentially less sewer and water line construction, potentially less stormwater collection system construction, and other economies.

Clustering also reduces post construction costs. A variety of studies from the landmark *Costs of Sprawl* study and later updates have shown that delivery of a variety of municipal services such as street maintenance, sewer and water services, and trash collection are more economical on a per person or per house basis when development is clustered. Even services such as police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values. Analyses of market prices of conventional development over time in contrast with comparable cluster developments (where size, type, and quality of the house itself is held constant) have indicated that clustered developments with their proximity to permanently protected open space increase in value at a more rapid rate than conventionally designed developments, even though clustered housing occurs on considerably smaller lots than the conventional residences.



Figure 5.1-6. Woodland removal for steep slope development with retaining walls.

Specifications

Clustering is not a new concept and has been defined, discussed, and evaluated in many different texts, reports, references and sources detailed in the References for BMP 5.5.1

BMP 5.4.2: Protect /Conserve/Enhance Riparian Areas



The Executive Council of the Chesapeake Bay Program defines a Riparian Forest Buffer as "an area of trees, usually accompanied by shrubs and other vegetation, that is adjacent to a body of water and which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering and converting sediments, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife."

Key Design Elements

- Linear in Nature
- Provide a transition between aquatic and upland environments
- Forested under natural conditions in Pennsylvania
- Serve to create a "Buffer" between development and aquatic environment
- Help to maintain the hydrologic, hydraulic, and ecological integrity of the stream channel.
- Comprised of three "zones" of different dimensions:
  - **Zone 1**: Adjacent to the stream and heavily vegetated under ideal conditions (Undisturbed Forest) to shade stream and provide aquatic food sources.
  - **Zone 2**: Landward of Zone 1 and varying in width, provides extensive water quality improvement. Considered the Managed Forest.
  - **Zone 3**: Landward of Zone 2, and may include BMPs such as Filter Strips.

Potential Applications

Residential:
Commercial: Ultra Yes Yes
Urban: Industrial: Yes Yes
Retrofit: Yes Yes
Highway/Road:

Stormwater Functions

Volume Reduction: Medium
Recharge: Medium
Peak Rate Control: Low/Med.
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

There are two components to Riparian Buffers to be considered in the development process:

1. Protecting, maintaining, and enhancing existing Riparian Forest Buffers.
2. Restoring Riparian Forest Buffers that have been eliminated or degraded by past practices.

BMP 5.4.2 focuses on protection, maintenance, and enhancement of existing Riparian Forest Buffers. Restoration of Riparian Forest Buffers is treated in Chapter 6 as a Structural BMP.

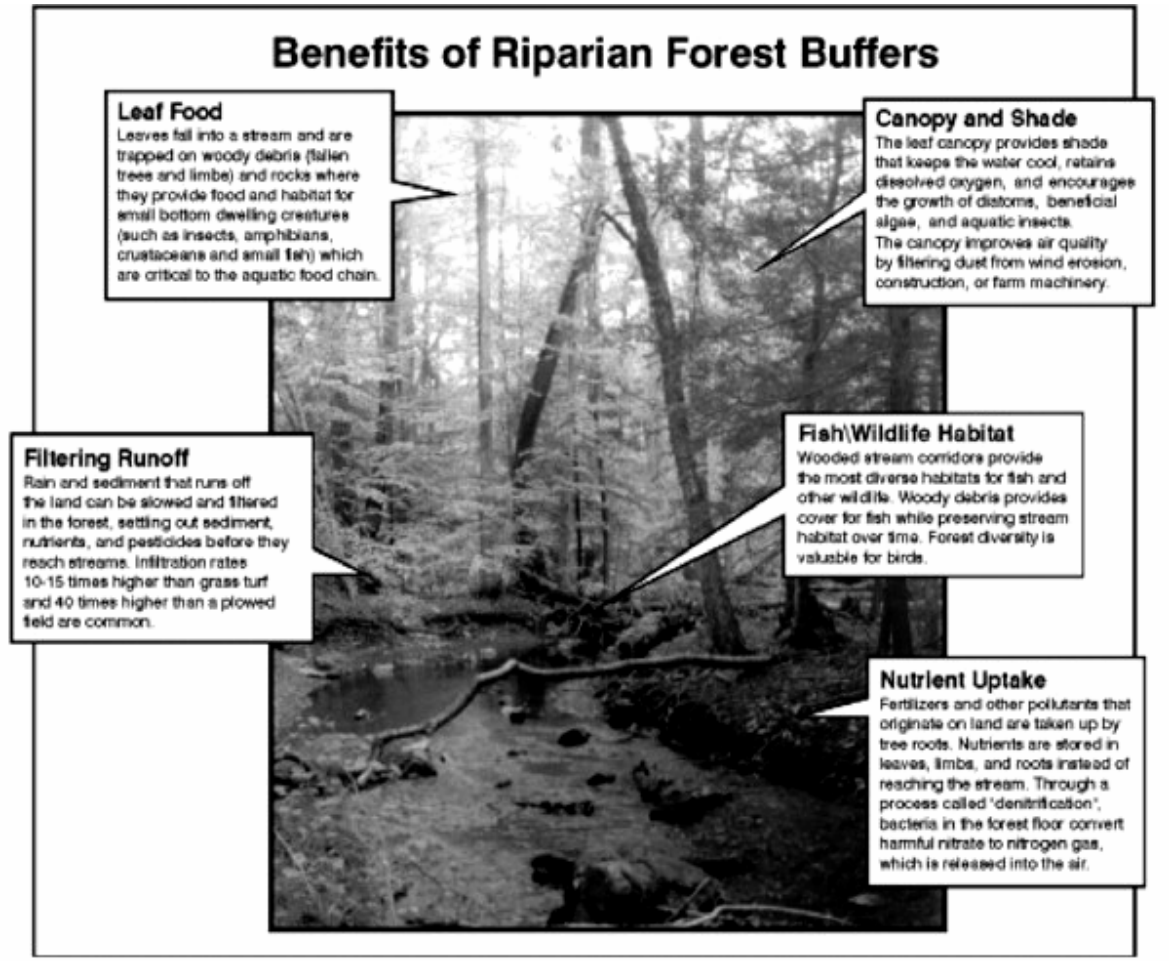


Figure 5.2-1. Riparian buffer zones support various ecological functions.

Detailed Stormwater Functions

Riparian Corridors are vegetated ecosystems along a waterbody that serve to buffer the waterbody from the effects of runoff by providing water quality filtering, bank stability, recharge, rate attenuation and volume reduction, and shading of the waterbody by vegetation. Riparian corridors also provide habitat and may include streambanks, wetlands, floodplains, and transitional areas. Functions can be identified and sorted more specifically by Zone designation:

Zone 1: Provides stream bank and channel stabilization; reduces soil loss and sedimentation/nutrient and other pollution from adjacent upslope sheet flow; roots, fallen logs, and other vegetative debris slow stream flow velocity, creating pools and habitat for macroinvertebrates, in turn enhancing biodiversity; decaying debris provides additional food source for stream-dwelling organisms; tree canopy shades and cools water temperature, critical to sustaining certain macroinvertebrates, as well as critical diatoms, which are essential to support high quality species/cold water species. Zone 1 functions are essential throughout the stream system, especially in 1st order streams.

Zone 2: Removes, transforms, and stores nutrients, sediments, and other pollutants flowing as sheet flow as well as shallow sub-surface flow. A healthy Zone 2 has the potential to remove substantial quantities of excess nitrates through root zone uptake. Nitrates customarily can be significantly elevated when adjacent land uses are agricultural or urban/suburban. Healthy vegetation in Zone 2 slows surface runoff while filtering sediment and particulate bound phosphorus. Total nutrient removal is facilitated through a variety of complex processes: long-term nutrient storage through microbe uptake, denitrification through bacterial conversion to nitrogen gases and additional microbial degradation processes.

Zone 3: Provides the first stage in managing upslope runoff so that runoff flows are slowed and evenly dispersed into Zone 2. Some physical filtering of pollutants may be accomplished in Zone 3 as well as some limited amount of infiltration.

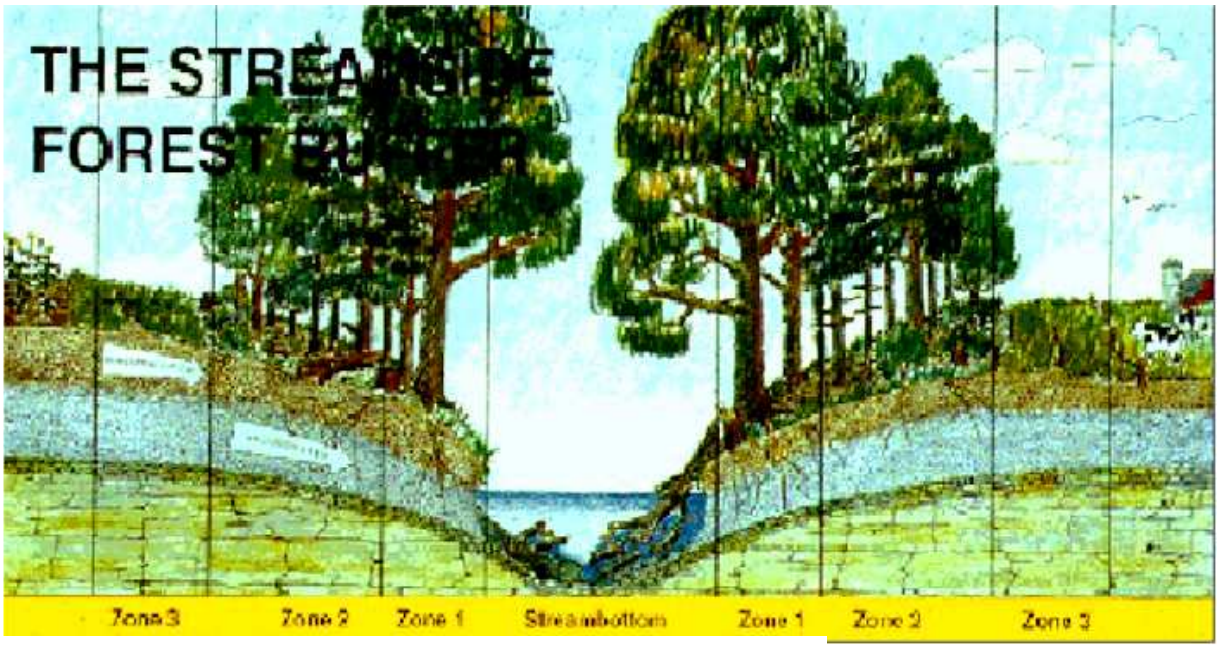


Figure 5.2-2. Riparian buffer zones (DJ Welsh, 1991).

Design Considerations/Variations

Although this manual refers frequently to the Chesapeake Bay Program's Riparian Handbook, many different sources of guidance have been developed in recent years. Not all of these are exactly comparable in terms of their recommendations and specifications. To some extent these variations relate to different land use development contexts.

Riparian Forest Buffer Zone widths should be adjusted according to site conditions and type of upslope development. Variation in standards (see Specifications below) should vary with the function to be performed by the forested buffer. In undisturbed forested areas where minimal runoff is expected to be occurring, standards can be made more flexible than in agricultural contexts where large quantities of natural vegetation have been removed and significant quantities of runoff are expected. In addition to factors related to technical need, practical and political factors also must be considered. In urbanized settings where hundreds, if not thousands of small lots may abut riparian areas and already intrude into potential forested buffer zones, buffer standards must be practicable.

Lastly, confusion has emerged between the concept of floodplain and riparian forest buffer. In many cases, mapped and delineated floodplain may overlap and even largely coincide with riparian forest buffer zones. On the other hand, mapped 100-year floodway/floodplain may not coincide with the forest buffer due to either very steep topography or very moderate slopes. A second important clarification is that floodplain ordinances typically manage use to prevent flood damage, which contrasts to riparian forest buffer regulation which manages clearing and grading actions in the zones, specifically for environmental reasons.

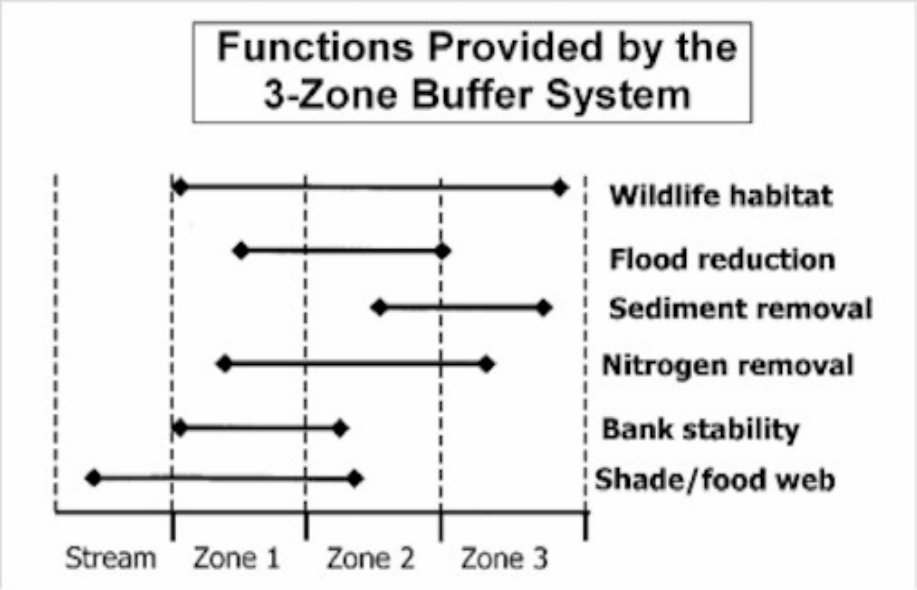


Figure 5.2-3. Riparian buffer zone functions.

Construction Issues

Riparian Forest Buffer Protection should be defined and included in municipal ordinances, including both the zoning ordinance and subdivision and land development ordinance (SALDO). The Riparian Forest Buffer should be defined and treated from the initial stages of the land development process, similar to floodplain, wetland or any other primary conservation value. It is the municipality's responsibility to determine a fair and effective riparian forest buffer program, balancing the full range of water resource and watershed objectives along with other land use objectives. A fair and effective program should evolve for all municipal landowners and stakeholders. State-supported River Conservation Plans, Act 167 Stormwater Management Plans, and other planning may contribute to this effort.

Whether a respective municipality has included riparian forest buffers in its ordinances or not, landowners/developers/applicants should include riparian forest buffers in their site plans from the initiation of the site planning process. If standards and guidelines have been set forth by the municipality or by other relevant planning group, these standards and guidelines should be followed. If none of these exist, standards recommended in this manual should be followed.

The ease of accommodating a riparian forest buffer can be expected to vary based on intensity of land use, zoning at the site and size of the parcel. Holding all other factors constant, as site size decreases, the challenges posed by riparian zone accommodation can be expected to increase. As sites become extremely small, reservation of site area for riparian forest buffer may become problematic, thereby requiring riparian forest buffer modification in order to accommodate a reasonable building program for the site. Zoned land use intensity is another factor to be considered. As this intensity increases and specifications for maximum building area and impervious area and total disturbed area are allowed to grow larger, reserving site area for the riparian forest buffer becomes more challenging. Riparian forest buffer programs need to be sensitive to these constraints.

All of these factors should be reviewed and integrated by the municipality as the riparian forest buffer program is being developed.

Cost Issues

Costs of riparian forest buffer establishment are not significant, defined in terms of direct development. In these cases, costs can be reasonably defined as the lost opportunity costs of not being able to use acreage reserved for the riparian forest buffer in the otherwise likely land use. A likely land use might be defined in terms of zoned land use. Depending upon the zoning category provisions and the degree to which a riparian forest buffer's Zone 1 or Zone 2 or Zone 3 might be able to be included as part of a land development plan or as part of yard provisions for lots in a residential subdivision acreage included within the riparian forest buffer may or may not be able to be included as part of the development. If riparian acreage must be totally subtracted, then it's fair value should be assessed as a cost. If riparian forest buffers can be credited as part of yards (though still protected), then that acreage should not be considered to be a cost. Any one-time capital cost can be viewed alternatively as an annualized cost.

To the extent that the riparian forest buffer coincides with the mapped and regulated floodplain, where homes and other structures and improvements should not be located, then attributing any lost opportunity costs exclusively to riparian forest buffers is not reasonable. The position can be argued that any riparian forest buffer area, which is included within floodplain limits, should not be double-counted as a riparian forest buffer cost. Alternatively, any riparian forest buffer area that extends beyond the floodplain could be assigned a cost.

Lost opportunity costs can be expected to vary depending upon land use. Alternative layouts, including reduced lot size configurations, may be able to provide the same or close to the same number of units and the same level of profitability.

Over the long-term, some modest costs are required for periodic inspection of the riparian forest buffer plus modest levels of maintenance. Generally, the buffers require very little in the way of operating and maintenance costs.

If objective cost-benefit analysis were to be undertaken on most riparian forest buffers, results would be quite positive, demonstrating that the full range of environmental and non-environmental benefits substantially exceeds costs involved. Protection of already existing vegetated areas located adjacent to streams, rivers, lakes, and other waterways is of tremendous importance, given their rich array of functional benefits.

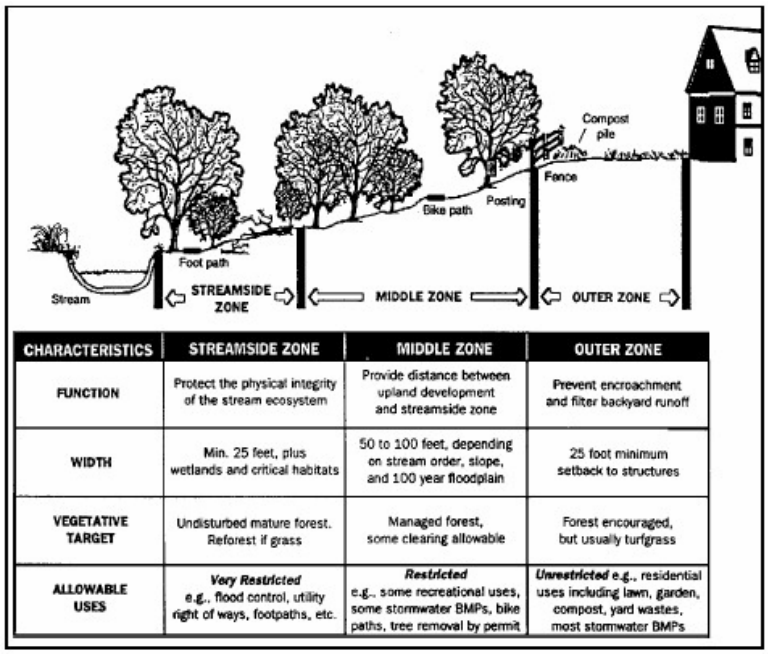
Stormwater Management Calculations

Stormwater calculations in most cases for Volume Control and Recharge and Peak Rate will not be affected dramatically. See Chapter 8 for more discussion relating to Water Quality.

Specifications

The Chesapeake Bay Program's Riparian Handbook provides an in-depth discussion of establishing the proper riparian forest buffer width, taking into consideration:

1. existing or potential value of the resource to be protected,
2. site, watershed, and buffer characteristics,
3. intensity of adjacent land use, and
4. specific water quality and/or habitat functions desired. (Handbook, p. 6-1)



CHARACTERISTICS	STREAMSIDE ZONE	MIDDLE ZONE	OUTER ZONE
FUNCTION	Protect the physical integrity of the stream ecosystem	Provide distance between upland development and streamside zone	Prevent encroachment and filter backyard runoff
WIDTH	Min. 25 feet, plus wetlands and critical habitats	50 to 100 feet, depending on stream order, slope, and 100 year floodplain	25 foot minimum setback to structures
VEGETATIVE TARGET	Undisturbed mature forest. Reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	***Very Restricted*** e.g., flood control, utility right of ways, footpaths, etc.	***Restricted*** e.g., some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	***Unrestricted*** e.g., residential uses including lawn, garden, compost, yard wastes, most stormwater BMPs

Figure 5.2-4. Three zone urban buffer system (Schueler, 1995 and Metropolitan COG, 1995).

At the core of the scientific basis for riparian forest buffer establishment are a variety of site-specific factors, including: watershed condition, slope, stream order, soil depth and erodibility, hydrology, floodplains, wetlands, streambanks, vegetation type, and stormwater system, all of which are discussed in the Handbook. Positively, this body of scientific literature has expanded tremendously in recent years and provides excellent support for effective buffer management. The downside is that this scientific literature now exceeds quick and easy summary. Fortunately, this Handbook and many additional related references are available online without cost (given the comprehensiveness of the Handbook itself, it is recommended that the reader start here).

Zone 1: Also termed the "streamside zone," this zone "…protects the physical and ecological integrity of the stream ecosystem. The vegetative target is mature riparian forest that can provide shade, leaf litter, woody debris, and erosion protection to the stream. The minimum width is 25 feet from each streambank (approximately the distance of one or two mature trees from the streambank), and land use is highly restricted…." (Handbook, p. 11-8)

Zone 2: Also termed the "middle zone," this zone"…extends from the outward boundary of the streamside zone and varies in width depending on stream order, the extent of the 100-year flood plain, adjacent steep slopes, and protected wetland areas. The middle zone protects key components of the stream and provides further distance between upland development and the stream. The minimum width of the middle core is approximately 50 feet, but it is often expanded based on stream order, slope of the presence of critical habitats, and the impact of recreational or utility uses. The vegetative target for this zone is also mature forest, but some clearing is permitted for stormwater management Best Management Practices (BMPs), site access, and passive recreational uses…." (Handbook, p. 11-8)

Zone 3: Also termed the "outer zone," this zone "…is the 'buffer's buffer.' It is an additional 25-foot setback from the outward edge of the middle zone to the nearest permanent structure. In many urban situations, this area is a residential backyard. The vegetative character of the outer zone is usually turf or lawn, although the property owner is encouraged to plant trees and shrubs to increase the total width

of the buffer… The only significant restrictions include septic systems and new permanent structures." (Handbook, p. 11-9)

The Handbook also provides more detailed specifications for riparian forest buffers (Appendix 1), as developed by the USDA's Forest Service.

BMP 5.4.3: Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design



Identify, protect, and utilize the site's natural drainage features as part of the stormwater management system.

Key Design Elements

- Identify and map natural drainage features (swales, channels, ephemeral streams, depressions, etc.)
- Use natural drainage features to guide site design
- Minimize filling, clearing, or other disturbance of drainage features
- Utilize drainage features instead of engineered systems whenever possible
- Distribute non-erosive surface flow to natural drainage features
- Keep non-erosive channel flow within drainage pathways
- Plant native vegetative buffers around drainage features

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: No
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low
Peak Rate Control: Med./High
Water Quality: Medium

Water Quality Functions

TSS: 30%
TP: 20%
NO3: 0%

Description

Most natural sites have identifiable drainage features such as swales, depressions, watercourses, ephemeral streams, etc. which serve to effectively manage any stormwater that is generated on the site. By identifying, protecting, and utilizing these features a development can minimize its stormwater impacts. Instead of ignoring or replacing natural drainage features with engineered systems that rapidly convey runoff downstream, designers can use these features to reduce or eliminate the need for structural drainage systems. Naturally vegetated drainage features tend to slow runoff and thereby reduce peak discharges, improve water quality through filtration, and allow some infiltration and evapotranspiration to occur. Protecting natural drainage features can provide for significant open space and wildlife habitat, improve site aesthetics and property values, and reduce the generation of stormwater runoff. If protected and used properly, natural drainage features generally require very little maintenance and can function effectively for many years.

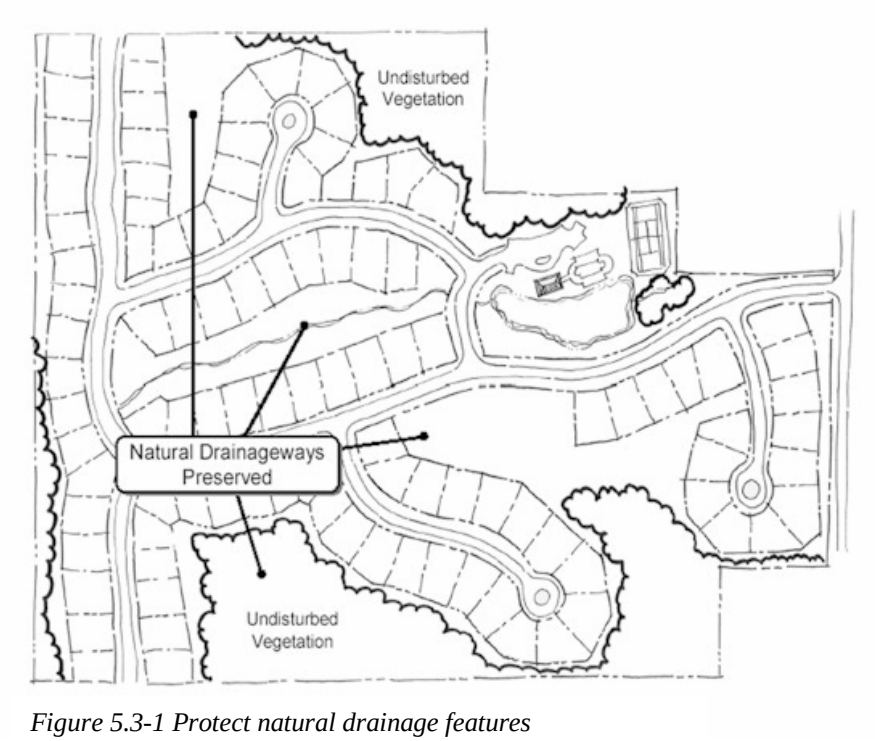


Figure 5.3-1 Protect natural drainage features

Variations

Natural drainage features can also be made more effective through the design process. Examples include constructing slight earthen berms around natural depressions or other features to create additional storage, installing check dams within drainage pathways to slow runoff, and planting additional native vegetation.

Applications

- **Use buffers to treat stormwater runoff.**

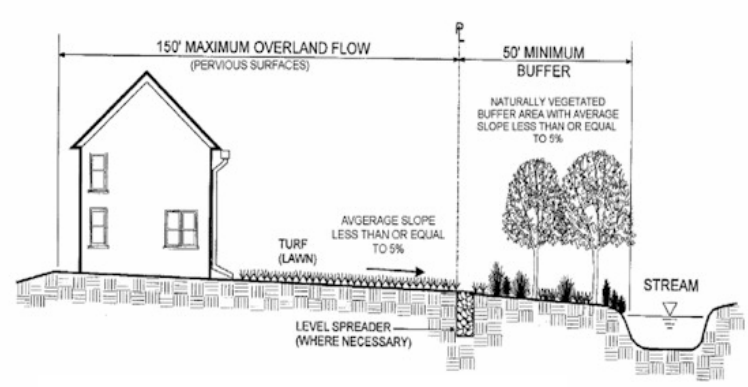


Figure 5.3-2 Section of buffer utilization

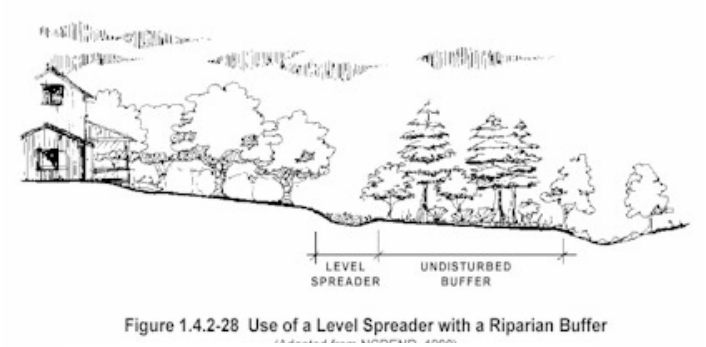


Figure 5.3-3 Section of buffer utilization

- Use natural drainage pathways instead of structural drainage systems

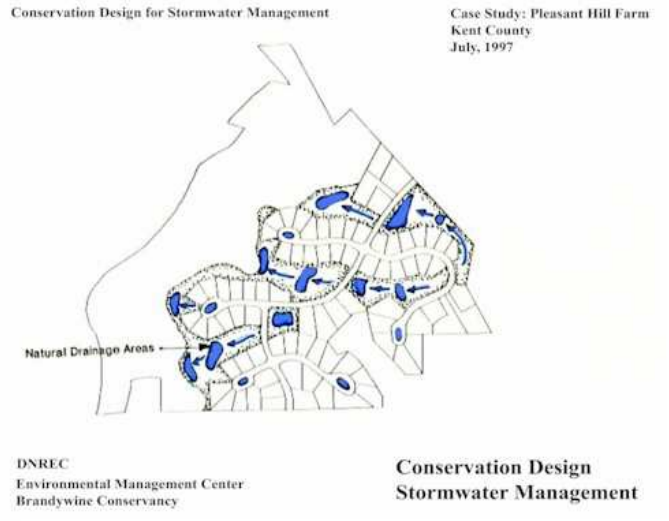


Figure 5.3-4 The natural surface can provide stormwater drainage pathways

- Use natural drainage features to guide site design

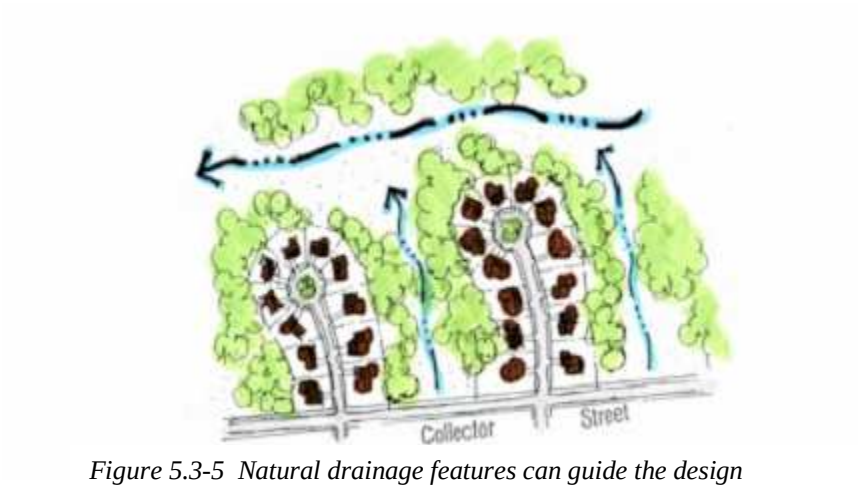


Figure 5.3-5 Natural drainage features can guide the design

- Others…



Figure 5.3-6 Natural surface depressions can temporarily store stormwater.

Design Considerations

1. IDENTIFICATION OF NATURAL DRAINAGE FEATURES. Identifying and mapping natural drainage features is generally done as part of a comprehensive site analysis. This process is an integral part of site design and is the first step for many of the non-structural BMPs described in this Chapter.

2. NATURAL DRAINAGE FEATURES GUIDE SITE DESIGN. Instead of imposing a two-dimensional 'paper' design on a particular site, designers can use natural drainage features to steer the site layout. Drainage features can be used to define contiguous open space/undisturbed areas as well as road alignment and building placement. The design should minimize disturbance to natural drainage features and crossings of them. Drainage features that are to be protected should be clearly shown on

all construction plans. Methods for protection, such as signage and fencing, should also be noted on applicable plans.

3. UTILIZE NATURAL DRAINAGE FEATURES. Natural drainage features should be used in place of engineered stormwater conveyance systems wherever possible. Site designs should use and/or improve natural drainage pathways to reduce or eliminate the need for stormwater pipe networks. This can reduce costs, maintenance burdens, disturbance/earthwork related to pipe installation, and the size of other stormwater management facilities. Natural drainage features should be protected from any increased runoff volumes and rates due to development. The design should prevent the erosion and degradation of natural drainage features through the use of upstream volume and rate control BMPs. Level spreaders, erosion control matting, re-vegetation, outlet stabilization and check dams can also be used to protect natural drainage features, where appropriate.

4. NATIVE VEGETATION. Natural drainage pathways should be provided with native vegetative buffers and the features themselves should include native vegetation where applicable. If drainage features have been previously disturbed, they can be restored with native vegetation and buffers.

Detailed Stormwater Functions

Volume Reduction Calculations
Protecting/utilizing natural drainage features can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the volume of runoff through infiltration and evapotranspiration. This will be self-crediting in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. Utilizing natural drainage features can reduce runoff volumes because natural drainage pathways allow infiltration to occur, especially during smaller storm events. Encouraging infiltration in natural depressions also reduces stormwater volumes. Employing strategies that direct non-erosive sheet flow onto naturally vegetated areas can allow considerable infiltration. See Chapter 8 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations
Protecting/utilizing natural drainage features can reduce the anticipated peak rate of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the runoff rate. This will be self-crediting in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and longer times of travel. Using natural drainage features can lower discharge rates significantly by slowing runoff and increasing on-site storage.

Water Quality Improvement
Protecting/utilizing natural drainage features can improve water quality through filtration, infiltration, sedimentation, and thermal mitigation. See Chapter 8 for Water Quality Improvement methodologies.

Construction Issues

1. At the start of construction, natural drainage features to be protected should be flagged/fenced with signage as shown on the construction drawings.
2. Non-disturbance and minimal disturbance zones should be strictly enforced.
3. Natural drainage features must be protected from excessive sediment and stormwater loads while their drainage areas remain in a disturbed state.

Maintenance Issues

Natural drainage features that are properly protected/utilized as part of site development should require very little maintenance. However, periodic inspections and maintenance actions (if necessary) are important. Inspections should assess erosion, bank stability, sediment/debris accumulation, and vegetative conditions including the presence of invasive species. Problems should be corrected in a timely manner. If native vegetation is being established it may require some support – watering, weeding, mulching, replanting, etc. – during the first few years. Undesirable species should be removed and desirable replacements planted if necessary.

Protected drainage features on private property should have an easement, deed restriction, or other legal measure to prevent future disturbance or neglect. DEP has worked with the Pennsylvania Land Trust Association (PALTA) to develop an easement template with guiding commentary for permanently protecting forest riparian buffers. The model is tailored to protect a relatively narrow ribbon of land along a waterway or lake. Presumably, the riparian buffers will most often comprise lands of severely limited development potential and the landowner will not be seeking a charitable federal income tax deduction.

In preparing the model, it was also assumed that landowners would be receiving no more than a nominal sum for placing the restrictive covenants on their land. To promote landowner donation, the model was drafted to be as brief as possible while providing core protections to forest riparian buffers. The model with guiding commentary is available at http://conserveland.org/model_documents/#riparian PALTA is now offering landowners who use this model a grant of up to $6000 to cover associated costs such as attorney's fees.

Cost Issues

Protecting/utilizing natural drainage features generally results in a significant construction cost savings. Protecting these features results in less disturbance, clearing, earthwork, etc. and requires less re-vegetation. Utilizing natural drainage features can reduce the need and size of costly, engineered stormwater conveyance systems. Together, protecting and utilizing drainage features can reduce or eliminate the need for stormwater management facilities (structural BMPs), lowering costs even more.

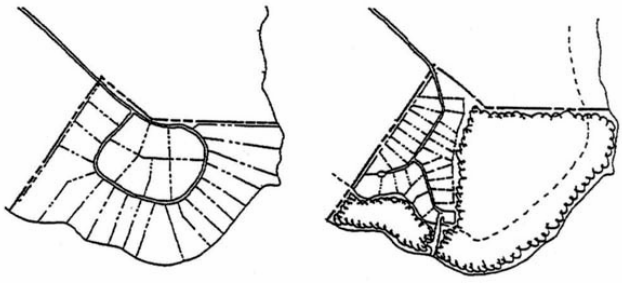
Design costs may increase slightly due to a more thoughtful, site-specific design.

Specifications

Not applicable

5.5 Cluster and Concentrate

BMP 5.5.1: Cluster Uses at Each Site; Build on the Smallest Area Possible



DNREC and Brandywine Conservancy, 1997)

As density is held constant, lot size is reduced, disturbed area is decreased, and undisturbed open space is increased.

Key Design Elements

- Reduce total site disturbance/total site maintenance and increase undisturbed open space by clustering proposed uses on a total site basis through moving uses closer together (i.e., reducing lot size) and/or through stacking uses (i.e., building vertically), even as amount of use (i.e., gross density) is held constant as per existing zoning (or any other gross density determination). As density is held constant (Example A), lot size is reduced, disturbed area decreases, and undisturbed open space increases (Example B).
- Per lot values/prices may decline marginally; however, development costs also decrease.
- Cluster provisions may/may not be allowed by municipal zoning; if no zoning exists, ability to cluster may not be clear (lacking zoning, has the municipality in any way set standards for site uses, gross densities of these uses, etc.?).
- Pending answers to above questions, have lot sizes been reduced to the minimum, given proposed uses? Given existing ordinance provisions? Given other development feasibility factors such as public water/sewer vs. on-site water and sewer and others?
- Is the applicant maximizing clustering as much as possible legally?
- Is the applicant maximizing clustering functionally within municipal ordinance limits?

Potential Applications

Residential: Yes
Commercial: Yes*
Ultra Urban: Limited
Industrial: Limited
Retrofit: Yes
Highway/Road: No

*Depending on site size, constraints and other factors.

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Description

See Key Design Elements.

Variations

- Clustering can be mandated by a municipality as the so-called by-right provision of the zoning district, rather than allowed as a zoning option.

- Density bonus with reduced lot size. In some cases, when lot size is reduced, gross density allowed at the site may be increased, in order to balance what might be lesser values/profitability from smaller lots (Example C). Extent of bonus density is variable, becoming larger as lot size reduction increases (net effect is to always reduce net disturbed area); density bonuses may be made to increase as total undisturbed open space provisions are increased (e.g., for every 10 percent increase in undisturbed open space being provided, density is allowed to increase by 5 percent, and so forth; Example D).

- Extreme Clustering in the form of the Growing Greener 4-Step Design Process which includes: Step 1: Map of Primary and Secondary Conservation Areas; Step 2: Map of Potential Development Area with Yield Plan, calculated as per allowed gross density; Step 3: Map of Street and Trail Connection; Step 4: Map of Lot Lines

Applications

- Residential Clustering:
    - Example A, shown in Figure 5.4-1: The kind of subdivision most frequently created in Pennsylvania is the type which blankets the development parcel with house lots and pays little attention to designing around the special features of the property. In this example, the house placement avoids the primary conservation areas, but disregards the secondary conservation features. Such a sketch can provide a useful estimate of a site's capacity to accommodate new houses at the base density allowed under zoning- and is therefore known as a "Yield Plan."



Figure 5.4-1 Conventional Development, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

- Example B, shown in Figure 5.4-2: Density-neutral with Pre-existing Zoning; 18 lots; Lot Size Range: 20,000 to 40,000 sq. ft.; 50% undivided open space
- Example C, shown in Figure 5.4-3: Enhanced Conservation and Density; 24 lots; Lot Size Range: 12,000 to 24,000 sq. ft.; 60% undivided open space
- Example D, shown in Figure 5.4-4: Hamlet or Village; 36 lots; Lot Size Range: 6,000 to 12,000 sq. ft.; 70% undivided open space

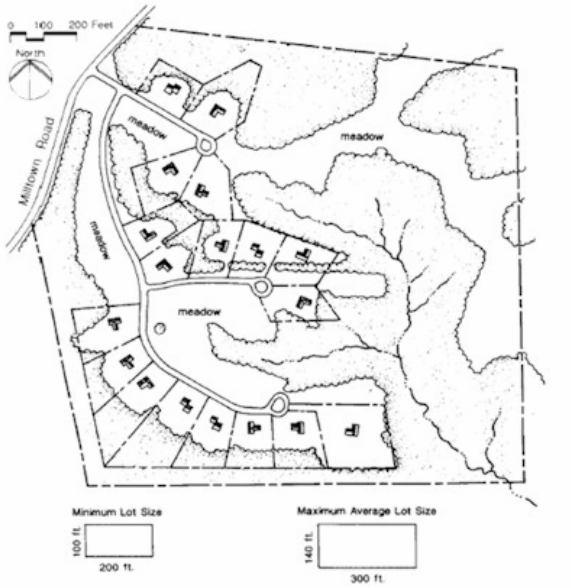


Figure 5.4-2 Clustered Development, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

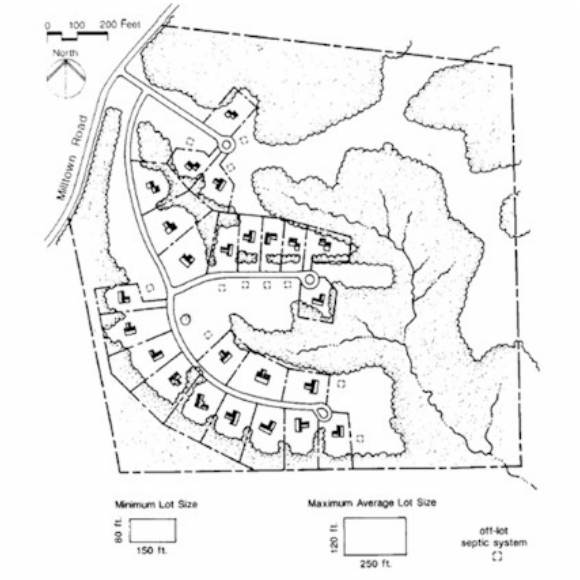


Figure 5.4-3 Modest Density Bonus, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

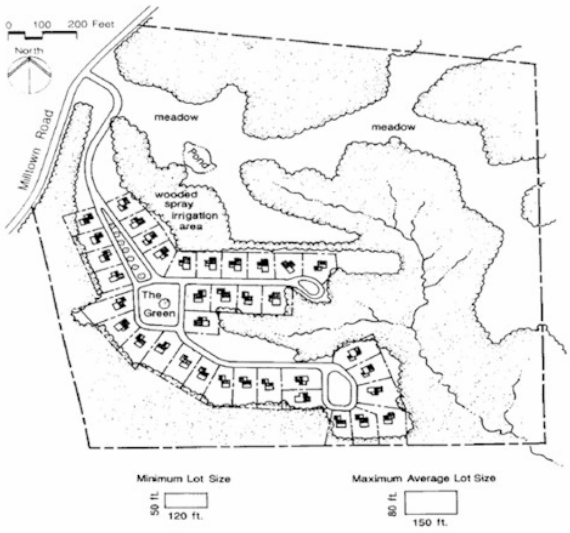


Figure 5.4-4 Hamlet or Village, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

- Non-Residential Clustering:
    - Conventional Development
    - Preferred Vertical Neo-Traditional Development

Design Considerations

Objectives:

- Maximize open space, especially when it includes sensitive areas (primary and secondary).
- Maximize access to open space.
- Maximize sense of place design qualities.
- Balance infrastructure needs (sewer, water, roads, etc.)

Clustering should respond to a variety of site considerations. This BMP discussion assumes that proper and effective work has been undertaken by the municipality to determine the proper site by site land uses and the proper densities/intensities of these land uses. The question is then: *how can X amount of Y uses be best clustered at a particular site*?

Detailed Stormwater Functions

Clustering, as defined here, is self-reinforcing. Clustering reduces total impervious areas, including street lengths and total paved area and is likely to link with other BMPs, as defined in this Chapter, including reduced imperviousness, reduced setbacks, reduced areas for drives and walkways, and so forth. All of this directly translates into reduced volumes of stormwater being generated and reduced peak rates of stormwater being generated, thereby benefiting stormwater planning. Additionally, clustering translates into reduced disturbance and increased preservation of the natural landscape and natural vegetative land cover, which further translates into reduced stormwater runoff, volume and peak. To the extent that this clustering BMP also involves increased vertical development, net site roof area and impervious area is reduced, holding number of units and amount of square footage of a use constant. In all cases, density bonuses, if utilized, should be scrutinized to make sure that additional density allowed is more than balanced by additional open space being provided, including further reductions in street lengths, other impervious surfaces, other disturbed areas, and so forth.

Water quality is affected by non-point source pollutant load from impervious areas, as well as the pollutant load from the newly created maintained landscape, much of which is soluble in form (especially fertilizer-linked nitrogen forms). Clustering, alone and when combined with other Chapter 5 Non-Structural BMPs, minimizes impervious areas and the pollutant loads related to these impervious areas. Similarly, clustering minimizes pollutant loads from lawns and other mowed areas. After Chapter 5 BMPs are optimized, “unavoidable” stormwater is then directed into BMPs as set forth in Chapter 6, to be properly treated. Chemical pollution prevention accomplished through Non-Structural BMPs is especially important because Structural BMPs remain poor performers in terms of mitigating/removing soluble pollutants that are especially problematic in terms of this pervious maintained landscape. See Appendix A for additional documentation of the water quality benefits of clustering.

See Chapter 8 for volume reduction calculation work sheets, peak rate reduction calculation work sheets, and water quality mitigation work sheets.

Construction Issues

Application of this BMP clearly is required from the start of the site planning and development process. Not only must the site owner/builder/developer embrace BMP 5.5.1 Cluster Uses at Each Site from the

start of the process, the respective municipal officials must have included clustering in municipal codes and ordinances, as is the case with so many of these Chapter 5 Non-Structural BMPs. Any areas to be protected from development must be clearly marked in the field prior to the beginning of construction.

Maintenance Issues

As with all Chapter 5 BMPs, maintenance issues are of a different nature and extent then the more specific Chapter 6 Structural BMPs. Typically, the primary issue is "who takes care of the open space?" Legally, the designated open space may be conveyed to the municipality, although most municipalities prefer not to receive these open space portions, including all of the maintenance and other legal responsibilities associated with open space ownership. Ideally, open space reserves will merge to form a unified open space system, integrating important conservation areas throughout the municipality and beyond. In reality, these open space segments may exist dispersed and unconnected for a considerable number of years. For those Pennsylvania municipalities that allow for and enable creation of homeowners associations or HOA's, the HOA, may assume ownership of the open space. The HOA is usually the simplest solution to the "who takes care of the open space" question.

In contrast to some of the other long-term maintenance responsibilities of a new subdivision and/or land development (such as maintenance of streets, water and sewers, play and recreation areas, etc.), the maintenance requirements of "undisturbed open space" should be minimal. The objective here is conservation of the natural systems already present, with minimal intervention and disturbance. Nevertheless, invariably some legal responsibilities must be assumed and need to be covered.

Cost Issues

Clustering is beneficial from a cost perspective in several ways. Costs to build a single-family residential development is less when clustered than when not clustered, holding the home type and all other relevant infrastructure constant. Costs are decreased because of less land clearing and grading, less road construction (including curbing), less sidewalk construction, less lighting and street landscaping, potentially less sewer and water line construction, potentially less stormwater collection system construction, and similar savings.

Clustering also reduces post construction costs. A variety of studies from the landmark *Costs of Sprawl* study and later updates have shown that delivery of a variety of municipal services such as street maintenance, sewer and water services, and trash collection are more economical on a per person or per house basis when development is clustered. Even services such as police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values. Analyses of market prices over time of conventional development in contrast with comparable residential units in clustered developments have indicated that clustered developments with their proximity to permanently protected open space increase in value at a more rapid rate than conventionally designed developments, even though clustered housing occurs on considerably smaller lots than the conventional residences.

Specifications

Clustering is not a new concept and has been defined, discussed, and evaluated in many different texts, reports, references, sources, as set forth below.

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BMP 5.5.2: Concentrate Uses Area wide through Smart Growth Practices

On a municipal, multi-municipal or areawide basis, use of "smart growth" planning techniques, including neo-Traditional/New Urban planning principles, to plan and zone for concentrated development patterns can accommodate reasonable growth and development. These practices direct growth to areas or groups of parcels in the municipality that are most desirable and away from areas or groups of parcels that are undesirable. BMP 5.5.2 can be thought of as Super Clustering that transcends the reality of the many different large and small parcels that exist in most Pennsylvania municipalities. Clustering parcel by parcel simply cannot accomplish the growth management that is so essential to conserve special environmental and cultural values and protect special sensitivities. These smart growth techniques include but are not limited to, transfer of development rights (TDR), urban growth boundaries, effective agricultural zoning, purchase of development rights (PDR) by municipalities, donation of conservation easements by owners, limited development and bargain sales by owners, and other private sector landowner options. "Desirability" is defined in terms of environmental, historical and archaeological, scenic and aesthetic, "sense of place," and quality of life sensitivities and values.

Key Design Elements

- Establish baseline growth and development context for the municipality or multi-municipal area (how much of what by when and where, using decade increments, plus ultimate build out).
- On macro level (defined as municipality-wide, multi-municipality-wide, areawide), define criteria for growth "desirability" (opportunities) and "undesirability" (constraints) on a multi-site and/or municipality-wide and/or areawide basis.
- Apply these "desirability" and "undesirability" criteria.
- Contrast baseline growth and development (first step) with third step; highlight problems.
- Apply smart growth techniques as needed to re-form "business as usual" future to max out "desirability" and "undesirability" performance. Techniques include: transfer of development rights (TDR), urban growth boundaries, effective agricultural zoning, purchase of development rights (PDR), donation of conservation easements by owners, limited development and bargain sales by owners, and other private sector landowner options.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Variations

Because of the broadness of this BMP and its macro scale, variations in this BMP can be substantial. Variations include: 1) how areas deemed to be desirable for growth are defined, whether clusters, hamlets, villages, towns and/or cities; 2) how areas deemed undesirable for growth are defined (conserving natural resources, agricultural lands and other vital resources); and 3) how any of this is made to happen and what blend of smart growth techniques can be applied (where and when) to implement 1 and 2.

1. Defining Desirable Growth – Opportunities for Growth: Clusters, Hamlets, Villages, Towns and Cities

The vision for growth and development can take many different forms and can vary substantially depending upon the respective municipality, group of municipalities, or area. Rural areas (Figure 5.5-1) striving to preserve their rural character can concentrate development through adherence to building onto or even creating Hamlets and Villages. If adjacent communities exist, development can be directed into the town or at the town edge (Figure 5.5-2). Clustering (see BMP 5.5.1) on a site-by-site basis is superior from a site perspective but yields a pattern that is less than optimal from a multi-site or area wide perspective (Figure 5.5-3). However, this overall pattern is vastly preferable to the business as usual approach across many different sites comprising the entire area (Figure 5.5-4).



Figure 5.5-1 Rural landscape of Pennsylvania

Areas already developed and urbanized are likely to define appropriate in-fill development and re-development at higher densities. Multiple community planning sources with specific community building standards and specifications are available for reference. The importance of careful definition of growth zones and the performance standards that define these growth zones cannot be overemphasized. Often this BMP has been driven by environmental conservation objectives such as saving the undesirable growth areas (Sending Zones in TDR parlance) as discussed below but every bit as much care must be taken in defining and planning the desirable growth areas (Receiving Zones).



Figure 5.5-2 Use of TDR to protect rural landscapes and direct development into the Town or Town Edge



Figure 5.5-3 Site clustering provides a partial open space network, though less than that provided by TDR



Figure 5.5-4 Large lot zoning ignores natural and cultural resource values.

2. Defining Undesirable Growth Areas – Constraints: High Value Watershed Areas, Agricultural Areas, Eco-Sensitive Habitat Areas, Headwaters, and Stream Designations

Criteria used by a municipality or area for managing development may be expected to vary to some extent. Municipalities may include special watershed areas, which have Pennsylvania Code Chapter 93 Special Protection Waters designation (Exceptional Value and High Quality), as well as critical headwater (first order streams) portions of watersheds. Source Water Protection zones may exist, including areas of especially important groundwater recharge, or habitat areas where the Pennsylvania Natural Diversity Inventory (PNDI) indicates especially important species presence. Also, important wetlands, floodplains and other natural features may exist. Prime Agricultural Lands and Agricultural Security Districts may be deserving of conservation. Areas may be especially sensitive due to rugged topography or steep slopes. Areas may be sensitive due to richness of historical and archaeological and even scenic values. All of these important values are likely to extend well beyond individual parcel boundaries and require smart growth area wide growth management techniques.

3. Mixing and Matching Smart Growth Techniques: Public and Private

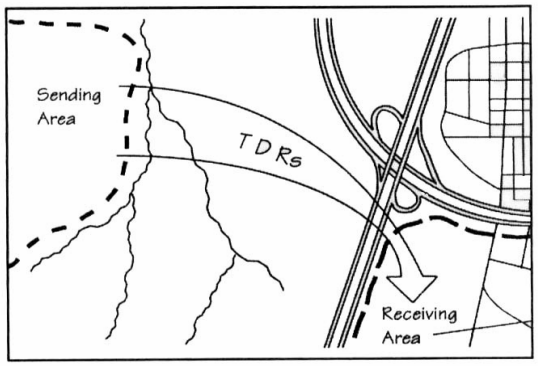
If a municipality consists of only a handful of enormous parcels where BMP 5.5.1 Clustering can work together to achieve the areawide "desirable growth" and "undesirable growth" patterns for the entire municipality as described above, BMP 5.5.2 would be made unnecessary. Such is usually not the case. A municipality may decide to use all or most of the smart growth techniques discussed here. A municipality may decide that "less is more" and try to achieve its objectives with the most simple growth management program possible, using the fewest techniques. The blend of public techniques versus private techniques is also important. Most of what is involved here entails public sector management action, such as zoning ordinance provisions. A few municipalities in Pennsylvania (West Marlborough, Chester County) have achieved municipality-wide success through private landowner actions, such as voluntary donation of conservation easements to conservancies and land trusts.

The optimal blend of smart growth techniques is not easily determined. Each technique has pros and cons, in terms of technical effectiveness, ease of implementation, political and socioeconomic implications, and integration with the local culture. Municipalities may decide to hire a local planning consultant (contact the Pennsylvania Planning Association for additional references), or may decide to consult with a free or low cost information resource such as the Pennsylvania Environmental Council or 10,000 Friends of Pennsylvania. The direct state government agency contact is the Pennsylvania Department of Community and Economic Development. These organizations and agencies offer a variety of planning resources by providing information on smart growth techniques and their potential usefulness in any one particular municipal setting. The organizations' respective websites should be consulted for more detailed information.

Applications

Transfer of Development Rights (TDR)

Transfer of Development Rights (TDR, see Figure 5.5-5) is allowed as an option in Pennsylvania under the Municipalities Planning Code. TDR creates an overlay (Sending Zone) in the zoning ordinance where property owners are allowed to sell development rights for properties where growth is deemed to be less than desirable for any number of reasons. In a second created overlay zone (Receiving Zone), these development rights that have been purchased may be used to increase development density, above the maximum baseline or conventional zoned density. TDR has been in existence for some years and has been used by a relatively small number of Pennsylvania municipalities, although it has been used more widely in New Jersey and several other states. Although TDR is created in the municipal zoning ordinance, all TDR transactions or transfers of development rights may occur within the private sector, between Sending Zone owners and Receiving Zone purchasers or developers. TDR has been used in Buckingham Township (Bucks County), West Bradford and West Vincent Townships (Chester County), Manheim and Warwick Townships (Lancaster County).

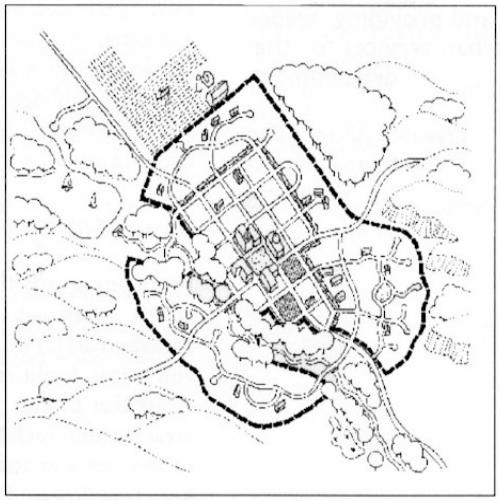


Source: Maryland Office of Planning

Figure 5.5-5 Example of Transfer of Development Rights

Growth Boundaries:

Growth Boundaries (Urban Growth Boundaries, see Figure 5.5-6) are based on the concept that infrastructure such as public road systems and public water and wastewater treatment systems have a powerful growth inducing and growth shaping influence on an area wide basis. By controlling the location and timing of this infrastructure through municipal or public sector action, municipalities can encourage development in certain areas and discourage development in others. Growth Boundaries define where municipalities will directly and indirectly encourage, and even provide infrastructure services, significantly increasing zoned densities. Areas lacking such infrastructure services are zoned at significantly decreased densities. The State of Oregon has been a leading advocate of Growth Boundaries. Lancaster County for some years has been applying Growth Boundary principles in its comprehensive planning (go to their website to the annual Growth Tracking reports which document how their planning is achieving Growth Boundary objectives).



Source: Greenbelt Alliance

Figure 5.5-6 Example of Urban Growth Boundary

Effective Agricultural Zoning:

Large lot zoning (usually defined as zoning that requires average lot size to be greater than 2 acres per lot) has been rejected by Pennsylvania courts as exclusionary and unacceptable. However, very large minimum lot size to maintain existing agricultural uses has been deemed to be acceptable by Pennsylvania courts and is being practiced throughout Pennsylvania, especially in intensive agricultural communities in southcentral Pennsylvania (e.g., multiple municipalities in Adams, Berks, Chester, Lancaster, York, etc.). Effective agricultural zoning may take the form of a specified mapped zoning category with a minimum lot size of 10,15, 20, or 25 acres (this varies). Sliding scale agricultural

zoning is a popular variation, where additional lots to be created and subdivided are a function of the size of the total agricultural tract (though gross density remains very low). The intent is to allow a small number of lots to be created over time, possibly for family members or for agricultural workers, but to keep the functioning farms as intact as possible without residential subdivision or any other development intrusion. The concept here is that the so-called "highest and best use of the land" is agricultural use, which will be best maintained through protection of the farming community and through this very low-density zoning. Application of Agricultural Zoning has been restricted to areas where agriculture can be defined explicitly, typically in the presence of prime farmland soils, intensive agricultural activity, formation of Agricultural Security Districts, or other indicators of important agricultural activity. Obviously, this smart growth technique has limited application in terms of a growth management technique.

Purchase of Development Rights:
Similar to TDR, the concept of Conservation Easements hinges on the notion that development rights for any particular property can be defined and separated from a property. These development rights can then be purchased and in a sense retired from the open market. The Pennsylvania Farmland Preservation Program, which purchases development rights from existing agricultural owners and allows farmers to continue their ownership and their agricultural activities, has become one of the most successful agricultural preservation programs in the country. This program is highly competitive and obviously limited to agricultural properties and contexts. The Farmland Preservation Program is a priority of the current administration, will continue to be funded, and has been reinforced in several counties with county-funded farmland preservation programs in order to stretch the state dollars.

Some counties (Bucks, Chester, Montgomery Counties) and municipalities (North Coventry, East Bradford, Pennsbury, Solebury, West Vincent and others) have enacted special open space and recreation acquisition programs. They are funded in various ways (bond issues, real estate taxes, small payroll taxes) to purchase additional county-owned and municipality-owned lands, for use as active and passive recreation as well as open space conservation. These efforts can be used in conjunction with TDR programs, whereby a municipality funds a revolving fund-supported land development bank which purchases development rights from vulnerable and high priority properties in Sending Zones. It later sells these development rights (Warwick Township in Lancaster County has done this) to Receiving Zone developers.

Conservation Easements (Donation and Purchase): Brandywine Conservancy, Natural Lands Trust, Western Pennsylvania Conservancy, Others
Similar to TDR, the concept of Conservation Easements hinges on the notion that development rights for any particular property can be defined and separated from a property. These development rights can then be donated to an acceptable organization to support the public's health, safety and welfare, in the form of a conservation easement which restricts the owner's ability to develop the property in perpetuity, regardless of municipal zoning. Historically, a major incentive for these conservation easement donations has been the major tax benefits afforded such donations. Organizations such as the Brandywine Conservancy, Natural Lands Trust, the Western Pennsylvania conservancy and many others have protected thousands of acres of otherwise developable property in Pennsylvania through privately donated conservation easements, with absolutely no public expenditure of funds. Brandywine's 30,000 acres of conservation easements in the Brandywine Creek Watershed is an excellent case in point. Municipalities such as West Marlborough Township in Chester County have large portions of their jurisdictions permanently conserved as the result of this Conservation Easement program. Conservation Easements also can be purchased by a conservation organization or government agency. National organizations such as the Nature Conservancy, the Trust for Public Land, the Land Trust Alliance, and others are active in Pennsylvania and are excellent sources of technical information relating to this smart growth technique. In parts of Pennsylvania, these larger

organizations are helping fledgling local land trusts form and begin their important work of land conservation.

Bargain Sale/Limited Development Options:
A variation on the donation of development rights through conservation easements is a "bargain sale," where a portion of the development rights value is donated (in the manner described above) but the property owner still enjoys a return on his/her property. In any number of development-pressured municipalities in Pennsylvania, fair market value for a large 100-acre farm to be developed as single-family residences or some other use may reach 2 or 3 million dollars. The owner, beyond tax benefits, may need a monetary settlement, though not in the order of 2 to 3 million dollars. In such cases, a defined "bargain sale" might be arranged if a source of funds can be located to provide a partial financial settlement for the owner. The owner benefits from an approved donation of the remainder of the value that can reduce the owner's tax bill. The property is conserved.

A further variation would be a limited development option wherein a substantially reduced development program is developed which conserves much if not most of the property in question. An existing farmstead or homestead is retained and the property owner may even retain this farmstead/homestead. A much smaller number of lots surrounded by open space is carefully created; these lots typically command a considerably higher value than would be the case for a conventional subdivision. A large amount of open space is created and protected through a conservation easement, which may be donated as well, providing further tax benefit. The outcome is that the property owner, after taxes, may be almost as well off after a Limited Development approach to the property than would be the case with a complete conventional "as of right" approach to development. If the Limited Development concept has been prepared carefully, total property disturbance can be substantially reduced.

Sustainable Watershed Management and Water-Based Zoning: Green Valleys Association and the Brandywine Conservancy

Design Considerations:

Objectives for BMP 5.5.2 resemble BMP 5.5.1, although they must be understood as municipality-wide, rather than just site-wide:

- Maximize open space, especially sensitive areas (primary and secondary) and areas of special value.
- Maximize "sense of place" design qualities where growth is desirable.
- Balance infrastructure needs (sewer, water, roads, etc.) and use infrastructure to shape desirable growth

BMP 5.5.2 relies on application of smart growth techniques. The specific optimal blend of these smart growth techniques should respond to a variety of municipality characteristics and considerations. This BMP discussion assumes that proper and effective work has been undertaken by the municipality to determine the proper land uses and the proper densities/intensities of these land uses, municipality-wide. The question is then: how can these uses – this future development - be best planned within the municipality, achieving the best and most livable communities for the future, even as disruption to the natural landscape is minimized?

Detailed Stormwater Functions

Concentrating growth, as defined here, is self-reinforcing from a stormwater management perspective – in terms of peak rate reduction, runoff volume reduction, and nonpoint source load reduction. Concentrating growth reduces total impervious areas and is likely to link with other BMP's in this Section, including reduced imperviousness, reduced setbacks, reduced areas for drives and walkways, etc. All of this directly translates into reduced volumes of stormwater being generated and reduced peak rates of stormwater being generated, thereby benefiting stormwater planning. Additionally, concentrating growth translates into reduced disturbance and increased preservation of the natural landscape and natural vegetative land cover, which further translates into reduced stormwater runoff. To the extent that this BMP also involves increased vertical development, net site roof area and impervious area is reduced, holding number of units and amount of square footage of a use constant. In all cases, density bonuses, if utilized in Receiving Zones, should be scrutinized to make sure that additional density allowed is more than balanced by additional open space being provided, including further reductions in street lengths, other impervious surfaces, other disturbed areas, and so forth. If properly implemented, these smart growth techniques such as TDR and Growth Boundaries will almost always translate into reduced total disturbed area and reduced total impervious area, even more dramatically than non-structural techniques such as clustering.

Documentation of the positive water quality effects of area wide growth concentration, holding total growth and development constant, is provided by the City of Olympia's (Washington) *Impervious Surface Reduction Study: Final Report 1995*. Holding population projected to 2015 constant, two dramatically different scenarios of land development (a baseline pattern of low density unconcentrated development reflecting recent development trends versus a concentrated pattern of increased density development in and near existing developed areas) were defined. These were mapped (Figure 5.5-7) and tested for a variety of stormwater-related impacts (total impervious area, total disturbed area, stormwater generation, non-point source pollutant generation). The analysis results indicated that the concentrated development scenario significantly reduced total impervious area. This was due to significant reductions in impervious surfaces being created in outlying rural and low density areas and more efficient utilization of impervious surfaces already created in areas of existing development. Other studies focusing on concentrated growth patterns have similarly confirmed these relationships and further documented a reduction in total disturbed areas created, stormwater being generated, and total non-point source pollutant loads being generated.

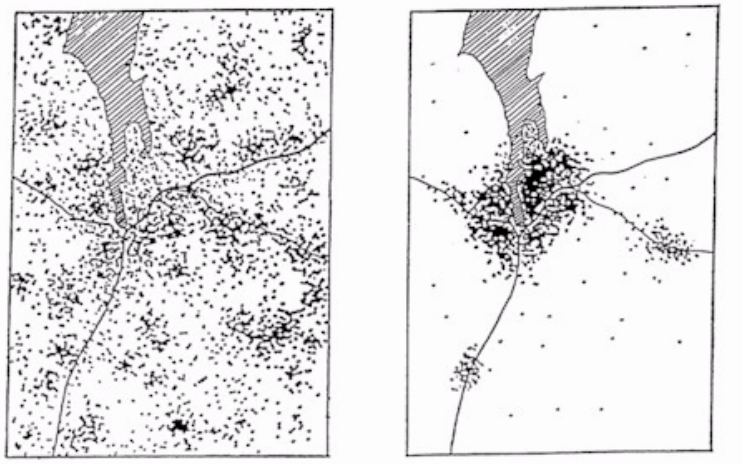


Figure 5.5-7 Dispersed versus Concentrated Development at the Regional Scale, (Source: "Impervious Surface Reduction Study", City of Olympia, 1995)

As stated above in BMP 5.5.1, water quality issues include all the non-point source pollutant load from impervious areas, a well as all the pollutant load from the newly created maintained landscape (i.e., lawns and other), much of which is soluble in form (especially fertilizer-linked nitrogen forms). Concentrating growth as defined in BMP 5.5.2, and combined with other Chapter 5 Non-Structural BMP's, minimizes impervious areas and the pollutant loads related to these impervious areas. After Chapter 5 BMP's are optimized, "unavoidable" stormwater is then directed into BMP's as set forth in Chapter 6, to be

properly treated. Similarly, for all that non-point source pollutant load generated from the newly-created maintained landscape and combined with other Chapter 5 Non-Structural BMP's, minimizes pervious areas and the pollutant loads related to these pervious areas, thereby reducing the opportunity for fertilization and other chemical application. Prevention of water quality degradation accomplished through Non-Structural BMP's in Chapter 5 is especially important because Chapter 6 Structural BMP's remain poor performers in terms of mitigating/removing soluble pollutants that are especially problematic in terms of this pervious maintained landscape. See Appendix A for additional documentation of the water quality benefits of clustering.

See Chapter 8 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

Construction Sequence

Application of this BMP must be undertaken by the municipality and must precede the start of any individual site planning and development process. In most cases, the municipality must take action in its comprehensive plan and then in its zoning and SLDO to incorporate the optimal blend of these smart growth techniques in their respective municipal planning and growth management program (the proactive municipality may act further to program for use of conservation easements, creation of a local land trust, and the like). At the same time, the site owner/builder/developer may elect to embrace options set forth in BMP 5.5.2 Concentrate Uses Area wide from the start of the process. Use of conservation easement donation, bargain sale or limited development all require careful consideration by the site owner/builder/developer from the beginning of the site development process.

Maintenance Issues

Very few maintenance problems or issues are generated by BMP 5.5.2. Because most of these smart growth techniques are preventive in nature and in fact translate into maximum retention of undisturbed open space and the natural features contained within this open space, typically in private ownership, specific maintenance requirements as defined in a conventional manner are extremely limited, if not nonexistent.

Cost Issues

According to Delaware's recent *Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development*, application of the municipality-wide or areawide smart growth techniques will require some additional costs. Application of an optional TDR program or Growth Boundary program could cost a municipality in technical planning fees, including incorporation into the comprehensive plan and zoning ordinance (other costs may be required as well). Although it is hard to specifically document, a program of structural BMP's which mitigate adverse impacts of land development and achieve the same level of water resource (quantity and quality) performance throughout the municipality and its respective watershed areas becomes much more difficult to achieve, and much more expensive when all development and all lots are tallied. Prevention is simply much more cost effective.

Furthermore, BMP 5.5.2's preventive smart growth techniques, when fully applied, achieve a level of performance that exceed even the best structural BMP's. This clearly demonstrates why non-structural BMP's are important for all Pennsylvania watersheds, but especially important for Special Protection Waters where High Quality and Exceptional Value designations call for extremely high levels of water resource protection. In these cases, significant amounts of development watershed-wide, even

assuming use of Chapter 6 structural BMP's, may fail to provide the water resource protection which is needed to sustain special Protection Waters' values over the long-term.

Specifications

BMP 5.5.2 is not a new concept and has been defined, discussed, and evaluated in many different texts, reports, references, sources, as set forth below. More specifications for clustering can be found in references that are included in above discussions.

5.6 Minimize Disturbance and Minimize Maintenance

BMP 5.6.1: Minimize Total Disturbed Area - Grading



Without changing the building program, you can reduce site grading, removal of existing vegetation (clearing and grubbing) and total soil disturbance. This eliminates the need for re-establishment of a new maintained landscape for the site and lot-by-lot, by modifying the proposed road system and other relevant infrastructure as well as the building location and elevations to better fit the existing topography.

Key Design Elements

- Identify and avoid special value and environmentally sensitive areas
- Minimize overall disturbance at the site
- Minimize disturbance at the individual lot level
- Maximize soil restoration to restore permabilities
- Minimize construction-traffic locations
- Minimize stockpiling and storage areas

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Limited
Highway/Road: Limited

Stormwater Functions

Volume Reduction: High
Recharge: High
Peak Rate Control: High
Water Quality: High

Water Quality Functions

TSS: 40%
TP: 0%
NO3: 0%

Description

This Non-Structural BMP assumes that the special value and sensitive resource areas have been identified on a given development parcel and have been protected, and that clustering and area wide concentration of uses also have been considered and included in the site design. All of these BMPs serve to reduce site grading and to minimize disturbance/minimize maintenance. This BMP specifically focuses on how to minimize the grading and overall site disturbance required to build the desired program while maximizing conservation of existing site vegetation.

Reduction of site disturbance by grading can be accomplished in several ways. The requirements of grading for roadway alignment (curvature) and roadway slope (grade) frequently increase site disturbance throughout a land development site and on individual lots. Most land development plans are formulated in 2-dimensional plan, based on the potential zoned density, and seldom consider the constraints presented by topographic variation (slope) on the site. The layout and design of internal roadways on a land development site with significant topographic variation (slope) can result in extensive earthwork and vegetation removal (i.e., grading). Far less grading and a far less disruptive site design can be accomplished if the site design is made to better conform with the existing topography and land surface, where road alignments strive to follow existing contours as much as possible, varying the grade and alignment criteria as necessary to comply with safety limits.

Site design criteria have evolved in municipalities to make sure that developments meet safety standards (sight distance, winter icing, and so forth) as well as certain quality or appearance standards. A common perception among municipal officials is that little deviation should be allowed in order to maintain the integrity of the community. In fact, roadway design criteria should be made flexible in order to better fit a given parcel and achieve a more “fluid” roadway alignment. The avoidance of sensitive site features, such as important woodlands, may be facilitated through flexible roadway layout. Additionally, rigorous parcel criteria (front footage, property setbacks, etc.) often add to this “plane geometry” burden. Although the rectilinear grid layout is the most efficient in terms of maximizing the number of potential lots created at a development site, the end result is a “cookie cutter” pattern normally found in residential sites and the “strip” development found in most highway commercial districts, all of which are apt to translate into significant resource loss.



Figure 5.6-1 Residential Area with Disturbance Minimized

From the perspective of a single lot, the municipally-required conventional lot layout geometry can also impose added earthwork and grading that could be avoided. Lot frontage criteria, yard criteria, and driveway criteria force the placement of a structure in the center of every lot, often pushed well back from the roadway. Substantial terracing of the lot with added grading and vegetation removal is required in many cases. Although the intent of these municipal requirements is to provide privacy and spacing between units, the end result is often totally cleared, totally graded lots, which can be visually monotonous. Configuring lots in a rectilinear shape may optimize the number of units but municipalities should require that the site design in total should be made to fit the land as much as possible.

Municipal criteria that impose road geometry are usually contained within the subdivision and land development ordinance (SALDO), while densities, lot and yard setbacks, and minimum frontages are usually contained in the zoning ordinance. Variations in these land development standards should be

accepted by the local government where appropriate, which should modify their respective ordinances. Municipalities should consider being more flexible without compromising public safety in terms of:

- Road vertical alignment criteria (maximum grade or slope).
- Road horizontal alignment criteria (maximum curvature)
- Road frontage criteria (lot dimensions)
- Building setback criteria (yards dimensions)

Related Non-Structural BMPs, such as road width dimensions, parking ratios, impervious surface reduction, chemical maintenance of newly created landscapes, and others are discussed as separate BMPs in this Chapter, though are all substantially interrelated.

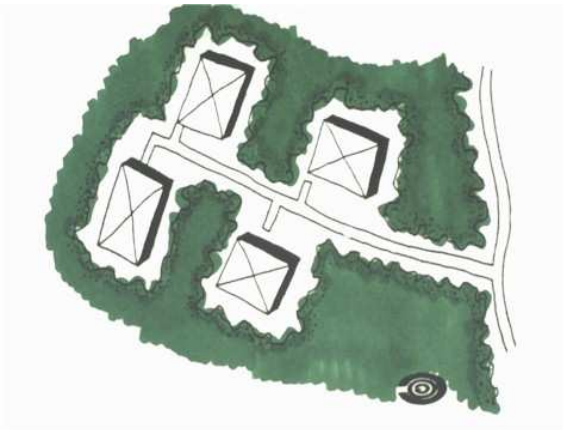


Figure 5.6-2 Minimally Disturbed Development

Detailed Stormwater Functions

Volume Reduction Calculations: Minimizing Total Disturbed Area can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the anticipated volume of runoff through increased infiltration and increased evapotranspiration. This practice will be self-crediting in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. Minimizing Total Disturbed Area can reduce anticipated runoff volumes because undisturbed areas of existing vegetation allow more infiltration to occur, especially during smaller storm events. Furthermore, employing strategies that direct non-erosive sheet flow onto naturally vegetated areas can allow considerable infiltration to occur and can be coupled with level spreading devices (see Chapter 6) and possibly other BMPs to more actively manage stormwater that cannot be avoided. In other words, Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) not only prevents increased stormwater generation (a volume and peak issue), but also offers an opportunity for managing stormwater generation that cannot be avoided. See Chapter 8 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations: Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) can reduce the peak rate of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the runoff rate. This will be self-crediting in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and longer times of travel. Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) can lower discharge rates significantly by slowing runoff and increasing on-site storage.

Water Quality Improvement: Minimizing Total Disturbed Area can improve water quality preventively by reducing construction phase sediment-laden runoff. Water quality benefits also by maximizing preservation of existing vegetation at a site (e.g., meadow, woodlands) where post-construction maintenance including application of fertilizers and pesticides/herbicides is avoided. Given the high rates of chemical application which have been documented at newly created maintained areas for both residential and non-residential land uses, eliminating the opportunity for chemical application is important for water quality – perhaps the most effective management technique. In terms of water quality mitigative functions, Minimizing Total Disturbed Area provides filtration and infiltration opportunities, assuming that undisturbed areas are being used to manage

stormwater generated elsewhere on the development site, as well as thermal mitigation. See Chapter 8 for Water Quality Improvement methodologies.

Design Considerations

During the initial conceptual design phase of a land development project, the applicant's design engineer should provide the following information, ideally through development of a Minimum Disturbance/Minimum Maintenance Plan:

1. Identify and Avoid Special Value/Sensitive Areas (see BMP 5.4.1)



Figure 5.6-3 Woodlands Protected through Minimum Disturbance Practices

Delineate and avoid environmentally sensitive areas (e.g., Primary and Secondary Conservation areas, as defined in BMP 5.4.1); delineation of Woodlands, broadly defined to include areas of immature and mixed tree growth, is especially important; configure the development program on the balance of the parcel (i.e., Development Areas as discussed in BMP 5.4.1).

2. Minimize Disturbance at Site

Modify road alignments (grades, curvatures, etc.), lots, and building locations to minimize grading, earthwork, overall site disturbance, as necessary to maintain safety standards. Minimal disturbance design shall allow the layout to best fit the land form without significant earthwork. The limit of grading and disturbance should be designated on the plan documentation submitted to the municipality for review/approval, and should be physically designated at the site during construction by flagging, fencing, or other methods.

3. Minimize Disturbance at Lot

Limit lot grading to roadways and building footprints. Municipalities should establish Minimum Disturbance/Minimum Maintenance Buffers, designed to be rigorous but reasonable in terms of current feasible site construction practices. These standards may need to vary with the type of development being proposed and the context of that development (the required disturbance zone around a low density single-family home can be expected to be less than disturbance necessary for a large commercial structure), given the necessity for use of different types of construction equipment and the realities of different site conditions. For example, the U.S. Green Building Council's Leadership in Energy & Environmental Design Reference Guide (Version 2.0 June 2001) specifies the following:

"…limit site disturbance including earthwork and clearing of vegetation to **40 feet** beyond the building perimeter, **5 feet** beyond the primary roadway curbs, walkways, and main utility branch trenches, and **25 feet** beyond pervious paving areas that require additional staging areas in order to limit compaction in the paved area…"

Municipalities in New Jersey's Pinelands Preservation Zone for years have supported ordinances where limits are more restrictive than the LEED footages (e.g., clearing around single-family homes is reduced to 25 feet). Again, such requirements can be made to be flexible with special site factors and conditions. The limit of grading and disturbance should be designated on the plan documentation submitted to the municipality for review/approval, and should be physically designated at the lot during construction by flagging, fencing or other marking techniques.

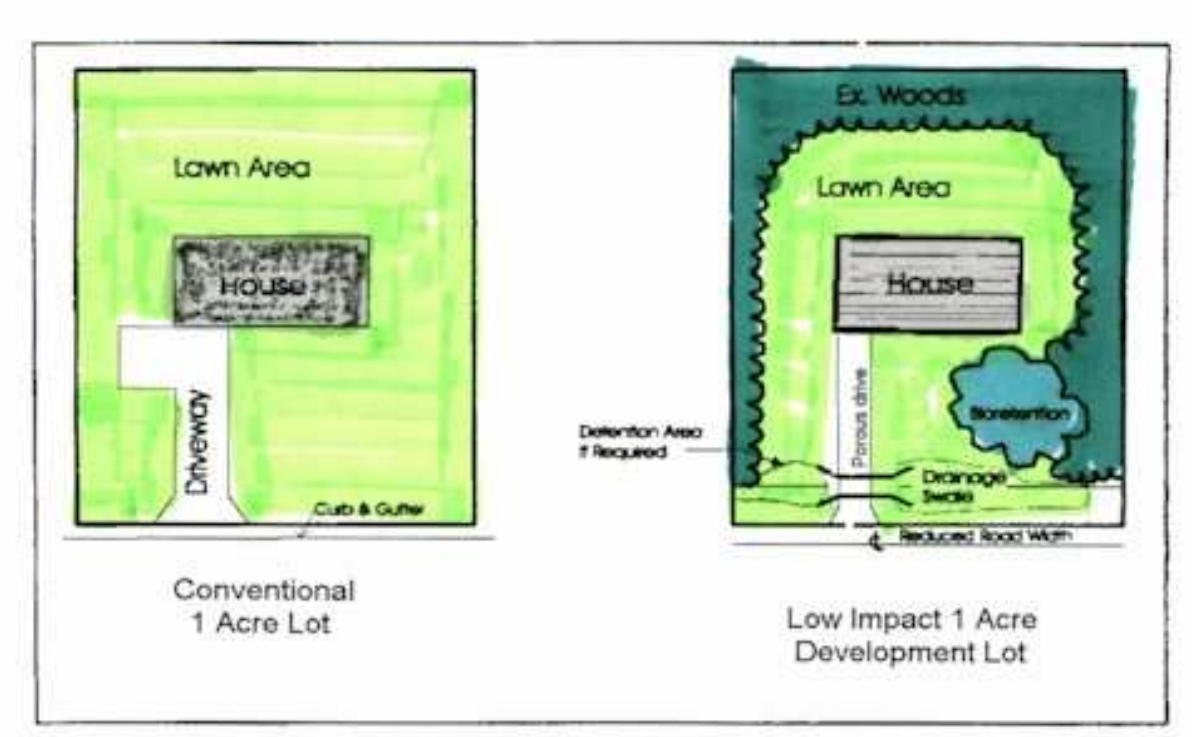


Figure 5.6-4 Convential Development Versus Low Impact Development

4. Maximize Soil Restoration

Where construction activity does require grading and filling and where compaction of soil can be expected, this disturbance should be limited. Soil treatments/amendments should be considered for such disturbed areas to restore permeability. If the bulk density is not reduced following fill, these areas will be considered semi-impervious after development and runoff volumes calculated accordingly.

5. Minimize Construction Traffic Areas

Areas where temporary construction traffic is allowed should be clearly delineated and limited. These areas should be restored as pervious areas following development through a required soil restoration program.

6. Minimize Stockpiling and Storage Areas

All areas used for materials storage during construction should be clearly delineated with the surface maintained, and subject to a soil restoration program following development. For low-density developments, the common practice of topsoil stripping might be unnecessary and should be minimized, if not avoided.

Construction Issues

Most of the measures discussed above are part of the initial concept site plan and site design process. Only those measures that restore disturbed site soils are related to the construction and post-construction phase, and may be considered as avoidance of impacts.

Cost Issues

Cost avoidance as a result of reduced grading and earthwork should benefit the developer. This BMP is considered to be self-crediting, given the benefits resulting from reduced costs. Cost issues include reduced grading and related earthwork (see Site Clearing and Strip Topsoil and Stockpile below), as well as reduced costs involved with site preparation, fine grading, and stabilization.

Calculation of reduced costs is difficult due to the extreme variation in site factors that will affect costs (amount of grading, cutting/filling, haul distances for required trucking, and so forth). Some relevant costs factors are as follows (as based on R.S. Means, *Site Work & Landscape Cost Data*, 2002):

Site Clearing

Cut & chip light trees to 6" diameter	$2,900/acre
Grub stumps and remove	$1,400/acre
Cut & chip light trees to 24" diameter	$9,700/acre
Grub stumps and remove	$5,600/acre

Strip Topsoil and Stockpile

Ranges from $0.52 to $1.78 / cy because of Dozer horse power, and ranges from ideal to adverse conditions
Assuming 8" of topsoil, the price per sq. yd. is $0.12 – $0.40
Assuming 8" of topsoil, the price per acre is $560 – $1,936

Site Preparation, Fine Grading, Seeding

Fine grading w/ seeding $2.33 /sq. yd.
Fine grading w/ seeding $11,277 /acre

In sum, total costs appear to approximate $20,000 per acre and could certainly exceed that figure in more challenging sites. Reducing graded and disturbed acreage clearly translates into substantial cost reductions.

Stormwater Management Calculations

No calculations are applicable for this BMP.

Specifications

The modification of road geometry is a site-specific issue, but in general any criteria that will result in significant earthwork should be reconsidered and evaluated.

BMP 5.6.2: Minimize Soil Compaction in Disturbed Areas



Minimizing Soil Compaction and Ensuring Topsoil Quality is the practice of enhancing, protecting, and minimizing damage to soil quality caused by land development.

Image Source: "Developing an Effective Soil Management Strategy: Healthy Soil Is At the Root Of Everything", Ocean County Soil Conservation District

Key Design Elements

- Protecting disturbed soils areas from excessive compaction during construction
- Minimizing large cleared areas and stockpiling of topsoil
- Using quality topsoil
- Maintaining soil quality after construction
- Reducing the Site Disturbance Area through design and construction practices
- Soil Restoration for areas that are not adequately protected or have been degraded by previous activities (Section 6)

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: High
Water Quality: Very High

Water Quality Functions

TSS: 30%
TP: 0%
NO3: 0%

Description:

Soil is a physical matrix of weathered rock particles and organic matter that supports a complex biological community. This matrix has developed over a long time period and varies greatly within the state. Healthy soils, which have not been compacted, perform numerous valuable stormwater functions, including:

- Effectively cycling nutrients
- Minimizing runoff and erosion
- Maximizing water-holding capacity
- Reducing storm runoff surges
- Adsorbing and filtering excess nutrients, sediments, pollutants to protect surface and groundwater
- Providing a healthy root environment and creating habitat for microbes, plants, and animals
- Reducing the resources needed to care for turf and landscape plantings

Once natural soils are overly compacted and permeability is drastically reduced, these functions are lost and can never be completely restored (Hanks and Lewandowski, 2003). In fact, the runoff response of vegetated areas with highly compacted soils closely resembles that of impervious areas, especially during large storm events (Schueler, undated). Therefore this BMP is intended to prevent compaction or minimize the degree and extent of compaction in areas that are to be "pervious" following development.

Although erosion and sediment control practices are equally important to protect soil, this BMP differs from them in that it is intended to reduce the area of soil that experiences excessive compaction during construction activities.

Applications

This BMP can be applied to any land development that has existing areas of relatively healthy soil and proposed "pervious" areas. If existing soils have already been excessively compacted, Soil Restoration is applicable (Chapter 6).



Figure 5.7-1 Example of development with site compaction of soils

Design Considerations

Early in the design phase of a project, the designer should develop a soil management plan based on soil types and existing level of disturbance (if any), how runoff will flow off existing and proposed impervious areas, areas of trees and natural vegetation that can be preserved, and tests indicating soil depth and quality. The plan should clearly show the following:

1. **Protected Areas.** Soil and vegetation disturbance is not allowed. Protection of healthy, natural soils is the most effective strategy for preserving soil functions. Not only can the functions be maintained but protected soil organisms are also available to colonize neighboring disturbed areas after construction.

2. **Minimal Disturbance Areas.** Limited construction disturbance occurs - soil amendments may be necessary for such areas to be considered fully pervious after development. Areas to be vegetated after development should be designated Minimal Disturbance Areas.

3. **Construction Traffic Areas.** Areas where construction traffic is allowed - if these areas are to be considered fully pervious following development, a program of Soil Restoration will be required.

4. **Topsoil Stockpiling and Storage Areas.** These areas should be protected and maintained and are subject to Soil Restoration (including compost and other amendments) following development.

5. **Topsoil Quality and Placement.** Soil tests are recommended. Topsoil applied to disturbed areas should meet certain parameters as shown in Appendix C. Adequate depth (4" minimum for turf, more for other vegetation), organic content (5% minimum), and reduced compaction (1400 kPa maximum) are especially important (Hanks and Lewandowski, 2001). To allow water to pass from one layer to the other, topsoil must be "bonded" to the subsoil when it is reapplied to disturbed areas.



Figure 5.7-2 Example of site development with extreme soil compaction on steep slope

The first two areas (Protected and Minimal Disturbance) should be made as large as possible, identified by signage, and fenced off from construction traffic. Construction Traffic Areas should be as small as practicable.

Detailed Stormwater Functions

Volume Reduction Calculations

Minimizing Soil Compaction and Ensuring Topsoil Quality can reduce the volume of runoff by maintaining soil functions related to stormwater and thereby increasing infiltration and evapotranspiration. This can be credited in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. See Chapter 8 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations

Minimizing Soil Compaction and Ensuring Topsoil Quality can reduce the rate of runoff by maintaining soil functions related to stormwater. This can be credited in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and/or longer times of travel. See Chapter 8 for peak rate calculation methodologies.

Water Quality Improvement

Minimizing Soil Compaction and Ensuring Topsoil Quality can improve water quality through infiltration, filtration, chemical and biological processes in the soil, and a reduced need for fertilizers and pesticides after development. See Chapter 8 for Water Quality Improvement methodologies.

Construction Issues

1. At the start of construction, Protected and Minimal Disturbance Areas must be identified with signage and fenced as shown on the construction drawings.
2. Protected and Minimal Disturbance Areas should be strictly enforced.
3. Protected and Minimal Disturbance Areas should be protected from excessive sediment and stormwater loads while upgradient areas remain in a disturbed state.
4. Topsoil storage areas should be maintained and protected at all times. When topsoil is reapplied to disturbed areas it must be “bonded” with the subsoil. This can be done by spreading a thin layer of topsoil (2 to 3 inches), tilling it into the subsoil, and then applying the remaining topsoil. Topsoil must meet certain requirements as detailed in Appendix C.

Maintenance Issues

Sites that have minimized soil compaction properly during the development process should require considerably less maintenance than sites that have not. Landscape vegetation will likely be healthier, have a higher survival rate, require less irrigation and fertilizer, and even look better.

Some maintenance activities such as frequent lawn mowing can cause considerable soil compaction after construction and should be avoided whenever possible. Planting low-maintenance native vegetation is the best way to avoid damage due to maintenance.

Protected Areas on private property could have an easement, deed restriction, or other legal measure to prevent future disturbance or neglect.

Cost Issues

Minimizing Soil Compaction and Ensuring Topsoil Quality generally results in a significant construction cost savings. Minimizing soil compaction can reduce disturbance, clearing, earthwork, the need for Soil Restoration, and the size and extent of costly, engineered stormwater management systems. Ensuring topsoil quality can significantly reduce the cost of landscaping vegetation (higher survival rate, less replanting) and landscaping maintenance.

Design costs may increase slightly due to a more thoughtful, site-specific design.

Specifications

Soil Restoration specifications can be found in Chapter 6.

References

Hanks, D. and Lewandowski, A. *Protecting Urban Soil Quality: Examples for Landscape Codes and Specifications*. USDA-NRCS, 2003.

Ocean County Soil Conservation District. *Impact of Soil Disturbance during Construction on Bulk Density and Infiltration in Ocean County, New Jersey*. 2001. Available at http://www.ocscd.org/publications.shtml as of May 2004.

Schueler, T. "The Compaction of Urban Soils," Technical Note #107 from *Watershed Protection Techniques.* 3(2): 661-665, undated.

BMP 5.6.3: Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species



Sites that require landscaping and re-vegetation should select and use vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides.

Image: Rose Mallow, Bowman's Hill Wildflower Preserve, www.bhwp.org

Key Design Elements

- Preserve all existing high quality plant materials and soil mantle wherever possible
- Protect these areas during construction
- Develop Landscape Plan using native species
- Reduce landscape maintenance, especially grass mowing
- Reduce or eliminate chemical applications to the site, wherever possible
- Reduce or eliminate fertilizer and chemical-based pest control programs, wherever possible

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med
Peak Rate Control: Low/Med.
Water Quality: Very High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 50%

Description of BMP

Minimum Disturbance/Minimum Maintenance is comprised of two distinct steps, neither of which involves structural BMPs. The first step is to preserve existing vegetation on the development site as defined in BMP 5.6.1, so as to minimize the need for landscaping and re-vegetation. This BMP emphasizes the second step - the selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides. Implicit in this BMP is the assumption that native species have the greatest tolerance and resistance to pests and require less fertilization and chemical application than non-native species. Landscape architects specializing in the local plant community usually are able to identify a variety of species that meet these criteria.

The production of biomass, such as grass clippings, is a significant pollutant source for water quality (if this biomass is not removed, over time this biomass decays and is converted to additional nutrient sources which add to the water quality problem). Native grasses and other herbaceous materials that do not require mowing are preferred. Because the selection of such materials begins at the concept design stage, where lawns are avoided or eliminated and landscaping species selected, this Non-Structural BMP can generally result in a site with reduced runoff volume and rate, as well as significant nonpoint source load reduction/prevention.

A native landscape may take several forms in Pennsylvania, ranging from re-establishment of woodlands to re-establishment of meadow. It should be noted that as this native landscape grows and matures, the positive stormwater benefits relating to volume control and peak rate control increase and these landscapes become much more effective in reducing runoff volumes than maintained landscapes such as lawns.

The elimination of traditional lawnscapes as a site design element can be an extremely difficult BMP to implement, given the extent to which the traditional lawn as an essential landscape design feature is embedded in current national culture.

Additional information relating to native species and their use in landscaping is available through PADCNR and its website: http://www.dcnr.state.pa.us/forestry/wildplant/native.aspx

Detailed Stormwater Functions

Volume Reduction Calculations and **Peak Rate Calculations** are not affected substantially by this BMP - at least in the short term. In the longer term, as species grow and mature, the runoff volume production of more mature native species can reasonably be expected to be lower than a conventionally maintained landscape (especially the conventionally mowed lawn). Native species are customarily strong growers with stronger and denser root and stem systems, thereby generating less runoff. If the objective is re-vegetation with woodland species, the longer-term effect is a significant reduction in runoff volumes, with increases in infiltration, evapotranspiration, and recharge, when contrasted with a conventional lawn planting. Peak rate reduction also is achieved. Similarly, meadow re-establishment is also more beneficial than a conventional lawn planting, although not so much as the woodland landscape. Again, these benefits are long term in nature and will not be forthcoming until the species have had an opportunity to grow and mature (one advantage of the meadow is that this maturation process requires considerably less time than a woodland area).

Water Quality Improvement
Minimizing Disturbance/Minimizing Maintenance through Use Native Species for Landscaping and Re-Vegetation can improve water quality preventively by minimizing application of fertilizers and pesticides/herbicides. Given the high rates of chemical application which have been documented at

newly created maintained areas for both residential and non-residential land uses, eliminating the opportunity for chemical application is important for water quality – perhaps the most effective management technique. Of special importance here is the reduction in fertilization and nitrate loadings. For example, Delaware's *Conservation Design for Stormwater Management* lists multiple studies, which document high fertilizer application rates, including both nitrogen and phosphorus, in newly created landscapes in residential and non-residential land developments. Expansive lawn areas in low density single-family residential subdivisions as well as large office parks – development which has and continues to proliferate in Pennsylvania municipalities - typically receives intensive chemical application, both fertilization and pest control, which can exceed application rates being applied to agricultural fields. Avoidance of this nonpoint pollutant source is an important water quality objective. See Chapter 8 for Water Quality Improvement methodologies.

Design Considerations

Native species is a broad term. Different types of native species landscapes may be created, from meadow to woodland areas, obviously requiring different approaches to planting. In terms of woodland areas, Delaware's *Conservation Design for Stormwater Management* states, "…a mixture of young trees and shrubs is recommended…. Tree seedlings from 12 to 18 inches in height can be used, with shrubs at 18 to 24 inches. Once a ground cover crop is established (to offset the need for mowing), trees and shrubs should be planted on 8-foot centers, with a total of approximately 430 trees per acre. Trees should be planted with tree shelters to avoid browse damage in areas with high deer populations, and to encourage more rapid growth." (p.3-50). As tree species grow larger, both shrubs and ground covers recede and yield to the more dominant tree species. The native tree species mix of small inexpensive saplings should be picked for variety and should reflect the local forest communities. Annual mowing to control invasives may be necessary, although the quick establishment of a strong-growing ground cover can be effective in providing invasive control. Native meadow planting mixes also are available. A variety of site design factors may influence the type of vegetative community, which is to be planned and implemented. In so many cases, the "natural" vegetation of Pennsylvania's communities is, of course, woodland.

Native species plantings can achieve variation in landscape across a variety of characteristics, such as texture, color, and habitat potential. Properly selected mixes of flowering meadow species can provide seasonal color; native grasses offer seasonal variation in texture. Seed production provides a food source and reinforces habitat. In all cases, selection of native species should strive to achieve species variety and balance, avoiding creation of single-species or limited species "monocultures" which pose multiple problems. In sum, many different aspects of native species planting reinforce the value of native landscaping, typically increasing in their functional value as species grow and mature over time.

Maintenance Issues

Although many conventional landscape management requirements are made unnecessary with this BMP, Using Native Species for Landscaping and Re-Vegetation can be expected to require some level of management – especially in the short term immediately following installation. Woodland areas planted with a proper cover crop can be expected to require annual mowing in order to control invasives. Application of a carefully selected herbicide around the protective tree shelters/tubes may be necessary, reinforced by selective cutting/manual removal, if necessary. This initial maintenance routine is necessary for the first 2 to 3 years of growth and may be necessary for up to 5 years until tree growth and tree canopy begins to form, naturally inhibiting weed growth. Once shading is adequate, growth of invasives and other weeds will be naturally prevented, and the woodland becomes self-maintaining. Review of the new woodland should be undertaken intermittently to determine if replacement trees should be provided (some modest rate of planting failure is typical). Meadow

management is somewhat more straightforward; a seasonal mowing may be required, although care must be taken to make sure that any management is coordinated with essential reseeding and other important aspects of meadow re-establishment.

Construction Issues

During the initial conceptual design phase of a project, the design engineer should develop a Minimum Disturbance/Minimum Maintenance concept plan that includes the following:

- Areas of Existing Vegetation Being Preserved
- Areas to Be Re-Vegetated/Landscaped by Type (i.e., Native Species Woodland, Meadow, etc. plus Non-Native Conventional Areas)
- A landscape maintenance plan that avoids/minimizes mowing and other maintenance, except for limited areas of high visibility, special needs, etc.; specific landscape areas not to receive fertilization and other chemical applications should be identified in plan documentation

This information needs to appear on the plan drawings and receive municipal review and approval. Existing Vegetation Being Preserved must be flagged or fenced in the field. In terms of specific construction sequencing, all plantings including native species should be installed during the final construction phase of the project. Because native species plantings are likely to have a less "finished" appearance than conventionally landscaped areas, additional field identification for these areas through flagging or fencing similar to Existing Vegetation Being Preserved should be considered.

Cost Issues

BMP 5.6.3 cost implications are minimal during construction. Seeding for installation of a conventional lawn is likely to be less expensive than planting of a "cover" of native species, although when contrasted with a non-lawn landscape, "natives" often are not more costly than other non-native landscape species. In terms of woodland creation, somewhat dated (1997) costs have been provided by the *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*:

$860/acre trees with installation
$1,600/acre tree shelters/tubes and stakes
$300/acre for four waterings on average

Current values may be considerably higher, well over $3,000/acre for installation costs. Costs for meadow re-establishment are lower than those for woodland, in part due to the elimination of the need for shelters/tubes. Again, such costs can be expected to be greater than installation of conventional lawn (seeding and mulching), although the installation cost differences diminish when conventional lawn seeding is redefined in terms of conventional planting beds.

Cost differentials grow greater when longer term operating and maintenance costs are taken into consideration. If lawn mowing can be eliminated, or even reduced significantly to a once per year requirement, substantial maintenance cost savings result, often in excess of $1,500 per acre per year. If chemical application (fertilization, pesticides, etc.) can be eliminated, substantial additional savings result with use of native species. These reductions in annual maintenance costs resulting from a native landscape re-establishment very quickly outweigh any increased installation costs that are required at project initiation. Unfortunately, because developers pay for the installation costs and longer term

reduced maintenance costs are enjoyed by future owners, there is reluctance to embrace native landscaping concepts.

Stormwater Management Calculations

See Chapter 8 for calculations.

References

Bowman's Hill Wildflower Preserve, Washington Crossing Historic Park, PO Box 685, New Hope, PA 18938-0685, Tel (215) 862-2924, Fax (215) 862-1846, Native plant reserve, plant sales, native seed, educational programs, www.bhwp.org

Morris Arboretum of the University of Pennsylvania; 9414 Meadowbrook Avenue, Philadelphia, PA 19118, Tel (215) 247-5777, www.upenn.edu/morris, PA Flora Project Website: Arboretum and gardens (some natives), educational programs, PA Flora Project, www.upenn.edu/paflora

Pennsylvania Department of Conservation and Natural Resources; Bureau of Forestry; PO Box 8552, Harrisburg, PA 17105-8552, Tel (717)787-3444, Fax (717)783-5109, Invasive plant brochure; list of native plant and seed suppliers in PA; list of rare, endangered, threatened species.

Pennsylvania Native Plant Society, 1001 East College Avenue, State College, PA 16801 www.pawildflower.org

Western Pennsylvania Conservancy; 209 Fourth Avenue, Pittsburgh, PA 15222, Tel (412) 288-2777, Fax (412) 281-1792, www.paconserve.org

5.7 Reduce Impervious Cover

BMP 5.7.1: Reduce Street Imperviousness



Reduce impervious street areas by minimizing street widths and lengths.

Key Design Elements

- Evaluate traffic volume and on-street parking requirements.
- Consult with local fire code standards for access requirements.
- Minimize pavement by using alternative roadway layouts, restricting on-street parking, minimizing cul-de-sac radii, and using permeable pavers.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Limited
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: Medium

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Description

Reducing impervious street areas performs valuable stormwater functions, in contrast to conventional or baseline development. Some of these functions are increasing infiltration, decreasing stormwater runoff volume, increasing stormwater time of concentration, improving water quality by decreasing the pollutant loading of streams, improving natural habitats by decreasing the deleterious effects of stormwater runoff and decreasing the concentration and energy of stormwater. Imperviousness greatly influences stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources. Increased imperviousness alters an area's hydrology, habitat structure, and water quality. Stream degradation has been witnessed at impervious levels as low as 10-20% (Center for Watershed Protection, 1995).

Applications

Street Width

Streets comprise the largest single component of imperviousness in residential design. Universal application of high-volume, high-speed traffic design criteria results in many communities requiring excessively wide streets. Coupled with the perceived need to provide both on-street parking and emergency vehicle access, the end result of these requirements is residential streets that may be 36 feet or greater in width (Center for Watershed Protection, 1998).

The American Society of Civil Engineers (ASCE) and the American Association of State Highway and Transportation Officials (AASHTO) recommend that low traffic volume roads (less than 50 homes or 500 daily trips) can be as narrow as 22 feet. PennDot Pub. 70 gives a range of 18-22 foot width for low volume local roads. Some municipalities have reduced their lowest trafficable residential roads to 18 feet or less. Higher volume roads are recommended to be wider. Table 5.7-1 provides sample road widths from different jurisdictions.

The desire for adequate emergency vehicle access, notably fire trucks, also leads to wider streets. While it is perceived that very wide streets are required for fire trucks, some local fire codes permit roadway widths as narrow as 18 feet (as shown in Table 5.7-2). Concerns also exist about other vehicles and maintenance activities on narrow streets. School buses are typically nine feet wide from mirror to mirror; Prince George's and Montgomery Counties in Maryland require only a 12-foot driving lane for buses (Center for Watershed Protection, 1998). Similarly, trash trucks require only a 10-½ foot driving lane, as they are a standard width of nine feet (Waste Management, 1997; BFI, 1997). In some cases, road width for emergency vehicles may be added through use of permeable pavers for roadway shoulders (see Figure 5.7-1).

Snow removal on narrower streets is readily accomplished with narrow, 8-foot snowplows. Restricting parking to one side of the street allows accumulated snow to be piled on the other side. Safety concerns are also cited as a justification for wider streets, but increased vehicle-pedestrian accidents on narrower streets are not supported by research. The Federal Highway Administration states that narrower streets reduce vehicle travel speeds, decreasing the incidence and severity of accidents.

Higher density developments require wider streets, but alternative layouts can minimize street widths. For example, in instances where on-street parking is desired, impervious pavement is used for the travel lanes and permeable pavers are placed on the road apron for the parking lanes. The width of permeable pavers is often the width of a standard parking lane (six to eight feet). This design approach minimizes impervious area while also providing an infiltration and recharge area for the impervious roadway stormwater (Prince George's County, Maryland, 2002).

Table 5.7-1: Narrow Residential Street Widths

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking)	0-3,500
	28 ft. (parking on one side)	0-3,500
State of Delaware	12 ft. (alley)	---
	21 ft. (parking on one side)	---
Howard County, Maryland	24 ft. (parking not regulated)	1,000
Charles County, Maryland	24 ft. (parking not regulated)	---
Morgantown, West Virginia	22 ft. (parking on one side)	---
Boulder, Colorado	20 ft.	150
	20 ft. (no parking)	350-1,000
	22 ft. (parking on one side)	350
	26 ft. (parking on both sides)	350
	26 ft. (parking on one side)	500-1,000
Bucks County, Pennsylvania	12 ft (alley)	---
	16-18 ft. (no parking)	200
	20-22 ft. (no parking)	200-1,000
	26 ft. (parking on one side)	200
	28 ft. (parking on one side)	200-1,000

(Cohen, 1997; Bucks County Planning Commission, 1980; Center for Watershed Protection, 1998)

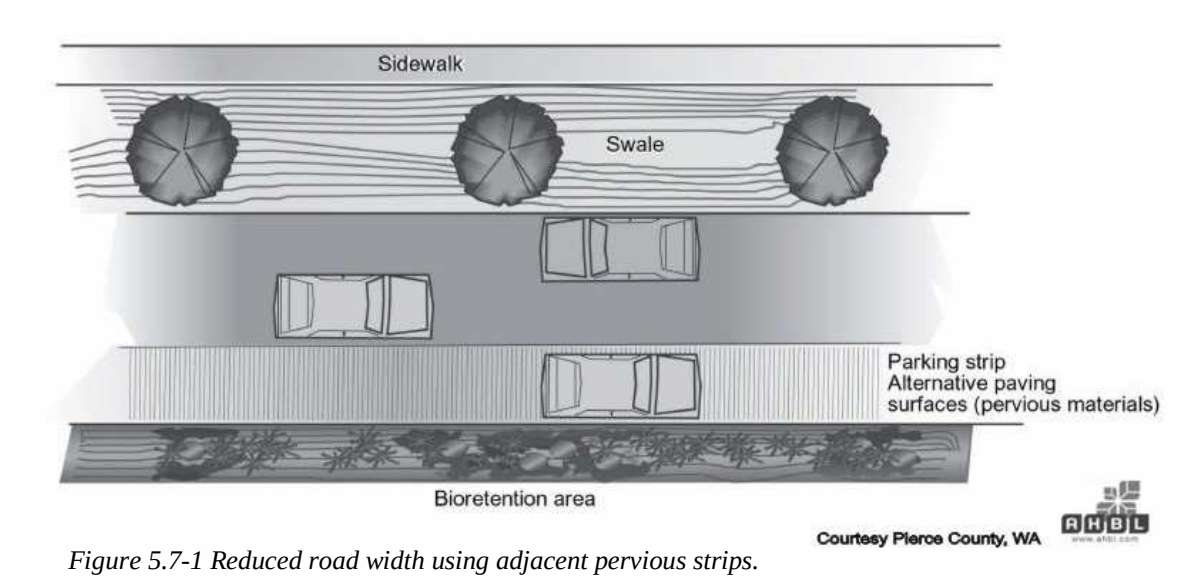


Figure 5.7-1 Reduced road width using adjacent pervious strips.

Table 5.7-2 Fire Vehicle Street Requirements

Source	Residential Street Width
U.S. Fire Administration	18-20 ft.
Baltimore County, Maryland Fire Department	16 ft. (no on-street parking) 24 ft. (on-street parking)
Virginia State Fire Marshall	18 ft. minimum
Prince George's County, Maryland Department of Environmental Resources	24 ft. (no parking) 30 ft. (parking on one side) 36 ft. (parking on both sides) 20 ft. (fire truck access)
Portland, Oregon Office of Transportation	18 ft. (parking on one side) 26 ft. (parking on both sides)

(Adapted from Center for Watershed Protection, 1998)

In residential neighborhoods, the perception of the need for large quantities of parking may lead developers to provide on-street parking; residential land use will greatly influence the quantity needed. Each on-street lane increases street impervious cover by 25%. Many communities require 2-2.5 parking spaces per residence. In single-lot neighborhoods, with both standard and reduced setbacks, parking requirements can likely be met using private driveways and garages. In townhouse communities, if on-street parking is required, providing one on-street space per residence is likely sufficient. Urban settings will require the greatest use of on-street parking. However, continuous parking lanes on both sides of the street, while common for all residential land uses, is often unnecessary.

When on-street parking is necessary, queuing lanes provide a parking system alternative that minimizes imperviousness. Communities are using queuing lanes to narrow roads while also providing two-way traffic access. In a queuing lane design, one traffic lane is used by moving traffic and the parking lanes allow oncoming traffic to pull over and let opposite traffic pass (Center for Watershed Protection, 1998). Figure 5.7-2 shows traditional and queuing lane designs.

Street Length

Numerous factors influence street length including clustering techniques (discussed in a separate Chapter). As with street width, street length greatly impacts the overall imperviousness of a developed site. While no one prescriptive technique exists for reducing street length, alternative street layouts should be investigated for options to minimize impervious cover.

Cul-de-sacs

The use of cul-de-sacs introduces large areas of imperviousness into residential developments, with some communities requiring the cul-de-sac radius to be as large as 50 to 60 feet. In most instances, and in large radius cul-de-sac designs especially, the full area of the circle is neither necessary nor utilized. When cul-de-sacs are necessary, two primary alternatives can reduce their imperviousness.

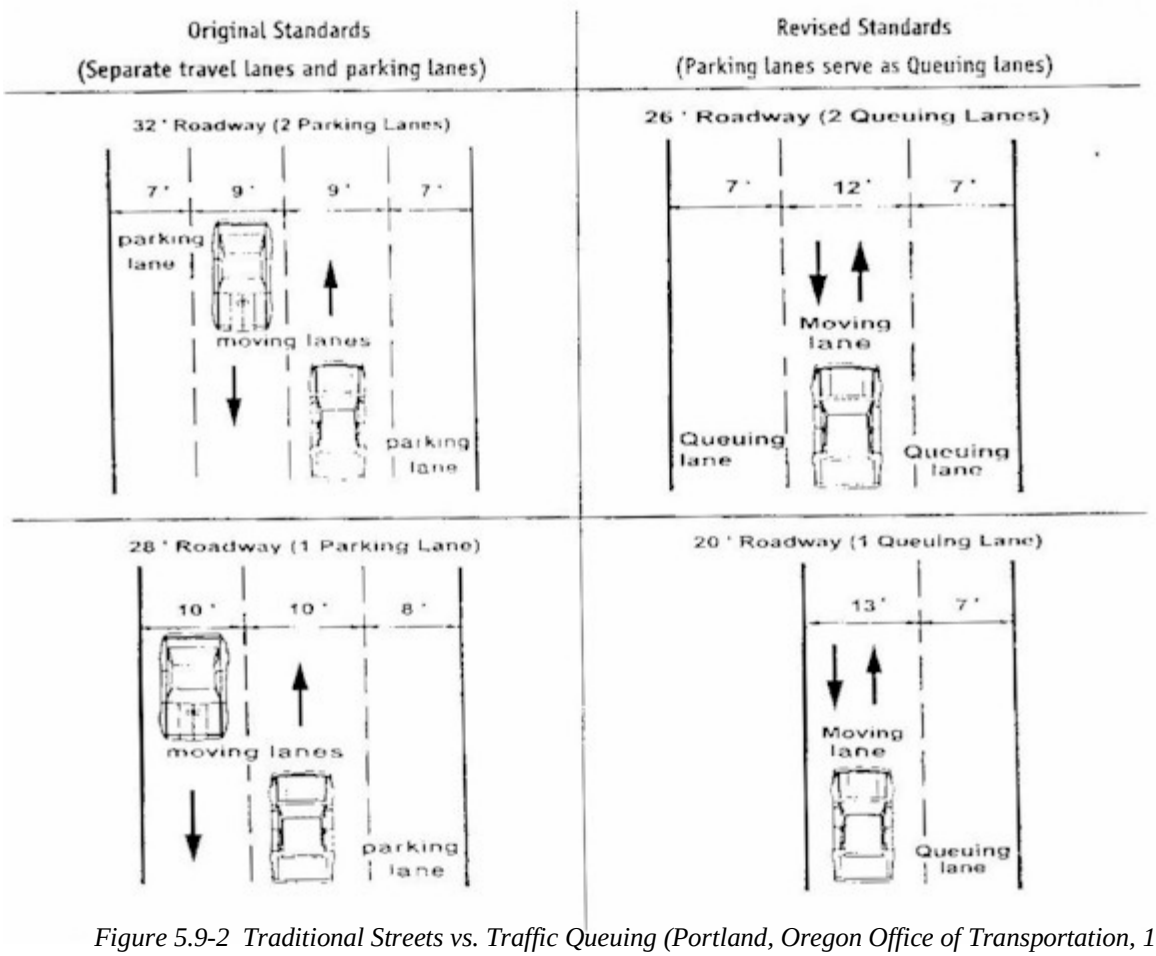


Figure 5.9-2 Traditional Streets vs. Traffic Queuing (Portland, Oregon Office of Transportation, 1994)

The first alternative is to reduce the required radius of the cul-de-sac. Many jurisdictions have identified required turnaround radii (shown in Table 5.7-3).

A second alternative is to incorporate a landscaped island into the center of the cul-de-sac. This design approach provides the necessary turning radius, minimizes impervious cover, and provides an aesthetic amenity to the community. In some instance, developments are placing bioretention cells (discussed in Chapter 6) in the center of cul-de-sacs to not only reduce imperviousness, but also provide a distributed method of treating stormwater runoff. Other cul-de-sac configurations have been developed which reduce impervious area.

Cost Issues

Street Width

Costs for paving have been estimated to be approximately $15/yd^2 (Center for Watershed Protection, 1998). At this cost, for each one-foot reduction in street width, estimated savings are $1.67 per linear foot of paved street. For example reducing the width of a 500-foot road by 5 feet would result in a savings of over $4,100. This cost is exclusive of other construction costs including grading and infrastructure.

Street Length

In addition to pavement, costs for street lengths, including traditional curb and gutter and stormwater management controls, are approximately $150 per linear foot of road (Center for Watershed Protection, 1998). Decreasing road length by 100 feet can produce a savings of $15,000. Simply factoring in pavement costs at $15/yd^2, a 100-foot length reduction in a 25-foot wide road would produce a savings in excess of $4,000.

Table 5.7-3: Example Cul-de-sac Turnaround Radii

Source	Residential Street Width
Portland, Oregon Office of Transportation	35 ft. (with Fire Deaprtment Approval)
Buck County, Pennsylvania Planning Commission	38 ft. (outside turning radius)
Fairfax County, Virginia Fire and Rescue	45 ft.
Baltimore County, Maryland Fire Department	35 ft. (with Fire Deaprtment Approval)
Montgomery County, Maryland Fire Department	45 ft.
Prince George's County, Maryland Fire Department	43 ft.

(Adapted from Center for Watershed Protection, 1998)

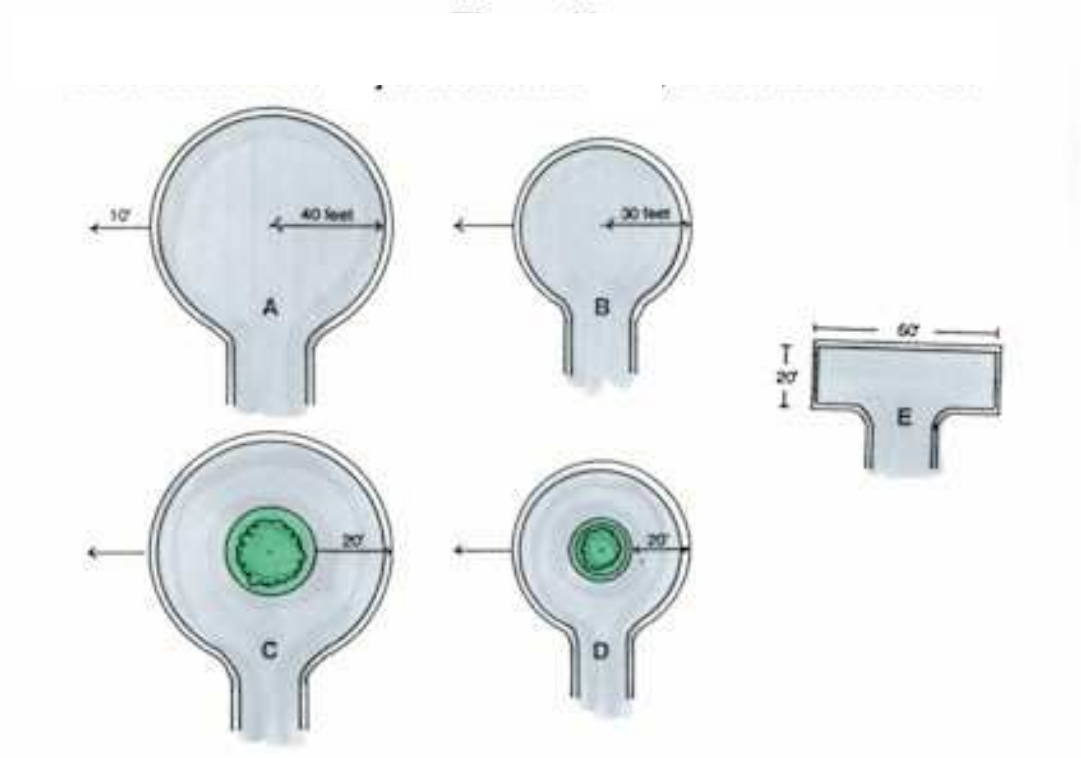


Figure 5.7-3 Five Turnaround Options for the end of a Residential Street, ("Better Site Design: A Handbook for Changing Development Rules in Your Community", Center for Watershed Protection, August, 1998)

BMP 5.7.2: Reduce Parking Imperviousness



Reduce imperviousness by minimizing imperviousness associated with parking areas.

Key Design Elements

- Evaluate parking requirements considering average demand as well as peak demand.
- Consider the application of smaller parking stalls and/or compact parking spaces.
- Analyze parking lot layout to evaluate the applicability of narrowed traffic lanes and slanted parking stalls.
- Where appropriate, minimize impervious parking area by utilizing overflow parking areas constructed of pervious paving materials.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Limited
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Description

Reducing parking imperviousness performs valuable stormwater functions in contrast to conventional or baseline development: Increasing infiltration; Decreasing stormwater runoff volume; Increasing stormwater time of concentration; Improving water quality by decreasing the pollutant loading of streams; Improving natural habitats by decreasing the deleterious effects of stormwater runoff; Decreasing the concentration and energy of stormwater. Imperviousness greatly influences stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources. Increased imperviousness alters an area's hydrology, habitat structure, and water quality. Stream degradation has been witnessed at impervious levels as low as 10-20% (Center for Watershed Protection, 1995).

Applications

In commercial and industrial areas, parking lots comprise the largest percentage of impervious area. Parking lot size is dictated by lot layout, stall geometry, and parking ratios. Modifying all or any of these three aspects can serve to minimize the total impervious areas associated with parking lots.

Parking Ratios

Parking ratios express the specified parking requirements provided for a given land use. These specified ratios are often set as minimum requirements. Many developers seeking to ensure adequate parking provide parking in excess of the minimum parking ratios. Additionally, commercial parking is often provided to meet the highest hourly demand of a given site, which may only occur a few times per year. Excess parking is often rationalized by the desire to avoid potential complaints from patrons that have difficulty finding parking. However, as shown in Table 5.7-4, average parking demand is generally less than typical required parking ratios and therefore much less than parking provided in excess of these ratios. The result of using typically specified parking ratios is parking capacity that is underutilized.

Table 5.7-4 Example Minimum Parking Ratios

Land Use	Parking Ratio	Average Parking Demand
Single Family Home	2 spaces per dwelling unit	1.1 spaces per dwelling unit
Shopping Center	5 spaces per 1,000 ft^2 of GFA	3.97 spaces per 1,000 ft^2 of GFA
Convenience Store	3.3 spaces per 1,000 ft^2 of GFA	Not available
Industrial	1 space per 1,000 ft^2 of GFA	1.48 spaces per 1,000 ft^2 of GFA
Medical/Dental Office	5.7 spaces per 1,000 ft^2 of GFA	4.11 spaces per 1,000 ft^2 of GFA

GFA – gross floor area, excluding storage and utility space

(Institute of Transportation Engineers, 1987; Smith, 1984; Wells, 1994)

In residential neighborhoods, the perception of the need for large quantities of parking may lead developers to provide on-street parking; residential land use will greatly influence the quantity needed. Each on-street lane increases street impervious cover by 25%. Many communities require 2-2.5 parking spaces per residence. In single-lot neighborhoods, with both standard and reduced setbacks, parking requirements can likely be met using private driveways and garages. In townhouse communities, if on-street parking is required, providing one on-street space per residence is likely

sufficient. Urban settings will require the greatest use of on-street parking. However, continuous parking lanes on both sides of the street, while common for all residential land uses, is often unnecessary. When on-street parking is necessary, queuing lanes (discussed in BMP 5.7.1) provide a parking system alternative that minimizes imperviousness.

Parking Spaces and Lot Layout

Parking spaces are comprised of five impervious components (Center for Watershed Protection, 1998):

1. The parking stall;
2. The overhang at the stall's edge;
3. A narrow curb or wheel stop;
4. The parking aisle that provides stall access; and
5. A share of the common impervious areas (e.g., fire lanes, traffic lanes).

Of these, the parking space itself accounts for approximately 50% of the impervious area, with stall sizes ranging from 160 to 190 ft^2. Several measures can be taken to limit parking space size. First, jurisdictions can review standard parking stall sizes to determine their appropriateness. A typical stall dimension may be 10 ft by 18 ft, much larger than needed for many vehicles; while the largest SUVs are wider, the great majority of SUVs and vehicles are less than 7 ft providing opportunity for making stalls slightly narrower and shorter. In addition, typical parking lot layout includes parking aisles that accommodate two-way traffic and perpendicularly oriented stalls. The use of one-way isles and angled parking stalls can reduce impervious area.

Jurisdictions can also stipulate that parking lots designate a percentage of stalls as compact parking spaces. Smaller cars comprise 40% or more of all vehicles and compact parking stalls create 30% less impervious cover than average-sized stalls (Center for Watershed Protection, 1998). This is currently an underutilized practice that has potential to reduce the total area of parking lots.

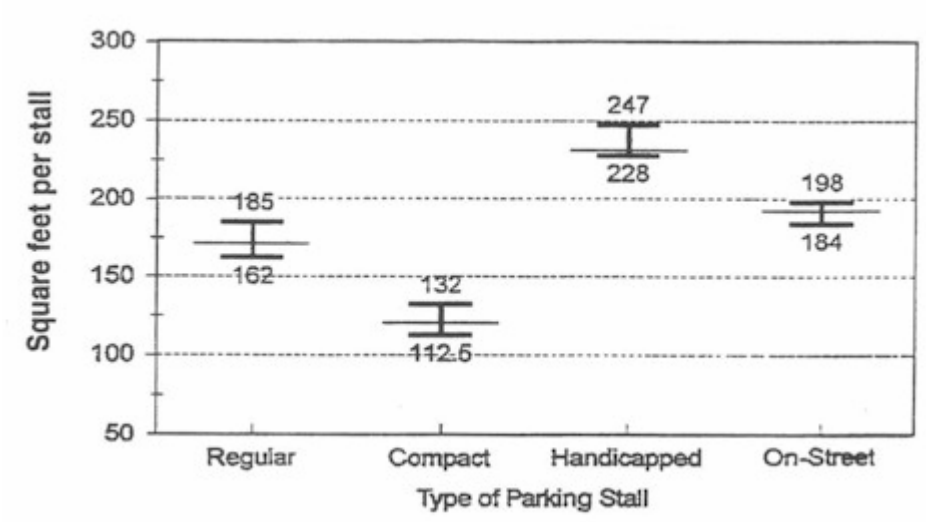


Figure 5.7-4 ("Conservation Design for Stormwater Management", DNREC, 1997)

Parking Lot Design

Because of parking ratio requirements and the desire to accommodate peak parking demand, even when it occurs only occasionally throughout the year, parking lots often provide parking capacity substantially in excess of average parking needs. This results in vast quantities of unused impervious surface.

A design alternative to this scenario is to provide designated overflow parking areas. The primary parking area, sized to meet average demand, would still be constructed on impervious pavement to meet local construction codes and American with Disabilities Act requirements. However, the overflow parking area, designed to accommodate increased parking requirements associated with peak demand, would be constructed on pervious materials (e.g., permeable pavers, grass pavers, gravel). This design approach focused on average parking demand will still meet peak parking demand requirements while reducing impervious pavement.



Figure 5.10-2 Overflow parking using permeable pavers

Cost Issues

Estimates for parking construction range from $1,200 to $1,500 dollars per space (Center for Watershed Protection, 1998). For example, assuming a cost of $1,200 per parking space, reducing the required parking ratio for a 20,000 ft^2 shopping center from 5 spaces per 1,000 ft^2 to 4 spaces per 1,000 ft^2 would represent a savings of $24,000.

Parking lots incorporating pervious overflow areas may not present cost savings, as permeable paving products are generally more expensive than traditional asphalt. However, the additional costs may be offset by reduced curb and gutter and stormwater management costs.

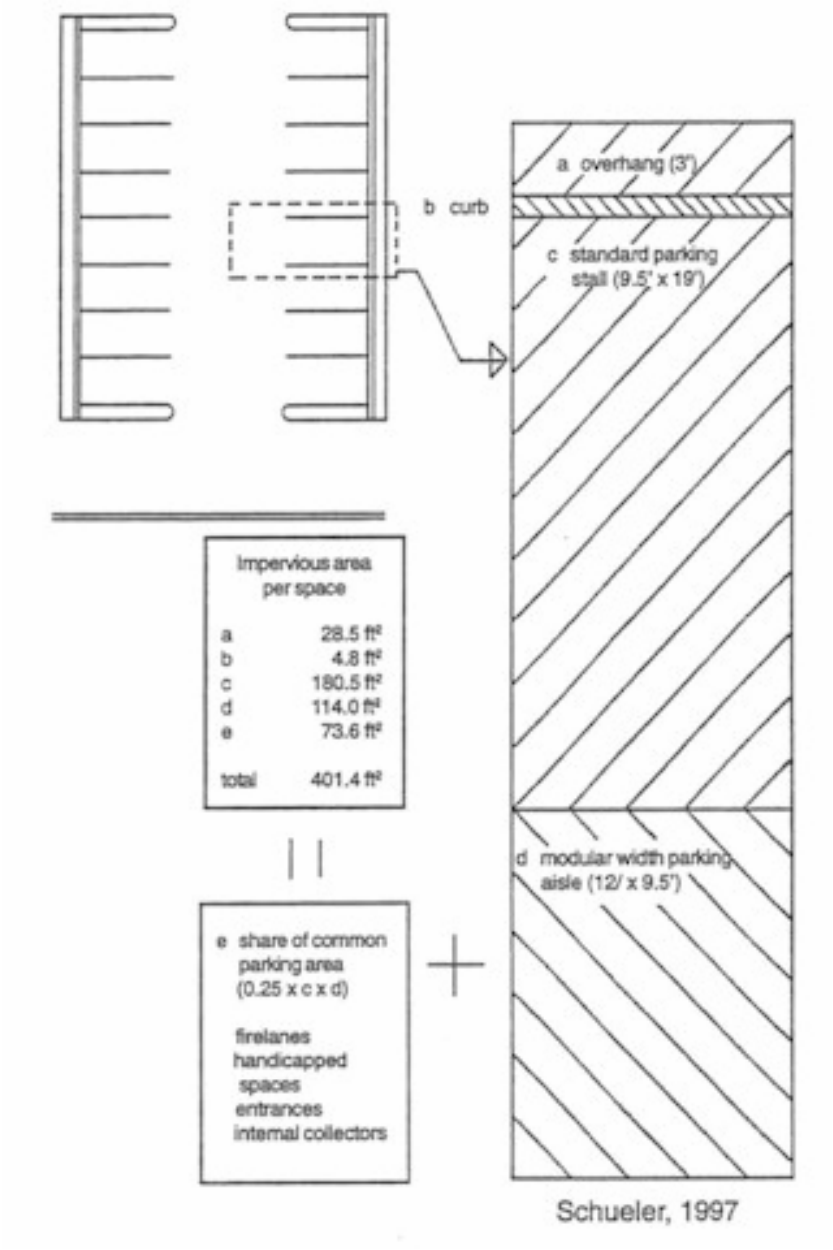


Figure 5.7-5 Parking Stall Dimensions (Schueler, 1997)

References

Center for Watershed Protection, 1998
Center for Watershed Protection, 1995

5.8 Disconnect/Distribute/Decentralize

BMP 5.8.1: Rooftop Disconnection



Minimize stormwater volume by disconnecting roof leaders and directing rooftop runoff to vegetated areas to infiltrate.

Key Design Elements

- Stormwater collection systems.
- Redirect rooftop overland flow to minimize rapid transport to conveyance structures and impervious areas, such as ditches and roadways.
- Direct runoff to vegetated areas designed to receive stormwater.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Limited
Retrofit: Limited
Highway/Road: Limited

Stormwater Functions

Volume Reduction: High
Recharge: High
Peak Rate Control: High
Water Quality: Low

Water Quality Functions

TSS: 30%
TP: 0%
NO3: 0%

Description

Traditionally, building codes have encouraged the rapid conveyance of rooftop runoff away from building structures. It is not uncommon for municipal codes to specify minimum slopes which serve to accelerate overland flow onto and across yards and lawns, directed ever more rapidly toward streets and gutters. Concerns pertaining to surface ponding of rooftop stormwater and potential ice formation on sidewalks and driveways are the main drivers of these lot requirements (Center for Watershed Protection, 1998). These requirements, stemming from a convention of rapid transmission of stormwater, serve to discourage on-site treatment of rooftop stormwater. This trend is further exacerbated in northern latitudes where icing concerns are paramount and, consequently, where downspouts may be connected directly to the stormwater collection system.

Disconnecting roof leaders from conventional stormwater conveyance systems allows rooftop runoff to be collected and managed on site. Rooftop runoff can be directed to designed vegetated areas (discussed in Chapter 6) for on-site storage, treatment, and volume control. This BMP offers a distributed, low-cost method for reducing runoff volume and improving stormwater quality through:

- Increasing infiltration and evapotranspiration.
- Increasing filtration.
- Decreasing stormwater runoff volume.
- Increasing stormwater time of concentration.

Variations

In addition to directing rooftop runoff to vegetated areas, runoff may also be discharged to non-vegetated BMPs, such as dry wells, rain barrels, and cisterns for stormwater retention and volume reduction. With proper design, this rooftop water can be used for lawn watering, gardening, toilet flushing and fire protection.

Applications

Routing rooftop runoff to naturally vegetated areas will reduce runoff volume and peak discharge, as well as improve water quality by slowing runoff, allowing for filtration, and providing opportunity for infiltration and evapotranspiration. The use of pervious areas for rooftop discharge has the ability to reduce the quantity of site stormwater runoff and improve the quality of the stormwater that does discharge from the site. Alternatives for disconnecting roof leaders and the use of vegetated areas should consider the following issues (Prince George's County Department of Environmental Protection, 1997; Maryland Department of the Environment, 1997).

- Encourage shallow sheet flow through vegetated areas, using flow spreading and leveling devices if necessary.
- Direct roof leader flow into BMPs designed specifically to receive and convey rooftop runoff.
- Direct flows into stabilized vegetated areas, including on-lot swales and bioretention areas.
- Rooftop runoff may also be directed to on-site depression storage areas.
- Runoff from industrial roofs and similar uses should not be directed to vegetated areas, if there is reason to believe that pollutant loadings will be elevated.
- Limit the contributing rooftop area to a maximum of 500 ft^2 per downspout.
- Flow from roof leaders should not contribute to basement seepage.

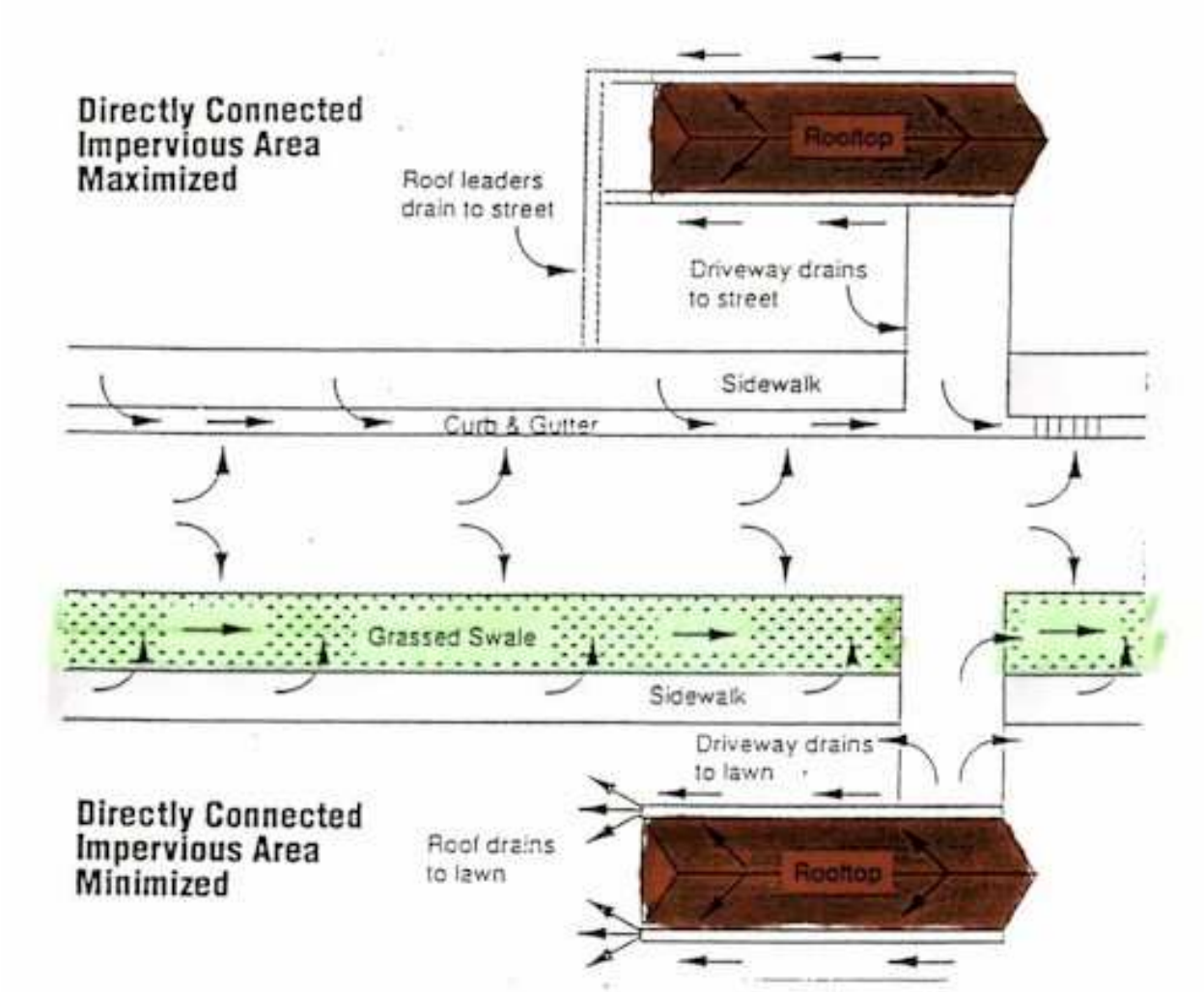


Figure 5.8-1 Examples of Directly Connected Impervious Areas (Roesner, ASCE, 1991)

Careful consideration should be given to the design of vegetated collection areas. Concerns pertaining to basement seepage and water-soaked yards are not unwarranted, with the potential arising for saturated depressed areas and eroded water channels. The proper design and use of bioretention areas, infiltration trenches, and/or dry wells will reduce or eliminate the potential of surface ponding and facilitate functioning during cold weather months.

Maintenance of the planted areas would be required, but would be limited. Routine maintenance would include a biannual health evaluation of the vegetation and subsequent removal of any dead or diseased vegetation plus mulch replenishment, if included in the design. This maintenance can be incorporated into regular maintenance of the site landscaping. If the vegetated area is located in a residential neighborhood, the maintenance responsibility could be delegated to the residents. The use of native plant species in the vegetated area will reduce fertilizer, pesticide, water, and overall maintenance requirements.

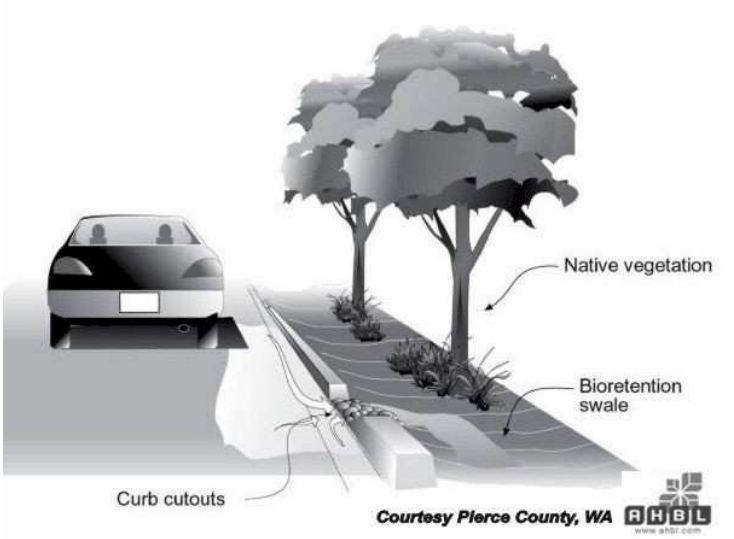
Cost Issues

Construction cost estimates for vegetated areas should be similar or in line with that of conventional landscaping. If bioretention areas are incorporated into the site, their costs are slightly more than costs required for conventional landscaping. Commercial, industrial, and institutional site costs range between $10 and $40 per square foot, based on the design of the bioretention area and the control structures included. These costs, however, can potentially be offset by the reduced costs of conventional stormwater management systems that otherwise would be required, if it were not for the reduction achieved through the application of this BMP.

References

Prince George's County Department of Environmental Protection, 1997
Maryland Department of the Environment, 1997
Center for Watershed Protection, 1998

BMP 5.8.2: Disconnection from Storm Sewers



Minimize stormwater volume by disconnecting impervious roads and driveways and directing runoff to grassed swales and/or bioretention areas to infiltrate.

Key Design Elements

- Disconnect road and driveways from stormwater collection systems.
- Redirect road and driveway runoff into grassed swales or other vegetated systems designed to receive stormwater.
- Eliminate curbs/gutters/conventional collection and conveyance.

Potential Applications

Residential:	Yes
Commercial:	Yes
Ultra Urban:	Limited
Industrial:	Limited
Retrofit:	Limited
Highway/Road:	Limited

Stormwater Functions

Volume Reduction:	High
Recharge:	High
Peak Rate Control:	High
Water Quality:	Low

Water Quality Functions

TSS:	30%
TP:	0%
NO3:	0%

Description

Impervious roads and driveways account for a large percentage of post-development imperviousness. These surfaces influence stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources. Considered a source of more potentially damaging pollution than rooftops, roads and driveways contribute toxic chemicals, oil, and metals to stormwater runoff.

Conventional stormwater management has involved the rapid removal and conveyance of stormwater from these surfaces. The result of this management system has been increased runoff volume, decreased time of concentration, and greater pollutant mobility. Distributed stormwater management through the use of vegetated swales and bioretention areas (discussed in Section 6.4.8 and 6.4.5) can reduce the volume of stormwater runoff while providing on-site treatment and pollutant removal, providing:

- Increased infiltration and evapotranspiration.
- Increased filtration.
- Decreased stormwater runoff volume.
- Increased stormwater time of concentration.

Variations

A variety of alternatives exist for redirecting road and driveway runoff away from stormwater collection systems. In addition to vegetated swales, infiltration trenches or bioretention areas may be utilized. Curbing may be eliminated entirely or selectively eliminated, as shown in Figure 5.8-2. The choice of BMP will depend upon site-specific characteristics including soil type, slope, and stormwater volume.

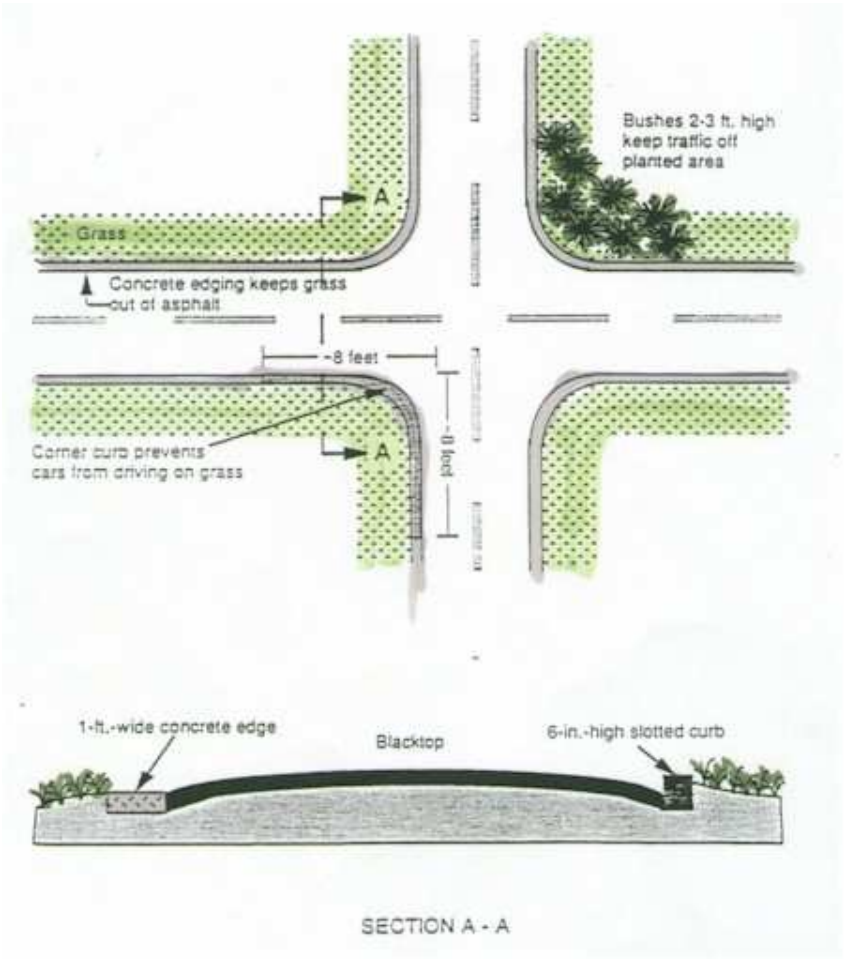


Figure 5.8-2 Example of Concrete Road Edging and Corner Curb (Roesner, ASCE, 1991)

Applications

Routing road and driveway runoff to vegetated swales will reduce runoff volume and peak discharge, as well as improve water quality by slowing runoff, allowing for filtration, and providing opportunity for infiltration and evapotranspiration. Most importantly, in contrast to conventional systems where roads and driveways are connected directly to the stormwater collection and conveyance system, vegetated swales offer the potential for pollutant reductions (see additional discussion in Section 6.8). When stormwater enters the stormwater system directly from road and driveways surfaces, a large variety of pollutants are introduced into the stormwater and eventually the receiving stream. These pollutants include toxic chemicals, oil, metals, and large particulate matter.

The use of vegetated swales, while slowing runoff discharge and permitting infiltration, also allows for pollutant reduction facilitated by the soil media complex and plant uptake. Thus, vegetated swales used in this manner serve a range of functions, intercepting runoff, reducing stormwater volume, and retaining and reducing pollutants. Proper design and implementation still allows stormwater to be quickly removed from road and driveway surfaces alleviating concerns over standing water.

The suitability of vegetated swales depends on land use, soil type, imperviousness of the contributing watershed, and dimensions and slope of the vegetated swale system. Use of natural low-lying areas is encouraged and natural drainage courses should be preserved and utilized.

Maintenance of the vegetated swale should include providing sufficient capacity of the channel and maintaining a dense, healthy vegetated cover. Maintenance activities should include periodic mowing (with plantings never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages.

Cost Issues

See discussion in Chapter 6.4.8. Vegetated swale construction costs are estimated at approximately \$0.25 per ft2. By including design costs, this estimated cost increases to \$0.50 per ft^2, allowing vegetated swales to compare favorably with other stormwater management practices.

5.9 Source Control

BMP 5.9.1: Streetsweeping



Use of one of several modes of sweeping equipment (e.g., mechanical, regenerative air, or vacuum filter sweepers) on a programmed basis to remove larger debris material and smaller particulate pollutants, preventing this material from clogging the stormwater management system and washing into receiving waterways/waterbodies.

Key Design Elements

- Use proper equipment; dry vacuum filters demonstrate optimal results, significantly better than mechanical and regenerative air sweeping, though move slowly and are most costly
- Develop a proper program; vary sweeping frequency by street pollutant load (a function of road type, traffic, adjacent land uses, other factors); sweep roads with curbs/gutters
- Develop a proper program; restrict parking when sweeping to improve removal.
- Develop a proper program; seasonal variation for winter applications as necessary.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/None
Recharge: Low/None
Peak Rate Control: Low/None
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 50%

Description

National Urban Runoff Program (NURP) studies from the 1980's reported generally very poor results from street sweeping. In some cases, results suggested that water quality effects of conventional mechanical street sweeping programs were actually negative. This is possibly explained by the fact that the superficial sweeping accomplished by mechanical sweepers removes a "crust" of large, coarser debris on many surfaces and exposes the finer particles to upcoming storm events. These particles are then washed into receiving water bodies. However, new street sweeping technology (see discussion below) has dramatically improved street sweeping performance. While these new street sweeping technologies are considerably more costly than previous street sweeping technologies, their pollutant reduction performance compares quite favorably to other pollutant reduction BMPs. Streetsweeping can actually be quite cost effective in terms of water quality performance.



Figure 5.13-1 Vacuum Filter Street sweeper

Variations

Variations in street sweeping relate primarily to differences in equipment but also relate to important aspects of the street sweeping programs, such as frequency of street sweeping, use of regulations such as parking prohibitions, and other program factors.

Equipment -

Mechanical broom: use of mechanical brooms/brushes with conveyor belts. Designed to remove standard road debris, using various types of circulating brushes that sweep material onto conveyors and then into bins. Some machines apply water to reduce dust. Includes the Elgin Pelican (3-wheel) and Eagle (4-wheel), Athey;s Mobile (3- and 4-wheel) and Schwarze M-series. Stormwater reports that the vast bulk of sweepers in use in the US are of this type. These sweepers are least expensive and vary in cost from (approximately $60,000 in 2002, according to Stormwater magazine).

Regenerative air: compressed air is directed onto the road surface, loosening fine particles that are then vacuumed. Includes Elgin's Crosswind J, Mobile's RA730 series, Schwarze's A-series, Tymco sweepers. About twice as expensive as mechanical sweepers ($120,000 in 2002, according to Stormwater magazine).

Vacuum filter: vacuum assisted small-micron particle sweepers, either wet or dry. Dry vacuum includes mechanical broom sweeping with a vacuum (Elgion's GeoVac and Whirlwind models and Schwarze's EV-series particulate management); this technology works well even in cold weather conditions. Wet vacuum uses water dust suppression with scrubbers that apply water to pavement; particles are suspended, and then vacuumed. Four to 5 times as expensive as mechanical sweepers, according to Stormwater magazine in 2002. Equipment has been constrained by slow driving speeds (max of 25 mph).

Tandem sweeping: using two machines, surfaces are mechanically swept and then vacuumed.

Applications

Streets weeping programs vary by sweeping frequency that in turn depends on several other factors. Certainly the most obvious factor is the intensity of the roadway and its expected pollutant load – the greater the traffic intensity, the greater the pollutant load. Other factors such as frequency and intensity of rainfall also affect desired street sweeping frequency. Sutherland and Jelen (1997), measuring sediment load reduction, found very high pollutant load reduction with weekly or greater sweeping frequencies in the Portland area with relatively frequent rainfall events.

Another factor to consider in street sweeping programs is "wash-on" or material that washes onto impervious areas from upgradient/upstream pervious surfaces. Obviously if large amounts of sediment and related-pollutants wash onto the paved surfaces during storm events themselves, street sweeping is going to be relatively ineffective. The Center for Watershed Protection maintains that as site imperviousness itself increases and as the imperviousness of upgradient watershed areas increases, potential for wash-on decreases and potential effectiveness of street sweeping increases (Article 121, Center for Watershed Protection *Technical Note 103 from Watershed Protection Techniques 3(1)*, pp. 601-604).

Lastly, pollutant loads being contributed by the rainfall itself, or wetfall (such as total solids, total nitrogen, chemical oxygen demand, extractable copper) will not be reduced or removed through street sweeping by definition. For example, research performed by the Metropolitan Washington Council of Governments found that 34 percent of total nitrogen, 24 percent of total solids, and 18 percent of COD occurred as wetfall (Urban Runoff in the Washington Metropolitan Area, 1983. Final Report: Washington DC Area Urban Runoff Project. USEPA Nationwide Urban Runoff Program, MWCOG Washington DC).

In general, the greater the traffic on a roadway and the greater the number of vehicles using a parking area, the greater the pollutant loads. The greater the pollutant loads, the greater the potential effectiveness of street sweeping. Winter road applications affect street sweeping programs

Cost Issues

Costs of street sweeping include capital costs of purchasing the equipment, annual costs of maintenance, annual costs of operation, plus costs of disposal of the material that is collected. According to the US Environmental Protection Agency's *Preliminary Data Summary of Urban Storm Water Best Management Practices* (August 1999, EPA-821-R-99-012), street sweeper costs are quite variable. A mechanical sweeper with $75,000 purchase price and a 5-year life cycle was found to cost $30 per curb mile (Finley, 1996 and SWRPC, 1991), while a vacuum street sweeper purchased at $150,000 and having an 8-year life cycle cost $15 per curb mile (Satterfield, 1996 and SWRPC, 1991). Further comparisons were made by the EPA, including the effects of varying frequency of sweeping (USEPA, 1999).

The point is that although mechanical sweepers are less expensive than vacuum sweepers, their economic life is shorter than vacuum sweepers. If pollutant removal effectiveness is included in the comparison, vacuum sweepers yield substantially better cost effectiveness in most cases.

Pollutant Removal Performance

Although pollutant removal performance for street sweeping will vary with the frequency of the street sweeping program, evaluations are demonstrating remarkably high pollutant removal, especially if the program includes weekly street sweeping. The Center for Watershed Protection reports one recent study with 45-65 percent removal of total suspended solids, 30-55 percent total phosphorus, 35-60 percent total lead, 25-50 percent total zinc, and 30-55 percent total copper (Kurahashi & Associates, Inc. 1997. *Port of Seattle, Stormwater Treatment BMP Evaluation*). In *Street Sweeping for Pollutant Removal* (Montgomery County Department of Environmental Protection, Montgomery County, Maryland, February 2002), additional pollutant removal effectiveness data is reported from studies performed by the Center for Watershed Protection (*Watershed Treatment Model,* 2001). Total suspended solids reduction ranged from 5 percent (major road) and 30 percent (residential street) for mechanical sweepers to 22 and 64 percent respectively for regenerative air and 79 to 78 percent respectively for vacuum sweepers. For nitrogen, mechanical sweeper pollutant removal was 4 and 24 percent removal for major roads and residential streets, regenerative air was 18 and 51 percent, and vacuum 53 and 62 percent. In summary, although pollutant removal performance for new mechanical sweepers has improved considerably over those of the past generation, the new vacuum technology is significantly better than either mechanical or even regenerative air sweepers and achieves a level of pollutant removal that is frequently better than all other BMPs.

References

Center for Watershed Protection, 2001. *Watershed Treatment Model.*

Center for Watershed Protection, *Article 121: Technical Note 103 from Watershed Protection Techniques 3(1)*, pp. 601-604

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Urban Runoff in the Washington Metropolitan Area, 1983. Final Report: Washington DC Area Urban Runoff Project. USEPA Nationwide Urban Runoff Program, MWCOG Washington DC

Pennsylvania Stormwater Best Management Practices Manual

Chapter 6

Structural BMPs



363-0300-002 / December 30, 2006

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6.1 Introduction

Twenty-one Structural BMPs are listed and described in this chapter. As indicated in both Chapters 4 and 5, many of these "structures" are natural system-based and include vegetation and soils mechanisms as part of their functioning. More conventional "bricks and mortar" structures are also included in this chapter.

Several of the BMPs presented in this chapter lead to variations on a central them. The vegetated swale is a good example of a core BMP that fosters numerous others. These variations have been included in this chapter with some explanation and reference made as to how and when such variations can be successfully applied. As lengthy as the list of Structural BMPs might be , many more BMPs are expected to emerge as stormwater management practices continue to evolve and mature.
Each BMP is outlined using approximately the same structure or outline as has been applied to the Non-Structural BMPs.

6.2 Groupings of Structural BMPs

Structural BMPs are grouped according to the primary, though not exclusive, stormwater functions, as follows:

Volume/Peak Rate Reduction by Infiltration BMPs
Volume/Peak Rate Reduction BMPs
Runoff Quality/Peak Rate BMPs
Restoration BMPs
Other BMPs

In all cases, these stormwater functions are linked to the Recommended Site Control Guidelines presented in Chapter 3. Most of the Structural BMPs fall into the category of Volume/Peak Rate Reduction. Some of these BMPs also possess excellent water quality protection capabilities as well. Volume and Peak Rate functions also can be provided by a smaller group of increasingly important Structural BMPs such as Vegetated Roofs and Roof Capture/Reuse (e.g., rain barrels and cisterns). Certain BMPs provide water quality and peak rate control functions, without any significant control of volume. The Restoration BMPs and Other BMP categories provide a mix of stormwater functions. Although these BMPs have not been frequently used in the past, they can offer real potential for many Pennsylvania municipalities in the future.

Lastly, two special lists of instructions, or Protocols, have been developed specifically for use with all infiltration-oriented structural BMPs and are presented in Appendix C.

Protocol 1: Site Evaluation and Soil Infiltration Testing
Protocol 2: Infiltration Systems Design and Construction Guidelines

These Protocols should be followed whenever infiltration-oriented BMPs are being developed. The Protocols set forth a variety of actions common to all infiltration BMPs. These actions should be taken to ensure that proper site conditions and constraints are being addressed, proper design considerations are being taken, and proper construction specifications are being integrated into the overall design of the BMP. An especially important aspect of these instructions focuses on full and careful testing of the soil, thereby necessitating a separate Protocol that addresses soil testing and analysis. If these Protocols are followed, the risk of failed infiltration BMPs will be minimized, if not eliminated.

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One of the most challenging technical issues considered in this manual involves the selection of BMPs with a high degree of pollutant reduction or removal efficiency. The Non-Structural BMPs described in Chapter 5 and the Structural BMPs presented in Chapter 6 are all rated in terms of their pollutant removal performance or effectiveness. The initial BMP selection process analyzes the final site plan and estimates the potential pollutant load, using Appendix A. The targeted reduction percentage for representative pollutants (such as 85% reduction in TSS and TP load and 50% reduction in the solute load) is achieved by a suitable combination of Non-Structural and Structural BMPs. This process is described in more detail in Chapter 8.

6.3 Manufactured Products

A variety of product suppliers, distributors, and manufacturers have provided extensive product information to PADEP during the preparation of this manual. Many of these products can be used in conjunction with the Non-Structural BMPs set forth in Chapter 5 as well as the Structural BMPs presented in this chapter. The proper application and use of many of these manufactured products can further the stormwater management goals and objectives of this manual. It should be noted that Pennsylvania does not have an established product review and testing function. The interested reader/user is directed to the following sources to learn about the performance of a specific product or technology:

The Technology Acceptance Reciprocity Partnership (TARP) – A partnership of the states of California, Illinois, Maryland, Massachusetts, New Jersey, New York, Pennsylvania and Virginia that establishes standardized methods to guide the collection and evaluation of new and innovative technology performance across the states. Information is available at: www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/index.htm

Environmental Technology Evaluation Center (EvTEC) of The Civil Engineering Research Foundation (CERF), including their Stormwater Best Management Practices (BMPs) Verification Program - information available at http://www.cerf.org/evtec/index.htm & http://www.cerf.org/evtec/eval/wsdot_qr.htm

U.S. EPA's Environmental Technology Verification Program (ETV) - information available at http://www.epa.gov/etv/

The University of New Hampshire's Center for Stormwater Technology Evaluation and Verification (CSTEV) - information available at http://www.unh.edu/erg/cstev/index.htm#

The Chesapeake Bay Program's Innovative Technology Task Force (ITTF) - information about the program as well as many useful links to other programs available at http://www.chesapeakebay.net/info/innov_tech.cfm

New Jersey's Energy and Environmental Technology Verification Program - results available through the New Jersey Corporation for Advanced Technology (NJCAT) at http://www.njcat.org/

Disclaimer: The technology descriptions contained in this document including, but not limited to, information on technology applications, performance, limitations, benefits, and cost, have been provided by vendors. No attempt was made to examine, screen or verify company or technology information. The Pennsylvania Department of Environmental Protection has not confirmed the

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accuracy or legal adequacy of any disclosures, product performance, or other information provided by the companies appearing here. The inclusion of specific products in this document does not constitute or imply their endorsement or recommendation by the Pennsylvania Department of Environmental Protection.

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6.4 Volume/Peak Rate Reduction by Infiltration BMPs

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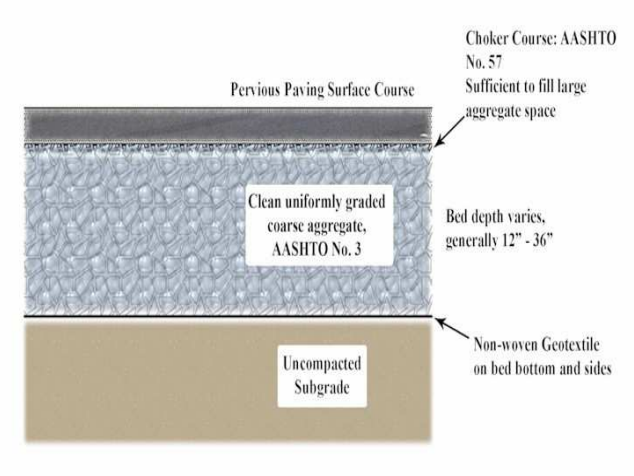
BMP 6.4.1: Pervious Pavement with Infiltration Bed



Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed which provides temporary storage for peak rate control and promotes infiltration. The surface course may consist of porous asphalt, porous concrete, or various porous structural pavers laid on uncompacted soil.

Key Design Elements

- Almost entirely for peak rate control
- Water quality and quantity are not addressed
- Short duration storage; rapid restoration of primary uses
- Minimize safety risks, potential property damage, and user inconvenience
- Emergency overflows
- Maximum ponding depths
- Flow control structures
- Adequate surface slope to outlet

Potential Applications

Residential: Limited
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Medium
Recharge: Medium
Peak Rate Control: Medium
Water Quality: Medium

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

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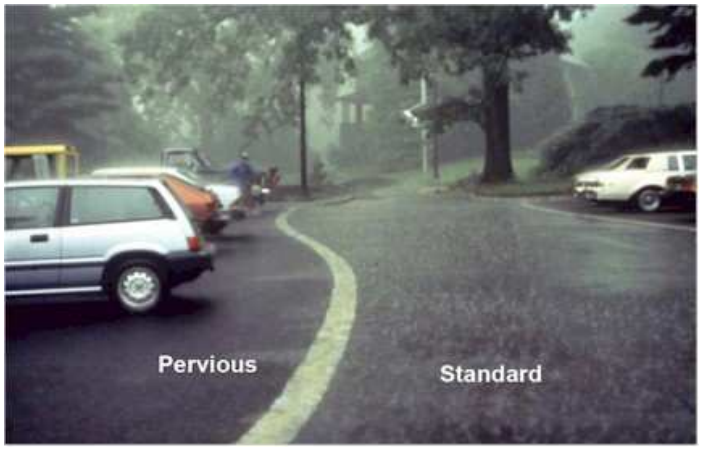
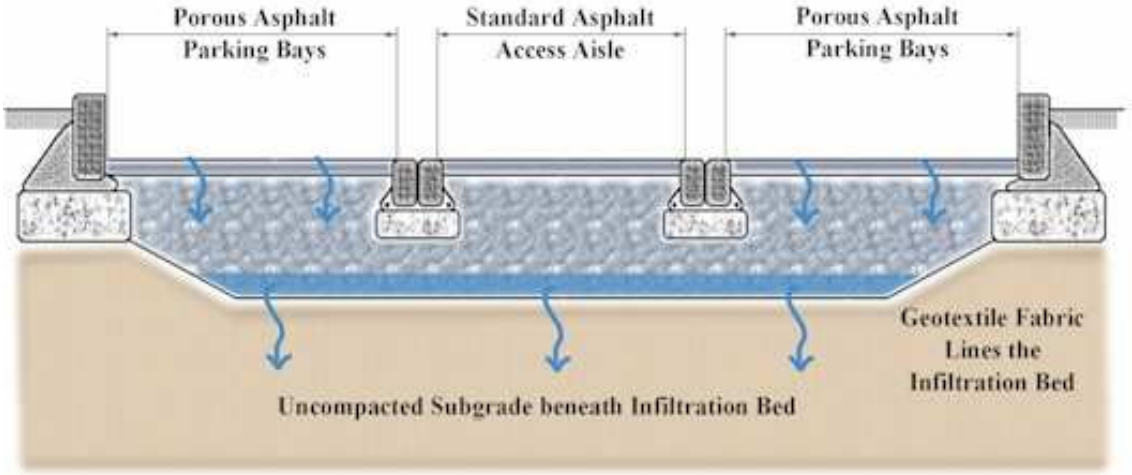
Description

A pervious pavement bed consists of a pervious surface course underlain by a stone bed of uniformly graded and clean-washed coarse aggregate, 1-1/2 to 2-1/2 inches in size, with a void space of at least 40%. The pervious pavement may consist of pervious asphalt, pervious concrete, or pervious pavement units. Stormwater drains through the surface, is temporarily held in the voids of the stone bed, and then slowly drains into the underlying, uncompacted soil mantle. The stone bed can be designed with an overflow control structure so that during large storm events peak rates are controlled, and at no time does the water level rise to the pavement level. A layer of geotextile filter fabric separates the aggregate from the underlying soil, preventing the migration of fines into the bed. The bed bottoms should be level and uncompacted. If new fill is required, it should consist of additional stone and not compacted soil.





Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses. Pervious pavement can be used in driveways if the homeowner is aware of the stormwater functions of the pavement. Pervious pavement roadways have seen wider application in Europe and Japan than in the U.S., although at least one U.S. system has been constructed . In Japan and the U.S., the application of an open-graded asphalt pavement of 1” or less on roadways has been used to provide lateral surface drainage and prevent hydroplaning, but these are applied over impervious pavement on compacted sub-grade. This application is not pervious pavement.

Properly installed and maintained pervious pavement has a significant life-span, and existing systems that are more than twenty years in age continue to function. Because water drains through the surface

course and into the subsurface bed, freeze-thaw cycles do not tend to adversely affect pervious pavement.

Pervious pavement is most susceptible to failure difficulties during construction, and therefore it is important that the construction be undertaken in such as way as to **prevent**:

- Compaction of underlying soil
- Contamination of stone subbase with sediment and fines
- Tracking of sediment onto pavement
- Drainage of sediment laden waters onto pervious surface or into constructed bed

Staging, construction practices, and erosion and sediment control must all be taken into consideration when using pervious pavements.

Studies have shown that pervious systems have been very effective in reducing contaminants such as total suspended solids, metals, and oil and grease. When designed, constructed, and maintained according to the following guidelines, pervious pavement with underlying infiltration systems can dramatically reduce both the rate and volume of runoff, recharge the groundwater, and improve water quality.



In northern climates, pervious pavements have less of a tendency to form black ice and often require less plowing. Winter maintenance is described on page 17. Pervious asphalt and concrete surfaces provide better traction for walking paths in rain or snow conditions.

Variations

Pervious Bituminous Asphalt

Early work on pervious asphalt pavement was conducted in the early 1970's by the Franklin Institute in Philadelphia and consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through small voids. Pervious asphalt is placed directly on the stone subbase in a single 3 ½ inch lift that is lightly rolled to a finish depth of 2 ½ inches.

Because pervious asphalt is standard asphalt with reduced fines, it is similar in appearance to standard asphalt. Recent research in open-graded mixes for highway application has led to additional improvements in pervious asphalt through the use of additives and higher-grade binders. Pervious asphalt is suitable for use in any climate where standard asphalt is appropriate.



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Pervious Concrete

Pervious Portland Cement Concrete, or pervious concrete, was developed by the Florida Concrete Association and has seen the most widespread application in Florida and southern areas. Like pervious asphalt, pervious concrete is produced by substantially reducing the number of fines in the mix in order to establish voids for drainage. In northern and mid-Atlantic climates such as Pennsylvania, pervious concrete should always be underlain by a stone subbase designed for stormwater management and should never be placed directly onto a soil subbase.

While pervious asphalt is very similar in appearance to standard asphalt, pervious concrete has a coarser appearance than its conventional counterpart. Care must be taken during placement to avoid working the surface and creating an impervious layer. Pervious concrete has been proven to be an effective stormwater management BMP. Additional information pertaining to pervious concrete, including specifications, is available from the Florida Concrete Association and the National Ready Mix Association.







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Pervious Paver Blocks



Pervious Paver Blocks consist of interlocking units (often concrete) that provide some portion of surface area that may be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, small parking areas, etc. A number of manufactured products are available, including (but not limited to):

- Turfstone; UNI Eco-stone; Checkerblock; EcoPaver

As products are always being developed, the designer is encouraged to evaluate the benefits of various products with respect to the specific application. Many paver products recommend compaction of the soil and do not include a drainage/storage area, and therefore, they do not provide optimal stormwater management benefits. A system with a compacted subgrade will not provide significant infiltration.

Reinforced Turf and Gravel Filled Grids

Reinforced Turf consists of interlocking structural units that contain voids or areas for turf grass growth and are suitable for traffic loads and parking. Reinforced turf units may consist of concrete or plastic and are underlain by a stone and/or sand drainage system for stormwater management There are also products available that provide a fully permeable surface through the use of plastic rings/grids filled with gravel..

Reinforced Turf applications are excellent for Fire Access Roads, overflow parking, occasional use parking (such as at religious facilities and athletic facilities). Reinforced turf is also an excellent application to reduce the required standard pavement width of paths and driveways that must occasionally provide for emergency vehicle access.

While both plastic and concrete units perform well for stormwater management and traffic needs, plastic units tend to provide better turf establishment and longevity, largely because the plastic will not absorb water and diminish soil moisture conditions. A number of products (e.g. Grasspave, Geoblock, GravelPave, Grassy Pave, Geoweb) are available and the designer is encouraged to evaluate and select a product suitable to the design in question.





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Applications

Parking

Walkways

Pervious Pavement Walkways

Pervious pavement has also been used in walkways and sidewalks. These installations typically consist of a shallow (8 in. minimum) aggregate trench that is sloped to follow the surface slope of the path. In the case of relatively mild surface slopes, the aggregate infiltration trench may be "terraced" into level reaches in order to maximize the infiltration capacity, at the expense of additional aggregate.





Playgrounds



Alleys

SARB_014713

Roof drainage; Direct connection of roof leaders and/or inlets





Limited use for roads and highways





Design Considerations

1. Protocol 1, Site Evaluation and Soil Infiltration Testing required (see Appendix C).

2. Protocol 2, Infiltration Systems Guidelines must be met (see Appendix C).

3. The overall site should be evaluated for potential pervious pavement / infiltration areas early in the design process, as effective pervious pavement design requires consideration of grading.

4. Orientation of the parking bays along the existing contours will significantly reduce the need for cut and fill.

5. Pervious pavement and infiltration beds **should not be placed on areas of recent fill** or compacted fill. Any grade adjust requiring fill should be done using the stone subbase material. Areas of historical fill (>5 years) may be considered for pervious pavement.

6. The bed bottom should not be compacted, however the stone subbase should be placed in lifts and lightly rolled according to the specifications.

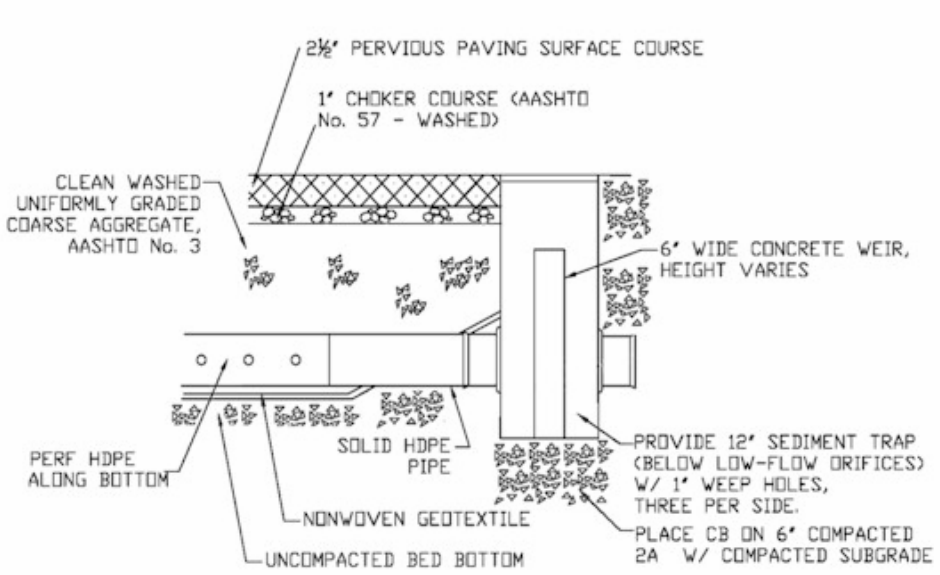
7. During construction, the excavated bed may serve as a temporary sediment basin or trap. This will reduce overall site disturbance. The bed should be excavated to within twelve (12) inches of the final bed bottom elevation for use as a sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established.

8. **Bed bottoms should be level or nearly level**. Sloping bed bottoms will lead to areas of ponding and reduced distribution.

9. **All systems should be designed with an overflow system**. Water within the subsurface stone bed should never rise to the level of the pavement surface. Inlet boxes can be used for cost-effective overflow structures. All beds should empty to meet the criteria in Chapter 3.

10. While infiltration beds are typically sized to handle the increased volume from a storm, they should also be able to convey and mitigate the peak of the less-frequent, more intense storms (such as the 100-yr). Control in the beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal weir and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it always should include positive overflow from the system.

11. The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, the need for a detention basin may be eliminated or reduced in size.



12. A weir plate or weir within an inlet or overflow control structure may be used to maximize the water level in the stone bed while providing sufficient cover for overflow pipes.

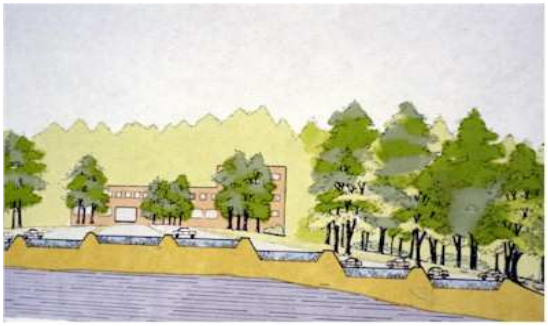
13. Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes should connect structures (such as cleanouts and inlet boxes). Pipes should lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

14. Roof leaders and area inlets may be connected to convey runoff water to the bed. Water Quality Inserts or Sump Inlets should be used to prevent the conveyance of sediment and debris into the bed.

15. Infiltration areas should be located within the immediate project area in order to control runoff at its source. Expected use and traffic demands should also be considered in pervious pavement placement.

16. Control of sediment is critical. Rigorous installation and maintenance of erosion and sediment control measures should be provided to prevent sediment deposition on the pavement surface or within the stone bed. Nonwoven geotextile may be folded over the edge of the pavement until the site is stabilized. The Designer should consider the placement of pervious pavement to reduce the likelihood of sediment deposition. Surface sediment should be removed by a vacuum sweeper and should not be power-washed into the bed.

17. Infiltration beds may be placed on a slope by benching or terracing parking bays**.** Orienting parking bays along existing contours will reduce site disturbance and cut/fill requirements.



18. The underlying infiltration bed is typically 12-36 inches deep and comprised of clean, uniformly graded aggregate with approximately 40% void space. AASHTO No.3, which ranges 1.5-2.5 inches in gradation, is often used. Depending on local aggregate availability, both larger and smaller size aggregate has been used. The critical requirements are that the aggregate be uniformly graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Infiltration beds are typically sized to mitigate the increased runoff volume from a 2-yr design storm.

19. Most pervious pavement installations are underlain by an aggregate bed; alternative subsurface storage products may also be employed. These include a variety of proprietary, interlocking plastic units that contain much greater storage capacity than aggregate, at an increased cost.

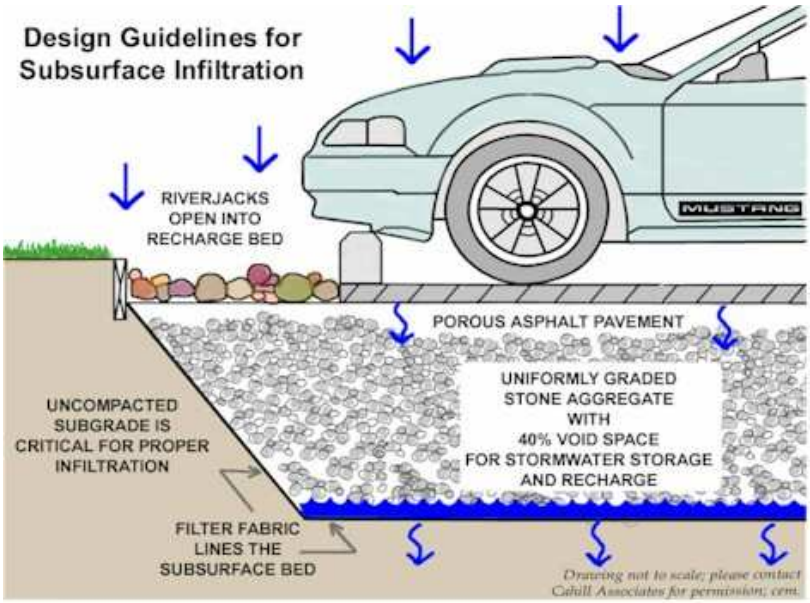
20. All pervious pavement installations should have a backup method for water to enter the stone storage bed in the event that the pavement fails or is altered. In uncurbed lots, this backup drainage may consist of an unpaved 2 ft wide stone edge drain connected directly to the bed. In curbed lots, inlets with water quality devices may be required at low spots. Backup drainage elements will ensure the functionality of the infiltration system, if the pervious pavement is compromised.



21. In areas with poorly draining soils, infiltration beds below pervious pavement may be designed to slowly discharge to adjacent wetlands or bioretention areas. Only in extreme cases (i.e. industrial sites with contaminated soils) will the aggregate bed need to be lined to prevent infiltration.

22. In those areas where the threat of spills and groundwater contamination is likely, pretreatment systems, such as filters and wetlands, may be required before any infiltration occurs. In hot spot areas, such as truck stops, and fueling stations, the appropriateness of pervious pavement must be carefully considered. A stone infiltration bed located beneath standard pavement, preceded by spill control and water quality treatment, may be more appropriate.

23. The use of pervious pavement must be carefully considered in areas where the pavement may be seal coated or paved over due to lack of awareness, such as individual home driveways. In those situations, a system that is not easily altered by the property owner may be more appropriate. An example would include an infiltration system constructed under a conventional driveway. Educational signage at pervious pavement installations may guarantee its prolonged use in some areas.



Detailed Stormwater Functions

Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf) x Void Space

*Depth is the depth of the water stored during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 72 hours.

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Peak Rate Mitigation
See in Chapter 8 for Peak Rate Mitigation methodology that addresses link between volume reduction and peak rate control.

Water Quality Improvement
See in Chapter 8 for Water Quality methodology that addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Due to the nature of construction sites, pervious pavement and other infiltration measures should by installed toward the end of the construction period, if possible. Infiltration beds under pervious pavement may be used as temporary sediment basins or traps provided that they are not excavated to within 12 inches of the designated bed bottom elevation. Once the site is stabilized and sediment storage is no longer required, the bed is excavated to the its final grade and the pervious pavement system is installed.

2. The existing subgrade under the bed areas should NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement.

3. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake (or equivalent) and light tractor. All fine grading shall be done by hand. All bed bottoms should be at a level grade.



4. Earthen berms (if used) between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.

5. Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation. Geotextile should be placed in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile should overlap a minimum of 16 in. It should also be secured at least 4 ft. outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back to bed edge.

6. Clean (washed) uniformly graded aggregate is placed in the bed in 8-inch lifts. Each layer should be lightly compacted, with the construction equipment kept off the bed bottom as much as possible. Once bed aggregate is installed to the desired grade, a +/- 1 in. layer of choker base course (AASHTO #57) aggregate should be installed uniformly over the surface in order to provide an even surface for paving.





7. The pervious pavement should be installed in accordance with current standards. Further information can be obtained from the appropriate Association.

The full permeability of the pavement surface should be tested by application of clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution devise. All applied water should infiltrate directly without puddle formation or surface runoff.

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Maintenance Issues

The primary goal of pervious pavement maintenance is to prevent the pavement surface and/or underlying infiltration bed from being clogged with fine sediments. To keep the system clean throughout the year and prolong its life span, the pavement surface should be vacuumed biannually with a commercial cleaning unit**. Pavement washing systems or compressed air units are not recommended.** All inlet structures within or draining to the infiltration beds should also be cleaned out biannually.

Planted areas adjacent to pervious pavement should be well maintained to prevent soil washout onto the pavement. If any washout does occur it should be cleaned off the pavement immediately to prevent further clogging of the pores. Furthermore, if any bare spots or eroded areas are observed within the planted areas, they should be replanted and/or stabilized at once. Planted areas should be inspected on a semiannual basis. All trash and other litter that is observed during these inspections should be removed.

Superficial dirt does not necessarily clog the pavement voids. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. Furthermore, all construction or hazardous materials carriers should be prohibited from entering a pervious pavement lot.

Special Maintenance Considerations:

- Prevent Clogging of Pavement Surface with Sediment
  - Vacuum pavement 2 or 3 times per year
  - Maintain planted areas adjacent to pavement
  - Immediately clean any soil deposited on pavement
  - Do not allow construction staging, soil/mulch storage, etc. on unprotected pavement surface
  - Clean inlets draining to the subsurface bed twice per year

Winter Maintenance

Winter maintenance for a pervious parking lot may be necessary but is usually less intensive than that required for a standard impervious surface. By its very nature, a pervious pavement system with subsurface aggregate bed has superior snow melting characteristics than standard pavement. The underlying stone bed tends to absorb and retain heat so that freezing rain and snow melt faster on pervious pavement. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms. Abrasives such as sand or cinders should not be applied on or adjacent to the pervious pavement. Snow plowing is fine, provided it is done carefully (i.e. by setting the blade slightly higher than usual, about an inch). Salt is acceptable for use as a deicer on the pervious pavement, though nontoxic, organic deicers, applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable.

Repairs

Potholes in the pervious pavement are unlikely; though settling might occur if a soft spot in the subgrade is not removed during construction. For damaged areas of less than 50 square feet, a declivity could be patched by any means suitable with standard pavement, with the loss of porosity of that area being insignificant. The declivity can also be filled with pervious mix. If an

area greater than 50 sq. ft. is in need of repair, approval of patch type should be sought from either the engineer or owner. Under no circumstance should the pavement surface ever be seal coated. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

Cost Issues

- Pervious asphalt, with additives, is generally 10% to 20% higher (2005) in cost than standard asphalt on a unit area basis.
- Pervious concrete as a material is generally more expensive than asphalt and requires more labor and experience for installation due to specific material constraints.
- Permeable interlocking concrete pavement blocks vary in cost depending on type and manufacturer.

The added cost of a pervious pavement/infiltration system lies in the underlying stone bed, which is generally deeper than a conventional subbase and wrapped in geotextile. However, this additional cost is often offset by the significant reduction in the required number of inlets and pipes. Also, since pervious pavement areas are often incorporated into the natural topography of a site, there generally is less earthwork and/or deep excavations involved. Furthermore, pervious pavement areas with subsurface infiltration beds often eliminate the need (and associated costs, space, etc.) for detention basins. When all of these factors are considered, pervious pavement with infiltration has proven itself less expensive than the impervious pavement with associated stormwater management. Recent (2005) installations have averaged between $2000 and $2500 per parking space, for the pavement and stormwater management.

Specifications

The following specifications are provided for informational purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Stone** for infiltration beds shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29. Choker base course aggregate for beds shall be 3/8 inch to 3/4 inch uniformly graded coarse aggregate AASHTO size number 57 per Table 4, AASHTO Specifications, Part I, 13th Ed., 1998 (p. 47).

2. **Non-Woven Geotextile** shall consist of needled nonwoven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
   c. Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft^2
   d. UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
   e. Heat-set or heat-calendared fabrics are not permitted.

   Acceptable types include Mirafi 140N, Amoco 4547, Geotex 451, or approved others.

3. **Pipe** shall be continuously perforated, smooth interior, with a minimum inside diameter of 6-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

4. **Storm Drain Inlets and Structures**
   a. Concrete Construction: Concrete construction shall be in accordance with PennDOT Pub. 4082003 including current supplements or latest edition.

   b. Precast concrete iInlets and manholes: Precast concrete inlets may be substituted for cast-in-place structures and shall be constructed as specified for cast-in-place. Standard inlet boxes will be modified to provide minimum 12" sump storage and bottom leaching basins, open to gravel sumps in sub-grade, when situated in the recharge bed.

   c. All PVC Catch Basins/Cleanouts/Inline Drains shall have H-10 or H-20 rated grates, depending on their placement (H-20 if vehicular loading).

   d. Steel reinforcing bars over the top of the outlet structure shall conform to ASTM A615, grades 60 and 40.

   e. Permanent turf reinforcement matting shall be installed according to manufacturers' specifications.

5. **Pervious Bituminous Asphalt**
   Bituminous surface course for **pervious paving** should be two and one-half (2.5) inches thick with a bituminous mix of 5.75% to 6% by weight dry aggregate. **In accordance with ASTM D6390, drain down of the binder shall be no greater than 0.3%**. If more absorptive aggregates, such as limestone, are used in the mix, then the amount of bitumen is to be based on the testing procedures outlined in the National Asphalt Pavement Association's Information Series 131 – "Pervious Asphalt Pavements" (2003) or PennDOT equivalent.

   Use neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22 as specified in AASHTO MP-1. The elastomer polymer shall be styrene-butadiene-styrene (SBS), or approved equal, applied at a rate of 3% by weight of the total binder. The composite materials shall be thoroughly blended at the asphalt refinery or terminal prior to being loaded into the transport vehicle. The polymer modified asphalt binder shall be heat and storage stable.

   Aggregate shall be minimum 90% crushed material and have a gradation of:

U.S. Standard Sieve Size	Percent Passing
½ (12.5 mm)	100
3/8 (9.5 mm)	92-98
4 (4.75 mm)	34-40
8 (2.36 mm)	14-20
16 (1.18 mm)	7-13
30 (0.60 mm)	0-4
200 (0.075mm)	0-2

   Add hydrated lime at a dosage rate of 1.0% by weight of the total dry aggregate to mixes containing granite. Hydrated lime shall meet the requirements of ASTM C 977. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a

required tensile strength ratio (TSR) of at least 80% on the asphalt mix when tested in accordance with AASHTO T 283. The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-1664. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

Pervious pavement shall not be installed on wet surfaces or when the ambient air temperature is 50 degrees Fahrenheit or lower. The temperature of the bituminous mix shall be between 300 degrees Fahrenheit and 350 degrees Fahrenheit (based on the recommendations of the asphalt supplier).

6. Pervious Concrete

GENERAL

Weather Limitations: Do not place Portland cement pervious pavement mixtures when the ambient temperature is 40 degrees Fahrenheit or lower or 90 degrees Fahrenheit or higher, unless otherwise permitted in writing by the Engineer.

Test Panels: Regardless of qualification, Contractor is to place, joint and cure at least two test panels, each to be a minimum of 225 sq. ft. at the required project thickness to demonstrate to the Engineer's satisfaction that in-place unit weights can be achieved and a satisfactory pavement can be installed at the site location.

Test panels may be placed at any of the specified Portland Cement pervious locations. Test panels shall be tested for thickness in accordance with ASTM C 42; void structure in accordance with ASTM C 138; and for core unit weight in accordance with ASTM C 140, paragraph 6.3.

Satisfactory performance of the test panels will be determined by:
Compacted thickness no less than ¼" of specified thickness.

Void Structure: 15% minimum; 21% maximum. Unit weight plus or minus 5 pcf of the design unit weight.

If measured void structure falls below 15% or if measured thickness is greater than ¼" less than the specified thickness of if measured weight falls less than 5 pcf below unit weight, the test panel shall be removed at the contractor's expense and disposed of in an approved landfill.

If the test panel meets the above-mentioned requirements, it can be left in-place and included in the completed work.

CONCRETE MIX DESIGN
Contractor shall furnish a proposed mix design with proportions of materials to the Engineer prior to commencement of work. The data shall include unit weights determined in accordance with ASTM C29 paragraph 11, jigging procedure.

MATERIALS
Cement: Portland Cement Type I or II conforming to ASTM C 150 or Portland Cement Type IP or IS conforming to ASTM C 595.

Aggregate: Use No 8 coarse aggregate (3/8 to No. 16) per ASTM C 33 or No. 89 coarse aggregate (3/8 to No. 50) per ASTM D 448. If other gradation of aggregate is to be used, submit data on proposed material to owner for approval.

Air Entraining Agent: Shall comply with ASTM C 260 and shall be used to improve resistance to freeze/thaw cycles.

Admixtures: The following admixtures shall be used:
Type D Water Reducing/Retarding – ASTM C 494.
A hydration stabilizer that also meets the requirements of ASTM C 494 Type B Retarding or Type D Water Reducing/Retarding admixtures. This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, which delays the particles from achieving initial set.

Water: Potable shall be used.

Proportions:
Cement Content: For pavements subjected to vehicular traffic loading, the total cementitious material shall not be less than 600 lbs. Per cy.
Aggregate Content: the volume of aggregate per cu. yd. shall be equal to 27 cu.ft. when calculated as a function of the unit weight determined in accordance with ASTM C 29 jigging procedure. Fine aggregate, if used, should not exceed 3 cu. ft. and shall be included in the total aggregate volume.

Admixtures: Shall be used in accordance with the manufacturer's instructions and recommendations.

Mix Water: Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (Mix water yielding a cement paste with a dull-dry appearance has insufficient water for hydration).

- Insufficient water results in inconsistency in the mix and poor bond strength.
- High water content results in the paste sealing the void system primarily at the bottom and poor surface bond.

An aggregate/cement (A/C) ratio range of 4:1 to 4.5:1 and a water/cement (W/C) ratio range of 0.34 to 0.40 should produce pervious pavement of satisfactory properties in regard to permeability, load carrying capacity, and durability characteristics.

INSTALLATION
Portland Cement Pervious Pavement Concrete Mixing, Hauling and Placing:
Mix Time: Truck mixers shall be operated at the speed designated as mixing speed by the manufacturer for 75 to 100 revolutions of the drum.

Transportation: The Portland Cement aggregate mixture may be transported or mixed on site and should be used within one (1) hour of the introduction of mix water, unless otherwise approved by an engineer. This time can be increased to 90 minutes when utilizing the specified hydration stabilizer. Each truck should not haul more than two (2) loads before being cycled to another type concrete. Prior to placing concrete, the subbase shall be moistened and in a wet condition. Failure to provide a moist subbase will result in a reduction in strength of the pavement.

Discharge: Each mixer truck will be inspected for appearance of concrete uniformity according to this specification. Water may be added to obtain the required mix consistency. A minimum of 20 revolutions at the manufacturer's designated mixing speed shall be required following any addition of water to the mix. Discharge shall be a continuous operation and shall be completed as quickly as possible. Concrete shall be deposited as close to its final position as practicable and such that fresh concrete enters the mass of previously placed concrete. The practice of discharging onto subgrade and pulling or shoveling to final placement is not allowed.

Placing and Finishing Equipment: Unless otherwise approved by the Owner or Engineer in writing, the Contractor shall provide mechanical equipment of either slipform or form riding with a following compactive unit that will provide a minimum of 10 psi vertical force. The pervious concrete pavement will be placed to the required cross section and shall not deviate more than +/- 3/8 inch in 10 feet from profile grade. If placing equipment does not provide the minimum specified vertical force, a full width roller or other full width compaction device that provides sufficient compactive effort shall be used immediately following the strike-off operation. After mechanical or other approved strike-off and compaction operation, no other finishing operation will be allowed. If vibration, internal or surface applied, is used, it shall be shut off immediately when forward progress is halted for any reason. The Contractor will be restricted to pavement placement widths of a maximum of fifteen (15') feet unless the Contractor can demonstrate competence to provide pavement placement widths greater than that to the satisfaction of the Engineer.

Curing: Curing procedures shall begin within 20 minutes after the final placement operations. The pavement surface shall be covered with a minimum six-(6) mil thick polyethylene sheet or other approved covering material. Prior to covering, a fog or light mist shall be sprayed above the surface when required due to ambient conditions (high temperature, high wind, and low humidity). The cover shall overlap all exposed edges and shall be secured (without using dirt) to prevent dislocation due to winds or adjacent traffic conditions.

Cure Time:

1. Portland Cement Type I, II, or IS – 7 days minimum.
2. No truck traffic shall be allowed for 10 days (no passenger car/light trucks for 7 days).

Jointing: Control (contraction) joints shall be installed at 20-foot intervals. They shall be installed at a depth of the 1/ 4 the thickness of the pavement. These joints can be installed in the plastic concrete or saw cut. If saw cut, the procedure should begin as soon as the pavement has hardened sufficiently to prevent raveling and uncontrolled cracking (normally after curing). Transverse constructions joints shall be installed whenever placing is suspended a sufficient length of time that concrete may begin to harden. In order to assure aggregate bond at construction joints, a bonding agent suitable for bonding fresh concrete shall be brushed, tolled, or sprayed on the existing pavement surface edge. Isolation (expansion) joints will not be used except when pavement is abutting slabs or other adjoining structures.

TESTING, INSPECTION, AND ACCEPTANCE

Laboratory Testing:
The owner will retain an independent testing laboratory. The testing laboratory shall conform to the applicable requirements of ASTM E 329 "Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction" and ASTM C 1077 "Standard Practice for Testing Concrete and Concrete Aggregates for use in Construction, and Criteria for Laboratory Evaluation" and shall be inspected and accredited by the Construction Materials Engineering Council, Inc. or by an equivalent recognized national authority.

The Agent of the testing laboratory performing field sampling and testing of concrete shall be certified by the American Concrete Institute as a Concrete Field Testing Technician Grade I, or by a recognized state or national authority for an equivalent level of competence.

Testing and Acceptance:
A minimum of 1 gradation test of the subgrade is required every 5000 square feet to determine percent passing the No. 200 sieve per ASTM C 117.
A minimum of one test for each day's placement of pervious concrete in accordance with ASTM C 172 and ASTM C 29 to verify unit weight shall be conducted. Delivered unit weights are to be determined in accordance with ASTM C 29 using a 0.25 cubic foot cylindrical metal measure. The measure is to be filled and compacted in accordance with ASTM C 29 paragraph 11, jigging procedure. The unit weight of the delivered concrete shall be +/- 5 pcf of the design unit weight.

Test panels shall have two cores taken from each panel in accordance with ASTM 42 at a minimum of seven (7) days after placement of the pervious concrete. The cores shall be measured for thickness, void structure, and unit weight. Untrimmed, hardened core samples shall be used to determine placement thickness. The average of all production cores shall not be less than the specified thickness with no individual core being more than ½ inch less than the specified thickness. After thickness determination, the cores shall be trimmed and measured for unit weight in the saturated condition as described in paragraph 6.3.1 of 'Saturation' of ASTM C 140 "Standard Methods of Sampling and Testing Concrete Masonry Units." The trimmed cores shall be immersed in water for 24 hours, allowed to drain for one (1) minute, surface water removed with a damp cloth, then weighed immediately. Range of satisfactory unit weight values are +/- 5 pcf of the design unit weight.

After a minimum of 7 days following each placement, three cores shall be taken in accordance with ASTM C 42. The cores shall be measured for thickness and unit weight determined as described above for test panels. Core holes shall be filled with concrete meeting the pervious mix design.

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BMP 6.4.2: Infiltration Basin



An Infiltration Basin is a shallow impoundment that stores and infiltrates runoff over a level, uncompacted, (preferably undisturbed area) with relatively permeable soils.

Key Design Elements

- Maintain a minimum 2-foot separation to bedrock and seasonally high water table, provide distributed infiltration area (5:1 impervious area to infiltration area - maximum), site on natural, uncompacted soils with acceptable infiltration capacity, and follow other guidelines described in Protocol 2: Infiltration Systems Guidelines
- Uncompacted sub-grade
- Infiltration Guidelines and Soil Testing Protocols apply
- Preserve existing vegetation, if possible
- Design to hold/infiltrate volume difference in 2-yr storm or 1.5" storm
- Provide positive stormwater overflow through engineered outlet structure.
- Do not install on recently placed fill (<5 years).
- Allow 2 ft buffer between bed bottom and seasonal high groundwater table and 2 ft buffer for rock.
- When possible, place on upland soils.
-

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes*
Retrofit: Yes
Highway/Road: Limited

* Applicable with specific consideration to design.

Stormwater Functions

Volume Reduction: High
Recharge: High
Peak Rate Control: Med./High
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

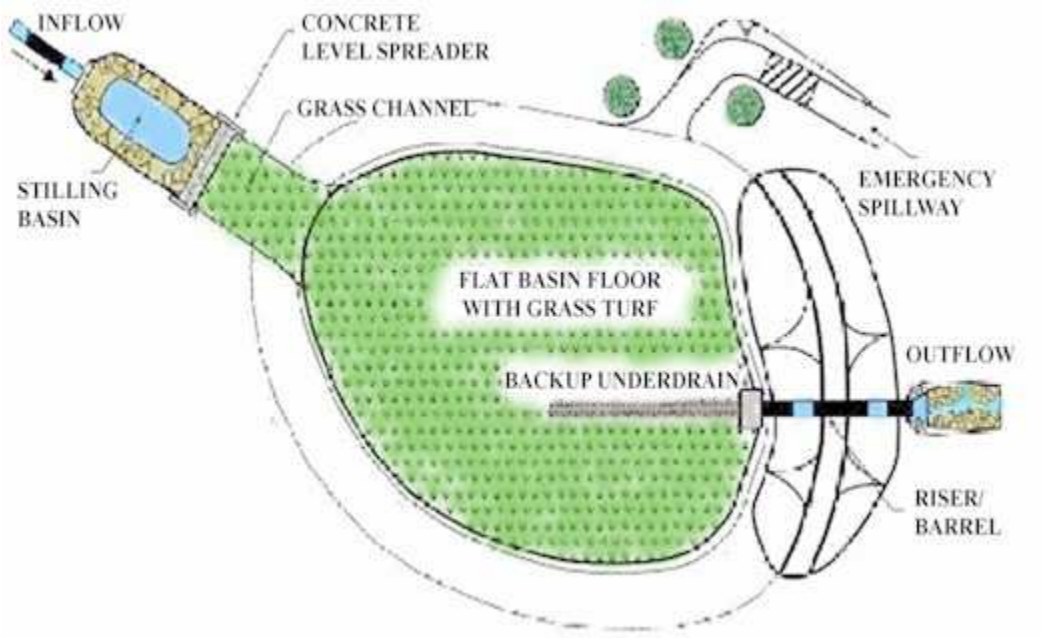
Other Considerations

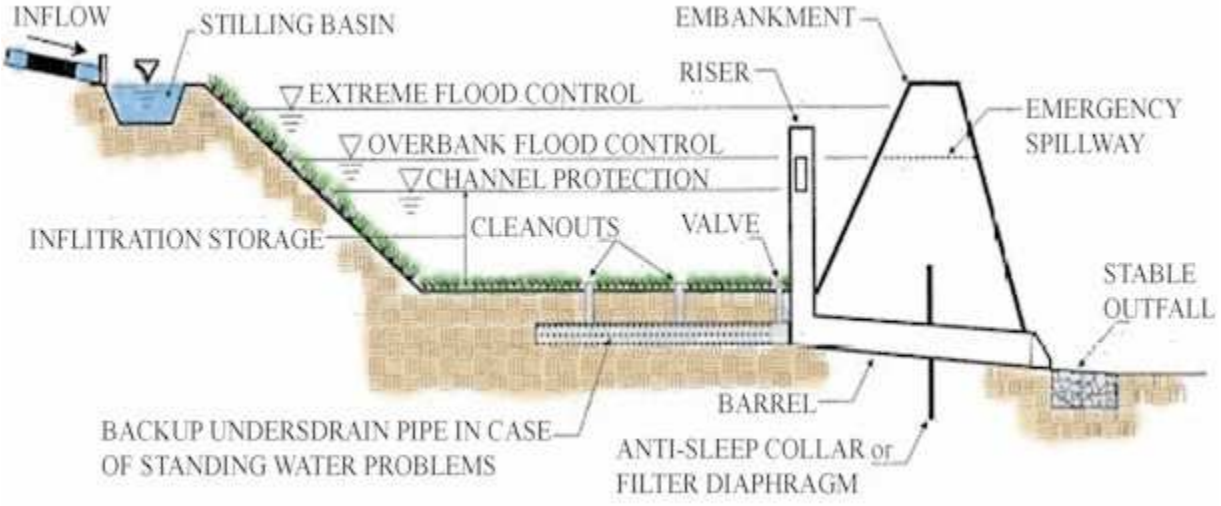
- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

SARB_014728

Description

Infiltration Basins are shallow, impounded areas designed to temporarily store and infiltrate stormwater runoff. The size and shape can vary from one large basin to multiple, smaller basins throughout a site. Ideally, the basin should avoid disturbance of existing vegetation. If disturbance is unavoidable, replanting and landscaping may be necessary and should integrate the existing landscape as subtly as possible and compaction of the soil must be prevented (see Infiltration Guidelines). Infiltration Basins use the existing soil mantle to reduce the volume of stormwater runoff by infiltration and evapotranspiration. The quality of the runoff is also improved by the natural cleansing processes of the existing soil mantle and also by the vegetation planted in the basins. The key to promoting infiltration is to provide enough surface area for the volume of runoff to be absorbed to meet the criteria in Chapter 3. An engineered overflow structure should be provided for the larger storms.





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Variations

- Re-Vegetation
  For existing unvegetated areas or for infiltration basins that require excavation, vegetation may be added. Planting in the infiltration area will improve water quality, encourage infiltration, and promote evapotranspiration. This vegetation may range from a meadow mix to more substantial woodland species. The planting plan should be sensitive to hydrologic variability anticipated in the basin, as well as to larger issues of native plants and habitat, aesthetics, and other planting objectives. **The use of turf grass is discouraged** due to soil compaction from the required frequent mowing and maintenance requirements.

- Usable Surface
  An Infiltration Basin can be used for recreation (usually informal) in dry periods. Heavy machinery and/or vehicular traffic of any type should be avoided so as not to compact the infiltration area.

- Soils with Poor Infiltration Rates
  A layer of sand (6") or gravel can be placed on the bottom of the Infiltration Basin, or the soil can be amended to increase the surface permeability of the basin. (See Soil Amendment & Restoration BMP 6.7.3 for details.)

Applications

- New Development
  Infiltration Basins can be incorporated into new development. Ideally, existing vegetation can be preserved and utilized as the infiltration area. Runoff from adjacent buildings and impervious surfaces can be directed into this area, which will "water" the vegetation, thereby increasing evapotranspiration in addition to encouraging infiltration.

- Retrofitting existing "lawns" and "open space"
  Existing grassed areas can be converted to infiltration basins. If the soil and infiltration capacity is determined to be sufficient, the area can be enclosed through creation of a berm and runoff can be directed to it without excavation. Otherwise, excavation can be performed as described below.

- Other Applications
  Other applications of Infiltration Basins may be determined by the Design Professional as appropriate.

Design Considerations

1. Soil Investigation and Infiltration Testing is required; site selection for this BMP should take soil and infiltration capacity into consideration.

2. Guidelines for Infiltration Systems should be met (i.e., depth to water table, setbacks, Loading Rates, etc.)

3. Basin designs that do not remove existing soil and/or vegetation are preferred.

4. The slope of the Infiltration Basin bottom should be level or with a slope no greater than 1%. A level bottom assures even water distribution and infiltration.

5. Basins may be constructed where impermeable soils on the surface are removed and where more permeable underlying soils then are used for the base of the bed; care must be taken in the excavation process to make sure that soil compaction does not occur.

6. The discharge or overflow from the Infiltration Basin should be properly designed for anticipated flows. Large infiltration basins may require multiple outlet control devices to effectively overflow water during the larger storms. See BMP 6.3.3 for more information on overflows and berms.

7. The berms surrounding the basin should be compacted earth with a slope of not steeper than 3:1(H:V), and a top width of at least 2 feet.

8. At least one foot of freeboard above the 100-year storm water elevation should be maintained.

9. Infiltration basins can be planted with natural grasses, meadow mix, or other “woody” mixes, such as trees or shrubs. These plants have longer roots than traditional grass and increase soil permeability. Native plants should be used wherever possible.

10. Use of fertilizer should be avoided.

11. The surface should be compacted as little as possible to allow for surface percolation through the soil layer.

12. When directing runoff from roadway areas into the basin, measures to reduce sediment should be used.

13. The inlets into the basin should have erosion protection.

14. Contributing inlets (up gradient) may have a sediment trap or water quality insert to prevent large particles from clogging the system based on the quality of the runoff.

15. Use of a backup underdrain or low-flow orifice may be considered in the event that the water in the basin does not drain within the criteria in Chapter 3. This underdrain valve should remain in the shut position unless the basin does not drain.

Detailed Stormwater Functions

Infiltration Area

The loading rate guidelines in Appendix C should be consulted
The Infiltration Area is the bottom area of the bed.

Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf)

*Depth is the depth of the water stored during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)

*Infiltration Period is equal to 2 hours or tne time of concentration, whichever is larger.

Peak Rate Mitigation Calculations: See Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement: See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Protect Infiltration basin area from compaction prior to installation.

2. If possible, install Infiltration basin during later phases of site construction to prevent sedimentation and/or damage from construction activity. After installation, prevent sediment-laden water from entering inlets and pipes.

3. Install and maintain proper Erosion and Sediment Control Measures during construction.

4. If necessary, excavate Infiltration basin bottom to an uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.

5. Install Outlet Control Structures.

6. Seed and stabilize topsoil. (Vegetate if appropriate with native plantings.)

7. Do not remove Inlet Protection or other Erosion and Sediment Control measures until site is fully stabilized.

Maintenance and Inspection Issues

- Catch Basins and Inlets (upgradient of infiltration basin) should be inspected and cleaned at least two times per year and after runoff events.

- The vegetation along the surface of the Infiltration basin should be maintained in good condition, and any bare spots revegetated as soon as possible.

- Vehicles should not be parked or driven on an Infiltration Basin, and care should be taken to avoid excessive compaction by mowers.

- Inspect the basin after runoff events and make sure that runoff drains down within 72 hours. Mosquito's should not be a problem if the water drains in 72 hours. Mosquitoes require a

considerably long breeding period with relatively static water levels.

- Also inspect for accumulation of sediment, damage to outlet control structures, erosion control measures, signs of water contamination/spills, and slope stability in the berms.
- Mow only as appropriate for vegetative cover species.
- Remove accumulated sediment from basin as required. Restore original cross section and infiltration rate. Properly dispose of sediment.

Cost Issues

The construction cost of Infiltration Basins can vary greatly depending on the configuration, location, site-specific conditions, etc.

Excavation (if necessary) - varies
Plantings - Meadow mix $2500 - $3500 / acre (2005)
Pipe Configuration – varies with stormwater configuration, may need to redirect pipes into the infiltration basin.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. Topsoil amend with compost if necessary or desired. (See Soil Amendment & Restoration BMP 6.7.2)

2. Vegetation See Native Plant List available locally, and/or see Appendix B.

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BMP 6.4.3: Subsurface Infiltration Bed



Subsurface Infiltration Beds provide temporary storage and infiltration of stormwater runoff by placing storage media of varying types beneath the proposed surface grade. Vegetation will help to increase the amount of evapotranspiration taking place.

Key Design Elements

- Maintain a minimum 2-foot separation to bedrock and seasonally high water table, provide distributed infiltration area (5:1 impervious area to infiltration area - maximum), site on natural, uncompacted soils with acceptable infiltration capacity, and follow other guidelines described in Protocol 2: Infiltration Systems Guidelines
- Beds filled with stone (or alternative) as needed to increase void space
- Wrapped in nonwoven geotextile
- Level or nearly level bed bottoms
- Provide positive stormwater overflow from beds
- Protect from sedimentation during construction
- Provide perforated pipe network along bed bottom for distribution as necessary
- Open-graded, clean stone with minimum 40% void space
- Do not place bed bottom on compacted fill

• Allow 2 ft. buffer between bed bottom and seasonal high groundwater table and 2 ft. for bedrock.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: High
Recharge: High
Peak Rate Control: Med./High
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

SARB_014734

Description

A Subsurface Infiltration Bed generally consists of a vegetated, highly pervious soil media underlain by a uniformly graded aggregate (or alternative) bed for temporary storage and infiltration of stormwater runoff. Subsurface Infiltration beds are ideally suited for expansive, generally flat open spaces, such as lawns, meadows, and playfields, which are located downhill from nearby impervious areas. Subsurface Infiltration Beds can be stepped or terraced down sloping terrain provided that the base of the bed remains level. Stormwater runoff from nearby impervious areas (including rooftops, parking lots, roads, walkways, etc.) can be conveyed to the subsurface storage media, where it is then distributed via a network of perforated piping.

The storage media for subsurface infiltration beds typically consists of clean-washed, uniformly graded aggregate. However, other storage media alternatives are available. These alternatives are generally variations on plastic cells that can more than double the storage capacity of aggregate beds, at a substantially increased cost. Storage media alternatives are ideally suited for sites where potential infiltration area is limited.

If designed, constructed, and maintained as per the following guidelines, Subsurface Infiltration features can stand-alone as significant stormwater runoff volume, rate, and quality control practices. These systems can also maintain aquifer recharge, while preserving or creating valuable open space and recreation areas. They have the added benefit of functioning year-round, given that the infiltration surface is typically below the frost line.

Variations

As its name suggests, Subsurface Infiltration is generally employed for temporary storage and infiltration of runoff in subsurface storage media. However, in some cases, runoff may be temporarily stored on the surface (to depths less than 6 inches) to enhance volume capacity of the system. The overall system design should ensure that within the criteria in Chapter 3, the bed is completely empty.

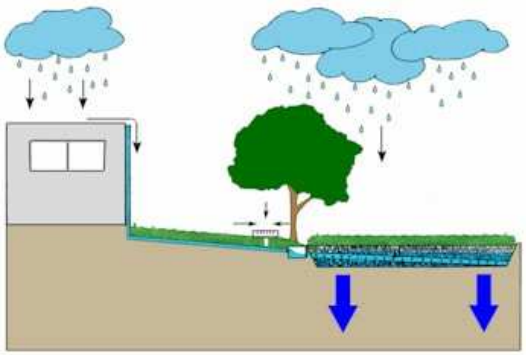
Applications

Connection of Roof Leaders

Runoff from nearby roofs may be directly conveyed to subsurface beds via roof leader connections to perforated piping. Roof runoff generally has relatively low sediment levels, making it ideally suited for connection to an infiltration bed. However, cleanout(s) with a sediment sump are still recommended between the building and infiltration bed.

Connection of Inlets

Catch Basins, inlets, and area drains may be connected to Subsurface Infiltration beds. However, sediment and debris removal should be provided. Storm structures should therefore include sediment trap areas below the inverts of discharge pipes to trap solids and debris. In areas of high traffic or excessive generation of sediment, litter, and other similar materials, a water quality insert or other pretreatment device may be needed.



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Under Recreational Fields

Subsurface Infiltration is very well suited below playfields and other recreational areas. Special consideration should be given to the engineered soil mix in those cases.



Under Open Space

Subsurface Infiltration is also appropriate in either existing or proposed open space areas. Ideally, these areas are vegetated with native grasses and/or vegetation to enhance site aesthetics and landscaping. Aside from occasional clean-outs or outlet structures, Subsurface Infiltration systems are essentially hidden stormwater management features, making them ideal for open space locations (deed-restricted open space locations are especially desirable because such locations minimize the chance that Subsurface Infiltration systems will be disturbed or disrupted accidentally in the future).

Other Applications

Other applications of Subsurface Infiltration beds may be determined by the Design Professional as appropriate.

Design Considerations

1. Soil Investigation and Infiltration Testing is needed (Appendix C).

2. Guidelines for Infiltration Systems should be met (Appendix C).

3. The overall site should be evaluated for potential Subsurface Infiltration areas early in the design process, as effective design requires consideration of existing site characteristics (topography, natural features/drainage ways, soils, geology, etc.).

4. Control of Sediment is critical. Rigorous installation and maintenance of erosion and sediment control measures is needed to prevent sediment deposition within the stone bed. Nonwoven geotextile may be folded over the edge of the bed until the site is stabilized.

5. The Infiltration bed should be wrapped in non-woven geotextile filter fabric.

6. Subsurface Infiltration areas should not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill should be done using the stone subbase material, or alternative. Areas of historical fill (>5 years) may be considered if other criteria are met.



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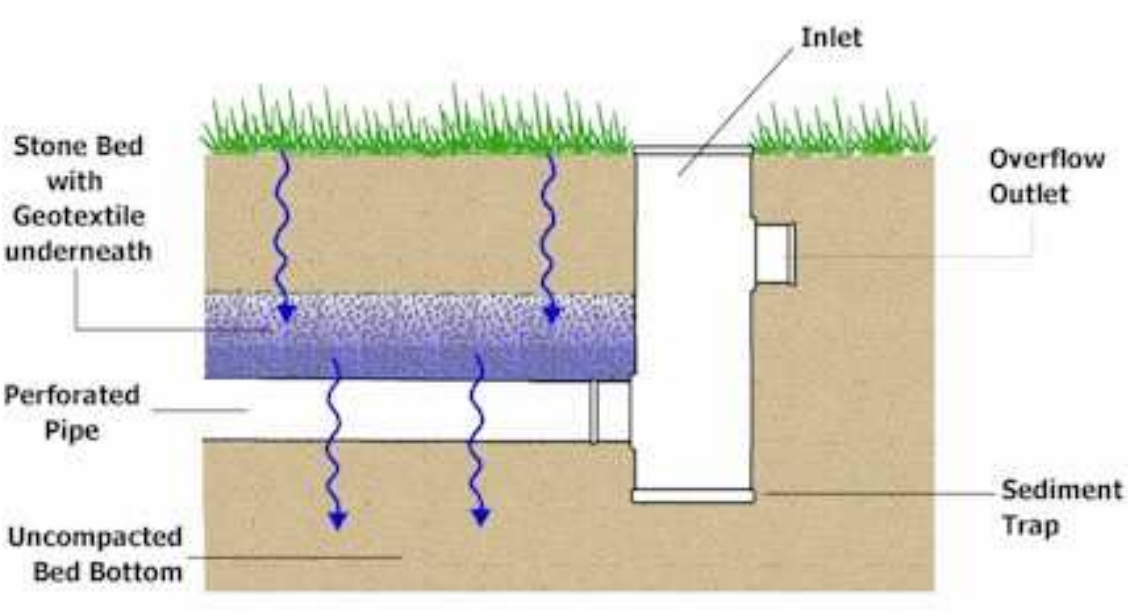
7. The subsurface infiltration bed is typically comprised of a 12 to 36 inch section of aggregate, such as AASHTO No.3, which ranges 1-2 inches in gradation. Depending on local aggregate availability, both larger and smaller size aggregate has been used. The critical requirements are that the aggregate be uniformly graded, clean-washed, and contain at least 40% void space. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, and site grading. Infiltration beds are typically sized to mitigate the increased runoff volume from the design storm.



8. Water Quality Inlet or Catch Basin with Sump is needed for all surface inlets, should be designed to avoid standing water for periods greater than the criteria in Chapter 3.

9. Infiltration beds may be placed on a slope by benching or terracing infiltration levels. The slope of the infiltration bed bottom should be level or with a slope no greater than 1%. A level bottom assures even water distribution and infiltration.

10. Perforated pipes along the bottom of the bed can be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes may connect structures (such as cleanouts and inlet boxes). Pipes should lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

11. Cleanouts or inlets should be installed at a few locations within the bed and at appropriate intervals to allow access to the perforated piping network and or storage media.

12. All infiltration beds should be designed with an overflow for extreme storm events. Control in the beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal concrete weir (or weir plate) and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it must always include positive overflow from the system. The overflow structure is used to maximize the water level in the stone bed, while providing sufficient cover for overflow pipes. Generally, the top of the outlet pipe should be 4 inches below the top of the aggregate to prevent saturated soil conditions in remote areas of the bed. As with all

infiltration practices, multiple discharge points are recommended. These may discharge to the surface or a storm sewer system.

13. Adequate soil cover (generally 12 - 18 inches) should be maintained above the infiltration bed to allow for a healthy vegetative cover.

14. Open space overlying infiltration beds can be vegetated with native grasses, meadow mix, or other low-growing, dense vegetation. These plants have longer roots than traditional grass and will likely benefit from the moisture in the infiltration bed, improving the growth of these plantings and, potentially increasing evapotranspiration.

15. Fertilizer use should be minimized.

16. The surface (above the stone bed) should be compacted as minimally as possible to allow for surface percolation through the engineered soil layer and into the stone bed.

17. When directing runoff from roadway areas into the beds, measures to reduce sediment should be used.

18. Surface grading should be relatively flat, although a relatively mild slope between 1% and 3% is recommended to facilitate drainage.

19. In those areas where the threat of spills and groundwater contamination exists, pretreatment systems, such as filters and wetlands, may be needed before any infiltration occurs. In Hot Spot areas, such as truck stops and fueling stations, the suitability of Subsurface Infiltration must be considered.

20. In areas with poorly-draining soils, Subsurface Infiltration areas may be designed to slowly discharge to adjacent wetlands or bioretention areas.

21. While most Subsurface Infiltration areas consist of an aggregate storage bed, alternative subsurface storage products may also be employed. These include a variety of proprietary, interlocking plastic units that contain much greater storage capacity than aggregate, at an increased cost.

22. The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, detention basins may be eliminated or significantly reduced in size.

23. During Construction, the excavated bed may serve as a Temporary Sediment Basin or Trap. This can reduce overall site disturbance. The bed should be excavated to at least 1 foot above the final bed bottom elevation for use as a sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established. In BMPs that will be used for infiltration in the future, use of construction equipment should be limited as much as possible.

Detailed Stormwater Functions

Infiltration Area

Loading rate quidelines in Appendix C should be consulted**.**

The Infiltration Area is the bottom area of the bed, defined as:

Length of bed x Width of bed = Infiltration Area (if rectangular)

Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf) x Void Space

*Depth is the depth of water stored during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)

*Infiltration Period is equal to 2 hours or the time of concentration, whichever is larger.

Additional storage/volume reduction can be calculated for the overlying soil as appropriate.

Peak Rate Mitigation Calculations

See in Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement: See in Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Due to the nature of construction sites, Subsurface Infiltration should be installed toward the end of the construction period, if possible. (Infiltration beds may be used as temporary sediment basins or traps as discussed above).

2. Install and maintain adequate Erosion and Sediment Control Measures (as per the Pennsylvania Erosion and Sedimentation Control Program Manual) during construction.

3. The existing subgrade under the bed areas should NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement.

4. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake (or equivalent) and light tractor. All fine grading should be done by hand. All bed bottoms should be at level grade.

5. Earthen berms (if used) between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.

6. Install upstream and downstream control structures, cleanouts, perforated piping, and all other necessary stormwater structures.

7. Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation and installation of structures. Geotextile should be placed in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile should overlap a minimum of 16 inches. It should also be secured at least 4 feet outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back to the edge of the bed.

8. Clean-washed, uniformly graded aggregate should be placed in the bed in maximum 8-inch lifts. Each layer should be lightly compacted, with construction equipment kept off the bed bottom as much as possible.

9. Approved soil media should be placed over infiltration bed in maximum 6-inch lifts.

10. Seed and stabilize topsoil.

11. Do not remove inlet protection or other Erosion and Sediment Control measures until site is fully stabilized.

Maintenance Issues

Subsurface Infiltration is generally less maintenance intensive than other practices of its type. Generally speaking, vegetation associated with Subsurface Infiltration practices is less substantial than practices such as Recharge Gardens and Vegetated Swales and therefore requires less maintenance. Maintenance activities required for the subsurface bed are similar to those of any infiltration system and focus on regular sediment and debris removal. The following represents the recommended maintenance efforts:

- All Catch Basins and Inlets should be inspected and cleaned at least 2 times per year.

- The overlying vegetation of Subsurface Infiltration features should be maintained in good condition, and any bare spots revegetated as soon as possible.

- Vehicular access on Subsurface Infiltration areas should be prohibited, and care should be taken to avoid excessive compaction by mowers. If access is needed, use of permeable, turf reinforcement should be considered.

Cost Issues

The construction cost of Subsurface Infiltration can vary greatly depending on design variations, configuration, location, desired storage volume, and site-specific conditions, among other factors. Typical construction costs are about $5.70 per square foot, which includes excavation, aggregate (2.0 feet assumed), non-woven geotextile, pipes and plantings.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Stone** for infiltration beds shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. **Non-Woven Geotextile** shall consist of needled non-woven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) 225 psi
   c. Flow Rate (ASTM-D4491) 95 gal/min/ft^2
   d. UV Resistance after 500 hrs (ASTM-D4355) 70%
   e. Heat-set or heat-calendared fabrics are not permitted
      Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. **Topsoil** may be amended with compost (See soil restoration BMP 6.7.2)

4. **Pipe** shall be continuously perforated, smooth interior, with a minimum inside diameter of 6-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

5. **Storm Drain Inlets and Structures**
   a. Concrete Construction: Concrete construction shall be in accordance with Section 1001, PennDOT Specifications, 1990 or latest edition.
   b. Precast Concrete Inlets and Manholes: Precast concrete inlets may be substituted for cast-in-place structures and shall be constructed as specified for cast-in-place.

      Precast structures may be used in only those areas where there is no conflict with existing underground structures that may necessitate revision of inverts. Type M standard PennDOT inlet boxes will be modified to provide minimum 12 inch sump storage and bottom leaching basins, open to gravel sumps in sub-grade, when situated in the recharge bed.
   c. All PVC Catch Basins/Cleanouts/Inline Drains shall have H-10 or H-20 rated grates, depending on their placement (H-20 if vehicular loading).
   d. Steel reinforcing bars over the top of the outlet structure shall conform to ASTM A615, grades 60 and 40.
   e. Permanent turf reinforcement matting shall be installed according to manufacturers' specifications.

6. **Alternative storage media:** Follow appropriate Manufacturers' specifications.

7. **Vegetation** see Local Native Plant List and Appendix B.

BMP 6.4.4: Infiltration Trench



An Infiltration Trench is a “leaky” pipe in a stone filled trench with a level bottom. An Infiltration Trench may be used as part of a larger storm sewer system, such as a relatively flat section of storm sewer, or it may serve as a portion of a stormwater system for a small area, such as a portion of a roof or a single catch basin. In all cases, an Infiltration Trench should be designed with a positive overflow.

Key Design Elements

- Continuously perforated pipe set at a minimum slope in a stone filled, level-bottomed trench
- Limited in width (3 to 8 feet) and depth of stone (6 feet max. recommended)
- Trench is wrapped in nonwoven geotextile (top, sides, and bottom)
- Placed on uncompacted soils
- Minimum cover over pipe is as per manufacturer.
- A minimum of 6" of topsoil is placed over trench and vegetated
- Positive Overflow always provided
  Deed restrictions recommended
  Not for use in hot spot areas without pretreatment

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Medium
Recharge: High
Peak Rate Control: Medium
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

SARB_014742

Description

An Infiltration Trench is a linear stormwater BMP consisting of a continuously perforated pipe at a minimum slope in a stone-filled trench (Figure 6.4-1). Usually an Infiltration Trench is part of a **conveyance system** and is designed so that large storm events are conveyed through the pipe with some runoff volume reduction. During small storm events, volume reduction may be significant and there may be little or no discharge. All Infiltration Trenches are designed with a **positive overflow** (Figure 6.4-2).

An Infiltration Trench differs from an Infiltration Bed in that it may be constructed without heavy equipment entering the trench. It is also intended to convey some portion of runoff in many storm events.

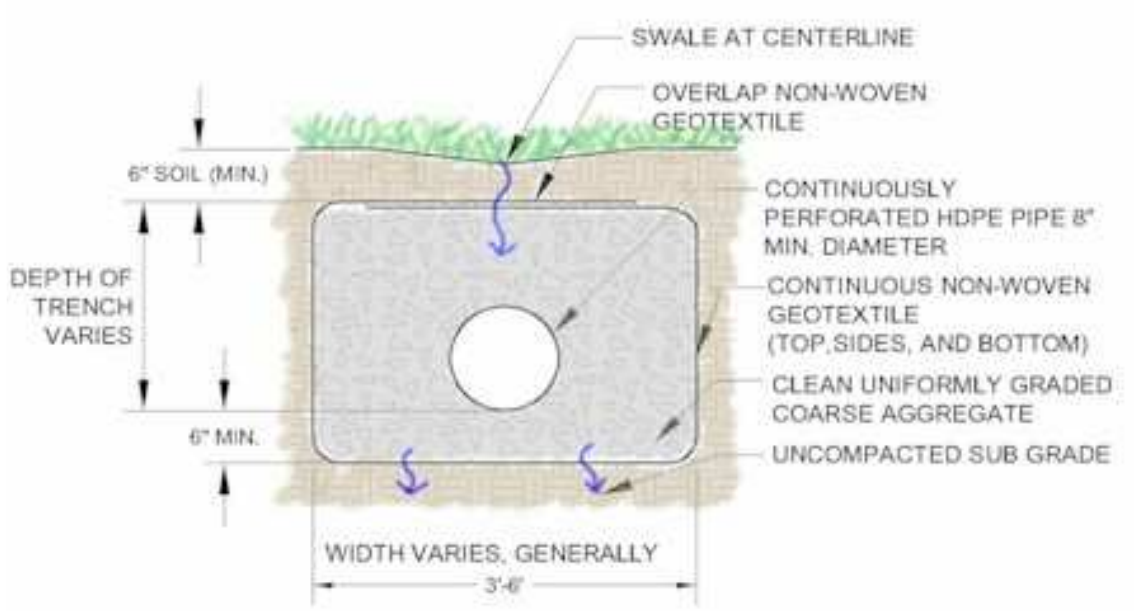


Figure 6.4-1

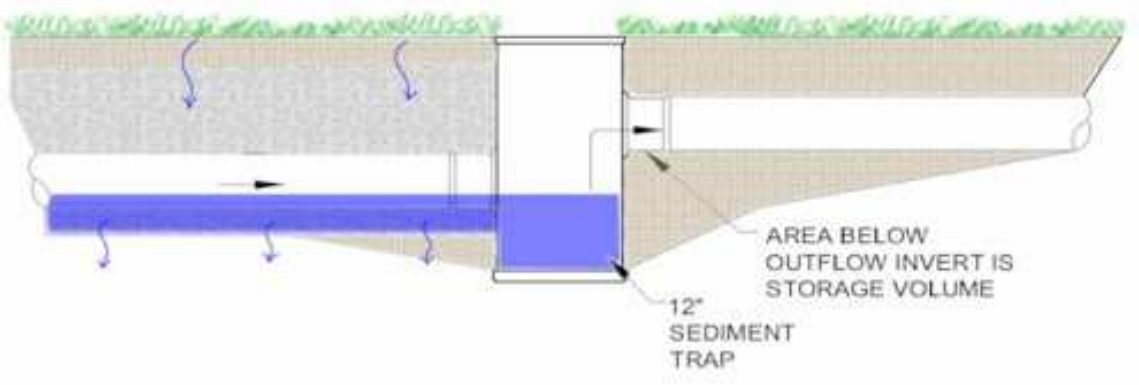


Figure 6.4-2

All Infiltration Trenches should be designed in accordance with Appendix C. Although the width and depth can vary, it is recommended that Infiltration Trenches be limited in depth to not more than six (6)

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feet of stone. This is due to both construction issues and Loading Rate issues (as described in the Guidelines for Infiltration Systems). The designer should consider the appropriate depth.

Variations

Infiltration Trenches generally have a vegetated (grassed) or gravel surface. Infiltration Trenches also may be located alongside or adjacent to roadways or impervious paved areas with proper design. The subsurface drainage direction should be to the downhill side (away from subbase of pavement), or located lower than the impervious subbase layer. Proper measures should be taken to prevent water infiltrating into the subbase of impervious pavement.

Infiltration Trenches may also be located down a mild slope by "stepping" the sections between control structures as shown in Figure 6.4-3. A level or nearly level bottom is recommended for even distribution.

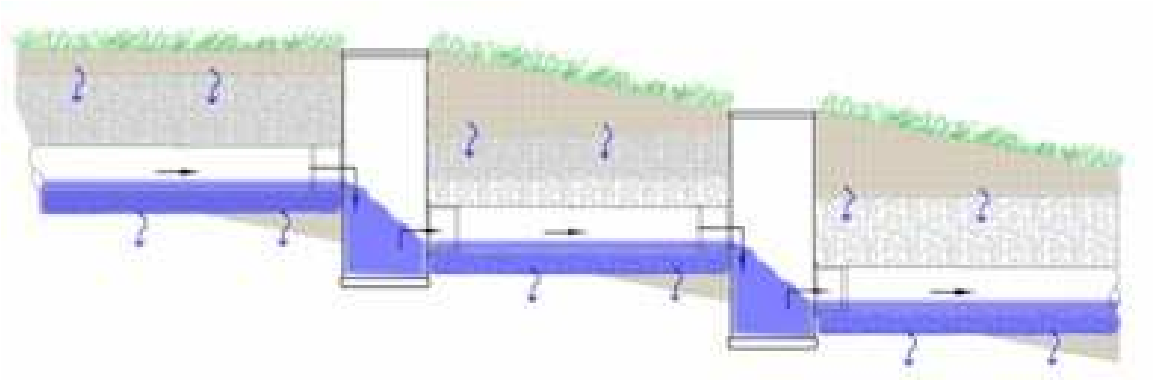
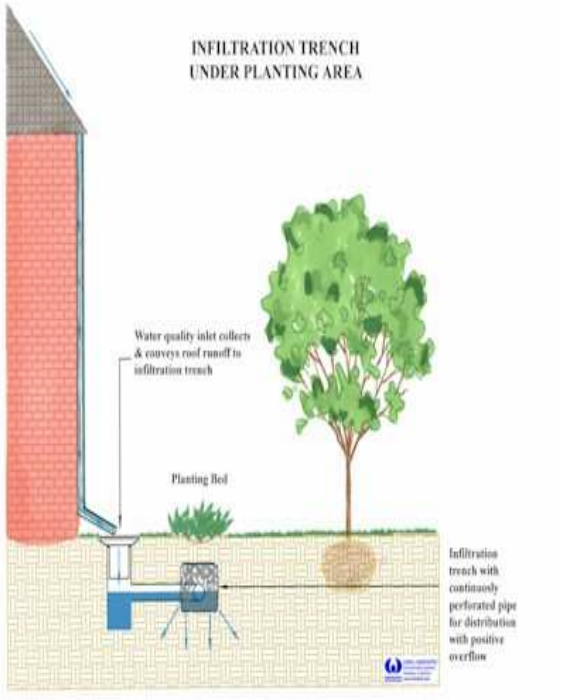


Figure 6.4-3

Applications

- **Connection of Roof Leaders**

Roof leaders may be connected to Infiltration Trenches. Roof runoff generally has lower sediment levels and often is ideally suited for discharge through an Infiltration Trench. A cleanout with sediment sump should be provided between the building and Infiltration Trench.



- **Connection of Inlets**

Catch Basins, inlets and area drains may be connected to Infiltration Trenches, however sediment and debris removal should be addressed. Structures should include a sediment trap area below the invert of the pipe for solids and debris. In areas of high traffic or areas where excessive sediment, litter, and other similar materials may be generated, a water quality insert or other pretreatment device is needed.

- **In Combination with Vegetative Filters**

An Infiltration Trench may be preceded by or used in combination with a Vegetative Filter, Grassed Swale, or other vegetative element used to reduce sediment levels

from areas such as high traffic roadways. Design should ensure proper functioning of vegetative system.

- **Other Applications**

Other applications of Infiltration Trenches may be determined by the design professional as appropriate.

Design Considerations

1. Soil Investigation and Percolation Testing is required (see Appendix C, Protocol 2)
2. Guidelines for Infiltration Systems should be met (i.e., depth to water table, setbacks, Loading Rates, etc. See Appendix C, Protocol 1)
3. Water Quality Inlet or Catch Basin with Sump (see Section 6.6.4) recommended for all surface inlets, designed to avoid standing water for periods greater than the criteria in Chapter 3.
4. A continuously perforated pipe should extend the length of the trench and have a positive flow connection designed to allow high flows to be conveyed through the Infiltration Trench.
5. The slope of the Infiltration Trench bottom should be level or with a slope no greater than 1%. The Trench may be constructed as a series of "steps" if necessary. A level bottom assures even water distribution and infiltration.
6. Cleanouts or inlets should be installed at both ends of the Infiltration Trench and at appropriate intervals to allow access to the perforated pipe.
7. The discharge or overflow from the Infiltration Trench should be properly designed for anticipated flows.

Detailed Stormwater Functions

Infiltration Area

The Infiltration Area is the bottom area of the Trench*, defined as:

Length of Trench x Width of Trench = Infiltration Area (Bottom Area)

This is the area to be considered when evaluating the Loading Rate to the Infiltration Trench.
* Some credit can be taken for the side area that is frequently inundated as appropriate.

Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf) x Void Space

*Depth is the depth of the water surface during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr)
x Infiltration period* (hr) x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltration. Not to exceed 72 hours.

The void ratio in stone is approximately 40% for AASTO No 3. If the conveyance pipe is within the Storage Volume area, the volume of the pipe may also be included. All Infiltration Trenches should be designed to infiltrate or empty within 72 hours.

Peak Rate Mitigation Calculations

See Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Protect Infiltration Trench area from compaction prior to installation.
2. If possible, install Infiltration Trench during later phases of site construction to prevent sedimentation and/or damage from construction activity. After installation, prevent sediment laden water from entering inlets and pipes.
3. Install and maintain proper Erosion and Sediment Control Measures during construction.
4. Excavate Infiltration Trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.
5. Place nonwoven geotextile along bottom and sides of trench*. Nonwoven geotextile rolls should overlap by a minimum of 16 inches within the trench. Fold back and secure excess geotextile during stone placement.
6. Install upstream and downstream Control Structures, cleanouts, etc.
7. Place uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
8. Install Continuously Perforated Pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
9. Fold and secure nonwoven geotextile over Infiltration Trench, with minimum overlap of 16-inches.
10. Place 6-inch lift of approved Topsoil over Infiltration Trench, as indicated on plans.
11. Seed and stabilize topsoil.
12. Do not remove Inlet Protection or other Erosion and Sediment Control measures until site is fully stabilized.
13. Any sediment that enters inlets during construction is to be removed within 24 hours.



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(from left to right) Installation of Inlets and Control Structure; Non-woven Geotextile is folded over Infiltration Trench; Stabilized Site







(Clockwise from top left) Infiltration Trench is on downhill side of roadway; Infiltration Trench is installed; Infiltration Trench is paved with standard pavement material

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Maintenance and Inspection Issues

- Catch Basins and Inlets should be inspected and cleaned at least 2 times per year.
- The vegetation along the surface of the Infiltration Trench should be maintained in good condition, and any bare spots revegetated as soon as possible.
- Vehicles should not be parked or driven on a vegetated Infiltration Trench, and care should be taken to avoid excessive compaction by mowers.

Cost Issues

The construction cost of infiltration trenches can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2003 dollars range from $4 - $9 per cubic foot of storage provided (SWRPC, 1991; Brown and Schueler, 1997). Annual maintenance costs have been reported to be approximately 5 to 10 percent of the capital costs (Schueler, 1987).

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. Stone for infiltration trenches shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. Non-Woven Geotextile shall consist of needled nonwoven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632)
b. Mullen Burst Strength (ASTM-D3786)
c. Flow Rate (ASTM-D4491)
d. UV Resistance after 500 hrs (ASTM-D4355) 70%
e. Heat-set or heat-calendared fabrics are not permitted
Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. Pipe shall be continuously perforated, smooth interior, with a minimum inside diameter of 8-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

References

Brown and Schueler, *Stormwater Management Fact Sheet: Infiltration Trench.* 1997.

Schueler, T., 1987. *Controlling urban runoff: a practical manual for planning and designing urban BMPs*, Metropolitan Washington Council of Governments, Washington, DC

SWRPC, The Use of of Best Management Practices (BMPs) in Urban Watersheds, US Environmental Protection Agency,1991.

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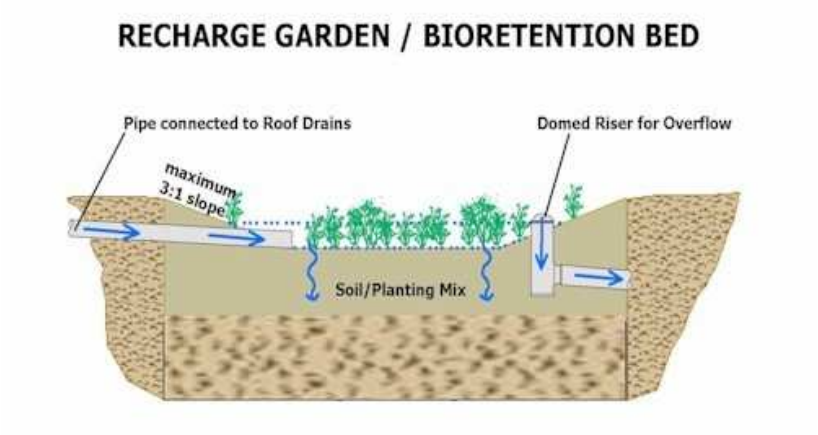
BMP 6.4.5: Rain Garden/Bioretention



A Rain Garden (also called Bioretention) is an excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff.

Key Design Elements

- Flexible in terms of size and infiltration
- Ponding depths generally limited to 12 inches or less for aesthetics, safety, and rapid draw down. Certain situations may allow deeper ponding depths.
- Deep rooted perennials and trees encouraged
- Native vegetation that is tolerant of hydrologic variability, salts and environmental stress
- Modify soil with compost.
- Stable inflow/outflow conditions
- Provide positive overflow
- Maintenance to ensure long-term functionality

Potential Applications

Residential:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway/Road:	Yes

Stormwater Functions

Volume Reduction:	Medium
Recharge:	Med./High
Peak Rate Control:	Low/Med.
Water Quality:	Med./High

Water Quality Functions

TSS:	TP: 85%	85%
	NO3: 30%	

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

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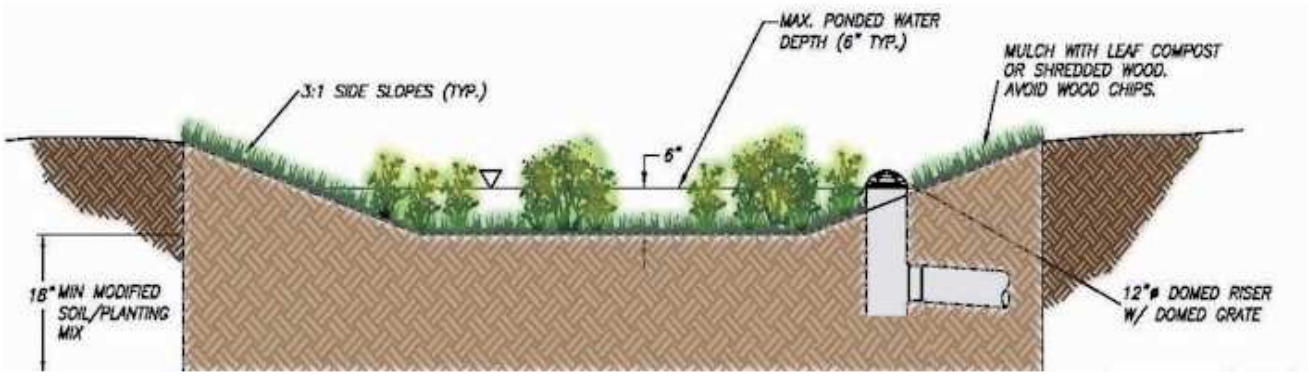
Description

Bioretention is a method of treating stormwater by pooling water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Bioretention techniques are used to accomplish water quality improvement and water quantity reduction. Prince George's County, Maryland, and Alexandria, Virginia have used this BMP since 1992 with success in many urban and suburban settings.

Bioretention can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater BMPs described in Chapter 5.

The vegetation serves to filter (water quality) and transpire (water quantity) runoff, and the root systems can enhance infiltration. The plants take up pollutants; the soil medium filters out pollutants and allows storage and infiltration of stormwater runoff; and the bed provides additional volume control. Properly designed bioretention techniques mimic natural ecosystems through species diversity, density and distribution of vegetation, and the use of native species, resulting in a system that is resistant to insects, disease, pollution, and climatic stresses.



Rain Gardens / Bioretention function to:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants)
- Recharge groundwater by infiltration
- Reduce stormwater temperature impacts
- Enhance evapotranspiration
- Enhance aesthetics
- Provide habitat

Primary Components of a Rain Garden/Bioretention System

The primary components (and subcomponents) of a rain garden/bioretention system are:

Pretreatment (optional)

- Sheet flow through a vegetated buffer strip, cleanout, water quality inlet, etc. prior to entry into the Rain Garden

Flow entrance

- Varies with site use (e.g., parking island versus residential lot applications)
- Water may enter via an inlet (e.g., flared end section)
- Sheet flow into the facility over grassed areas
- Curb cuts with grading for sheet flow entrance
- Roof leaders with direct surface connection
- Trench drain
- Entering velocities should be non-erosive.

Ponding area

- Provides temporary surface storage of runoff
- Provides evaporation for a portion of runoff
- Design depths allow sediment to settle
- Limited in depth for aesthetics and safety

Plant material

- Evapotranspiration of stormwater
- Root development and rhizome community create pathways for infiltration
- Bacteria community resides within the root system creating healthy soil structure with water quality benefits
- Improves aesthetics for site
- Provides habitat for animals and insects
- Reinforces long-term performance of subsurface infiltration
- Should be tolerant of salts if in a location that would receive snow melt chemicals

Organic layer or mulch

- Acts as a filter for pollutants in runoff
- Protects underlying soil from drying and eroding
- Simulates leaf litter by providing environment for microorganisms to degrade organic material
- Provides a medium for biological growth, decomposition of organic material, adsorption and bonding of heavy metals
- Wood mulch should be shredded - compost or leaf mulch is preferred.

Planting soil/volume storage bed

- Provides water/nutrients to plants
- Enhances biological activity and encourages root growth
- Provides storage of stormwater by the voids within the soil particles

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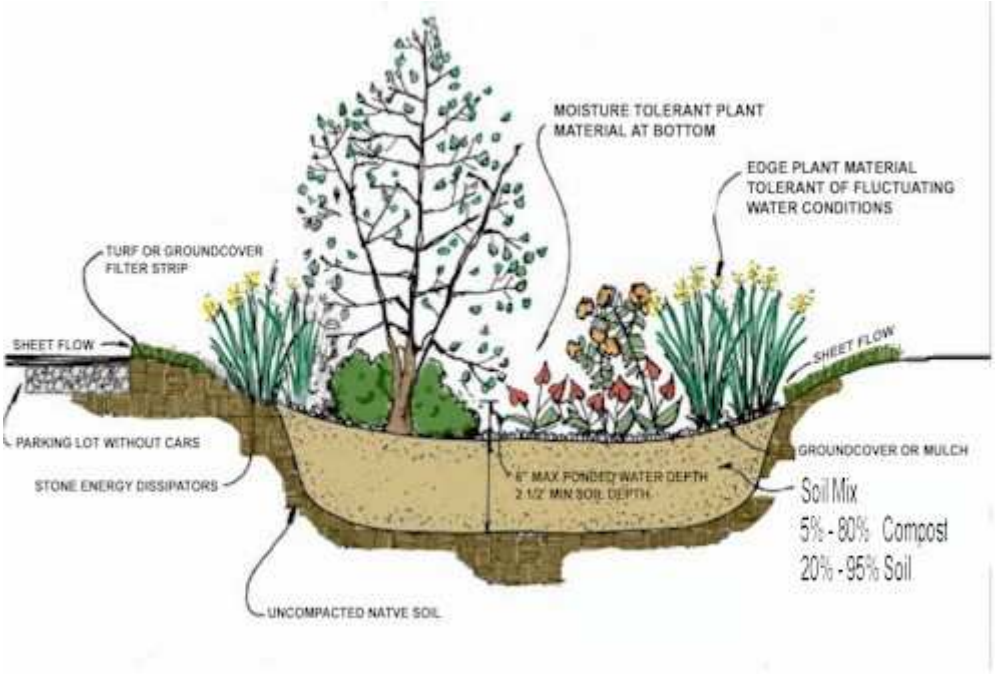
Positive overflow

- Will discharge runoff during large storm events when the storage capacity is exceeded.

Examples include domed riser, inlet, weir structure, etc.

- An underdrain can be included in areas where infiltration is not possible or appropriate.



Variations

Generally, a Rain Garden/Bioretention system is a vegetated surface depression that provides for the infiltration of relatively small volumes of stormwater runoff, often managing stormwater on a lot-by-lot basis (versus the total development site). If greater volumes of runoff need to be managed or stored, the system can be designed with an expanded subsurface infiltration bed or the Bioretention area can be increased in size.

The design of a Rain Garden can vary in complexity depending on the quantity of runoff volume to be managed, as well as the pollutant reduction objectives for the entire site. Variations exist both in the components of the systems, which are a function of the land use surrounding the Bioretention system.

The most common variation includes a gravel or sand bed underneath the planting bed. The original intent of this design, however, was to perform as a filter BMP utilizing an under drain and subsequent discharge. When a designer decides to use a gravel or sand bed for volume storage under the planting bed, then additional design elements and changes in the vegetation plantings should be provided.

Flow Entrance: Curbs and Curb Cuts



Flow Entrance: Trench Drain



Positive Overflow: Domed Riser



Positive Overflow: Inlet



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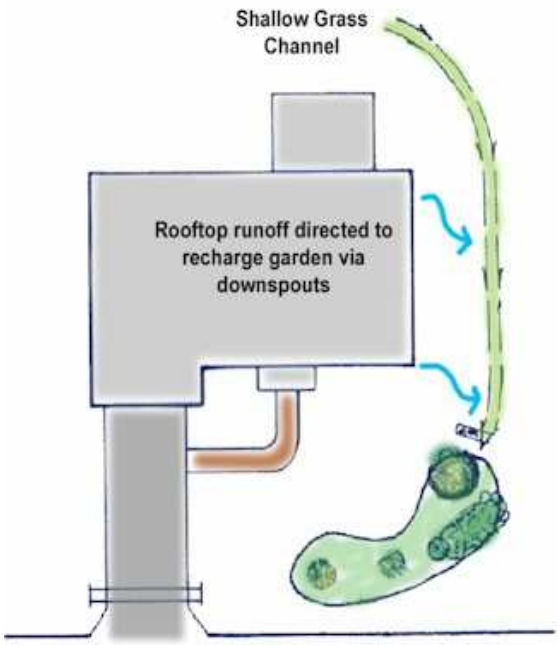
Applications

Bioretention areas can be used in a variety of applications: from small areas in residential lawns to extensive systems in large parking lots (incorporated into parking islands and/or perimeter areas).

- **Residential On-lot**

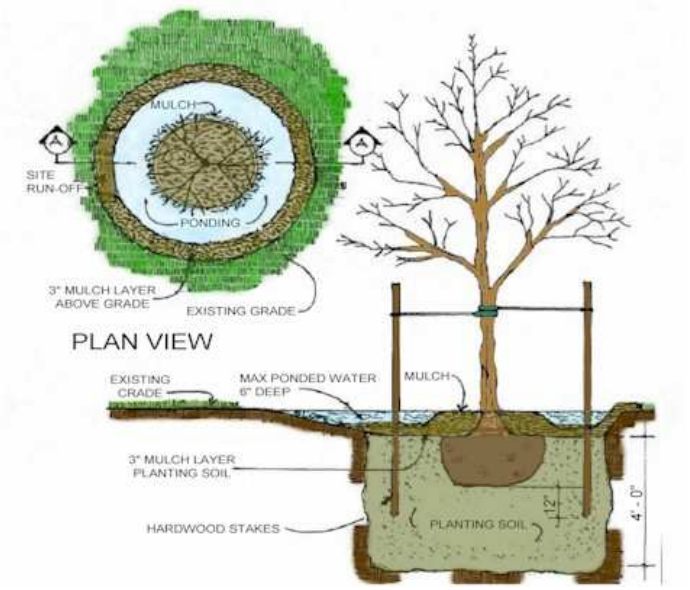
  Rain Garden (Prince George's County)
  Simple design that incorporates a planting bed in the low portion of the site





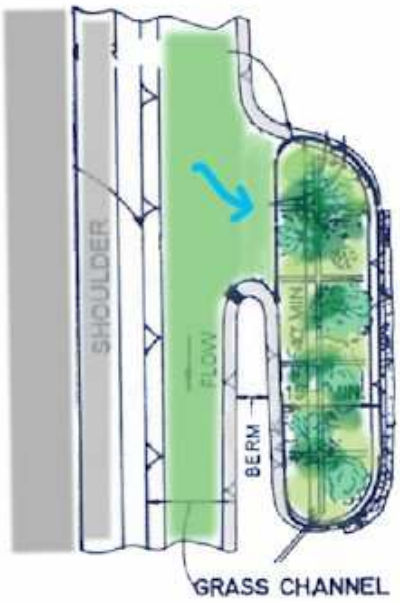
- **Tree and Shrub Pits**
  Stormwater management technique that intercepts runoff and provides shallow ponding in a dished mulched area around the tree or shrub.

  Extend the mulched area to the tree dripline



- **Roads and highways**





- **Parking Lots**
- **Parking Lot Island Bioretention**



- **Commercial/Industrial/Institutional**

In commercial, industrial, and institutional situations, stormwater management and greenspace areas are limited, and in these situations, Rain Gardens for stormwater management and landscaping provide multifunctional options.

- **Curbless (Curb cuts) Parking Lot Perimeter Bioretention**
  The Rain Garden is located adjacent to a parking area with no curb or curb cuts , allowing stormwater to sheet flow over the parking lot directly into the Rain Garden. Shallow grades should direct runoff at reasonable velocities; this design can be used in conjunction with depression storage for stormwater quantity control.



- **Curbed Parking Lot Perimeter Bioretention**



- **Roof leader connection from adjacent building**





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Design Considerations

Rain Gardens are flexible in design and can vary in complexity according to water quality objectives and runoff volume requirements. Though Rain Gardens are a structural BMP, the initial siting of bioretention areas should respect the Integrating Site Design Procedures described in Chapter 4 and integrated with the preventive non-structural BMPs.

It is important to note that bioretention areas are not to be confused with constructed wetlands or wet ponds which permanently pond water. Bioretention is best suited for areas with at least moderate infiltration rates (more than 0.1 inches per hour). In extreme situations where permeability is less than 0.1 inches per hour, special variants may apply, including under drains, or even constructed wetlands.

Rain Gardens are often very useful in retrofit projects and can be integrated into already developed lots and sites. An important concern for all Rain Garden applications is their long-term protection and maintenance, especially if undertaken in multiple residential lots where individual homeowners provide maintenance. In such situations, it is important to provide some sort of management that insures their long-term functioning (deed restrictions, covenants, and so forth).

1. **Sizing criteria**

   a. Surface area is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 5:1 (impervious drainage area to infiltration area; see Protocol 2. Infiltration Systems Guidelines (Appendix C) for additional guidance on loading rates.)

   b. Surface Side slopes should be gradual. For most areas, maximum 3:1 side slopes are recommended, however where space is limited, 2:1 side slopes may be acceptable.

   c. Surface Ponding depth should not exceed 6 inches in most cases and should empty within 72 hours.

   d. Ponding area should provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface storage/infiltration bed is used to supplement surface storage where feasible.

   e. Planting soil depth should generally be at least 18” where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased, depending on plant species.

2. **Planting Soil** should be a loam soil capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A typical organic amended soil is combined with 20-30% organic material (compost), and 70-80% soil base (preferably topsoil). Planting soil should be approximately 4 inches deeper than the bottom of the largest root ball.

3. **Volume Storage Soils** should also have a pH of between 5.5 and 6.5 (better pollutant adsorption and microbial activity), a clay content less than 10% (a small amount of clay is beneficial to adsorb pollutants and retain water), be free of toxic substances and unwanted plant material and have a 5 –10% organic matter content. Additional organic matter can be added to the soil to increase water holding capacity (tests should be conducted to determine volume storage capacity of amended soils).

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4. Proper **plant selection** is essential for bioretention areas to be effective. Typically, native floodplain plant species are best suited to the variable environmental conditions encountered. If shrubs and trees are included in a bioretention area (which is recommended), at least three species of shrub and tree should be planted at a rate of approximately 700 shrubs and 300 trees per acre (shrub to tree ratio should be 2:1 to 3:1). An experienced landscape architect is recommended to design native planting layout.

5. Planting periods will vary, but in general trees and shrubs should be planted from mid-March through the end of June, or mid-September through mid-November

6. A maximum of 2 to 3 inches of shredded **mulch** or leaf compost (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Wood chips should be avoided as they tend to float during inundation periods. Mulch / compost layer should not exceed 3" in depth so as not to restrict oxygen flow to roots.

7. Must be designed carefully in areas with **steeper slopes** and should be aligned parallel to contours to minimize earthwork.

8. Under drains should not be used except where in-situ soils fail to drain surface water to meet the criteria in Chapter 3.

Detailed Stormwater Functions

Infiltration Area

Volume Reduction Calculations

The storage volume of a Bioretention area is defined as the sum total of 1. and the smaller of 2a or 2b below. The surface storage volume should account for at least 50% of the total storage. Inter-media void volumes may vary considerably based on design variations.

1. Surface Storage Volume (CF) = Bed Area (ft^2) x Average Design Water Depth

2a. Infiltration Volume = Bed Bottom area (sq ft) x infiltration design rate (in/hr) x infiltration period (hr) x 1/12.
2b. Volume = Bed Bottom area (sq ft) x soil mix bed depth x void space.

Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

The following is a typical construction sequence; however, alterations might be necessary depending on design variations.

1. Install temporary sediment control BMPs as shown on the plans.
2. Complete site grading. If applicable, construct curb cuts or other inflow entrance but provide protection so that drainage is prohibited from entering construction area.
3. Stabilize grading within the limit of disturbance except within the Rain Garden area. Rain garden bed areas may be used as temporary sediment traps provided that the proposed finish elevation of the bed is 12 inches lower than the bottom elevation of the sediment trap.
4. Excavate Rain Garden to proposed invert depth and scarify the existing soil surfaces. Do not compact in-situ soils.
5. Backfill Rain Garden with amended soil as shown on plans and specifications. Overfilling is recommended to account for settlement. Light hand tamping is acceptable if necessary.
6. Presoak the planting soil prior to planting vegetation to aid in settlement.
7. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch or topsoil as specified on plans.
8. Plant vegetation according to planting plan.
9. Mulch and install erosion protection at surface flow entrances where necessary.



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Maintenance Issues

Properly designed and installed Bioretention areas require some regular maintenance.

- While vegetation is being established, pruning and weeding may be required.
- Detritus may also need to be removed every year. Perennial plantings may be cut down at the end of the growing season.
- Mulch should be re-spread when erosion is evident and be replenished as needed. Once every 2 to 3 years the entire area may require mulch replacement.
- Bioretention areas should be inspected at least two times per year for sediment buildup, erosion, vegetative conditions, etc.
- During periods of extended drought, Bioretention areas may require watering.
-
- Trees and shrubs should be inspected twice per year to evaluate health.

Cost Issues

Rain Gardens often replace areas that would have been landscaped and are maintenance-intensive so that the net cost can be considerably less than the actual construction cost. In addition, the use of Rain Gardens can decrease the cost for stormwater conveyance systems at a site. Rain Gardens cost approximately $5 to $7 (2005) per cubic foot of storage to construct.

Specifications

The following specifications are provided for informational purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1Vegetation - See Appendix B

2 Execution

a. Subgrade preparation

1. Existing sub-grade in Bioretention areas shall NOT be compacted or subject to excessive construction equipment traffic.
2. Initial excavation can be performed during rough site grading but shall not be carried to within one feet of the final bottom elevation. Final excavation should not take place until all disturbed areas in the drainage area have been stabilized.
3. Where erosion of sub-grade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material shall be removed with light

equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent by light tractor.

4. Bring sub-grade of bioretention area to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas shall be level grade on the bottom.
5. Halt excavation and notify engineer immediately if evidence of sinkhole activity or pinnacles of carbonate bedrock are encountered in the bioretention area.

b. Rain Garden Installation

1. Upon completion of sub-grade work, the Engineer shall be notified and shall inspect at his/her discretion before proceeding with bioretention installation.
2. For the subsurface storage/infiltration bed installation, amended soils should be placed on the bottom to the specified depth.
3. Planting soil shall be placed immediately after approval of sub-grade preparation/bed installation. Any accumulation of debris or sediment that takes place after approval of sub-grade shall be removed prior to installation of planting soil at no extra cost to the Owner.
4. Install planting soil (exceeding all criteria) in 18-inch maximum lifts and lightly compact (tamp with backhoe bucket or by hand). Keep equipment movement over planting soil to a minimum – **do not over compact**. Install planting soil to grades indicated on the drawings.
5. Plant trees and shrubs according to supplier's recommendations and only from mid-March through the end of June or from mid-September through mid-November.
6. Install 2-3" shredded hardwood mulch (minimum age 6 months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.
7. Protect Rain Gardens from sediment at all times during construction. Hay bales, diversion berms and/or other appropriate measures shall be used at the toe of slopes that are adjacent to Rain Gardens to prevent sediment from washing into these areas during site development.
8. When the site is fully vegetated and the soil mantle stabilized the plan designer shall be notified and shall inspect the Rain Garden drainage area at his/her discretion before the area is brought online and sediment control devices removed.
9. Water vegetation at the end of each day for two weeks after planting is completed.

Contractor should provide a one-year 80% care and replacement warranty for all planting beginning after installation and inspection of all plants.

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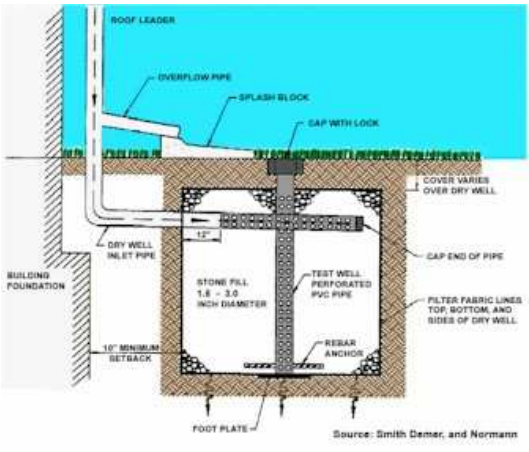
BMP 6.4.6: Dry Well / Seepage Pit



A Dry Well, or Seepage Pit, is a variation on an Infiltration system that is designed to temporarily store and infiltrate rooftop runoff.

Key Design Elements

- Fllow Infiltration System Guidelines in Appendix C
- Maintain minimum distance from building foundation (typically 10 feet)
- Provide adequate overflow outlet for large storms
- Depth of Dry Well aggregate should be between 18 and 48 inches
- At least one observation well; clean out is recommended
- Wrap aggregate with nonwoven geotextile
- Maintenance will require periodic removal of sediment and leaves from sumps and cleanouts
- Provide pretreatment for some situations

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Limited
Retrofit: Yes
Highway/Road: No

Stormwater Functions

Volume Reduction: Medium
Recharge: High
Peak Rate Control: Medium
Water Quality: Medium

Water Quality Functions

TSS: TP: 85% 85%
NO3: 30%

Other Considerations

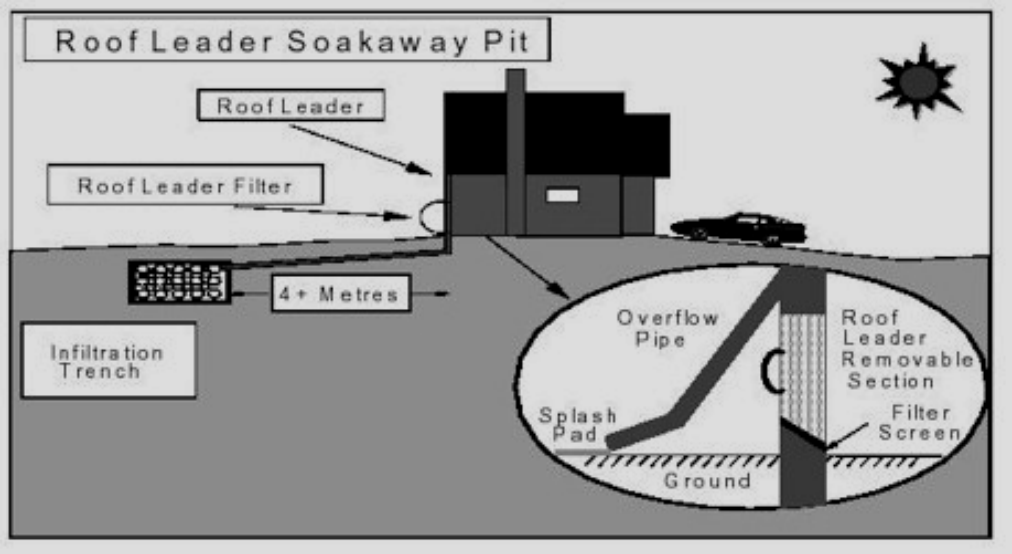
- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

SARB_014764

Description

A Dry Well, sometimes called a Seepage Pit, is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures. Roof leaders connect directly into the Dry Well, which may be either an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber or pipe segment. Dry Wells discharge the stored runoff via infiltration into the surrounding soils. In the event that the Dry Well is overwhelmed in an intense storm event, an overflow mechanism (surcharge pipe, connection to larger infiltration area, etc.) will ensure that additional runoff is safely conveyed downstream.

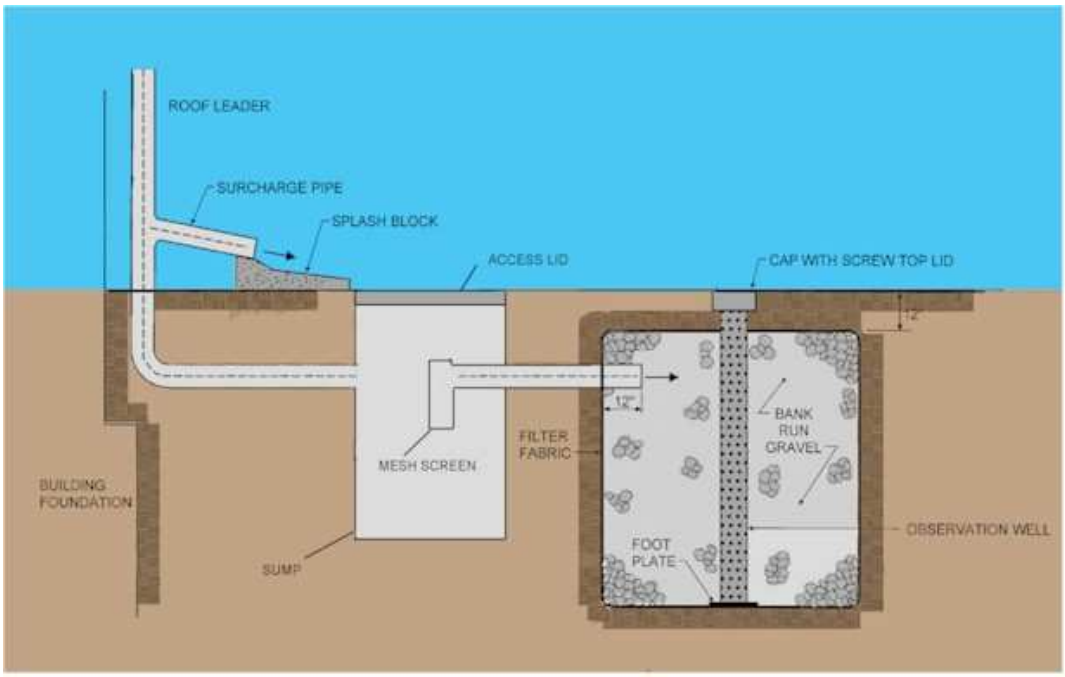
By capturing runoff at the source, Dry Wells can dramatically reduce the increased volume of stormwater generated by the roofs of structures. Though roofs are generally not a significant source of runoff pollution, they are still one of the most important sources of new or increased runoff volume from developed areas. By decreasing the volume of stormwater runoff, Dry Wells can also reduce runoff rate and improve water quality. As with other infiltration practices, Dry Wells may not be appropriate for "hot spots" or other areas where high pollutant or sediment loading is expected without additional design considerations. Dry Wells are not recommended within a specified distance to structures or subsurface sewage disposal systems. (see Appendix C, Protocol 2)



Variations

Intermediate "Sump" Box – Water can flow through an intermediate box with an outflow higher to allow the sediments to settle out. Water would then flow through a mesh screen and into the dry well.

Drain Without Gutters – For structures without gutters or downspouts, runoff is designed to sheetflow off a pitched roof surface and onto a stabilized ground cover (surface aggregate, pavement, or other means). Runoff is then directed toward a Dry Well via stormwater pipes or swales.





Prefabricated Dry Well – There are a variety of prefabricated, predominantly plastic subsurface storage chambers on the market today that can replace aggregate Dry Wells. Since these systems have significantly greater storage capacity than aggregate, space requirements are reduced and associated costs may be defrayed. Provided the following design guidelines are followed and infiltration is still encouraged, prefabricated chambers can prove just as effective as standard aggregate Dry Wells.

Applications

Any roof or impervious area with relatively low sediment loading

Design Considerations

1. Dry Wells are sized to temporarily retain and infiltrate stormwater runoff from roofs of structures. A dry well usually provides stormwater management for a limited roof area. Care should be taken not to hydraulically overload a dry well based on bottom area and drainage area. (See Appendix C, Protocol 2 for guidance)

2. Dry Wells should drain-down within the guidelines set in Chapter 3. Longer drain-down times reduce Dry Well efficiency and can lead to anaerobic conditions, odor and other problems.

3. Dry Wells typically consist of 18 to 48 inches of clean washed, uniformly graded aggregate with 40% void capacity (AASHTO No. 3, or similar). Dry Well aggregate is wrapped in a nonwoven geotextile, which provides separation between the aggregate and the surrounding soil. At least 12 inches of soil is then placed over the Dry Well. An alternative form of Dry Well is a subsurface, prefabricated chamber. A variety of prefabricated Dry Wells are currently available on the market.

4. Dry Wells are not recommended when their installation would create a significant risk for basement seepage or flooding. In general, 10 feet of separation is recommended between Dry Wells and building foundations. However, this distance may be shortened at the discretion of the designer. Shorter separation distances may warrant an impermeable liner to be installed on the building side of the Dry Well.

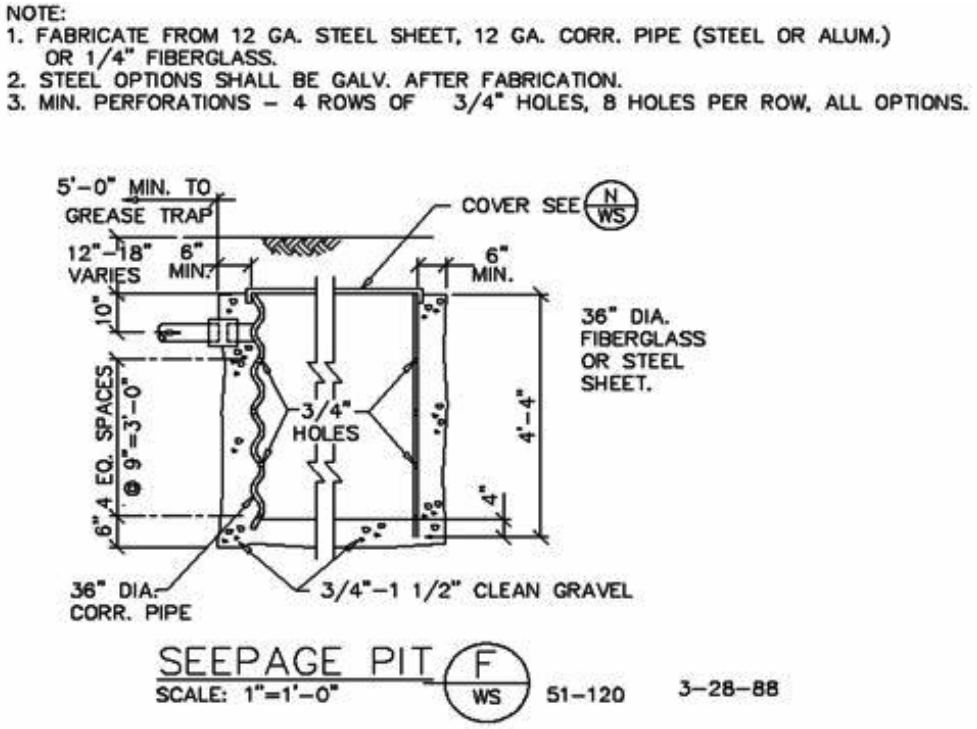
5. All Dry Wells should be able to convey system overflows to downstream drainage systems. System overflows can be incorporated either as surcharge (or overflow) pipes extending from roof leaders or via connections to more substantial infiltration areas.

6. The design depth of a Dry Well should take into account frost depth to prevent frost heave.

7. A removable filter with a screened bottom should be installed in the roof leader below the surcharge pipe in order to screen out leaves and other debris.

8. Adequate inspection and maintenance access to the Well should be provided. Observation wells not only provide the necessary access to the Well, but they also provide a conduit through which pumping of stored runoff can be accomplished in case of slowed infiltration.

9. Though roofs are generally not a significant source of runoff pollution, they can still be a source of particulates and organic matter, as well as sediment and debris during construction. Measures such as roof gutter guards, roof leader clean-out with sump, or an intermediate sump box can provide pretreatment for Dry Wells by minimizing the amount of sediment and other particulates that may enter it.



Detailed Stormwater Functions

Volume Reduction Calculations
The storage volume of a Dry Well is defined as the volume beneath the discharge invert. The following equation can be used to determine the approximate storage volume of an aggregate Dry Well:

Dry Well Volume = Dry well area (sf) x Dry well water depth (ft) x 40% (if stone filled)

Infiltration Area: A dry well may consider both bottom and side (lateral) infiltration according to design.

Peak Rate Mitigation Calculations
See Chapter 8 for corresponding peak rate reduction.

Water Quality Improvement
See Chapter 8

Construction Sequence

1. Protect infiltration area from compaction prior to installation.

2. If possible, install Dry Wells during later phases of site construction to prevent sedimentation and/or damage from construction activity.

3. Install and maintain proper Erosion and Sediment Control Measures during construction as per the Pennsylvania Erosion and Sediment Pollution Control Program Manual (March 2000, or latest edition).

4. Excavate Dry Well bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade. To the greatest extent possible, excavation should be performed with the lightest practical equipment. Excavation equipment should be placed outside the limits of the Dry Well.

5. Completely wrap Dry Well with nonwoven geotextile. (If sediment and/or debris have accumulated in Dry Well bottom, remove prior to geotextile placement.) Geotextile rolls should overlap by a minimum of 24 inches within the trench. Fold back and secure excess geotextile during stone placement.

6. Install continuously perforated pipe, observation wells, and all other Dry Well structures. Connect roof leaders to structures as indicated on plans.

7. Place uniformly graded, clean-washed aggregate in 6-inch lifts, lightly compacting between lifts.

8. Fold and secure nonwoven geotextile over trench, with minimum overlap of 12-inches.

9. Place 12-inch lift of approved Topsoil over trench, as indicated on plans.

10. Seed and stabilize topsoil.

11. Connect surcharge pipe to roof leader and position over splashboard.

12. Do not remove Erosion and Sediment Control measures until site is fully stabilized.

Maintenance Issues

As with all infiltration practices, Dry Wells require regular and effective maintenance to ensure prolonged functioning. The following represent minimum maintenance requirements for Dry Wells:

- Inspect Dry Wells at least four times a year, as well as after every storm exceeding 1 inch.
- Dispose of sediment, debris/trash, and any other waste material removed from a Dry Well at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.
- Evaluate the drain-down time of the Dry Well to ensure the maximum time of 72 hours is not being exceeded. If drain-down times are exceeding the maximum, drain the Dry Well via pumping and clean out perforated piping, if included. If slow drainage persists, the system may need replacing.
- Regularly clean out gutters and ensure proper connections to facilitate the effectiveness of the dry well.
- Replace filter screen that intercepts roof runoff as necessary.
- If an intermediate sump box exists, clean it out at least once per year.

Cost Issues

The construction cost of a Dry Well/Seepage Pit can vary greatly depending on design variability, configuration, location, site-specific conditions, etc. Typical construction costs in 2003 dollars range from $4 - $9 per cubic foot of storage volume provided (SWRPC, 1991; Brown and Schueler, 1997). Annual maintenance costs have been reported to be approximately 5 to 10 percent of the capital costs (Schueler, 1987). The cost of gutters is typically included in the total structure cost, as opposed

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. Stone for infiltration trenches shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size No. 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. Nonwoven Geotextile shall consist of needled nonwoven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632) ³ 120 lbs
b. Mullen Burst Strength (ASTM-D3786) ³ 225 psi
c. Flow Rate (ASTM-D4491) ³ 95 gal/min/ft^2
d. UV Resistance after 500 hrs (ASTM-D4355) ³ 70%
e. Heat-set or heat-calendared fabrics are not permitted
Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. Topsoil See Appendix C

4. Pipe shall be continuously perforated, smooth interior, with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S. 12 gauge aluminum or corrugated steel pipe may be used in seepage pits.

5. Gutters and splashboards shall follow Manufacturer's specifications.

References

New Jersey Department of Environmental Protection. *New Jersey Stormwater Best Management Practices Manual*. 2004.

New York Department of Environmental Conservation. *New York State Stormwater Management Design Manual.* 2003.

French Drains. http://www.unexco.com/french.html . 2004.

SWRPC, The Use of of Best Management Practices(BMPs) in Urban Watersheds, US Environmental Protection Agency,1991.

Brown and Schueler, *Stormwater Management Fact Sheet: Infiltration Trench.* 1997.

Schueler, T., 1987. *Controlling urban runoff: a practical manual for planning and designing urban BMPs*, Metropolitan Washington Council of Governments, Washington, DC

SARB_014771

BMP 6.4.7: Constructed Filter



Filters are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other filter media that reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants.

Key Design Elements

- Follow Infiltration Systems Guidelines in Appendix C
- Drain down – should empty within the guidelines in Chapter 3
- Minimum permeability of filtration medium required
- Minimum depth of filtering medium = 12"
- Perforated pipes in stone, as required
- May be designed to collect and convey filtered runoff down-gradient
- May be designed to infiltrate
- Pretreatment for debris and sediment may be needed
- Should be sized for drainage area
- Regular inspection and maintenance required for continued functioning
- Positive overflow is needed

Potential Applications

Residential: Limited
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction:	Low-High*
Recharge:	Low-High*
Peak Rate Control:	Low-High*
Water Quality:	High

* Depends on if infiltration is used

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C
- Certain applications may warrant spill containment.

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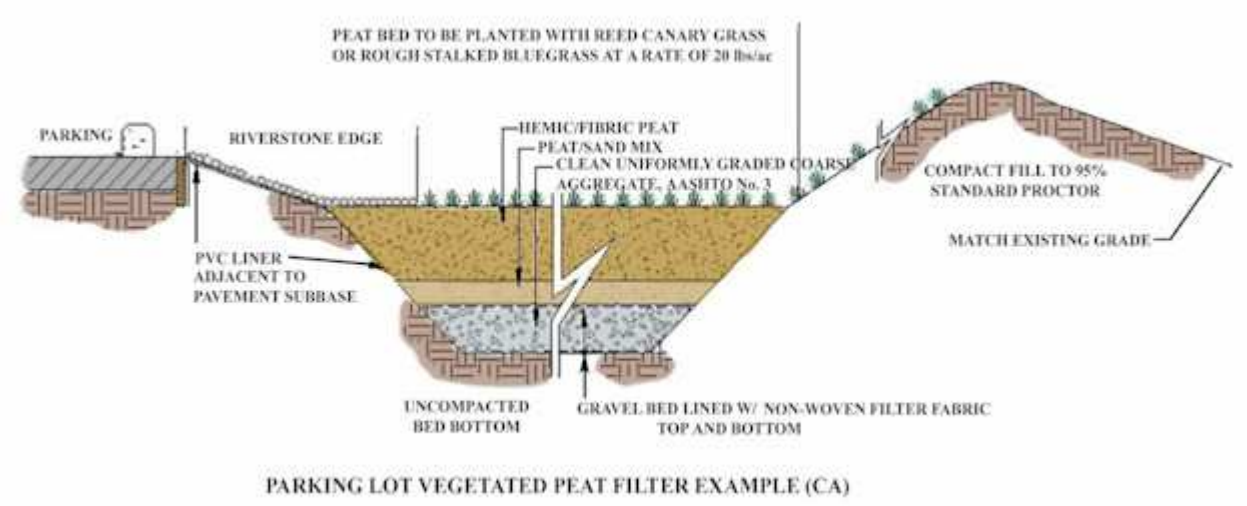
Description

A stormwater filter is a structure or excavation filled with material and designed to filter stormwater runoff to improve water quality. The filter media may be comprised of materials such as sand, peat, compost, granular activated carbon (GAC), perlite, or other material. Additional filtration media will be acceptable for use as long as data is available to verify the media is capable of meeting performance goals. In some applications the stormwater runoff flows through an open air, "pretreatment" chamber to allow the large particles and debris to settle out (sedimentation). Surface vegetation is another good option for pretreatment. The runoff then passes through the filter media where additional pollutants are filtered out, and is collected in an under-drain and returned to the conveyance system, receiving waters or infiltrated into the soil mantle.



PARKING LOT VEGETATED PEAT FILTER EXAMPLE (CA)

Variations

There are a wide variety of Filter Applications, including surface and subsurface, vegetated, perimeter, infiltration, and others. There are also a variety of filter products that may be purchased. Examples of these variations include:

Surface Non-vegetated Filter

A Surface Non-vegetated Filter is constructed by excavation or by use of a structural container. The surface may be covered in sand, peat, gravel, river stone, or similar material.





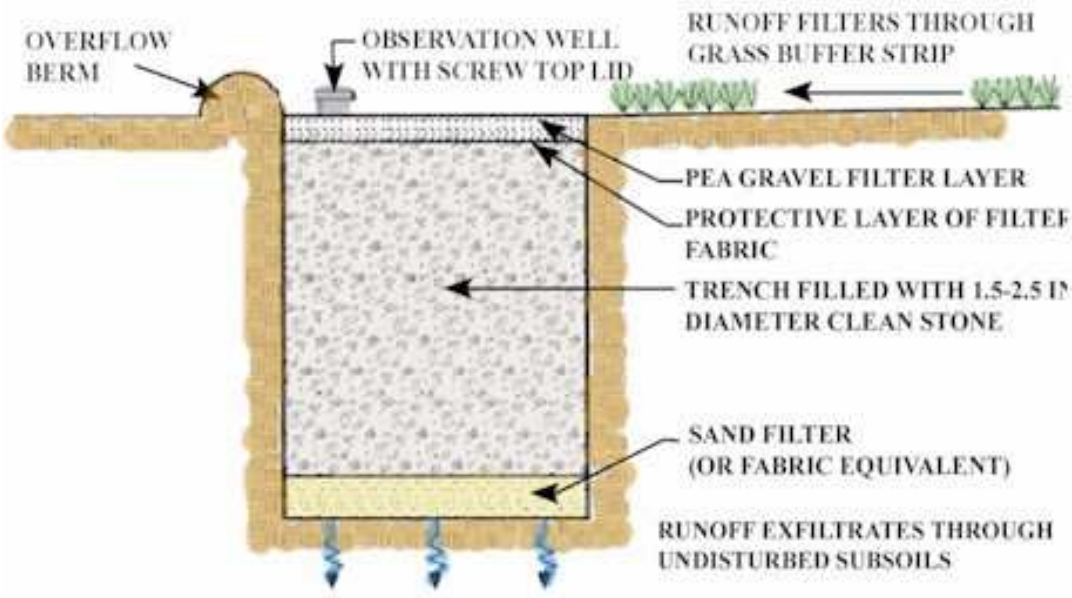
Vegetated Filter



A layer of vegetation is planted on top of the filtering medium. Composted amended soil may serve as a filter media. For filters composed of filtering media such as sand (where topsoil is required for vegetation) a layer of nonwoven, permeable geotextile should separate the topsoil and vegetation from the filter media.

Infiltration Filter

Filters may be designed to allow some portion of the treated water to infiltrate. Infiltration Design Criteria apply for all Filters designed with infiltration. In all cases, a positive overflow system is recommended.



Contained Filter



In contained Filters, infiltration is not incorporated into the design. Contained Filters may consist of a physical structure, such as a precast concrete box. For excavated filters, an impermeable liner is added to the bottom of the excavation to convey the filtered runoff downstream.

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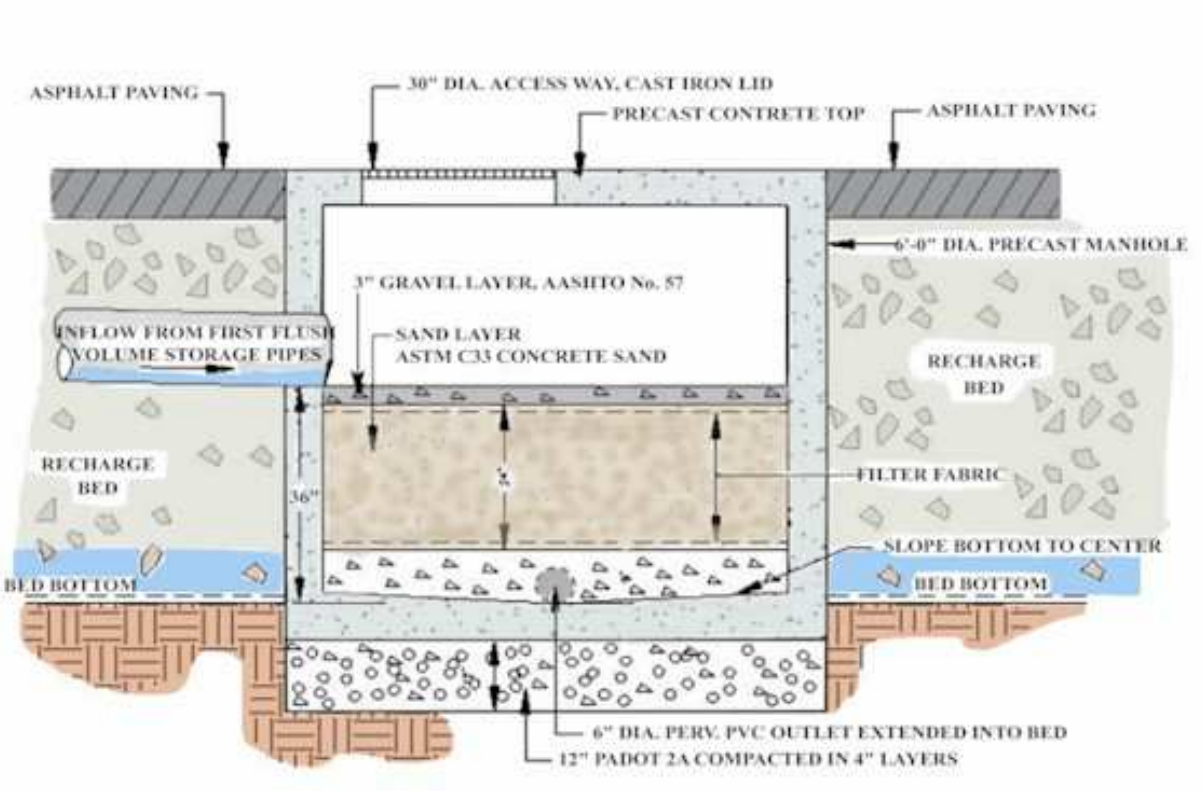
Linear "Perimeter" Filters



Perimeter Filters may consist of enclosed chambers (such as trench drains) that run along the perimeter of an impervious surface. Perimeter Filters may also be constructed by excavation and vegetated. All perimeter filters should be designed with the necessary filter medium and sized in accordance with the drainage area.

Small Subsurface Filter

A Small Subsurface filter is an inlet designed to treat runoff at the collection source by filtration. Small Subsurface filters are useful for Hotspot Pretreatment and similar in function to Water Quality Inserts. Small Subsurface filters should be carefully designed and maintained so that runoff is directed through the filter media.



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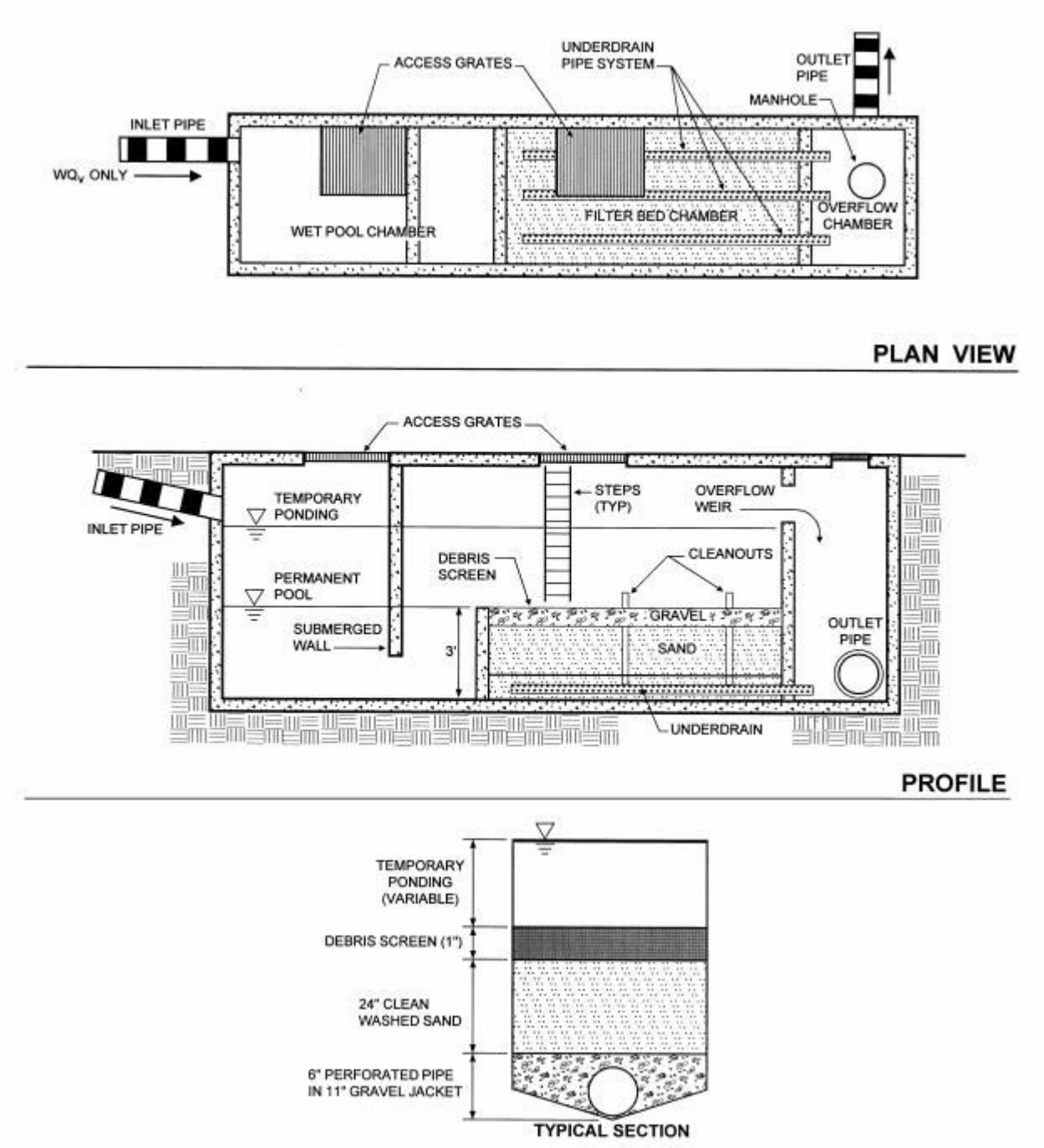
Large Subsurface Filter

Large Subsurface Filters receive relatively large amounts of flow directed into an underground box that has separate chambers, one to settle large particles, and one to filter small particles. The water discharges through an outlet pipe and into the stormwater system.



Manufactured Filtration Systems

There are a considerable number of manufactured filtration systems available, some of which also incorporate oil/water separators, vortex systems, etc. The Designer should obtain product specific information directly from the manufacturer.

Applications

Filters are applicable in urbanized areas having high pollutant loads and are especially applicable where there is limited area for construction of other BMPs. Filters may be used as a pretreatment BMP before other BMPs such as Wet Ponds or Infiltration systems. Filters may be used in Hot Spot areas for water quality treatment, and spill containment capabilities may be incorporated into a filter. Examples of typical areas that benefit from the use of a Filter BMP include:

- Parking lots
- Roadways and Highways
- Light Industrial sites
- Marina areas
- Transportation facilities
- Fast food and shopping areas
- Waste Transfer Stations
- Urban Streetscapes

Design Considerations

1. Filters should be sized as per the Control Guideline that applies. All filters should be designed so that **larger storms may safely overflow or bypass the filter**. Flow splitters, multistage chambers, and other devices may be used. A flow splitter may be necessary to allow only a portion of the runoff to enter the filter. This would create an “off-line” filter, where the volume and velocity of runoff entering the filter is controlled. If the filter is “on-line”, excess flow should be designed to bypass the filter and continue to another quality BMP.

2. **Entering velocity should be controlled**. A level spreader may be used to spread flow evenly across the filter surface during all storms without eroding the filter material. Parking lots may be designed to sheet flow to filters. Small riprap or riverstone edges may be used to reduce velocity and distribute flow.

3. **Pretreatment** may be necessary in areas with especially high levels of debris, large sediment, etc. Pretreatment may include oil/grit separators, vegetated filter strips, or grass swales. These measures will settle out the large particles and reduce velocity of the runoff before it enters the filter.

4. The **Filter Media** may be a variety of materials and in most cases should have a minimum depth of 12 inches and a maximum depth of 30 inches, although variations on these guidelines are acceptable if justified by the designer. Coarser materials allow for more hydraulic conductivity, but finer media filter particles of a smaller size. Sand has been found to be a good balance between these two criteria, but different types of media remove different pollutants. While sand is a reliable material to remove TSS, (Debusk and Langston, 1997) peat removes slightly more

TP, Cu, Cd, and Ni than sand. The Filter Media should have a minimum hydraulic conductivity (k) as follows:

- Sand 3.5 ft/day
- Peat 2.5 ft/day
- Leaf compost 8.7 ft/day

5. A **Gravel Layer** at least 6" deep is recommended beneath the Filter Media.

6. **Under drain piping** should be 4" minimum (diameter) perforated pipes, with a lateral spacing of no more than 10'. A collector pipe can be used, (running perpendicular to laterals) with a slope of 1%. All underground pipes should have clean-outs accessible from the surface.

7. A **Drawdown Time** of not more than 72 hours is recommended for Filters.

8. The **Size** of a Filter is determined by the Volume to be treated:

$$A = V \times d / (k \times t(h+d))$$

A = Surface area of Filter (square feet)
V = Water volume (cubic feet)
d = Depth of Filter Media (min 1.5 ft; max 2.5 ft)
t = Drawdown time (days), not to exceed 72 hours
h = Head (average in feet)
k = Hydraulic conductivity (ft/day)

9. When a Filter has accumulated sediment in its pore space, its hydraulic conductivity is reduced, and so is its ability to removal pollutants. **Maintenance and Inspection** are essential for continued performance of a Filter. Based upon inspection, some or all portions of the filter media may require replacement.

10. Filters should be designed with **sufficient maintenance access** (clean-outs, room for surface cleaning, etc.). Filters that are visible and simple in design are more likely to be maintained correctly.

Detailed Stormwater Functions

Volume Reduction Calculations
If a Filter is designed to include infiltration, the Volume Reduction is a function of the Area of the Filter and infiltration rate. There is minimal volume reduction for Filters that are not designed to infiltrate.

Volume = Infiltration Volume* + Filter Volume
Infiltration Volume = Bottom Area (sf) x Infil. Rate (in/hr) x Drawdown time** (hr)
Filter Volume = Area of filter (sf) x Depth (ft) x 20%***

*For filters with infiltration only
** Not to exceed 72 hours
***For sand, amended soil, compost, peat; Use 20% unless more specific data is available

Peak Rate Mitigation Calculations
See Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement
See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.



Construction Sequence

1. Permanent Filters should not be installed until the site is stabilized. Excessive sediment generated during construction can clog the Filter and prevent or reduce the anticipated post-construction water quality benefits. Stabilize all contributing areas before runoff enters filters.
2. Structures such as inlet boxes, reinforced concrete boxes, etc. should be installed in accordance with the manufacturers' or design engineers guidance.
3. Excavated filters that infiltrate or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the subbase. Structures may be set on a layer of clean, lightly compacted gravel (such as AASHTO #57).
4. Infiltration Filters should be underlain by a layer of permeable non-woven-geotextile.
5. Place underlying gravel/stone in minimum 6 inch lifts and lightly compact. Place underdrain pipes in gravel during placement.
6. Wrap and secure nonwoven geotextile to prevent gravel/stone from clogging with sediments.
7. Lay filtering material. Do not compact.
8. Saturate filter media and allow media to drain to properly settle and distribute.
9. For vegetated filters, a layer of nonwoven geotextile between non-organic filter media and planting media is recommended.
10. There should be sufficient space (head) between the top of the filtering bed and the overflow of the Filter to allow for the maximum head designed to be stored before filtration.

Maintenance and Inspection

Filters require a regular inspection and maintenance program in order to maintain the integrity of the filtering system and pollutant removal mechanisms. Studies have shown that filters are very effective upon installation, but quickly decrease in efficiency as sediment accumulates in the filter. (Urbonas, Urban Drainage and Flood Control District, CO) Odor is also a concern for filters that are not maintained. Inspection of the filter is recommended at least **four times a year**.

During inspection the following conditions should be considered:

- **Standing water** – any water left in a surface filter after the design drain down time indicates the filter is not optimally functioning.
- **Film or discoloration** of any surface filter material – this indicates organics or debris have clogged the filter surface.



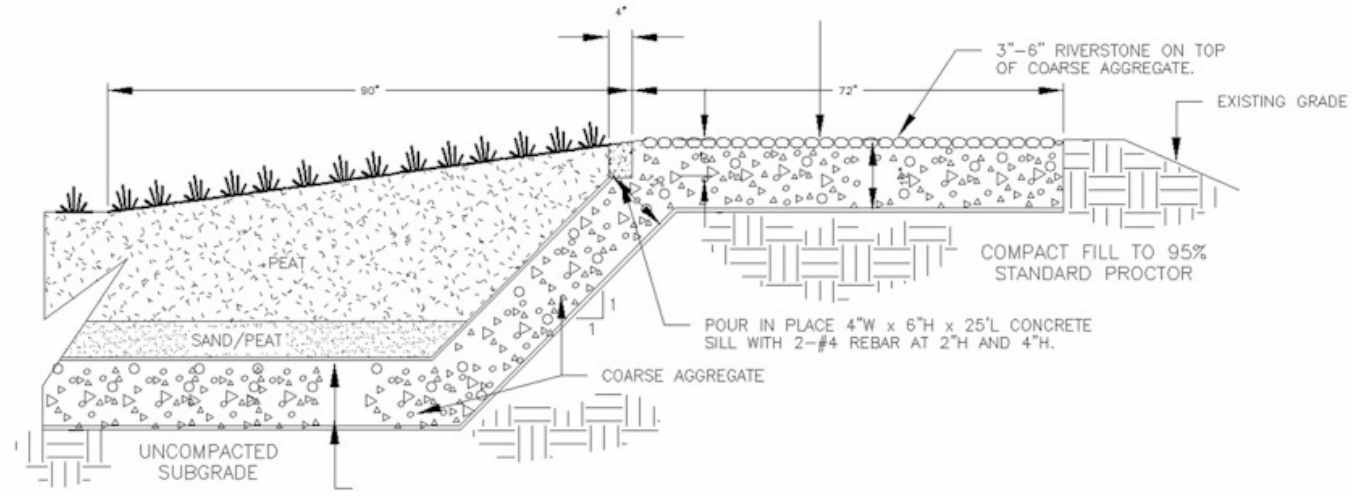
Filter Maintenance

- Remove trash and debris as necessary
- Scrape silt with rakes
- Till and aerate filter area
- Replace filtering medium if scraping/removal has reduced depth of filtering media

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all state and federal regulations.

Winter concerns

Pennsylvania's winter temperatures go below freezing about four months out of every year, and surface filtration may not take place as well in the winter. Peat and compost may hold water, freeze, and become impervious on the surface. Design options that allow directly for subsurface discharge into the filter media during cold weather may overcome this condition.



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Cost Issues

Filter costs vary according to the filtering medial (sand, peat, compost), land clearing, excavation, grading, inlet and outlet structures, perforated pipes, encasing structure (if used), and maintenance cost. Underground structures may contribute significantly to the cost of a Filter.

Specifications

1. **Stone/Gravel** shall be uniformly graded coarse aggregate, 1 inch to ¾ inch with a wash loss of no more than 0.5%, AASHTO size number 57 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. **Peat** shall have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

3. **Sand** shall be ASTM-C-33 (or AASHTO M-6) size (0.02" – 0.04"), concrete sand, clean, medium to fine sand, no organic material.

4. **Non-Woven Geotextile** shall consist of needled nonwoven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) ³ 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) ³ 225 psi
   c. Flow Rate (ASTM-D4491) ³ 95 gal/min/ft²
   d. UV Resistance after 500 hrs (ASTM-D4355) ³ 70%
   e. Heat-set or heat-calendared fabrics are not permitted

   Acceptable types include Mirafi 140N, Amoco 4547, Geotex 451, or approved others.

5. **Pipe** shall be continuously perforated, smooth interior, with a minimum inside diameter of 8-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

SARB_014781

References

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University of Minnesota Extension Service, Northeast Regional Correction Center (NERCC)

"Field Evaluation of a Stormwater Sand Filter" Ben R. Urbonas, John T. Doerfer and L. Scott Tucker www.udfcd.org/fhn96/flood1.html

"An Evaluation of Filter Media For Treating Stormwater Runoff" Thomas A DeBustk and Michael A. Langston, Benefict Schwegler, Scott Davidson, Fifth Biennial Stormwater Research Conference, November, 1997

"A Denitrification System For Septic Tank Effluent Using Sphagnum Peat Moss" E. S. Winkler, and P. L. M. Veneman

"Stormwater Sand Filter Sizing and Design – A Unit Operations Approach" Urbonas

New York Department of Environmental Conservation. *New York Stormwater Management Manual.* 2003.

California Stormwater Quality Association. *California Stormwater BMP Handbook.* January 2003.

SARB_014783

BMP 6.4.8: Vegetated Swale



A Vegetated Swale is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. In steeper slope situations, check dams may be used to further enhance attenuation and infiltration opportunities.

Key Design Elements

- Plant dense, low-growing native vegetation that is water-resistant, drought and salt tolerant, providing substantial pollutant removal capabilities
- Longitudinal slopes range from 1 to 6%
- Side slopes range from 3:1 to 5:1
- Bottom width of 2 to 8 feet
- Check-dams can provide limited detention storage, as well as enhanced volume control through infiltration. Care must be taken to prevent erosion around the dam
- Convey the 10-year storm event with a minimum of 6 inches of freeboard
- Designed for non-erosive velocities up to the 10-year storm event
- Design to aesthetically fit into the landscape, where possible
- Significantly slow the rate of runoff conveyance compared to pipes

Potential Applications

Residential:
Commercial: Yes Yes
Ultra Urban: Limited
Industrial: Yes Yes
Retrofit: Yes
Highway/Road:

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Med./High
Water Quality: Med./High

Water Quality Functions

TSS: 50%
TP: 50%
NO3: 20%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed whenever infiltration of runoff is desired, see Appendix C

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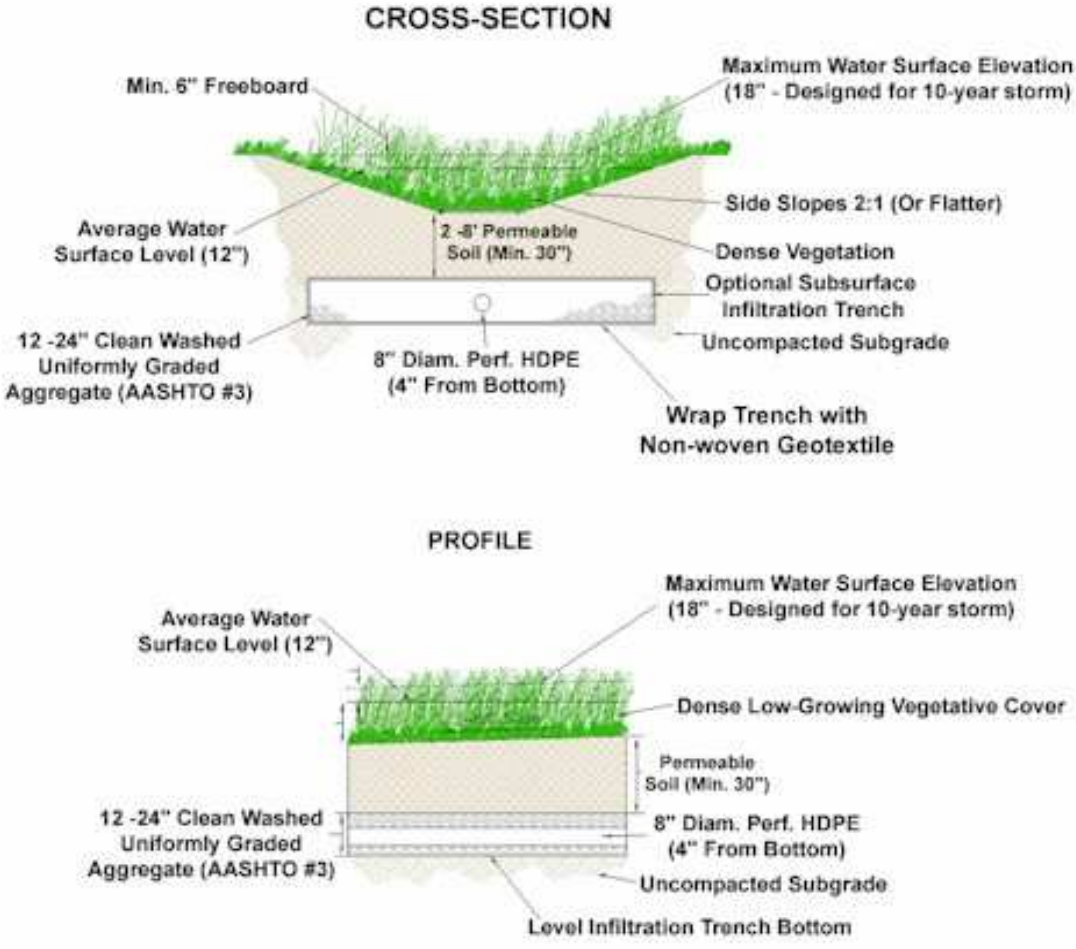
Description

Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated Swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems, while providing partially treated (pretreatment) and partially distributed stormwater flows to subsequent BMPs. Swales are often heavily vegetated with a dense and diverse selection of native, close-growing, water-resistant plants with high pollutant removal potential. The various pollutant removal mechanisms of a swale include: sedimentary filtering by the swale vegetation (both on side slopes and on bottom), filtering through a subsoil matrix, and/or infiltration into the underlying soils with the full array of infiltration-oriented pollutant removal mechanisms.

A Vegetated Swale typically consists of a band of dense vegetation, underlain by at least 24 inches of permeable soil. Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. A nonwoven geotextile should completely wrap the aggregate trench (See BMP 6.4.4 Infiltration Trench for further design guidelines).



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A major concern when designing Vegetated Swales is to make certain that excessive stormwater flows, slope, and other factors do not combine to produce erosive flows, which exceed the Vegetated Swale capabilities. Use of check dams or turf reinforcement matting (TRM) can enhance swale performance in some situations.

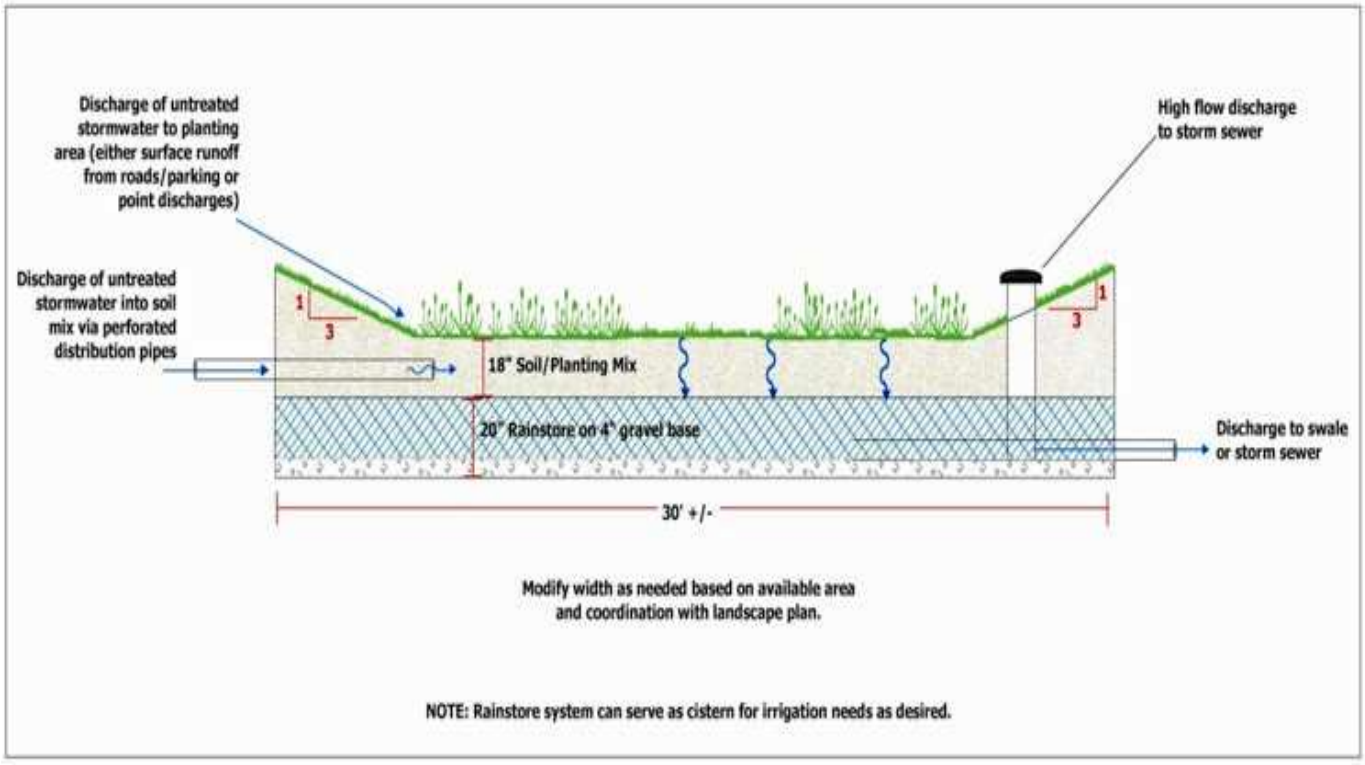


A key feature of vegetated swale design is that swales can be well integrated into the landscape character of the surrounding area. A vegetated swale can often enhance the aesthetic value of a site through the selection of appropriate native vegetation. Swales may also discreetly blend in with landscaping features, especially when adjacent to roads.

Variations

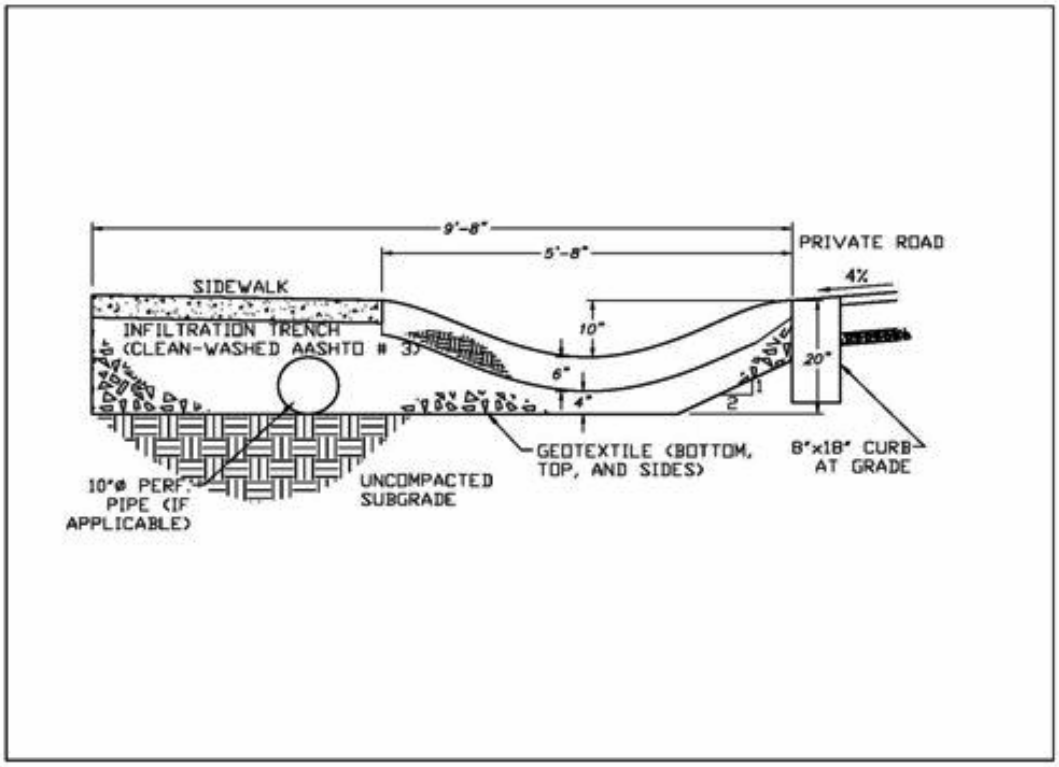
Vegetated Swale with Infiltration Trench

This option includes a 12 to 24 inch aggregate bed or trench, wrapped in a nonwoven geotextile (See BMP 6.4.4 Infiltration Trench for further design guidelines). This addition of an aggregate bed or trench substantially increases volume control and water quality performance although costs also are increased. Soil Testing and Infiltration Protocols in Appendix C should be followed.



Vegetated Swales with Infiltration Trenches are best fitted for milder sloped swales where the addition of the aggregate bed system is recommended to make sure that the maximum allowable ponding time of 72 hours is not exceeded. This aggregate bed system should consist of at least 12 inches of

uniformly graded aggregate. Ideally, the underdrain system shall be designed like an infiltration trench. The subsurface trench should be comprised of terraced levels, though sloping trench bottoms may also be acceptable. The storage capacity of the infiltration trench may be added to the surface storage volume to achieve the required storage of the 1-inch storm event.



Grass Swale

Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than swales with longer and denser vegetation. However, they provide far less infiltration and pollutant removal opportunities. Grass swales are to be used only as pretreatment for other structural BMPs. Design of grass swales is often rate-based. Grassed swales, where appropriate, are preferred over catch basins and pipes because of their ability to reduce the rate of flow across a site.



Wet Swales

Wet swales are essentially linear wetland cells. Their design often incorporates shallow, permanent pools or marshy conditions that can sustain wetland vegetation, which in turn provides potentially high pollutant removal. A high water table or poorly drained soils are a prerequisite for wet swales. The drawback with wet swales, at least in



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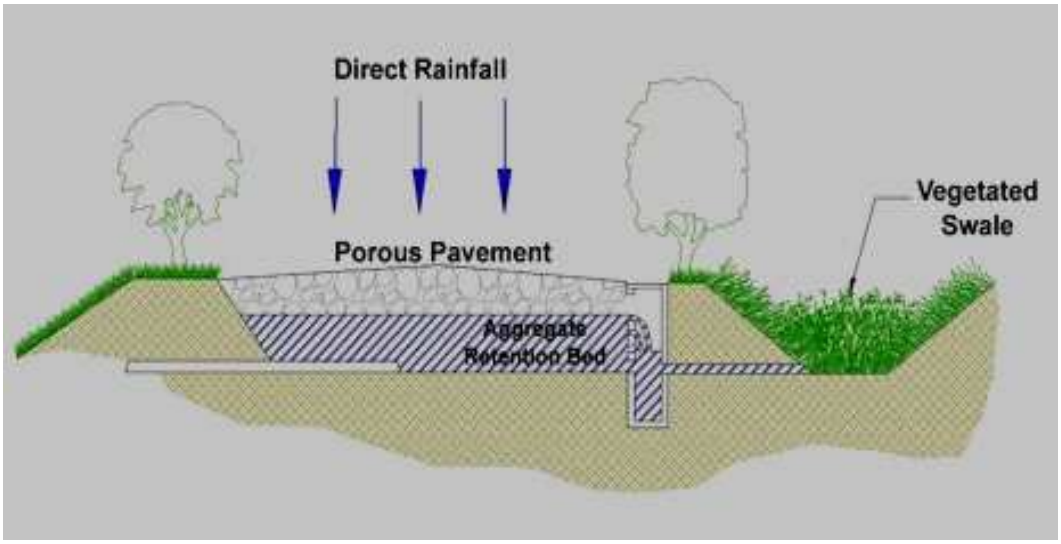
residential or commercial settings, is that they may promote mosquito breeding in the shallow standing water (follow additional guidance under Constructed Wetland for reducing mosquito population). Infiltration is minimal if water remains for extended periods.

Applications



- **Parking**
- **Commercial and light industrial facilities**
- **Roads and highways**
- **Residential developments**
- **Pretreatment for volume-based BMPs**
- **Alternative to curb/gutter and storm sewer**

Design Considerations

1. Vegetated Swales are sized to temporarily store and infiltrate the 1-inch storm event, while providing conveyance for up to the 10-year storm with freeboard; flows for up to the 10-year storm are to be accommodated without causing erosion. Swales should maintain a maximum ponding depth of 18 inches at the end point of the channel, with a 12-inch average maintained throughout. Six inches of freeboard is recommended for the 10-year storm. Residence times between 5 and 9 minutes are acceptable for swales without check-dams. The maximum ponding time is 48 hours, though 24 hours is more desirable (minimum of 30 minutes). Studies have shown that the maximum amount of swale filtering occurs for water depths below 6 inches. It is critical that swale vegetation not be submerged, as it could cause the vegetation to bend over with the flow. This would naturally lead to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.

2. Longitudinal slopes between 1% and 3% are generally recommended for swales. If the topography necessitates steeper slopes, check dams or TRM's are options to reduce the energy gradient and erosion potential.

3. Check dams are recommended for vegetated swales with longitudinal slopes greater than 3%. They are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity, and promote additional filtering and settling of nutrients and other pollutants. In effect, check-dams create a series of small, temporary pools along the length of the swale, which shall drain down within a maximum of 72 hours. Swales with check-dams are much more effective at mitigating runoff quantity and quality than those without. The frequency and design of check-dams in a swale will depend on the swale length and slope, as well as the desired amount of storage/treatment volume. Care must be taken to avoid erosion around the ends of the check dams.





Check-dams shall be constructed to a height of 6 to 12 in and be regularly spaced. The following materials have been employed for check-dams: natural wood, concrete, stone, and earth. Earthen check-dams however, are typically not recommended due to their potential to erode. A weep hole(s) may be added to a check-dam to allow the retained volume to slowly drain out. Care should be taken to ensure that the weep hole(s) is not subject to clogging. In the case of a stone check-dam, a better approach might be to allow low flows (2-year storm) to drain through the stone, while allowing higher flows (10-year storm) drain through a weir in the center of the dam. Flows through a stone check-dam are a function of stone size, flow depth, flow width, and flow path length through the dam. The following equation can be used to estimate the flow through a stone check dam up to 6 feet long:

$$q = h^{1.5} / (L/D + 2.5 + L^2)^{0.5}$$

where:

q = flow rate exiting check dam (cfs/ft)
h = flow depth (ft)
L = length of flow (ft)
D = average stone diameter (ft) (more uniform gradations are preferred)

For low flows, check-dam geometry and swale width are actually more influential on flow than stone size. The average flow length through a check-dam as a function of flow depth can be determined by the following equation:

$$L = (ss) \times (2d - h)$$

where:
ss = check dam side slope (maximum 2:1)
d = height of dam (ft)
h = flow depth (ft)

When swale flows overwhelm the flow-through capacity of a stone check-dam, the top of the dam shall act as a standard weir (use standard weir equation). (Though a principal spillway, 6 inches below the height of the dam, may also be required depending on flow conditions.) If the check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

4. The effectiveness of a vegetated swale is directly related to the contributing land use, the size of the drainage area, the soil type, slope, drainage area imperviousness, proposed vegetation, and the swale dimensions. Use of natural low points in the topography may be suited for swale location, as are natural drainage courses although infiltration capability may also be reduced in these situations. The topography of a site should allow for the design of a swale with sufficiently mild slope and flow capacity. Swales are impractical in areas of extreme (very flat or steep) slopes. Of course, adequate space is needed for vegetated swales. Swales are ideal as an alternative to curbs and gutters along parking lots and along small roads in gently sloping terrain.

   Siting of vegetated swales should take into account the location and function of other site features (buffers, undisturbed natural areas, etc.). Siting should also attempt to aesthetically fit the swale into the landscape as much as possible. Sharp bends in swales should be avoided.

   Implementing vegetated swales is challenging when development density exceeds four dwelling units per acre, in which case the number of driveway culverts often increases to the point where swales essentially become broken-pipe systems.

   Where possible, construct swales in areas of uncompacted cut. Avoid constructing side slopes in fill material. Fill slopes can be prone to erosion and/or structural damage by burrowing animals.

5. Soil Testing is required when infiltration is planned (see Appendix C).

6. Guidelines for Infiltration Systems should be met as necessary (see Appendix C).

7. Swales are typically most effective, when treating an area of 1 to 2 acres although vegetated swales can be used to treat and convey runoff from an area of 5 to 10 acres in size. Swales serving greater than 10-acre drainage areas will provide a lesser degree water quality treatment, unless special provisions are made to manage the increased flows.

8. Runoff can be directed into Vegetated Swales either as concentrated flows or as lateral sheet flow drainage. Both are acceptable provided sufficient stabilization or energy dissipation is

included (see #6). If flow is to be directed into a swale via curb cuts, provide a 2 to 3 inch drop at the interface of pavement and swale. Curb cuts should be at least 12 inches wide to prevent clogging and should be spaced appropriately.

9. Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially roadway runoff. However, when swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Pretreatment can dramatically extend the functional life of any BMP, as well as increase its pollutant removal efficiency by settling out some of the heavier sediments. This treatment volume is typically obtained by installing check dams at pipe inlets and/or driveway crossings. Pretreatment options include a vegetated filter strip, a sediment forebay (or plunge pool) for concentrated flows, or a pea gravel diaphragm (or alternative) with a 6-inch drop where parking lot sheet flow is directed into a swale.

10. The soil base for a vegetated swale must provide stability and adequate support for proposed vegetation. When the existing site soil is deemed unsuitable (clayey, rocky, coarse sands, etc.) to support dense vegetation, replacing with approximately 12 inches of loamy or sandy soils is recommended. In general, alkaline soils should be used to further reduce and retain metals. Swale soils should also be well-drained. If the infiltration capacity is compromised during construction, the first several feet should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth.

11. Swales are most efficient when their cross-sections are parabolic or trapezoidal in nature. Swale side slopes are best within a range of 3:1 to 5:1 and should not be greater than 2:1 for ease of maintenance and side inflow from sheet flow.

12. To ensure the filtration capacity and proper performance of swales, the bottom widths typically range from 2 to 8 feet. Wider channels are feasible only when obstructions such as berms or walls are employed to prohibit braiding or uncontrolled sub-channel formation. The maximum bottom width to depth ratio for a trapezoidal swale should be 12:1.

13. Ideal swale vegetation should consist of a dense and diverse selection of close-growing, water-resistant plants whose growing season preferably corresponds to the wet season. For swales that are not part of a regularly irrigated landscaped area, drought tolerant vegetation should be considered as well. Vegetation should be selected at an early stage in the design process, with well-defined pollution control goals in mind. Selected vegetation must be able to thrive at the specific site and therefore should be chosen carefully (See Appendix B). Use of native plant species is strongly advised, as is avoidance of invasive plant species. Swale vegetation must also be salt tolerant, if winter road maintenance activities are expected to contribute salt/chlorides.

Table 6.8.1

Commonly used vegetation in swale (New Jersey BMP Manual, 2004)		
Common Name	Scientific Name	Notes
Alkai Saltgrass	Puccinellia distans	Cool, good for wet, saline swales
Fowl Bluegrass	Poa palustris	Cool, good for wet swales
Canada Bluejoint	Calamagrostis canadensis	Cool, good for wet swales
Creeping Bentgrass	Agrostis palustris	Cool, good for wet swales, salt tolerant
Red Fescue	Festuca rubra	Cool, not for wet swales
Redtop	Agrostis gigantea	Cool, good for wet swales
Rough Bluegrass	Poa trivialis	Cool, good for wet, shady swales
Switchgrass	Panicum virgatum	Warm, good for wet swales, somwe salt tolerance
Wildrye	Elymus virginicus/rigarius	Cool, good for wet, shady swales

Notes: These grasses are sod forming and can withstand frequent inundation, and are idela for the swale or grass channel environment. A few are also salt tolerant. Cool refers to cool season grasses that grow during the colder temperatures of spring and fall. Warm refers to warm season grasses that grow most vigorously during the hot , mid summer months.

By landscaping with trees along side slopes, swales can be easily and aesthetically integrated into the overall site design without unnecessary loss of usable space. An important consideration however, is that tree plantings allow enough light to pass and sustain a dense ground cover. When the trees have reached maturity, they should provide enough shade to markedly reduce high temperatures in swale runoff.

14. Check the temporary and permanent stability of the swale using the standards outlined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual. Swales should convey either 2.75 cfs/acre or the calculated peak discharge from a 10-year storm event. The permissible velocity design method may be used for design of channel linings for bed slopes <0.10 ft/ft; use of the maximum permissible shear stress is acceptable for all bed slopes. Flow capacity, velocity, and design depth in swales are generally calculated by Manning's equation.

    Prior to establishment of vegetation, a swale is particularly vulnerable to scour and erosion and therefore its seed bed must be protected with temporary erosion control, such as straw matting, compost blankets, or curled wood blankets. Most vendors will provide information about the Manning's 'n' value and will specify the maximum permissible velocity or allowable shear stress for the lining material.

    The post-vegetation establishment capacity of the swale should also be confirmed. Permanent turf reinforcement may supersede temporary reinforcement on sites where not exceeding the maximum permissible velocity is problematic. If driveways or roads cross a swale, culvert capacity may supersede Manning's equation for determination of design flow depth. In these cases, the culvert should be checked to establish that the backwater elevation would not exceed the banks of the swale. If the culverts are to discharge to a minimum tailwater condition, the exit velocity for the culvert should be evaluated for design conditions. If the maximum permissible velocity is exceeded at the culvert outlet, energy dissipation measures should be implemented. The following tables list the maximum permissible shear stresses (for various channel liners) and velocities (for channels lined with vegetation) from the Pennsylvania Erosion and Sediment Pollution Control Program Manual.

Maximum Permissible Shear Stresses for Various Channel Liners

Lining Category	Lining Type	lb/ft2
Unlined - Erodible Soils*	Silts, Fine - Medium Sands	0.03
	Coarse Sands	0.04
	Very Coarse Sands	0.05
	Fine Gravel	0.10
Erosion Resistant Soils**	Clay loam	0.25
	Silty Clay loam	0.18
	Sandy Clay Loam	0.10
	Loam	0.07
	Silt Loam	0.12
	Sandy Loam	0.02
	Gravely, Stony, Channery Loam	0.05
	Stony or Channery Silt Loam	0.07
Temporary Liners	Jute	0.45
	Straw with Net	1.45
	Coir - Double Net	2.25
	Coconut Fiber - Double Net	2.25
	Curled Wood Mat	1.55
	Curled Wood - Double Net	1.75
	Curled Wood - Hi Velocity	2.00
	Synthetic Mat	2.00
Vegetative Liners	Class B	2.10
	Class C	1.00
	Class D	0.60
Riprap***	R-1	0.25
	R-2	0.50
	R-3	1.00
	R-4	2.00
	R-5	3.00
	R-6	4.00
	R-7	5.00
	R-8	8.00

* Soils having an erodibility "K" factor greater than 0.37

** Soils having an erodibility "K" factor less than or equal to 0.37

*** Permissible shear stresses based on rock at 165 lb/cuft. Adjust velocities for other rock weights used. See Table 12.

Manufacturer's shear stress values based on independent tests may be used.

Maximum Permissible Velocities for Channels Lined with Vegetation

Cover	Slope Range Percent	Erosion resistant Soil[1]	Easily Eroded Soil[2]
Kentucky Bluegrass	<5	7 [3]	5
Tall Fescue	5-10	6 [3]	4
	>10	5	3
Grass Mixture	<5	5	4
Reed Canarygrass	5-10	4	3
Serecea Lespedeza Weeping Lovegrass Redtop Red Fescue	<5	3.5	2.5
Annuals Temporary cover only Sudangrass	<5	3.5	2.5

[1]Cohesive (clayey) fine grain soils and coarse grain soils with a plasticity index OF 10 TO 40 (CL, CH, SC and GC). Soils with K values less than 0.37.

[2]Soils with K values greater than 0.37.

[3]Use velocities exceeding 5 ft/sec only where good cover and proper maintenance can be obtained.

15. Manning's roughness coefficient, or 'n' value, varies with type of vegetative cover and design flow depth. Two common methods are based on design depth (see adjacent graph) and based on vegetative cover (as defined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual). Either of these can be used in design.

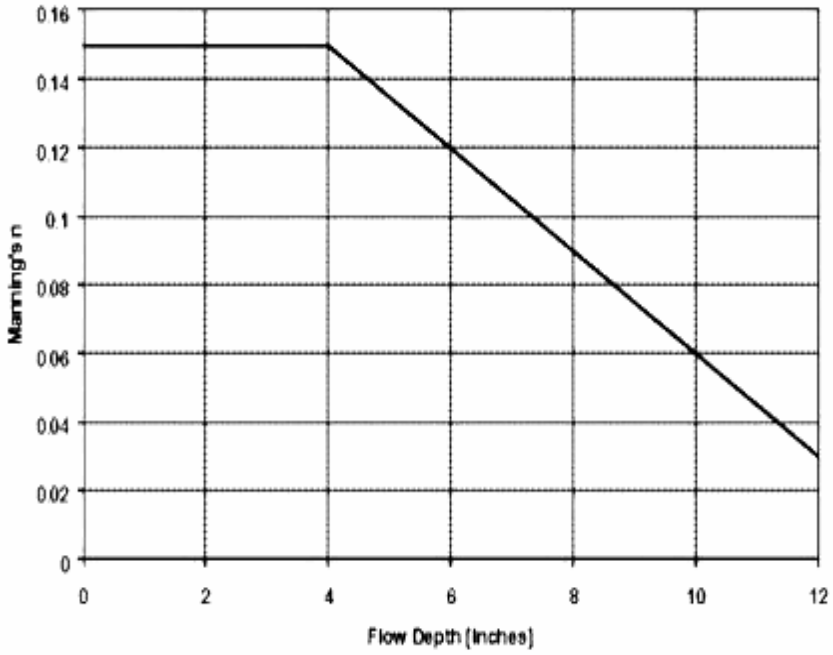


Figure D9.1 Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

16. If swales are designed according to the guidelines discussed in this section, significant levels of pollutant reduction can be expected through filtration and infiltration. In a particular swale reach, runoff should be well filtered by the time it flows over a check-dam. Thus, the stabilizing stone apron on the downhill side of the check-dam may be designed as an extension of an infiltration trench. In this way, only filtered runoff will enter a subsurface infiltration trench, thereby reducing the threat of groundwater contamination by metals.

17. Culverts are typically used in a vegetated swale at driveway or road crossings. By oversizing culverts and their flow capacity, cold weather concerns (e.g. clogging with snow) are lessened.

18. Where grades limit swale slope and culvert size, trench drains may be used to cross driveways.

19. Swales should discharge to another structural BMP (bioretention, infiltration basin, constructed wetlands, etc.), existing stormwater infrastructure, or a stable outfall.

Detailed Stormwater Functions

Infiltration Area (if needed)

Volume Reduction Calculations

The volume retained behind each check-dam can be approximated from the following equation:

Storage Volume = 0.5 x Length of Swale Impoundment Area Per Check Dam x Depth of Check Dam x (Top Width of Check Dam + Bottom Width of Check Dam) / 2

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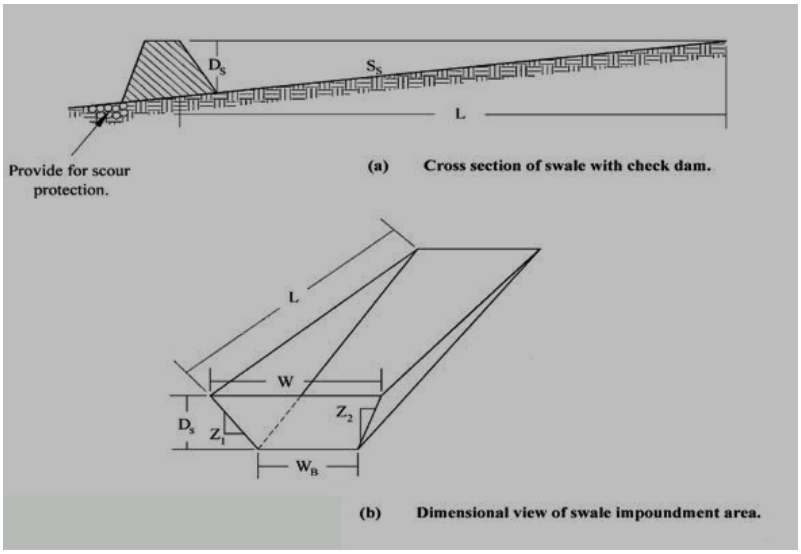

Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Begin vegetated swale construction only when the upgradient temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection's *Erosion and Sediment Pollution Control Program Manual,* March 2000 or latest edition.)

2. Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

3. Construct check dams, if required.

4. Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow conditions.

5. Seed, vegetate and install protective lining as per approved plans and according to final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

6. Once all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving upland stormwater flow.

7. Follow maintenance guidelines, as discussed below.

   Note: If a vegetated swale is used for runoff conveyance during construction, it should be regraded and reseeded immediately after construction and stabilization has occurred. Any damaged areas should be fully restored to ensure future functionality of the swale.

Maintenance Issues

Compared to other stormwater management measures, the required upkeep of vegetated swales is relatively low. In general, maintenance strategies for swales focus on sustaining the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a dense vegetative cover. Experience has proven that proper maintenance activities ensure the functionality of vegetated swales for many years. The following schedule of inspection and maintenance activities is recommended:

Maintenance activities to be done annually and within 48 hours after every major storm event (> 1 inch rainfall depth):

- Inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation (address when > 3 inches at any spot or covering vegetation)
- Inspect vegetation on side slopes for erosion and formation of rills or gullies, correct as needed
- Inspect for pools of standing water; dewater and discharge to an approved location and restore to design grade
- Mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation; dispose of cuttings in a local composting facility; mow only when swale is dry to avoid rutting
- Inspect for litter; remove prior to mowing
- Inspect for uniformity in cross-section and longitudinal slope, correct as needed
- Inspect swale inlet (curb cuts, pipes, etc.) and outlet for signs of erosion or blockage, correct as needed

Maintenance activities to be done as needed:

- Plant alternative grass species in the event of unsuccessful establishment

- Reseed bare areas; install appropriate erosion control measures when native soil is exposed or erosion channels are forming
- Rototill and replant swale if draw down time is more than 48 hours
- Inspect and correct check dams when signs of altered water flow (channelization, obstructions, erosion, etc.) are identified
- Water during dry periods, fertilize, and apply pesticide **only when absolutely necessary**

Most of the above maintenance activities are reasonably within the ability of individual homeowners. More intensive swales (i.e. more substantial vegetation, check dams, etc.) may warrant more intensive maintenance duties and should be vested with a responsible agency. A legally binding and enforceable maintenance agreement between the facility owner and the local review authority might be warranted to ensure sustained maintenance execution. Winter conditions also necessitate additional maintenance concerns, which include the following:

- Inspect swale immediately after the spring melt, remove residuals (e.g. sand) and replace damaged vegetation without disturbing remaining vegetation.
- If roadside or parking lot runoff is directed to the swale, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity and to reduce the impacts of deicing agents.
- Use nontoxic, organic deicing agents, applied either as blended, magnesium chloride-based liquid products or as pretreated salt.
- Use salt-tolerant vegetation in swales.

Cost Issues

As with all other BMPs, the cost of installing and maintaining Vegetated Swales varies widely with design variability, local labor/material rates, real estate value, and contingencies. In general, Vegetated Swales are considered relatively low cost control measures. Moreover, experience has shown that Vegetated Swales provide a cost-effective alternative to traditional curbs and gutters, including associated underground storm sewers. The following table compares the cost of a typical vegetated swale (15 ft top width) with the cost of traditional conveyance elements.

Structure:	**Swale**	**Underground Pipe**	**Curb & Gutter**
Construction Cost (per linear foot)	$4.50 - $8.50 (from seed) $15 - $20 (from sod)	$2 per foot per inch of diameter	$13 - $15
Annual O&M cost (per linear foot)	$0.75	No data	No data
Total Annual Cost (per linear foot)	$1 (from seed) $2 (from sod)	No data	No data
Lifetime (years	50		20

It is important to note that the costs listed above are strictly estimates and shall be used for design purposes only. Also, these costs do not include the cost of activities such as clearing, grubbing, leveling, filling, and sodding (if required). The Southeastern Wisconsin Regional Planning Commission (SEWRPC, 1991) reported that actual costs, which do include these activities, may range from $8.50 to $50.00 per linear foot depending on swale depth and bottom width. When all pertinent construction activities are considered, it is still likely that the cost of vegetated swale installation is less than that of traditional conveyance elements. When annual operation and maintenance costs are considered however, swales may prove the more expensive option, though they typically have a much longer lifespan.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Swale Soil** shall be USCS class ML (Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity), SM (Silty sands, poorly graded sand-silt mixtures), SW (Well-graded sands, gravelly sands, little or no fines) or SC (Clayey sands, poorly graded sand-clay mixtures). The first three of these designations are preferred for swales in cold climates. In general, soil with a higher percent organic content is preferred.

2. **Swale Sand** shall be ASTM C-33 fine aggregate concrete sand (0.02 in to 0.04 in).

3. **Check dams** constructed of natural wood shall be 6 in to 12 in diameter and notched as necessary. The following species are acceptable: Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut. The following species are not acceptable, as they can rot over time: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, and Willow. An earthen **check dam** shall be constructed of sand, gravel, and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone **check dam** shall be constructed of R-4 rip rap, or equivalent.

4. Develop a native **planting mix**. (see Appendix B)

5. If infiltration trench is proposed, see BMP 6.4.4 Infiltration Trench for specifications.

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BMP 6.4.9: Vegetated Filter Strip

The EPA defines a Vegetated Filter Strip as a "permanent, maintained strip of planted or indigenous vegetation located between nonpoint sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of nonpoint source pollutants such as nutrients, pesticides, sediments, and suspended solids."

Key Design Elements

- Sheet Flow across Vegetated Filter Strip
- Filter Strip length is a function of the slope, vegetative cover, and soil type.
- Minimum recommended length of Filter Strip is 25 ft, however shorter lengths provide some water quality benefits as well.
- Maximum Filter Strip slope is based on soil type and vegetated cover.
- Filter strip slope should never exceed 8%. Slopes less than 5% are generally preferred.
- Level spreading devices are recommended to provide uniform sheet flow conditions at the interface of the Filter Strip and the adjacent land cover.
- Maximum contributing drainage area slope is generally less than 5%, unless energy dissipation is provided.
- Minimum filter strip width should equal the width of the contributing drainage area.
- Construction of filter strip should entail as little disturbance to existing vegetation at the site as possible.
- See Appendix B for list of acceptable filter strip vegetation.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Limited
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

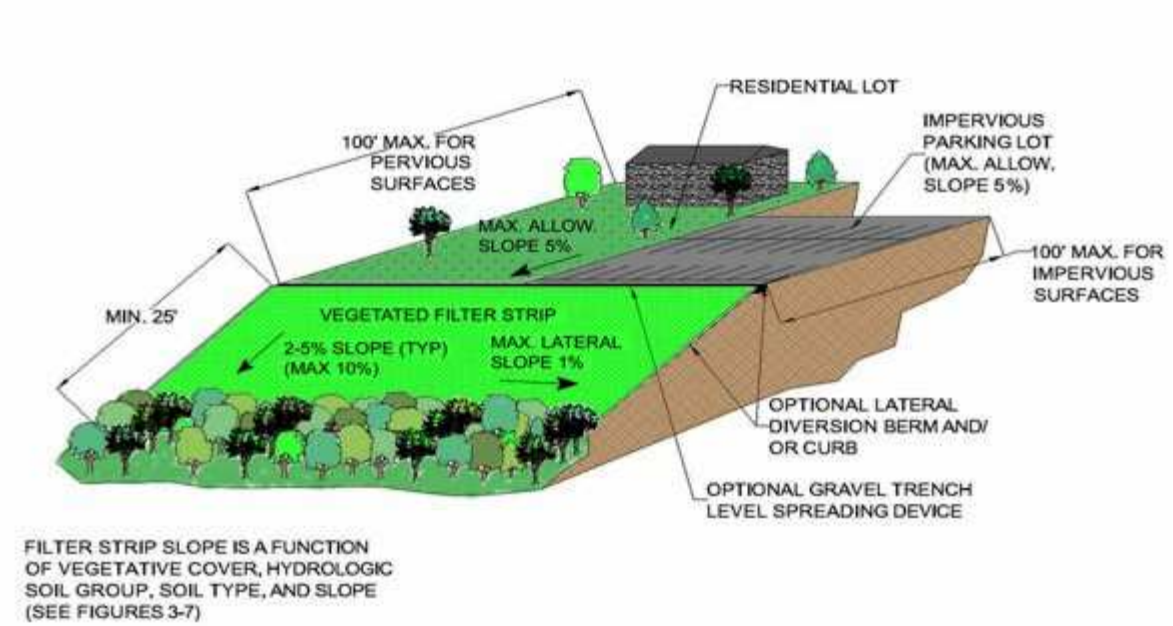
Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Low
Water Quality: High

Water Quality Functions

TSS: 30%
TP: 20%
NO3: 10%

Other Considerations

- Regular maintenance required for continued performance



Description

Filter strips are gently sloping, densely vegetated areas that filter, slow, and infiltrate sheet flowing stormwater. Filter strips are best utilized to treat runoff from roads and highways, roof downspouts, small parking lots, and pervious surfaces. In highly impervious areas, they are generally not recommended as "stand alone" features, but as pretreatment systems for other BMPs, such as Infiltration Trenches or Bioretention Areas. Filter Strips are primarily designed to reduced TSS levels, however pollutant levels of hydrocarbons, heavy metals, and nutrients may also be reduced. Pollutant removal mechanisms include sedimentation, filtration, absorption, infiltration, biological uptake, and microbial activity. Depending on hydrologic soil group, vegetative cover type, slope, and length, a filter strip can allow for a modest reduction in runoff volume through infiltration.

The vegetation for Filter Strips may be comprised of:

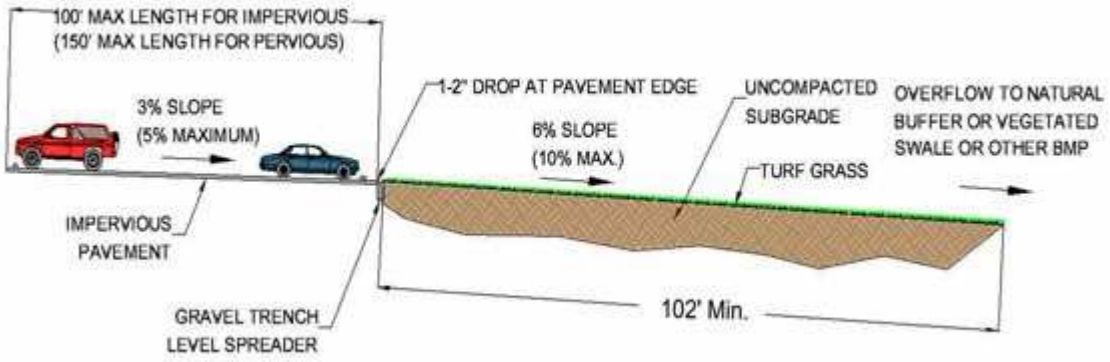
- Turf Grasses
- Meadow grasses, shrubs, and native vegetation, including trees
- Indigenous areas of woods and vegetation.

Filter strips may be comprised of a variety of trees, shrubs, and native vegetation to add aesthetic value as well as water quality benefits. The use of turf grasses will increase the required length of the filter strip, as compared to other vegetation options. The use of indigenous vegetated areas that have surface features that disperse runoff is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. Runoff must be distributed so that erosive conditions cannot develop.

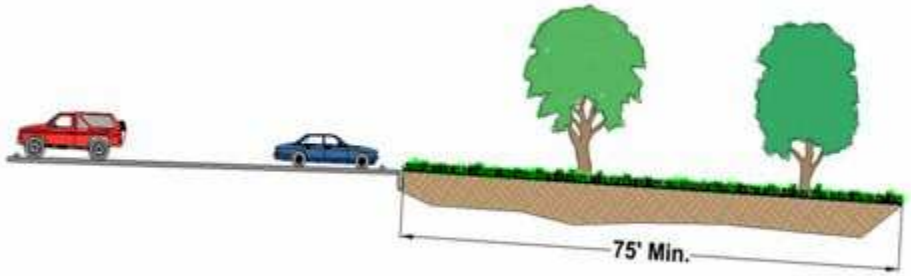
The vegetation in Filter Strips must be dense and healthy. Indigenous wooded areas should have a healthy layer of leaf mulch or duff. Indigenous areas that have surface features that concentrate flow are not acceptable.

The following example shows three filter strips that vary only by cover type. Each strip is on type 'C' soils and has a slope of 6%. Using the recommended sizing approach, the filter strip covered with turf grass required a length of 100 ft, while the strip with indigenous woods required only 50 ft. The strip covered with native grasses and some trees required 75 ft. Where the required length is not available, a filter strip can still be used but it will be less effective.

Filter Strip Example #1: Turf Grass



Filter Strip Example #2: Native Grasses and Planted Woods Grass



Filter Strip Example #3: Indigenous Woods



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Variations

Filter strip effectiveness may be enhanced through the addition of a pervious berm at the toe of the slope. A pervious berm allows for greater runoff velocity and volume reduction and thus better pollutant removal ability, by providing a very shallow, temporarily ponded area. The berm should have a height of not more than six to twelve inches and be constructed of sand, gravel, and sandy loam to encourage vegetative cover. An outlet pipe(s) or overflow weir should be provided and sized to ensure that the area drains within 24 hours, or to convey larger storm events. The berm must be erosion resistant under the full range of storm events. Likewise, the ponded area should be planted with vegetation that is resistant to frequent inundation.

Check dams may be implemented on filter strips with slopes exceeding 5%. Check dams shall be constructed of durable, nontoxic materials such as rock, brick, wood, not more than six inches in height, and placed at appropriate intervals to encourage ponding and prevent erosion. Care must be taken to prevent erosion around the ends of the check dams.



Applications

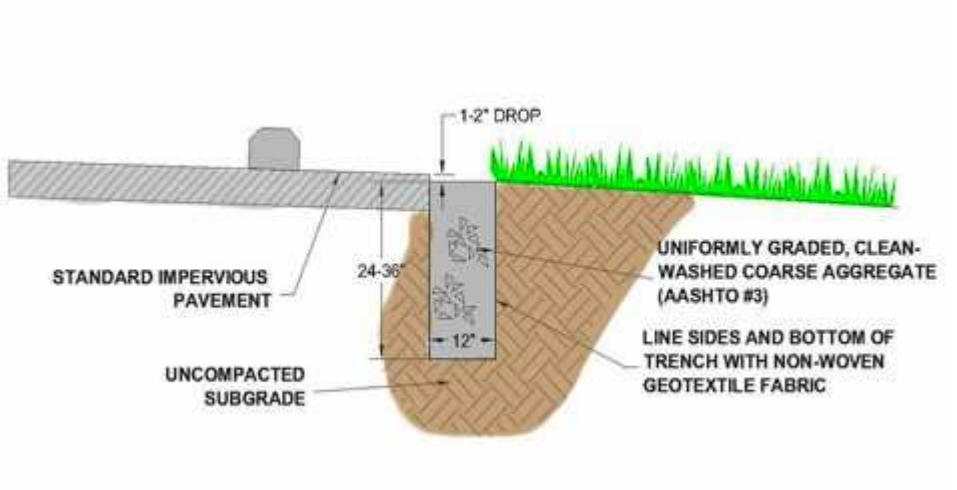
- Residential development lawn and housing areas
- Roads and highways
- Parking lots
- Pretreatment for other structural BMPs (Infiltration Trench, Bioretention, etc.)
- Commercial and light industrial facilities
- As part of a Riparian Buffer (located in Zone 3)

Design Considerations

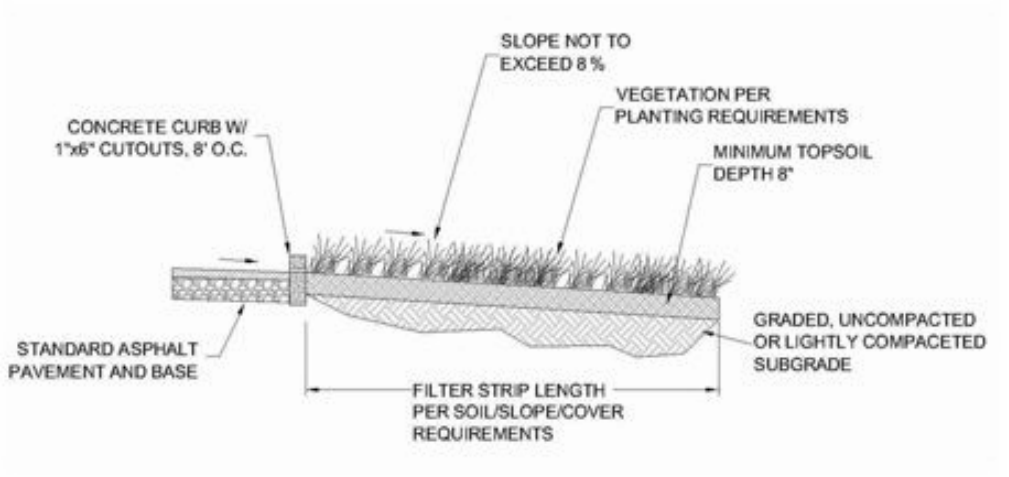
1. The design of vegetated filter strips is determined by site conditions (contributing drainage area, length, slope, etc.) site soil group, proposed cover type, and filter strip slope. The filter length can be determined from the appropriate graph shown below the text.

2. Level spreading devices or other measures may be required to provide uniform sheet flow conditions at the interface of the filter strip and the adjacent land cover. Concentrated flows are explicitly discouraged from entering filter strips, as they can lead to erosion and thus failure of the system. Examples of level spreader applications include:

    a. A gravel-filled trench, installed along the entire upgradient edge of the strip. The gravel in the trenches may range from pea gravel (ASTM D 448 size no. 6, 1/8" to 3/8") for most cases to shoulder ballast for roadways. Trenches are typically 12" wide, 24-36" deep, and lined with a nonwoven geotextile. When placed directly adjacent to an impervious surface, a drop (between the pavement edge and the trench) of 1-2" is recommended, in order to inhibit the formation of the initial deposition barrier.



    b. Curb stops



    c. Concrete sill (or lip)

    d. Slotted or depressed curbs

    e. An earthen berm with optional perforated pipe.

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3. Although in some locations more "natural" spreader designs and materials, such as earthen berms, are desirable, they can be more susceptible to failure due to irregularities in berm elevation and density of vegetation. When it is desired to treat runoff from roofs or curbed impervious areas, a more structural approach, such as a gravel trench, is required. In this case, runoff shall be directly conveyed, via pipe from downspout or inlet, into the subsurface gravel and uniformly distributed by a perforated pipe along the trench bottom.

4. The upstream edge of a filter strip should be level and directly abut the contributing drainage area.

5. The seasonal high water table should be at least 2 to 4 ft lower than any point along the filter strip.

6. In areas where the soil infiltration rate has been compromised (e.g. by excessive compaction), the filter strip shall be tilled prior to establishment of vegetation. However, tilling will only have an effect on the top 12-18 inches of the soil layer. Therefore, other measures, such as planting trees and shrubs, may be needed to provide deeper aeration. Deep root penetration will promote greater absorptive capacity of the soil.

7. The ratio of contributing drainage area to filter strip area should not exceed 6:1.

8. The filter strip area should be densely vegetated with a mix of salt- and drought- tolerant and erosion-resistant plant species. Filter strip vegetation, whether planted or indigenous, may range from turf and native grasses to herbaceous and woody vegetation. The optimal vegetation strategy consists of plants with dense growth patterns, a fibrous root system for stability, good regrowth ability (following dormancy and cutting), and adaptability to local soil and climatic conditions. Native vegetation is always preferred. (See Appendix B for vegetation recommendations.)

9. Natural areas, such as forests and meadows, should not be unduly disturbed by the creation of a filter strip. If these areas are not already functional as natural filters, they may be enhanced by restorative methods or construction of a level spreader.

10. Maximum lateral slope of filter strip is 1%.

11. To prohibit runoff from laterally bypassing a strip, berms and/or curbs can be installed along the sides of the strip, parallel to the direction of flow.

12. Pedestrian and/or vehicular traffic on filter strips should be strictly discouraged. Since the function of filter strips can be easily overlooked or forgotten over time, a highly visible, physical "barrier" is suggested. This can be accomplished, at the discretion of the owner, by simple post and chain, signage, or even the level-spreading device itself.

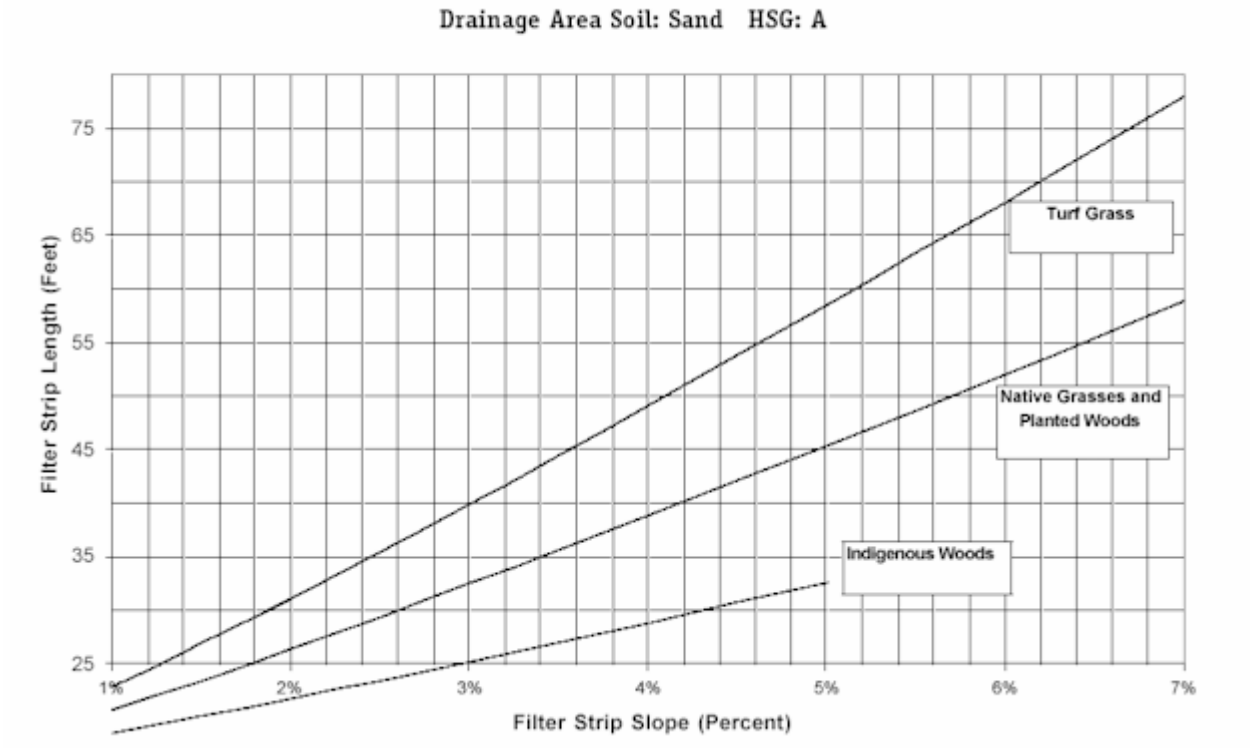
13. Vegetated filter strips may be designed to discharge to a variety of features, including natural buffer areas, vegetated swales, infiltration basins, or other structural BMPs.

14. In cold climates, the following recommendations should be considered:
    a. Filter strips often make convenient areas for snow storage. Thus, filter strip vegetation should be salt-tolerant and the maintenance schedule should involve removal of sand buildup at the toe of the slope.

b. The bottom of the gravel trench (if used as the level spreader) should be placed below the frost line to prohibit water from freezing in the trench. The perforated pipe in the trench should be at least 8 inches in diameter to further discourage freezing.
c. Other water quality options may be explored to provide backup to filter strips during the winter, when their pollutant removal ability is reduced.

Required Length as a Function of Slope, Soil Cover

Filter Strip Soil Type	Hydrologic Soil Group	Maximum Filter Strip Slope (Percent)	
		Turf Grass, Native Grasses and Meadows	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8



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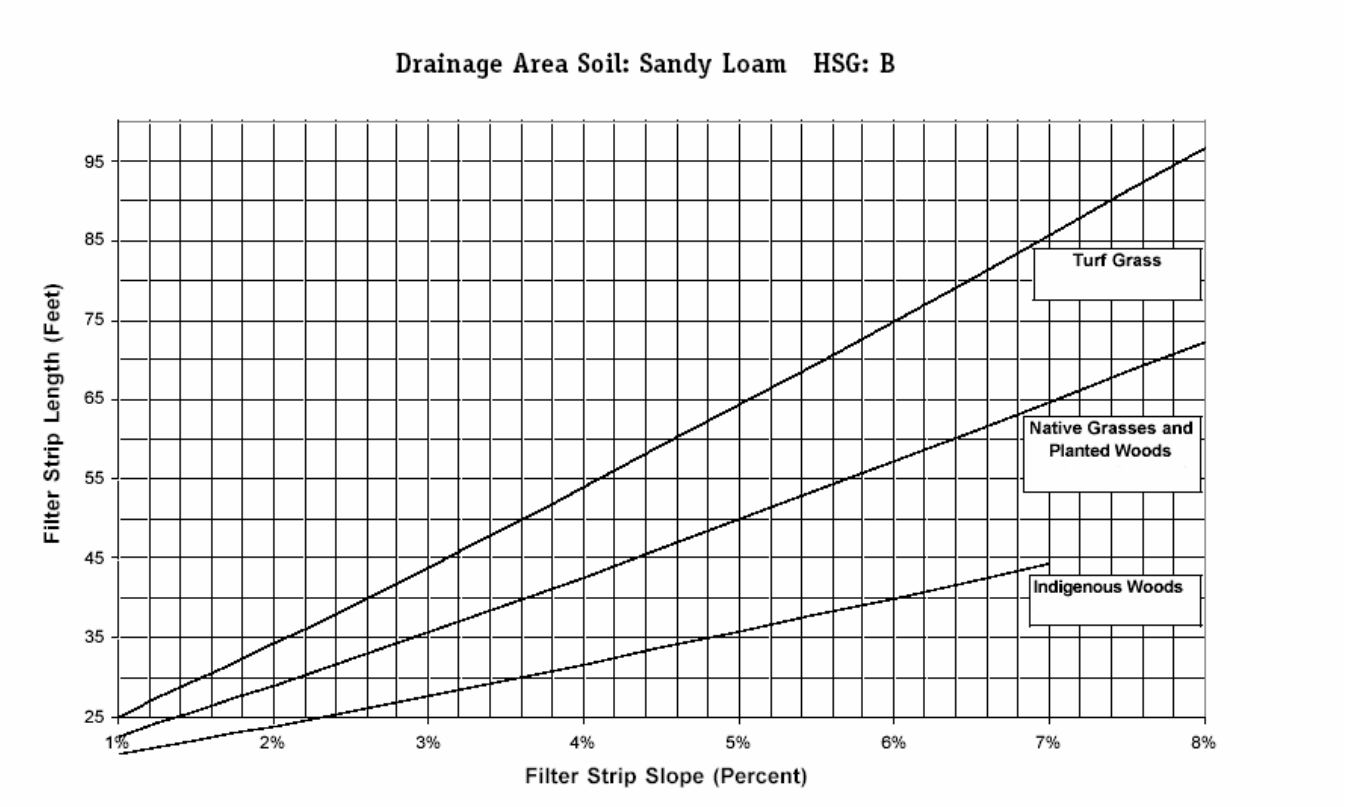
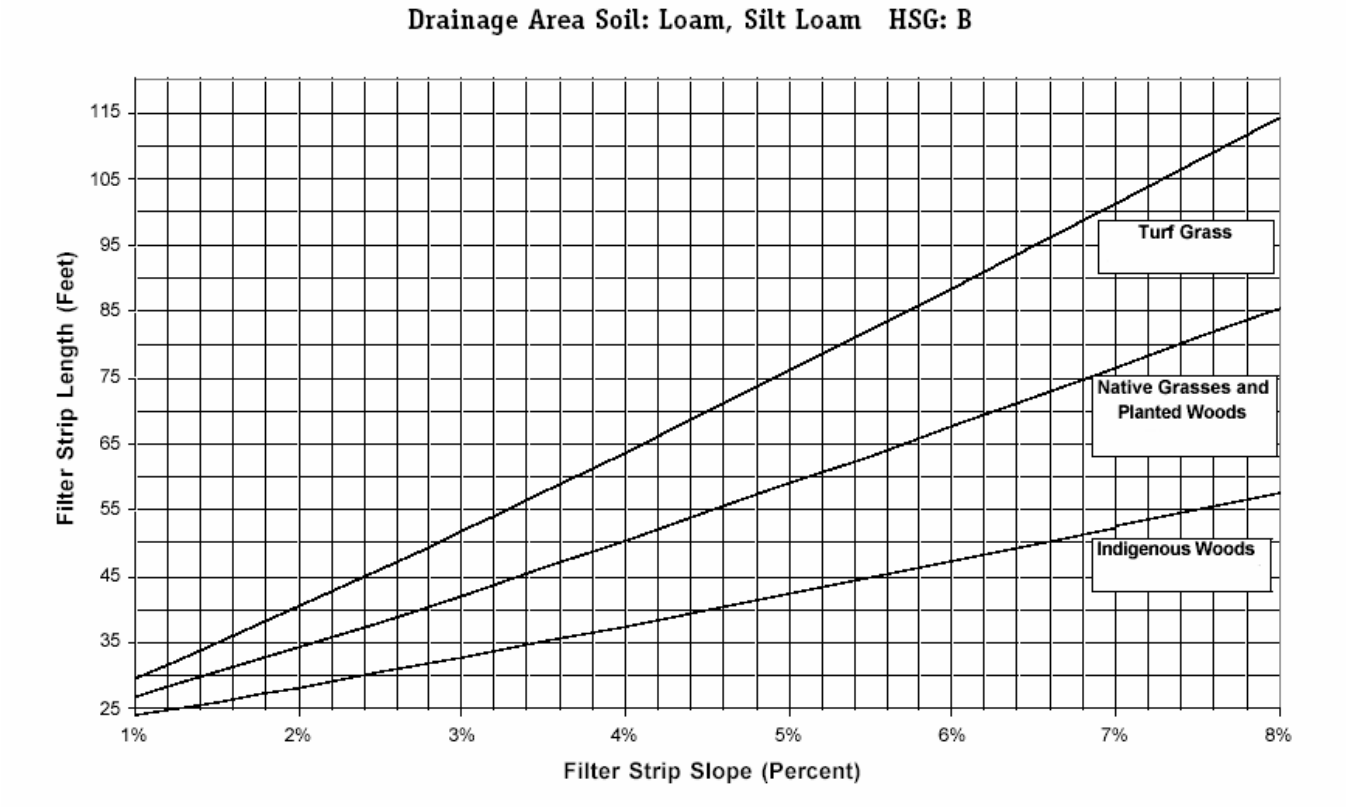

Drainage Area Soil: Sandy Loam HSG: B
Filter Strip Length (Feet)
95
85
75
65
55
45
35
25
1%
2%
3%
4%
5%
6%
7%
8%
Filter Strip Slope (Percent)
Turf Grass
Native Grasses and Planted Woods
Indigenous Woods


Drainage Area Soil: Loam, Silt Loam HSG: B
Filter Strip Length (Feet)
115
105
95
85
75
65
55
45
35
25
1%
2%
3%
4%
5%
6%
7%
8%
Filter Strip Slope (Percent)
Turf Grass
Native Grasses and Planted Woods
Indigenous Woods

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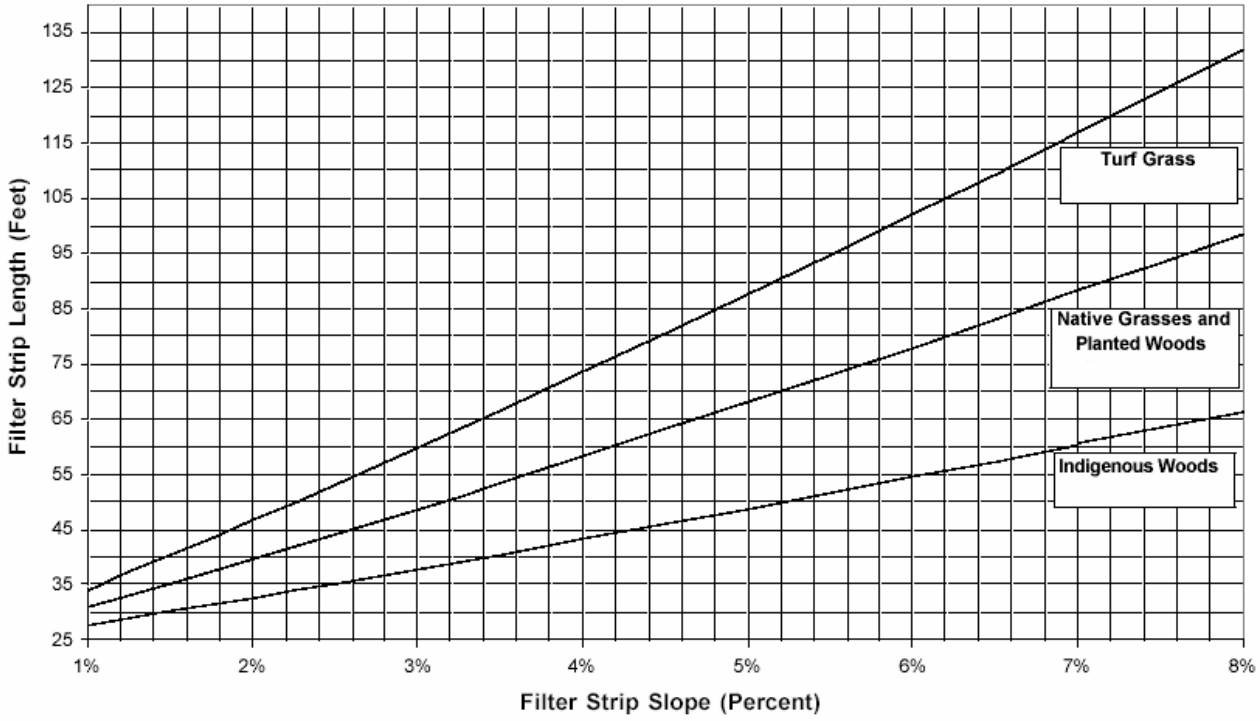
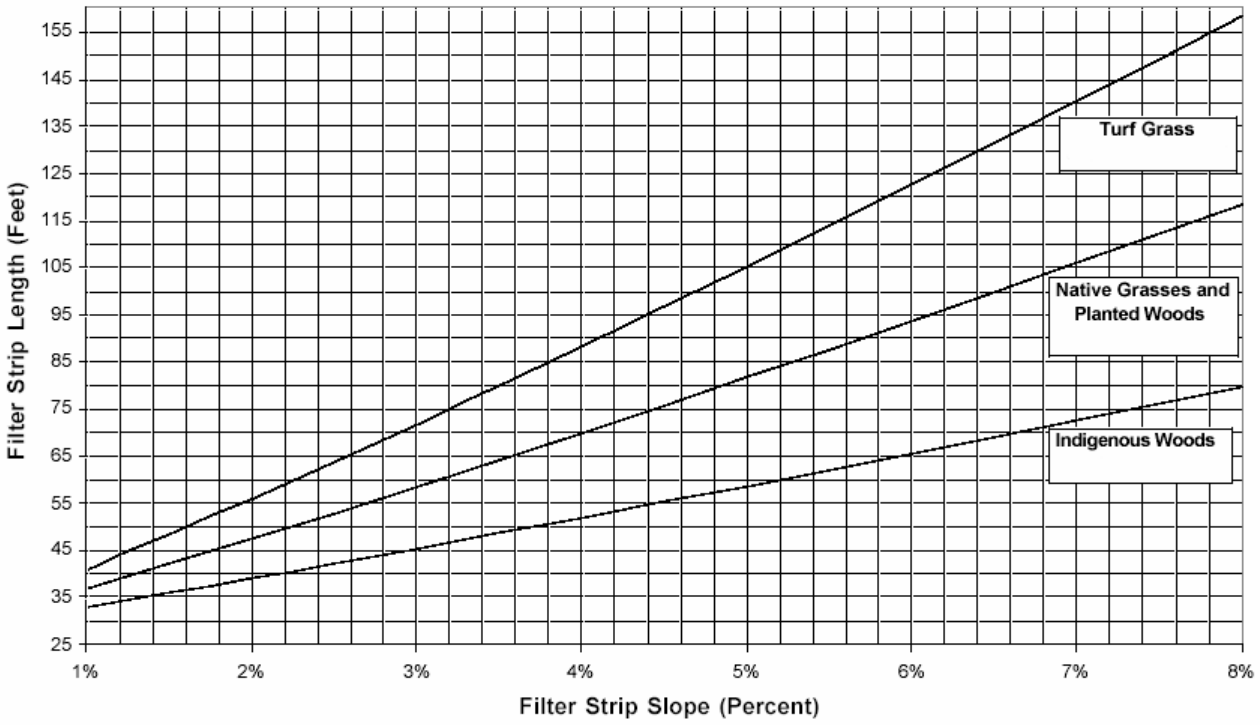
Drainage Area Soil: Sandy Clay Loam HSG: C



Drainage Area Soil: Clay Loam, Silty Clay, Clay HSG: D



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Detailed Stormwater Functions

Volume Reduction Calculations

To determine the volume reduction over the length of a filter strip the following equation is recommended:

Filter Strip Volume Reduction = Filter Strip Area x Infiltration Rate x Storm Duration

When a berm is positioned at the toe of the slope, the total volume reduction shall be defined as the amount calculated above plus the following:

Berm Storage Volume = (Cross-sectional Area Behind Berm x Length of Berm) + (Surface Area Behind Berm x Infiltration Rate x 12 hours)

The inundated area behind the berm should be designed to drain within 24 hours. An outlet pipe or overflow weir may be needed to provide adequate drain down. In that case, the infiltration volume behind the berm should be adjusted based on the invert of the overflow mechanism.

Peak Rate Mitigation Calculations

See in Section 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See in Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Begin filter strip construction only when the upgradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection's Erosion and Sediment Pollution Control Program Manual, March 2000 or latest edition.) The strip should be installed at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought.

2. For planted (not indigenous Filter Strips) clear and grub site as needed. Care should be taken to disturb as little existing vegetation as possible, whether in the designated filter strip area or in adjacent areas, and to avoid soil compaction. Grading a level slope may require removal of existing vegetation.

3. Rough grade the filter strip area, including the berm at the toe of the slope, if proposed. Use the lightest, least disruptive equipment to avoid excessive compaction and/or land disturbance.

4. Construct level spreader device at the upgradient edge of the strip. For gravel trenches, do not compact subgrade (Follow construction sequence for Infiltration Trench).

5. Fine grade the filter strip area. Accurate grading is crucial for filter strips. Even the smallest irregularities may compromise sheet flow conditions.

6. Seed or sod, as desired. Plant more substantial vegetation, such as trees and shrubs, if proposed. If sod is proposed, place tiles tightly enough to avoid gaps and stagger the ends to prevent channelization along the strip. Use a roller on sod to prevent air pockets between the sod and soil from forming.

7. Concurrent with #6, stabilize seeded filter strips with appropriate permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded filter strips should be maintained for at least the first 75 days following the first storm event of the season.

8. Once the filter strip is sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that filter strip vegetation be fully established before receiving upland stormwater flow. One full growing season is the recommended minimum time for establishment. Some seed mixtures may require a longer time period to become established.

9. Follow maintenance guidelines, as discussed below.

Note: When and if a filter strip is used for temporary sediment control, it might need to be regraded and reseeded immediately after construction and stabilization has occurred.

Maintenance Issues

As with other vegetated BMPs, filter strips should be properly maintained to ensure their effectiveness. In particular, it is critical that sheet flow conditions and infiltration are sustained throughout the life of the filter strip. Field observations of strips in more urban settings show that their effectiveness can deteriorate due to lack of maintenance, inadequate design/location, and poor vegetative cover. Compared with other vegetated BMPs, filter strips require only minimal maintenance efforts, many of which may overlap with standard landscaping demands.

Vegetated filter strip components that receive or trap sediment and debris should be inspected for clogging, density of vegetation, damage by foot or vehicular traffic, excessive accumulations, and channelization. Inspections should be made on a quarterly basis for the first two years following installation, and then on a biannual basis thereafter. Inspections should also be made after every storm event greater than 1 in during the establishment period. Guidance information, usually in written manual form, for operating and maintaining filter strips should be provided to all facility owners and tenants. Facility owners are encouraged to keep an inspection log, where they can record all inspection dates, observations, and maintenance activities.

Sediment and debris should be routinely removed (but never less than biannually), or upon observation, when buildup exceeds 2 inches in depth in either the strip itself or the level spreader. If erosion is observed, measures should be taken to improve the level spreader or other dispersion method to address the source of erosion. Rills and gullies observed along the strip may be filled with topsoil, stabilized with erosion control matting, and either seeded or sodded, as desired. For channels less than 12 inches wide, filling with crushed gravel, which allows grass to creep in over time, is acceptable. For wider channels, i.e. greater than 12 inches, regrading and reseeding may be necessary. (Small bare areas may only require overseeding.) Regrading may also be required when pools of standing water are observed along the slope. (In no case should standing water be tolerated for longer than 48-72 hours.) If check dams are proposed, they should be inspected for cracks, rot, structural damage, obstructions, or any other factors that cause altered flow patterns or channelization. Inlets or sediment sumps that drain to filter strips should be cleaned periodically or as needed.

Sediment should be removed when the filter strip is thoroughly dry. Trash and debris removed from the site should be deposited only at suitable disposal/recycling sites and must comply with applicable local, state, and federal waste regulations. In the case where a filter strip is used for sediment control, it should be regraded and reseeded immediately after construction has concluded.

Maintaining a vigorous vegetative cover on a filter strip is critical for maximizing pollutant removal efficiency and erosion prevention. Grass cover should be mowed, with low ground pressure equipment, as needed to maintain a height of 4-6 inches. Mowing should be done only when the soil is dry, in order to prevent tracking damage to vegetation, soil compaction, and flow concentrations. Generally speaking, grasses should be allowed to grow as high as possible, but mowed frequently enough to avoid troublesome insects or noxious weeds. Fall mowing should be controlled to a grass height of 6 inches, to provide adequate wildlife winter habitat. When and where cutting is desired for aesthetic reasons, a high blade setting should be used.

If vegetative cover is not fully established within the designated time, it should be replaced with an alternative species. It is standard practice to contractually require the contractor to replace dead vegetation. Unwanted or invasive growth should be removed on an annual basis. Biweekly inspections are recommended for at least the first growing season, or until the vegetation is permanently established. Once the vegetation is established, inspections of health, diversity, and density should be performed at least twice per year, during both the growing and non-growing season. Vegetative cover should be sustained at 85% and reestablished if damage greater than 50% is observed. Whenever possible, deficiencies in vegetation are to be mollified without the use of fertilizers or pesticides. These treatment options, as well as any other methods used to achieve optimum vegetative health, should only be used under special circumstances and if they do not compromise the functionality of the filter strip.

Two other maintenance recommendations involve soil aeration and drain down time. If a filter strip exhibits signs of poor drainage and/or vegetative cover, periodic soil aeration may be needed. In addition, depending on soil characteristics, the strip may need periodic liming. The design and maintenance plan of filter strips, especially those with flow obstructions should specify the approximate time it would take for the system to “drain down” the maximum design storm runoff volume. Post-rainfall inspections should include evaluations of the filter’s actual drain down time compared to the specified time. If significant differences (either increase or decrease) are observed, or if the 72 hour maximum time is exceeded, strip characteristics such as soils, vegetation, and groundwater levels should be reevaluated. Measures should be taken to establish, or reestablish as the case may be, the specified drain down time of the system.

Cost Issues

The real cost of filter strips is the land they require. When unused land is readily available at a site, filter strips may prove a sensible and cost-effective approach. However, where land costs are at a premium (i.e. not readily available), this practice may prove cost-prohibitive in the end. The cost of establishing a filter strip itself is relatively minor. Of course, the cost is even less when an existing grass or meadow area is identified as a possible filter strip area before development begins.

The cost of filter strips includes grading, sodding (when applicable), installation of vegetation (trees, shrubs, etc.), the construction of a level spreader, and the construction of a pervious berm, if proposed. Depending on whether seed or sod is applied, not to mention enhanced vegetation use or design variations, construction costs may range anywhere from $0 (assuming the area was to be grassed regardless of use as treatment) to $50,000 per acre. The annual cost of maintaining filter strips

(mowing, weeding, inspection, litter removal, etc.) generally runs from $100 to $1400 per acre and in fact, may overlap with standard landscape maintenance costs. Maintenance costs are highly variable, as they are a function of frequency and local labor rates.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Vegetation** – See Appendix B

2. **Erosion and Sediment** Control components shall conform to the Pennsylvania Department of Environmental Protection's Erosion and Sediment Pollution Control Program Manual, March 2000 or latest edition.

For a gravel trench level spreader:

3. **Pipe** should be continuously perforated, smooth interior, high-density polyethylene (HDPE) with a minimum inside diameter of 8-inches. The pipe should meet AASHTO M252, Type S or AASHTO M294, Type S.

4. **Stone** for infiltration trenches should be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and should have voids ≥ 35% as measured by ASTM-C29.

   Pea gravel (clean bank-run gravel) may also be used. Pea gravel should meet ASTM D 448 and be sized as per No.6 or 1/8" to 3/8".

5. **Non-Woven Geotextile** should consist of needled non-woven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
   c. Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
   d. UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
   e. Heat-set or heat-calendared fabrics are not permitted
      Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

6. **Check dams** constructed of natural wood should be 6 in to 12 in inches diameter and notched as necessary. The following species are acceptable: Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut. The following species are not acceptable since they can rot over time: Ash, Beech, Birch, Elm, Hackberry, Hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, and Willow. An earthen check dam should be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone check dam should be constructed of R-4 rip rap, or equivalent.

7. **Pervious Berms** The berm should have a height of 6-12 in and be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02”-0.04”, Gravel: AASHTO M-43 ½” to 1”)

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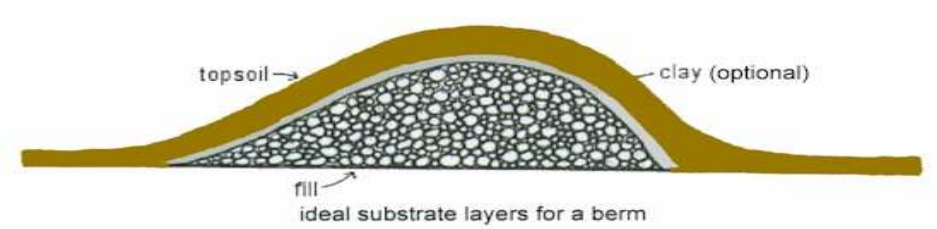
BMP 6.4.10: Infiltration Berm & Retentive Grading



An Infiltration Berm is a mound of compacted earth with sloping sides that is usually located along a contour on relatively gently sloping sites. Berms can also be created through excavation/removal of upslope material, effectively creating a Berm with the original grade. Berms may serve various stormwater drainage functions including: creating a barrier to flow, retaining flow and allowing infiltration for volume control, and directing flows. Grading may be designed in some cases to prevent rather than promote stormwater flows, through creation of "saucers" or "lips" in site yard areas where temporary retention of stormwater does not interfere with use.

Key Design Elements

- Maintain a minimum 2-foot separation to bedrock and seasonally high water table, provide distributed infiltration area (5:1 impervious area to infiltration area - maximum), site on natural, uncompacted soils with acceptable infiltration capacity, and follow other guidelines described in Protocol 2: Infiltration Systems Guidelines
- Berms should be relatively low, preferably no more than 24 inches in height.
- If berms are to be mowed, the berm side slopes should not exceed a ratio of 4:1 to avoid "scalping" by mower blades.
- The crest of the berm should be located near one edge of the berm, rather than in the middle, to allow for a more natural, asymmetrical shape.
- Berms should be vegetated with turf grass at a minimum, however more substantial plantings such as meadow vegetation, shrubs and trees are recommended.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low
Peak Rate Control: Medium
Water Quality: Med./High

Water Quality Functions

TSS: 60%
TP: 50%
NO3: 40%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

SARB_014814

Description

Infiltration Berms are linear landscape features located along (i.e. parallel to) existing site contours in a moderately sloping area. They can be described as built-up earthen embankments with sloping sides, which function to divert, retain and promote infiltration, slow down, or divert stormwater flows. Berms are also utilized for reasons independent of stormwater management, such as to add interest to a flat landscape, create a noise or wind barrier, separate land uses, screen undesirable views or to enhance or emphasize landscape designs. Berms are often used in conjunction with recreational features, such as pathways through woodlands. Therefore, when used for stormwater management, berms and other retentive grading techniques can serve multifunctional purposes and are easily incorporated into the landscape.

Infiltration Berms create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater. Infiltration berms may be constructed in series along a gradually sloping area.

1. Infiltration berms can be constructed on disturbed slopes and revegetated as part of the construction process. Infiltration berms should not be installed on slopes where soils having low shear strength (or identified as “slip prone” or “landslide prone”, etc.) have been mapped.
2. They can be installed along the contours within an existing woodland area to slow and infiltrate runoff from a development site.
3. May be constructed in combination with a subsurface infiltration trench at the base of the berm.

Infiltration Berms can provide runoff rate and volume control, though the level to which they do is limited by a variety of factors, including design variations (height, length, etc.), soil permeability rates, vegetative cover, and slope. Berms are ideal for mitigating runoff from relatively small impervious areas with limited adjacent open space (e.g. roads, small parking lots). Systems of parallel berms have been used to intercept stormwater from roadways or sloping terrain. Berms can sometimes be threaded carefully along contour on wooded hillsides, minimally disturbing existing vegetation and yet still gaining stormwater management credit from the existing woodland used. Conversely, berms are often incapable of controlling runoff from very large, highly impervious sites. Due to their relatively limited volume capacity, the length and/or number of berms required to retain large quantities of runoff make them impractical as the lone BMP in these cases. In these situations, berms are more appropriately used as pre- or additional-treatment for other more distributed infiltration systems closer to the source of runoff (i.e. porous pavement with subsurface infiltration).

Retentive grading may be employed in portions of sites where infiltration has been deemed to be possible and where site uses are compatible. Ideally, such retentive grading will serve to create subtle “saucers,” which contain and infiltrate stormwater flows. The “lip” of such saucers effectively function as a very subtle berm, which can be vertically impervious when vegetated and integrated into the overall landscape.

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Variations

Diversion Berms

Diversion Berms can be used to protect slopes from erosion and to slow runoff rate. They can also be used to direct stormwater flow in order to promote longer flow pathways, thus increasing the time of concentration. Diversion berms often:

1. Consist of compacted earth ridges usually constructed across a slope in series to intercept runoff.
2. Can be incorporated within other stormwater BMPs to increase travel time of stormwater flow by creating natural meanders while providing greater opportunity for pollutant removal and infiltration.





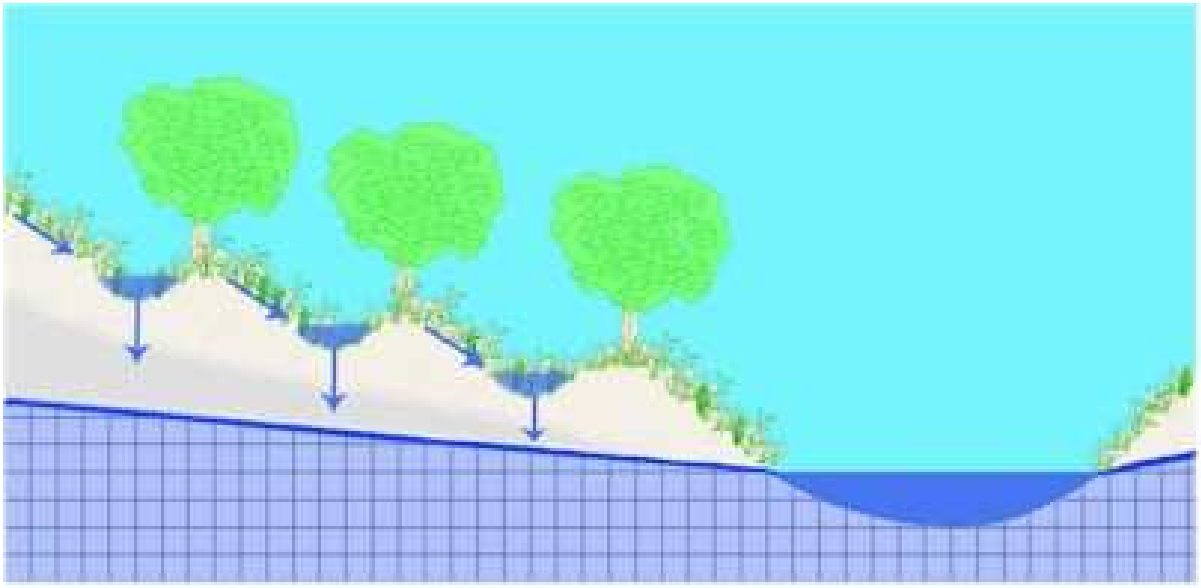
Applications

- **Meadow/Woodland Infiltration Berms**
  Infiltration Berms effectively control both the rate and volume of stormwater runoff. The berms are constructed along the contours and serve to collect and retain stormwater runoff, allowing it to infiltrate through the soil mantle and recharge the groundwater. Depressed areas adjacent to the berms should be level so that concentrated flow paths are not encouraged. Infiltration berms may have a variety of vegetative covers but meadow and woodland are recommended in order to reduce maintenance. If turf grass is used, berms in series should be constructed with enough space between them to allow access for maintenance vehicles. Also, berm side slopes should not exceed a 4:1 ratio. Woodland infiltration berms can sometimes be installed within existing wooded areas for additional stormwater management. Berms in wooded areas can even improve the health of existing vegetation, through enhanced groundwater recharge. Care should be taken during construction to ensure minimum disturbance to existing vegetation, especially tree roots.

- **Slope Protection**
  Diversion Berms can be used to help protect steeply sloping areas from erosion. Berms may divert concentrated discharge from a developed area away from the sloped area. Additionally, berms may be installed in series down the slope to retain flow and spread it out along multiple level berms to discourage concentrated flow.

- **Flow Pathway Creation**
  Berms may be utilized to create or enhance stormwater flow pathways within existing or proposed BMPs, or as part of an LID (Low Impact Development) strategy. Berms can be installed such that vegetated stormwater flow pathways are allowed to "meander" so that stormwater travel time is increased. For example, berms can be utilized within existing BMPs as part of a retrofit strategy to eliminate short-circuited inlet/outlet situations within detention basins provided care is taken to ensure the required storage capacity of the basin is maintained. Flow pathway creation can be utilized as part of an LID strategy to disconnect roof leaders and attenuate runoff, while increasing pervious flow pathways within developed areas. Berms should be designed to compliment the landscape while diverting runoff across vegetated areas and allowing for longer travel times to encourage pollutant removal and infiltration.

- **Constructed Wetland Berms**
  Berms are often utilized within constructed wetland systems in order to create elongated flow pathways with a variety of water depths. See BMP 6.6.1 – Constructed Wetlands.



Design Considerations

1. Sizing criteria are dependent on berm function, location and storage volume requirements.
   a. Low **berm height** (less than or equal to 24 inches) is recommended to encourage maximum infiltration and to prevent excessive ponding behind the berm. Greater heights may be used where berms are being used to divert flow or to create "meandering" or lengthened flow pathways. In these cases, stormwater is designed to flow adjacent to (parallel to), rather than over the crest of the berm. Generally, more berms of smaller size are preferable to fewer berms of large size.

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b. **Berm length** is dependent on functional need and site size. Berms installed along the contours should be level and located across the slope. Maximum length will depend on width of the slope. Generally speaking, diversion berm length will vary with the size and constraints of the site in question.

2. **Infiltration Berms** should be constructed along (parallel to) contours at a constant elevation.

3. **Soil**. A berm may consist entirely of high quality topsoil. To reduce cost, only the top foot needs to consist of high quality Topsoil, with well-drained soil making up the remainder of the berm. The use of gravel is not recommended in the layers directly underneath the topsoil because of the tendency of the soil to wash through the gravel. In some cases, the use of clay may be required due to its cohesive qualities (especially where the berm height is high or relatively steeply sloped). However, well-compacted soil usually is sufficient provided that the angle of repose (see below) is not exceeded for the soil medium used.

   A more sustainable alternative to importing berm soil from off-site is to balance berm cut and fill material as much as possible, provided on-site soil is deemed suitable as per the Specifications below. Ideally, the concave segment (infiltration area) of the berm is excavated to a maximum depth of 12 inches and then used to construct the convex segment (crest of berm).

4. The **Angle of Repose of Soil** is the angle at which the soil will rest and not be subject to slope failure. The angle of repose of any soil will vary with the texture, water content, compaction, and vegetative cover. Typical angles of repose are given below:

   a. Non-compacted clay: 5-20%
   b. Dry Sand: 33%
   c. Loam: 35-40%
   d. Compacted clay: 50-80%

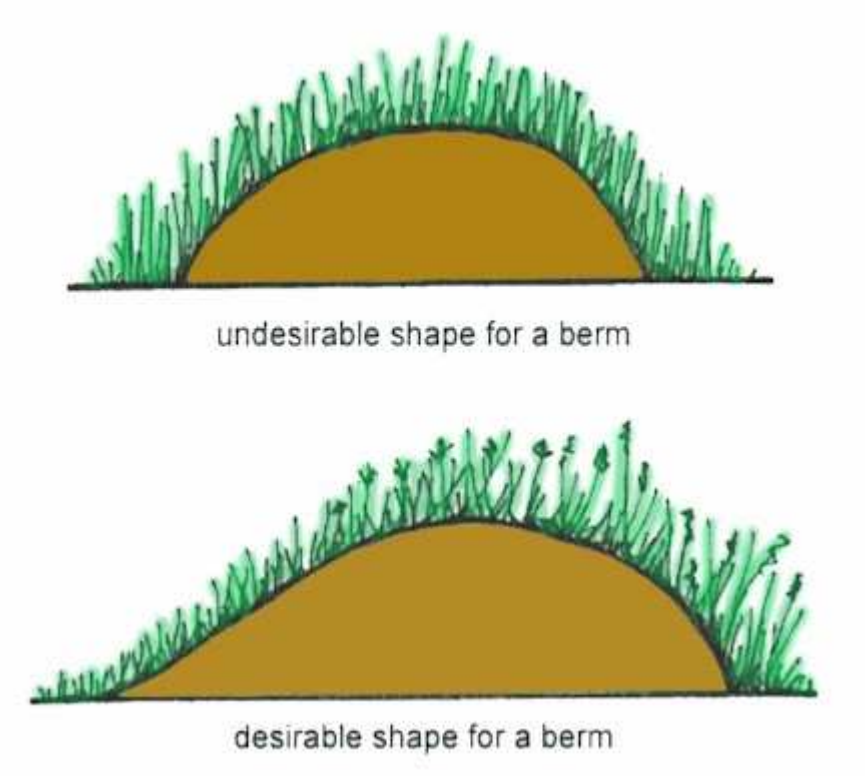
5. **Side Slopes**. The angle of repose for the soil used in the berm should determine the maximum slope of the berm with additional consideration to aesthetic, drainage, and maintenance needs. If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid “scalping” by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 ratio. Other herbaceous plants, which do not require mowing, can tolerate slopes of 3:1. Berm side slopes should not exceed a 2:1 ratio.

6. **Plant Materials.** It is important to consider the function and form of the berm when selecting plant materials. If using trees, plant them in a pattern that appears natural and accentuates the berm’s form. Consider tree species appropriate to the proposed habitat. If turf will be combined with woody and herbaceous plants, the turf should be placed to allow for easy maneuverability while mowing. Low maintenance plantings, such as trees and meadow plants, rather than turf and formal landscaping, are encouraged.

7. **Infiltration Design.** Infiltration berms located along slopes should be composed of low berms (less than 12 inches high) and should be vegetated. Subsurface soils should be uncompacted to encourage infiltration behind the berms. Soil testing is not required where berms are located within an existing woodland, but soil maps/data should be consulted when siting the berms. Where feasible, surface soil testing should be conducted in order to estimate potential infiltration rates.

8. **Infiltration Trench Option.** Soil testing is recommended for infiltration berms that will utilize a subsurface infiltration trench. Infiltration trenches are not recommended in existing woodland areas as excavation and installation of subsurface trenches could damage tree root systems. See BMP 6.4.4 – Infiltration Trench, for information on infiltration trench design.

9. **Aesthetics.** To the extent possible, berms should reflect the surrounding landscape. Berms should be graded so that the top of the berm is smoothly convex and the toes of the berms are smoothly concave. Natural, asymmetrical berms are usually more effective and attractive than symmetrical berms. The crest of the berm should be located near one end of the berm rather than in the middle.



Detailed Stormwater Functions

Infiltration Area

The Infiltration Area is the ponding area behind the berm, defined as:
Length of ponding x Width ponding area = Infiltration Area (Ponding Area)

Volume Reduction Calculations

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Storage volume can be calculated for Infiltration Berms. The storage volume is defined as the ponding area created behind the berm, beneath the discharge invert (i.e. the crest of the berm). Storage volume can be calculated differently depending on the variations utilized in the design.

Surface Storage Volume is defined as the volume of water stored on the surface at the ponding depth. This is equal to:
Cross-sectional area of ponded water x Berm length = Surface Storage Volume

Peak Rate Mitigation:

See Section 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement:

See Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

The following is a typical construction sequence for a infiltration berm without a subsurface infiltration trench, though alterations will be necessary depending on design variations.

1. Install temporary sediment and erosion control BMPs as per the Pennsylvania Erosion and Sediment Pollution Control Program Manual.

2. Complete site grading and stabilize within the limit of disturbance except where Infiltration Berms will be constructed; make every effort to minimize berm footprint and necessary zone of disturbance (including both removal of exiting vegetation and disturbance of empty soil) in order to maximize infiltration.

3. Lightly scarify the soil in the area of the proposed berm before delivering soil to site.

4. Bring in fill material to make up the major portion of the berm. Soil should be added in 8-inch lifts and compacted after each addition according to design specifications. The slope and shape of the berm should graded out as soil is added.

5. Protect the surface ponding area at the base of the berm from compaction. If compaction of this area does occur, scarify soil to a depth of at least 8 inches.

6. Complete final grading of the berm after the top layer of soil is added. Tamp soil down lightly and smooth sides of the berm. The crest and base of the berm should be at level grade.

7. Plant berm with turf, meadow plants, shrubs or trees, as desired.

8. Mulch planted and disturbed areas with compost mulch to prevent erosion while plants become established.

Maintenance Issues

Infiltration Berms have low to moderate maintenance requirements, depending on the design.

Infiltration Berms

- Regularly inspect to ensure they are infiltrating; monitor drawdown time after major storm events
- Inspect any structural components, such as inlet structures to ensure proper functionality
- If planted in turf grass, maintain by mowing. Other vegetation will require less maintenance. Trees and shrubs may require annual mulching, while meadow planting requires annual mowing and clippings removal.
- Avoid running heavy equipment over the infiltration area at the base of the berms. The crest of the berm may be used as access for heavy equipment when necessary to limit disturbance.
- .
- Routinely remove accumulated trash and debris.
- Remove invasive plants as needed
- Inspect for signs of flow channelization; restore level gradient immediately after deficiencies are observed

Diversion Berms

- Regularly inspect for erosion or other failures.
- Regularly inspect structural components to ensure functionality.
- Maintain turf grass and other vegetation by mowing and re-mulching.
-
- Remove invasive plants as needed.
- Routinely remove accumulated trash and debris.

Cost Issues

Infiltration berms can be less expensive than other BMPs options because extensive clearing and grubbing is not necessary. Cost will depend on height, length and width of berms as well as desired vegetation.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Soil Materials**
   a. Satisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GW, GP, GM, SM, SW, and SP.
   b. Unsatisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GC, SC, ML, MH, CL, CH, OL, OH, and PT.
   c. Topsoil: Topsoil stripped and stockpiled on the site should be used for fine grading. Topsoil is defined as the top layer of earth on the site, which produces heavy growths of crops, grass or other vegetation.

d. Soils excavated from on-site may be used for berm construction provided they are deemed satisfactory as per the above recommendations or by a soil scientist.

2. Placing and Compacting of Berm Area Soil

a. Ground Surface Preparation: Remove vegetation, debris, unsatisfactory soil materials, obstructions, and deleterious materials from ground surface prior to placement of fill. Plow strip, or break up sloped surfaces steeper than I vertical to 4 horizontal so that fill material will bond with existing surface.

b. When existing ground surface has a density less than that specified under g. (below) for particular area classification, break up ground surface, pulverize, bring the moisture-condition to optimum moisture content, and compact to required depth and percentage of maximum density.

c. Place backfill and fill materials in layers not more than 8 inches in loose depth for material to be compacted by heavy compaction equipment, and not more than 4 inches in loose depth for material to be compacted by hand-operated tampers.

d. Before compaction, moisten or aerate each layer as necessary to provide optimum moisture content. Compact each layer to required percentage of maximum dry density or relative dry density for each area classification. Do not place backfill or fill material on surfaces that are muddy, frozen, or contain frost or ice.

e. Place backfill and fill materials evenly adjacent to structures, piping, or conduit to required elevations. Prevent wedging action of backfill against structures or displacement of piping or same elevation in each lift.

f. Control soil and fill compaction, providing minimum percentage of density specified for each area classification indicated below. Correct improperly compacted areas or lifts if soil density tests indicate inadequate compaction.

g. Percentage of Maximum Density Requirements: Compact soil to not less than the following percentages of maximum density, in accordance with ASTM D 1557:

- Under lawn or unpaved areas, compact top 6 inches of subgrade and each layer of backfill or fill material at 85 percent maximum density.
- Under infiltration areas no compaction shall be permitted.

3. Grading

a. General: Uniformly grade areas within limits of grading under this section, including adjacent transition areas. Smooth finished surface within specified tolerances; compact with uniform levels or slopes between points where elevations are indicated or between such points and existing grades.

b. Lawn or Unpaved Areas: Finish areas to receive topsoil to within not more than 0.10 foot above or below required subgrade elevations.

c. Compaction: After grading, compact subgrade surfaces to the depth and indicated percentage of maximum or relative density for each area classification.

4. Temporary Seeding

a. Temporary seeding and mulching shall be required on all freshly graded areas immediately following earth moving procedures. Seed-free straw or salt hay mulch shall be applied at a rate of 75 lbs. per 1,000 square feet over temporary seeded areas. Straw bale barriers shall be placed in swale areas until vegetation is established.

b. Should temporary seeding not be possible or not establish itself properly, mulch as described above, pending fine grading or permanent seeding.

5. Finish Grading

a. Spreading of topsoil and finish grading shall be coordinated with the work of the Landscape Contractor.
b. Verify that the rough grades meet requirements for tolerances, materials, and compaction.
c. Surface of subgrades shall be loosened and made friable by cross-discing or harrowing to a depth of 2 inches. Stones and debris more than 1-1.5 inches in any dimension shall be raked up and grade stakes and rubbish removed.
d. Topsoil shall be uniformly spread to minimum depths after settlement of 6 inches on areas to be seeded and 4 inches on areas to be sodded. Correct any surface irregularities to prevent formation of low spots and pockets that would retain water.
e. Topsoil shall not be placed when the subgrade is frozen, excessively wet, or extremely dry and no topsoil shall be handled when in a frozen or muddy condition. During all operations following topsoil spreading, the surface shall be kept free from stones over 1-1.5 inches in size or any rubbish, debris, or other foreign material.
f. After placing topsoil rake soil to a smooth, even-draining surface and compact lightly with an empty water roller. Leave finish graded areas clean and well raked, ready for lawn work.

References

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Williams, G.P. *Canadian Building Digest - Drainage and Erosion at Construction Sites*. National Research Council Canada. 2004. <http://irc.nrc-cnrc.gc.ca/cbd/cbd183e.html>

6.5 Volume/Peak Rate Reduction BMPs

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SARB_014825

BMP 6.5.1: Vegetated Roof



An extensive vegetated roof cover is a veneer of vegetation that is grown on and completely covers an otherwise conventional flat or pitched roof (≤30° slope), endowing the roof with hydrologic characteristics that more closely match surface vegetation than the roof. The overall thickness of the veneer may range from 2 to 6 inches and may contain multiple layers, consisting of waterproofing, synthetic insulation, non-soil engineered growth media, fabrics, and synthetic components. Vegetated roof covers can be optimized to achieve water quantity and water quality benefits. Through the appropriate selection of materials, even thin vegetated covers can provide significant rainfall retention and detention functions.

Key Design Elements

- 2-6 inches of engineered media; assemblies that are 4 inches and deeper may include more than one type of engineered media
- Engineered media should have a high mineral content. Engineered media for extensive vegetated roof covers is typically 85% to 97% non-organic (wet combustion or loss on ignition methods).
- Vegetated roof covers intended to achieve water quality benefits should not be fertilized
- Irrigation is not a desirable component of vegetated covers used as best management practices
- Internal building drainage, including provisions to cover and protect deck drains or scuppers, must anticipate the need to manage large rainfall events without inundating the cover.
- Assemblies planned for roofs with pitches steeper than 2:12 must incorporate supplemental measures to insure stability against sliding.

Structural considerations are required.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: None

Stormwater Functions

Volume Reduction: Med/High
Recharge: None
Peak Rate Control: Low
Water Quality: Medium

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- The roof structure must be evaluated for compatibility with the maximum predicted dead and live loads. Typical dead loads for wet extensive vegetated covers range from 8 to 36 pounds per square foot. Live load is a function of rainfall retention. For example, 2 inches of rain equals 10.4 lbs. per square foot of live load. It requires 20 inches of snow to have the same live load per square foot.
- The waterproofing must be resistant to biological and root attack. In many instances a supplemental root-fast layer is installed to protect the primary waterproofing membrane from plant roots.
- Standards and guidelines (in English) for the design of green roofs are available from FLL[1], a European non-profit trade organization. In the United States, guidelines are in development by ASTM (American Standard Testing Methods).

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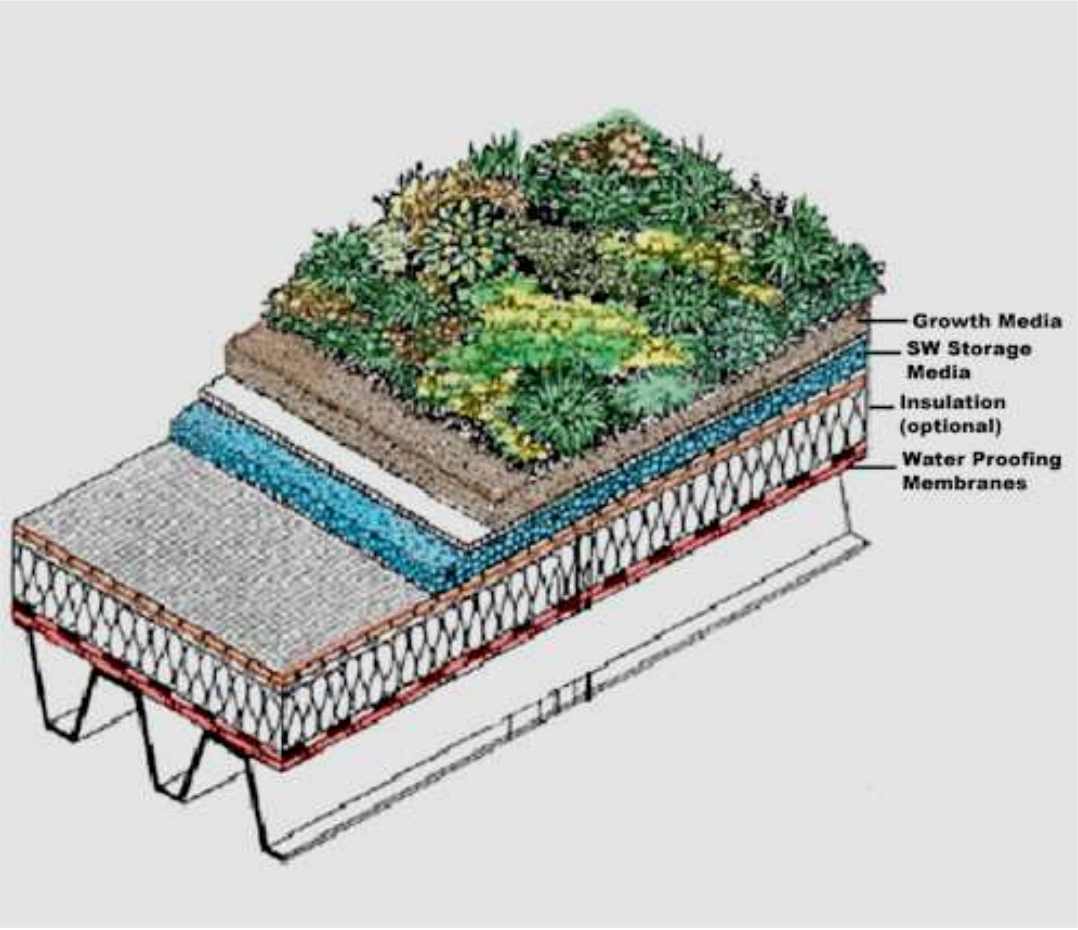
Description

Extensive vegetated roof covers are usually 6 inches or less in depth and are typically intended to achieve a specific environmental benefit, such as rainfall runoff mitigation. For this reason they are most commonly not irrigated. While some installations are open to public access, most extensive vegetated roof covers are for public viewing only. In order to make them practical for installation on conventional roof structures, lightweight materials are used in the preparation of most engineered media. Developments in the last 40 years that have made these systems viable include: 1) recognition of the value of vegetated covers in restoring near open-space hydrologic performance on impervious surfaces, 2) advances in waterproofing materials and methods, and 3) development of a reliable temperate climate plant list that can thrive under the extreme growing conditions on a roof.

Vegetated roof covers that are 10 inches, or deeper, are referred to as 'intensive' vegetated roof covers. These are more familiar in the United States and include many urban landscaped plazas. Intensive assemblies can also provide substantial environmental benefits, but are intended primarily to achieve aesthetic and architectural objectives. These types of systems are considered "roof gardens" and are not to be confused with the simple "extensive" design. Benefits beyond the stormwater considerations include temperature moderation and roof longevity.



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Variations

Most extensive vegetated roof covers fall into three categories

- Single media with synthetic under-drain layer
- Dual media
- Dual media with synthetic retention/detention layer

All vegetated roof covers will require a premium waterproofing system. Depending on the waterproofing materials selected, a supplemental root-fast layer may be required to protect the primary waterproofing membrane from plant roots.

Insulation, if included in the roof covering system, may be installed either above or below the primary waterproofing membrane. Most vegetated roof cover system can be adapted to either roofing configuration. In the descriptions that follow, the assemblies refer to the conventional configuration, in which the insulation layer is below the primary waterproofing.

All three extensive roof cover variations can be installed without irrigation. Non irrigated assemblies are strongly recommended. While this may place some limits on the type of plants that can be grown, the benefits are that the assembly will perform better as a stormwater BMP, and the maintenance requirements will be substantially reduced.

Some assemblies are installed in tray-like modules to facilitate installation, especially in confined locations.

Single media assemblies
Single media assemblies are commonly used for pitched roof applications and for thin and lightweight installations. These systems typically incorporate very drought tolerant plants and utilize coarse engineered media with high permeability. A typical profile would include the following layers.

- Waterproofing membrane
- **Root-barrier** (optional, depending on the root-fastness of the waterproofing)
- Semi-rigid plastic **geocomposite drain** or **mat** (typical mats are made from non-biodegradable fabric or plastic foam)
- Separation geotextile
- Engineered **growth media**
- Foliage layer

Pitched roof applications may require the addition of slope bars, rigid slope stabilization panels, cribbing, reinforcing mesh, or similar method minimizing sliding instability.

Flat roof applications with mats as foundations typically require a network of perforated internal drainage conduit to enhance drainage of percolated rainfall to the deck drains or scuppers.

Assemblies with mats can be irrigated from beneath, while assemblies with drainage composites require direct drainage.

Dual media assemblies
Dual media assemblies utilize two types of non-soil media. In this case a finer-grained media with some organic content is placed over a basal layer of coarse lightweight mineral aggregate. They do not include a geocomposite drain. The objective is to improve drought resistance by replicating a natural

growing environment in which sandy topsoil overlies gravelly subsoil. These assemblies are typically 4 to 6 inches thick and include the following layers:

- Waterproofing membrane
- Protection layer
- Coarse-grained **drainage media**
- Root-permeable nonwoven separation geotextile
- Fine-grained engineered growth media layer
- Foliage layer



These assemblies are suitable for roofs with pitches less than, or equal to, 1.5:12. Large vegetated covers will generally incorporate a network of perforated internal drainage conduit.

Dual media systems are ideal for use in combination with base irrigation methods.

Dual media with synthetic retention/detention layer
These assemblies introduce plastic panels with cup-like receptacles on their upper surface (i.e., a modified geocomposite drain sheet). The panels are in-filled with coarse lightweight mineral aggregate. The cups trap and retain water. They also introduce an air layer at the bottom of the assembly. A typical profile would include:

- Waterproofing membrane
- Felt fabric
- Retention/detention panel
- Coarse-grained drainage media
- Separation geotextile
- Fine grained 'growth' media layer
- Foliage layer

These assemblies are suitable on roof with pitches less than or equal to 1:12. Due to their complexity, these system are usually 5 inches or deeper.

If needed, irrigation can be provided via surface spray or mid-level drip.

- **Stormwater Volume and Rate Control**
  Vegetated roof covers are an "at source" measure for reducing the rate and volume of runoff released during rainfall events. The water retention and detention properties of vegetated roof covers can be enhanced through proper selection of the engineered media and plants.

- **Runoff Water Quality Improvements**
  Direct runoff from roofs is often a contributor to NPS pollutant discharges. Vegetated roof covers can significantly reduce this source of pollution. Assemblies intended to produce water quality benefits should employ engineered media with 100% mineral content. Following the plant establishment period (usually about 18 months), on-going fertilization of the cover should not be permitted. Experience indicates that it will take five or more years for a water quality vegetated cover to attain its maximum potential pollutant removal efficiency.

- **In Combination with Infiltration Measures**
  Vegetated roof covers are frequently combined with ground infiltration measures. Vegetated roof covers improve the efficiency of infiltration devices by:

  - Reducing the peak runoff rate
  - Prolonging the runoff
  - Filtering runoff to produce a clear effluent

  Roofs that are designed to achieve water quality improvements will also reduce pollutant inputs to infiltration devices.

- **Habitat Restoration/Creation**
  Vegetated roof covers have been used to create functional meadows and wetlands to mitigate the development of open space. This can be accomplished with assemblies as thin as 6 inches.

Design Considerations

1. Live and **dead load** bearing capacity of the roof need to be established. Dead loads should be estimated using media weights determined using a standardized laboratory procedure.[1]

2. Waterproofing materials must be durable under the conditions associated with vegetated covers. A supplemental root-barrier layer should be installed in conjunction with materials that are not root-fast.

3. Roof flashings should extend 6 inches higher than the top of the growth media surface and be protected by counter-flashings.

4. The design should incorporate measures to protect the waterproofing membrane from physical damage during and after installation of the vegetated cover assembly.

5. Vegetated roof covers should incorporate internal drainage capacity sufficient to accommodate a two-year return frequency rainfall without generating surface runoff flow.

6. Deck drains, scuppers, or gravel stops serving as methods to discharge water from the roof area should be protected with **access chambers**. These enclosures should include removable lids in order to allow ready access for inspection.

7. The physical properties of the engineered media should be selected appropriately in order to achieve the desired hydrologic performance.

8. Engineered media should contain no clay size particles and should contain no more than 15% **organic matter** (wet combustion or loss on ignition methods)

9. Media used in constructing vegetated roof covers should have a maximum moisture capacity[2] of between 30% and 40%.

10. Plants should be selected which will create a vigorous, drought-tolerant ground cover. In Pennsylvania the most successful and commonly used ground covers for non irrigated projects are varieties of Sedum and Delosperma. In the Pennsylvania climate Delosperma is deciduous. Both deciduous and evergreen varieties of *Sedum* are available. Deeper assemblies (i.e., 4 to 6 inches) can also incorporate a wider range of plants including *Dianthus, Phlox, Antennaria,* and *Carex.*

11. Roofs with pitches exceeding 2:12 should be provided with supplemental measures to insure stability against sliding





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Detailed Stormwater Functions

The performance of vegetated roof covers as stormwater best management practices cannot be represented by a simple algebraic expression. Conventional methods are used to estimate surface runoff from various types of surfaces. In the analysis of vegetated roof covers, the water that is discharged from the roof is not surface runoff, but rather underflow, (i.e., percolated water). The rate and quantity of water released during a particular design storm can be predicted based on knowledge of key physical properties, including:

- Maximum media water retention
- Field capacity
- Plant cover type
- Saturated hydraulic conductivity
- Non-capillary porosity

The maximum media water retention is the maximum quantity of water that can be held against gravity under drained conditions. Standards that have been developed specifically for measuring this quantity in roof media are available from FLL and ASTM (draft).

Peak Rate Mitigation

Vegetated roof covers can exert an influence on runoff peak rates derived from roofs.
A general rule is to consider the first portion of the rainfall fills the volume reduction capacity (see below).

Volume Reduction Calculations

All vegetated roof covers have both a retention and a detention volume component. Benchmarks for these volumes can be developed from the physical properties described above (*Detailed Stormwater Functions*).

The interaction of retention and detention produce both short-term effects (i.e., control of single storms) and long-term effects (i.e., reductions in total seasonal or annual roof runoff). Continuous simulation using a representative annual rainfall record from a local weather station is required in order to predict the long-term runoff versus rainfall benefit. The effectiveness of vegetated roof covers will vary according to the regional pattern of rainfall.

Using the German RWS program, the designer could generate a table of volume reductions for several regions in Pennsylvania. The table would relate the runoff ratio (runoff/rainfall) based on one or two types of cover assemblies and selected regions in PA for which good weather data is available. For the table to be used, a vegetated cover would have to comply with European guidelines.

Water Quality Improvement

Once the plant cover is established, nutrient additions should be suspended. Experience indicates that the efficiency of vegetated covers in reducing pollutant and nutrient releases from roofs will increase with time. The vegetated cover should reach its optimum performance after about five years.

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See Section 8 for Water Quality Improvement methodology that addresses pollutants removal effectiveness of this BMP.



Construction Sequence

1. Visually inspect the completed waterproofing to identify any apparent flaws, irregularities, or conditions that will be interfere with the security or functionality of the vegetated covers system. The waterproofing should be tested for watertightness by the roofing applicator.

2. Institute a leak protection program

3. Introduce measures to protect the finished waterproofing from physical damage

4Install slope stabilization measures (pitched roofs with pitches in excess of 2:12). In some installations slope stabilizing measures can be introduced as part of the roof structure and will be already be in-place at the start of the construction sequence.

5. If the waterproofing materials are not root fast, install a root-barrier layer
6. Layout key drainage and irrigation components, including drain access chambers, internal drainage conduit, confinement border units, and isolation frames (for roof-top utilities, hatches and penetrations)

7. Install walkways and paths (projects with public access)

8. Test irrigation systems (as relevant for roof gardens)

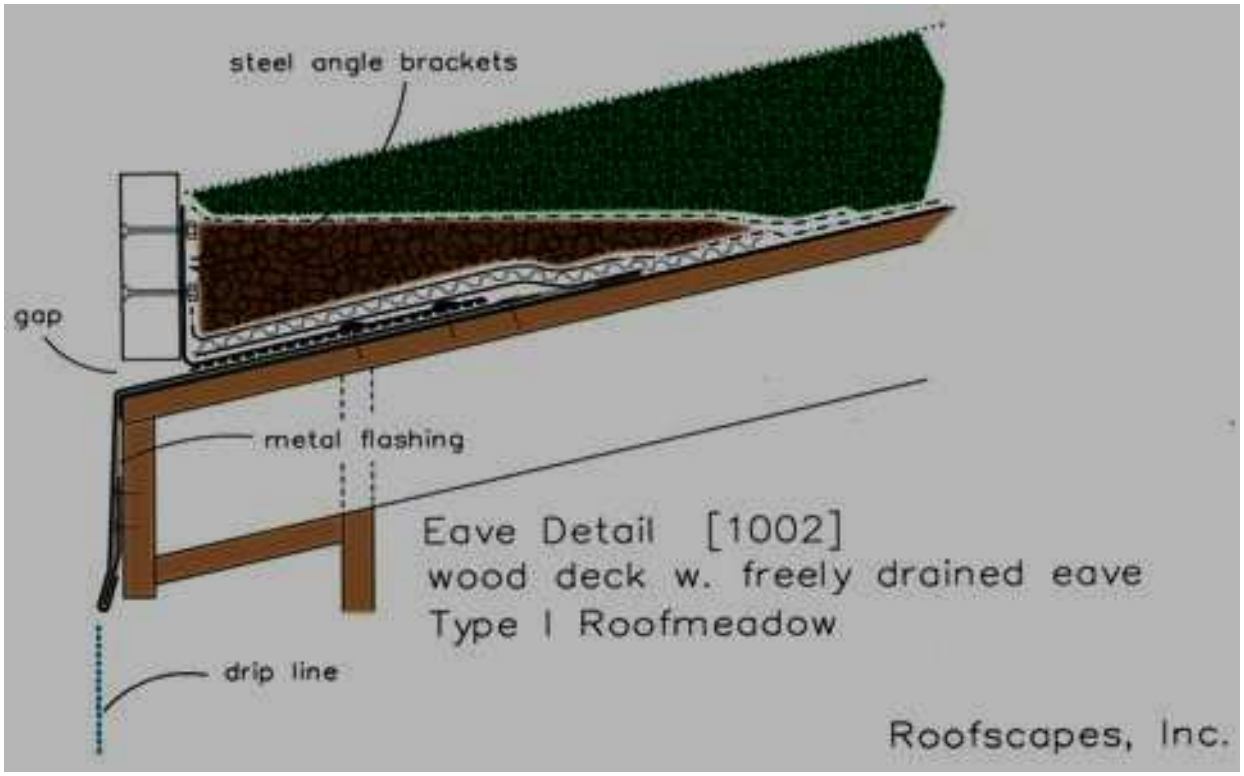
9. Install the drainage layer. Depending on the variation type, this could be a geocomposite drain, mat, or course of drainage media.

10. Cover the drainage layer with the separation fabric (in some assemblies, the separation fabric is pre-bonded to a synthetic drainage layer.

11. Install the upper growth media layer (dual media assemblies only)

12. Establish the foliage cover plantings from cuttings, seed, plugs or pre-grown mats

13. Provide protection from wind disruptions as warranted by the project conditions, and plant establishment method.



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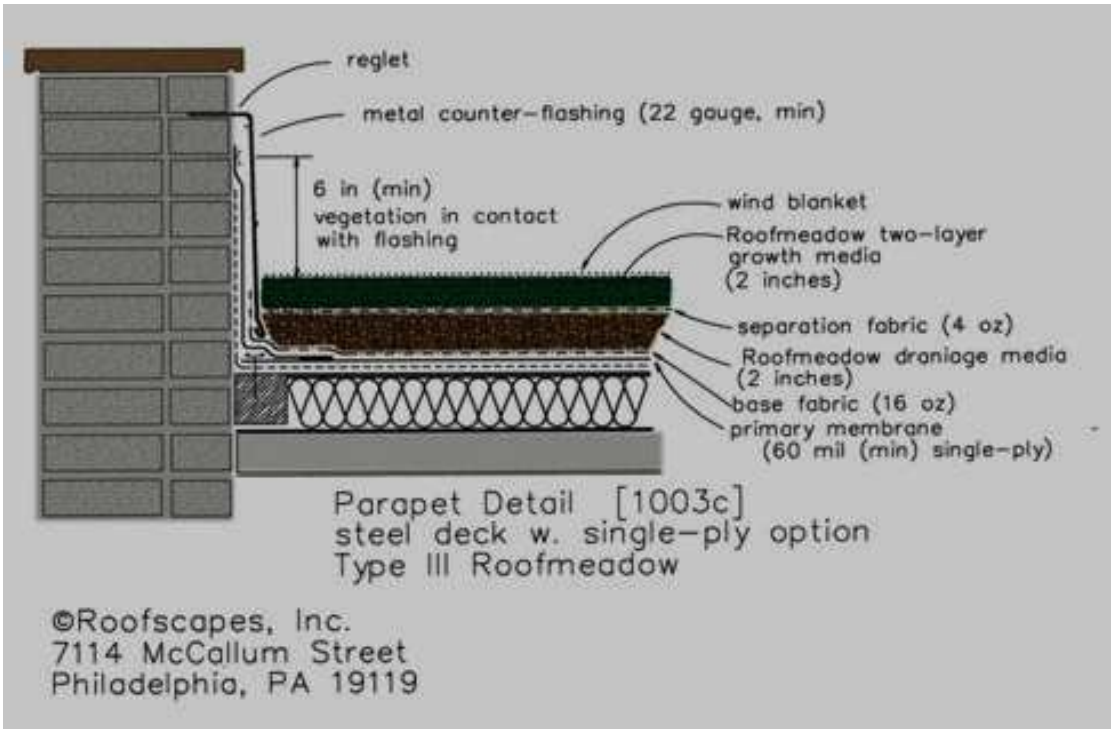

Maintenance Issues

- During the plant establishment period, periodic irrigation may be required

- During the plant establishment period, three to four visits to conduct basic weeding, fertilization, and in-fill planting is recommended. Thereafter, only two annual visits for inspection and light weeding should be needed (irrigated assemblies will require more intensive maintenance).

Cost Issues

The construction cost of vegetated roof covers can vary greatly, depending on factors such as:

- Height of the building
- Accessibility to the structure by large equipment such as cranes and trailers
- Depth and complexity of the assembly
- Remoteness of the project from sources of material supply
- Size of the project

However, under present market conditions (2004), extensive vegetated covers for roof will typically range between $8 and $15 per square foot, including design, installation, and warranty service. Basic maintenance for extensive vegetated covers typically requires about 3 man-hours per 1,000 square feet, annually.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Due to the very large variation in assembly types and methods, it is not possible to provide a comprehensive specification. Performance specifications, describing the assembly elements and their physical properties can be obtained from commercial providers of vegetated roof covers. The references provided also offer specific guidance for the selection of materials and methods.

Some key components and associated performance-related properties are as follows:

1. **Root-barriers** should be thermoplastic membranes with a thickness of at least 30 mils. Thermoplastic sheets can be bonded using hot-air fusion methods, rendering the seams safe from root penetration. Membranes that have been certified for use as root-barriers are recommended. At present only FLL offers a recognized test for root-barriers. Several FLL-certified materials are available in the United States. Interested American manufactures can submit products for testing to FLL-certified labs.

2. **Granular drainage media** should be a non-carbonate mineral aggregate conforming to the following specifications:

Saturated Hydraulic Conductivity[2]	25 in/min
Total Organic Matter, by Wet Combustion (MSA)	1%
Abrasion Resistance (ASTM-C131-96)	25% loss
Soundness (ASTM-C88 or T103 or T103-91)	5% loss
Porosity (ASTM-C29)	25%
Alkalinity, CaCO3 equivalents (MSA)	1 %
Grain-Size Distribution (ASTM-C136)	
Pct. Passing US#18 sieve	1%
Pct. Passing ¼-inch sieve	30%
Pct. Passing 3/8-inch sieve	80%

3. **Growth media** should be a soil-like mixture containing not more than 15% organic content (wet combustion or loss on ignition methods). The appropriate grain-size distribution is essential for achieving the proper moisture content, permeability, nutrient management, and non-capillary porosity, and 'soil' structure. The grain-size guidelines vary for single and dual media vegetated cover assemblies.

Non-capillary Pore Space at Field Capacity, 0.333 bar (TMECC 03.01, A)	15% (vol)
Moisture Content at Field Capacity (TMECC 03.01, A)	12% (vol)
Maximum Media Water Retention (FLL)	30% (vol)
Alkalinity, Ca CO3 equivalents (MSA)	2.5%

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Total Organic Matter by Wet Combustion (MSA)	3-15% (dry wt.)
pH (RCSTP)	6.5-8.0
Soluble Salts (DTPA saturated media extraction)"(RCSTP)	6 mmhos/cm
Cation exchange capacity (MSA)	10 meq/100g
Saturated Hydraulic Conductivity for Single Media Assemblies (FLL)[3]	0.05 in/min
Saturated Hydraulic Conductivity for Dual Media Assemblies (FLL)	0.30 in/min

Grain-size Distribution of the Mineral Fraction (ASTM-D422)

Single Media Assemblies

Clay fraction (2 micron)	0
Pct. Passing US#200 sieve (i.e., silt fraction)	5%
Pct. Passing US#60 sieve	10%
Pct. Passing US#18 sieve	5 - 50%
Pct. Passing 1/8-inch sieve	20 - 70%
Pct. Passing 3/8-inch sieve	75 -100%

Dual Media Assemblies

Clay fraction (2 micron)	0
Pct. Passing US#200 sieve (i.e., silt fraction)	5-15%
Pct. Passing US#60 sieve	10-25%
Pct. Passing US#18 sieve	20 - 50%
Pct. Passing 1/8-inch sieve	55 - 95%
Pct. Passing 3/8-inch sieve	90 -100%

Macro- and micro-nutrients shall be incorporated in the formulation in initial proportions suitable for support the specified planting.

4. **Separation fabric** should be readily penetrated by roots, but provide a durable separation between the drainage and growth media layers (Only lightweight nonwoven geotextiles are recommended for this function.

Unit Weight (ASTM-D3776)	4.25 oz/yd2
Grab tensile (ASTM-D4632)	90 lb
Mullen Burst Strength (ASTM-D4632)	135 lb/in
Permittivity (ASTM-D4491)	2 sec-1

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References

FLL: Guidelines for the Planning, Installation, and Maintenance in Roof Greening, 1995, English Version (*Richtlinen für die Planung, Ausführung und Pflege von Dachbegrünungen*), Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.

ASTM: American Standard Testing Methods

Planting Green Roofs and Living Walls, 2004, Dunnett, N, and Kingsbury, N, Timber Press [ISBN 0-88192-640-X]

Penn State Center For Green Roof Research, http://hortweb.cas.psu.edu/research/greenroofcenter/

FOOTNOTES

[1] FLL or ASTM procedures for determining the maximum density and associated moisture content under compressed and hydrated conditions. See ASTM Draft: Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems , and ASTM Draft Standard Practice for Determination of Dead Loads and Live Loads f or Green Roof Systems

[2] ASTM Draft: Standard Test Method for Saturated Hydraulic Conductivity of Granular Drainage Media [Falling-Head Method] for Green Roof Systems

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BMP 6.5.2: Runoff Capture & Reuse



Capture and Reuse encompasses a wide variety of water storage techniques designed to “capture” precipitation, hold it for a period of time, and reuse the water. Heavy rainfall may require slow release over time. A water budget must be developed to ensure that the water will be used to allow for more runoff capture

Key Design Elements

- Storage techniques may include cisterns, underground tanks, above-ground vertical storage tanks, rain barrels or other systems
- Storage devices designed to capture a portion of the small, frequent storm events
- Most effective when designed to meet a specific water need for reuse
- Systems must for bypass or overflow of large storm events
- Water budget analysis incorporating anticipated water inflow and usage is required
- Collection and placement of storage elements up gradient of areas of reuse may reduce or eliminate pumping needs

Maintenance - periodic tank and sump cleanout is required

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction:	Med/High
Recharge:	Low
Peak Rate Control:	Low
Water Quality:	Medium

Water Quality Functions

TSS: 100%
TP: 100%
NO3: 100%

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Description

Cisterns, Rain Barrels, Vertical Storage, and similar devices have been used for centuries to capture storm water from the roofs of buildings, and in many parts of the world these systems serve as a primary water supply source. The reuse of stormwater for potable needs is not advised without water treatment, although many homes in the U.S. were storing water in cisterns for reuse as little as a century ago. These systems can reduce potable water needs for uses such as irrigation and fire protection while also reducing stormwater discharges.

Storage/reuse techniques range from small, residential systems such as Rain Barrels that are maintained by the homeowner to supplement garden needs, to large, "vertical storage" units that can provide firefighting needs. Storage/reuse techniques are useful in urban areas where there is little physical space to manage storm water.

Variations

Cisterns – large, underground or surface containers designed to hold large volumes of water (500 gallons or more). Cisterns may be comprised of fiberglass, concrete, plastic, brick or other materials.





Rain barrels – barrel (or large container) that collect drainage from roof leaders and store water until needed for irrigation.





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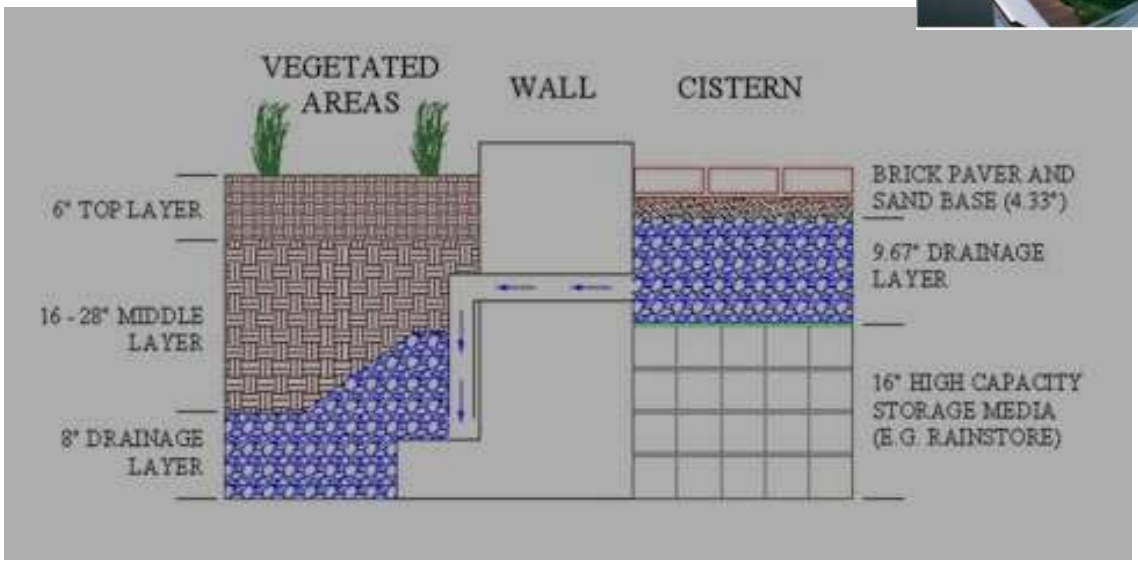
Vertical Storage – stand along “towers”, or “fat downspouts” that usually rest against a building performing the same capture, storage and release functions as cisterns and rain barrels.



Storage Beneath Structure – Storage may be incorporated into elements such as paths and walkways to supplement irrigation with the use of structural plastic storage units





Applications

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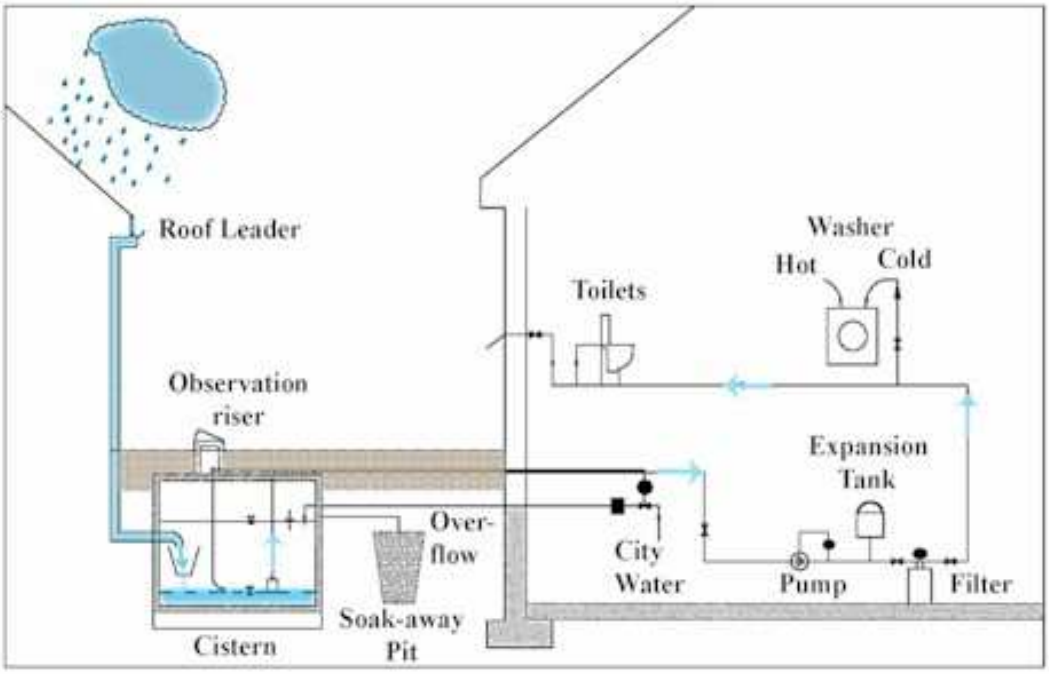
- **Landscaped areas and gardens to meet irrigation needs**
- **Storage for firefighting needs**
- **Urban areas and Combined Sewer areas to reduce peak surcharges.**
- **Reuse for greywater needs such as flushing toilets.**
- **Reuse for athletic field irrigation**





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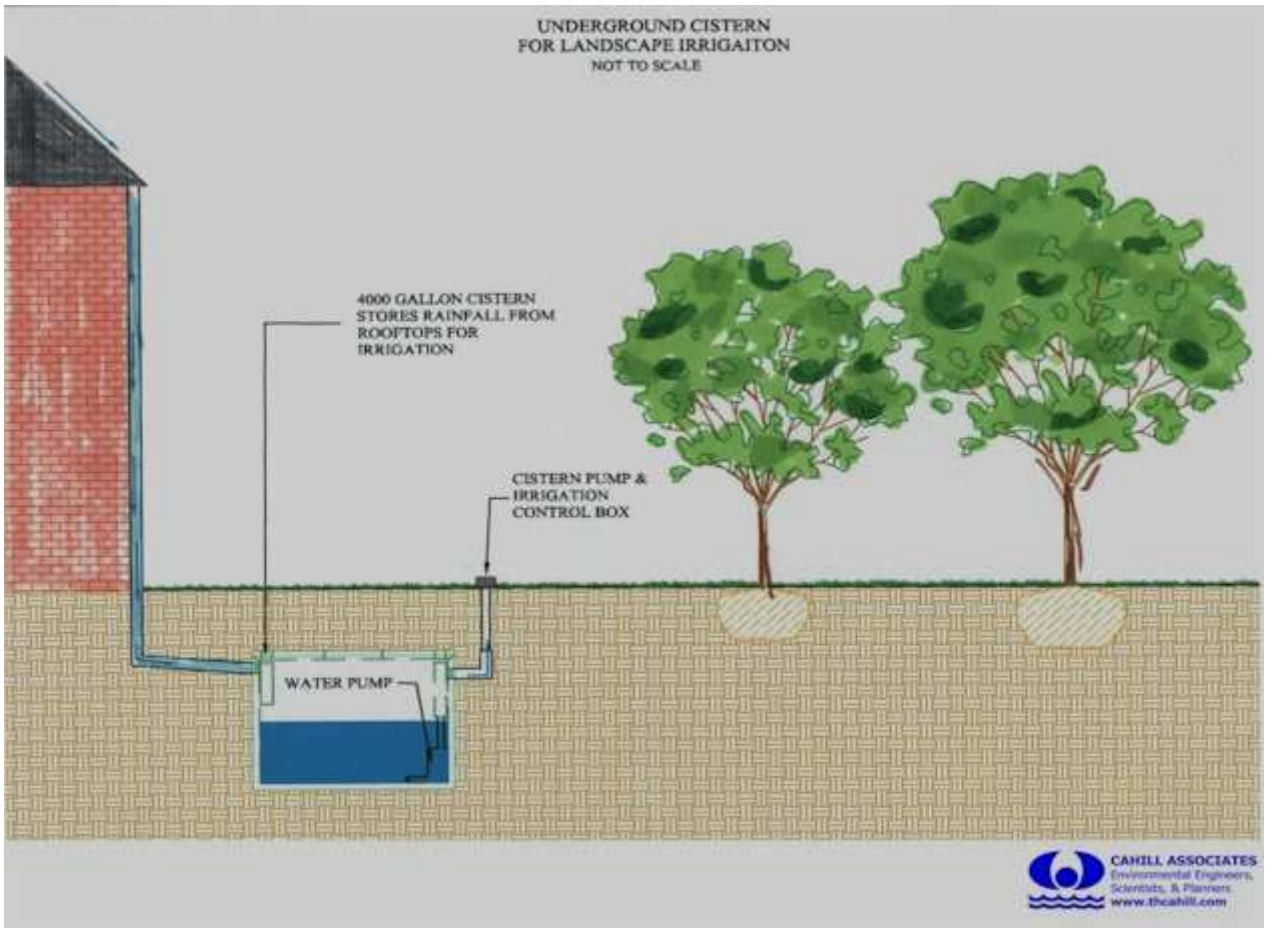

Design Considerations

1. The Designer should **calculate the water need** for the intended uses. For example, what will the collected water be used for and when will it be needed? If a 2,000 square foot area of lawn requires irrigation for 4 months in the summer at a rate of 1" per week, how much will be needed and how often will the storage unit be refilled? The usage requirements and the expected rainfall volume and frequency should be determined.

2. **Drawdown** – the Designer should provide for use or release of the stored water between storm events in order for the necessary stormwater storage volume to be available.

3. The **Catchment Area** on which the rain falls should be considered. The catchment area typically handles roof runoff.

4. The **Conveyance System** should keep reused stormwater or greywater from other potable water piping systems. Do not connect to domestic or commercial potable water system.

5. Pipes or storage units should be clearly marked "Caution: Reclaimed water, Do Not Drink".

6. Screens may be used to filter debris from storage units.

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7. The **first flush** runoff may be diverted away from storage in order to minimize sediment and pollutant entry. However, rooftop runoff contains very low concentrations of pollutants.

8. Storage elements should be protected from direct sunlight by positioning and landscaping. (Limit light into devices to minimize algae growth.)

9. The proximity to building foundations should be considered for overflow conditions.

10. Climate is an important consideration, and capture/reuse systems should bedesigned to account for the potential of freezing.

11. Cisterns should be watertight (joints sealed with nontoxic waterproof material) with a smooth interior surface, and capable of receiving water from rainwater harvesting system.

12. Covers (lids) should have a tight fit to keep out surface water, animals, dust and light.

13. Positive outlet for overflow should be provided a few inches from the top of the cistern.

14. Observation risers should be at least 6" above grade for buried cisterns.

15. Reuse may require pressurization. Water stored has a pressure of 0.43 psi per foot of water elevation. A ten-foot tank would have a pressure of 0.43*10 = 4.3 psi. at the bottom of the tank. Most irrigation systems require at least 15 psi. To add pressure, a pump, pressure tank and fine mesh filter can be used, which adds to the cost of the system, but creates a more usable system.

Capacities of Various sized Cisterns (cf)

	Diameter of Round Types (ft)						
Depth (ft)	**6**	**8**	**10**	**12**	**14**	**16**	**18**
6	1266	2256	3522	5076	6906	9018	11412
8	1688	3008	4696	6768	9208	12024	15216
10	2110	3760	5870	8460	11510	15030	19020
12	2532	4512	7044	8532	13812	18036	22824
14	2954	5264	8218	11844	16114	21042	26628
* Harvested Rainwater Guidelines, GreenBuilder.com							

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Annual Rainfall Yield in Gallons for Various Impervious Surface Sizes and Rainfall Amounts

Impervious Surface Area	Rainfall (inches)								
sf	20	24	28	32	36	40	44	48	52
1000	11844	14213	16582	18951	21319	23688	26057	28426	30795
1100	13029	15634	18240	20846	23451	26057	28663	31268	33874
1200	14213	17056	19898	22741	25583	28426	31268	34111	36954
1300	15397	18477	21556	24636	27715	30795	33874	36954	40033
1400	16582	19898	23214	26531	29847	33164	36480	39796	43113
1500	17766	21319	24873	28426	31979	35532	39086	42639	46192
1600	18951	22741	26531	30321	34111	37901	41691	45481	49272
1700	20135	24162	28189	32216	36243	40270	44297	48324	52351
1800	21319	25583	29847	34111	38375	42639	46903	51167	55431
1900	22504	27005	31505	36006	40507	45008	49508	54009	58510
2000	23688	28426	33164	37901	42639	47377	52114	56852	61589
2100	24873	29847	34822	39796	44771	49745	54720	59694	64669
2200	26057	31268	36480	41691	46903	52114	57326	62537	67748
2300	27241	32690	38138	43586	49035	54483	59931	65380	70828
2400	28426	34111	39796	45481	51167	56852	62537	68222	73907
2500	29610	35532	41454	47377	53299	59221	65143	71065	76987
2600	30795	36954	43113	49272	55431	61589	67748	73907	80066
2700	31979	38375	44771	51167	57562	63958	70354	76750	83146
2800	33164	39796	46429	53062	59694	66327	72960	79593	86225

* Values represent 95% of actual precipitation to account for any storage and/or losses.

Detailed Stormwater Functions

Volume Reduction Calculations

Volume reduction is the actual volume of the storage container, taking into consideration how many times it is emptied.

Peak Rate Mitigation Calculations:

Capture and reuse takes a volume of water out of site runoff. This reduction in volume will translate to a lower overall peak rate for the site.

Water Quality Improvement

Pollutant removal takes place through filtration of recycled primary storage, and/or natural filtration through soil and vegetation for overflow discharge. Quantifying pollutant removal will depend on design. Sediment removal will depend on area below outlet that is designed for sediment accumulation, time in storage, and maintenance frequency. Filtration through soil will depend on flow rate, the type of soil (infiltration capacity), and design specifics (stone bed, etc.).

Construction Sequence

Install per manufacturer's instructions.

Maintenance Issues

Flush cisterns to remove sediment. Brush the inside surfaces and thoroughly disinfect.

Winter concern: Do not allow water to freeze in devices. (Empty out before water freezes.)

Cost Issues

Rain Barrel: ranges from $80 to $200, average for residential use is $150 (2005)

Cistern: varies, depending on material used (reinforced concrete, steel, plastic are common), size, and pump characteristics

Vertical Storage: ranges from $88 for 64-gallon capacity to $10,516 for 12,000-gallon capacity (for a plastic, manufactured product). Storage costs $1.25/gallon (2005).

General: the reuse of water for irrigation or other uses saves money on water costs over time.

Specifications:

The following specifications are provided for informational purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Vertical Storage** All storage containers should meet FDA specifications for stored drinking water if potable water is the intended use. Follow Manufacturer's specifications for vertical storage containers.

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References

City of Tucson, Water Harvesting Guidance Manual, March 2003 (edited by Ann Audrey Phillips, prepared for the City of Tucson, Department of Transportation, Stormwater Section)

"What are Rainwater Harvesting and Stormwater Recycling?" Heather Kinkade-Levario, ASLA and Hari Krishna Ph.D., P.E., Ann Phillips, Tim Pope

Sustainable Building Sourcebook, "Harvested Rainwater Guidelines", sections 1.0, 2.0, 3.0 www.greenbuilder.com

"Rainwater Harvesting" www.ci.austin.tx.us/greenbuilder/fs_rainharvest.htm City of Austin, TX

Portland, OR's Code Guide Office of Planning & Development Review "Rainwater Harvesting – ICC – RES/34/#1 & UPC/6/#2, March 2001

U.S. EPA National Pollutant Discharge Elimination System, "Post-Construction Storm Water Management in New Development & Redevelopment, On-Lot Treatment"

City of Vancouver, Engineering Services, Water and Sewers "Rain Barrel Program"

"Cisterns/Rainwater Harvesting Systems, www.advancedbuildings.org Technologies and Practices, Plumbing & Water Heating

CSIRO, Land and Water, "Urban Water Reuse – Frequently Asked Questions" (south Australia)

"Rain Barrels – Truth or Consequences" Karen Sands, AICP and Thomas Chapman, P.E., Milwaukee Metropolitan Sewerage District, Milwaukee, Wisconsin

"Hydrologic Processes at the Residential Scale" Qingfu Xiao, E. Gregory McPherson, James R. Simpson, Hydrologic Sciences Program, UC Davis, Center for Urban Forest Research, USDA Forest Service

"Black Vertical Storage Tanks by Norwesco" www.precisionpump.net/storagetanksystems.htm

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6.6 Runoff Quality/Peak Rate BMPs

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SARB_014851

BMP 6.6.1: Constructed Wetland



Constructed Wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff.

Key Design Elements

- Adequate drainage area (usually 5 to 10 acres minimum) or proof of sustained base flow
  May require investigation of water supply to ensure a sustained baseflow to maintain the wetland
- Maintenance of permanent water surface
- Multiple vegetative growth zones through varying depths
- Robust and diverse vegetation
- Relatively impermeable soils or engineered liner
- Sediment collection and removal
- Adjustable permanent pool and dewatering mechanism
  Maintenance - periodic sediment removal from the forebay and vegetation maintenance

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low
Recharge: Low
Peak Rate Control: High
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

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Description

Constructed Wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, Constructed Wetlands (CWs) can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. CWs use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface.

Variations

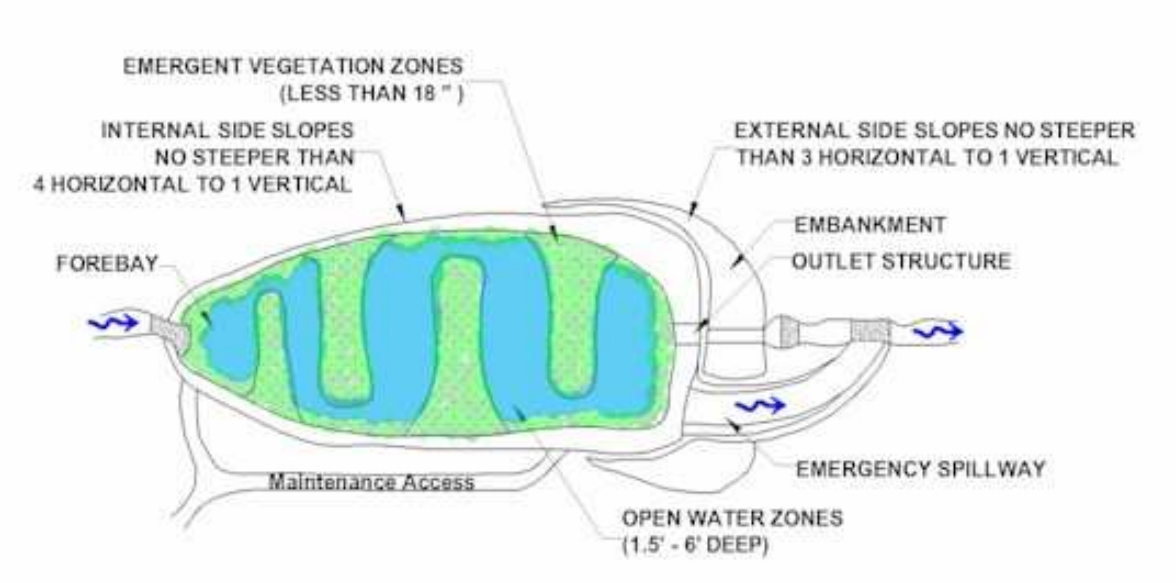
Constructed Wetlands can be designed as either an online or offline facilities. They can also be used effectively in series with other flow/sediment reducing BMPs that reduce the sediment load and equalize incoming flows to the CWs. Constructed Wetlands are a good option for retrofitting existing detention basins. CWs are often organized into four groups:

- Shallow Wetlands are large surface area CWs that primarily accomplish water quality improvement through displacement of the permanent pool.
- Extended Detention Shallow Wetlands are similar to Shallow Wetlands but use extended detention as another mechanism for water quality and peak rate control.
- Pocket Wetlands are smaller CWs that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table.
- Pond/Wetland systems are a combination of a wet pond and a constructed wetland.

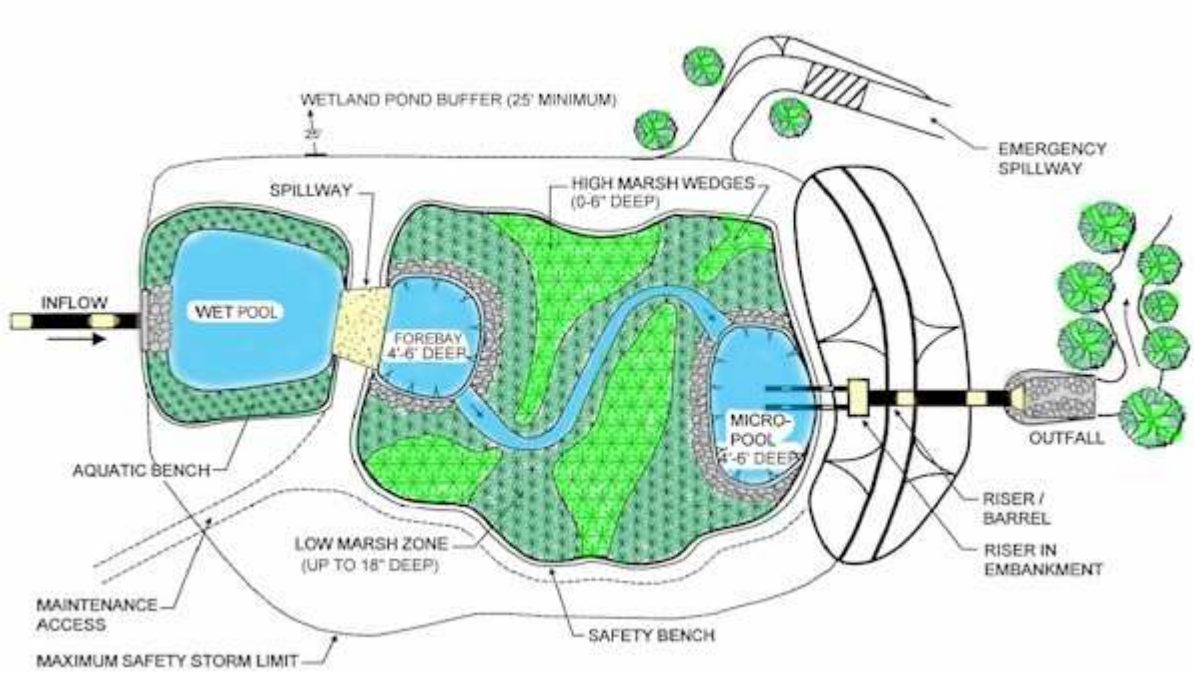
Although this BMP focuses on surface flow Constructed Wetlands as described above, subsurface flow CWs can also be used to treat stormwater runoff. While typically used for wastewater treatment, subsurface flow CWs for stormwater may offer some advantages over surface flow wetlands, such as improved reduction of total suspended solids and oxygen demand. They also can reduce the risk of vectors (especially mosquitoes) and safety risks associated with open water. However, nitrogen removal may be deficient (Campbell and Ogden, 1999). Perhaps the biggest disadvantage is the relatively low treatment capacities of subsurface flow CWs – they are generally only able to treat small flows. For more information, please consult the “References and Additional Resources” list.

Applications

- **Alternating bands of deeper water and shallow marsh.**



- **Wet Pond/Wetland System**



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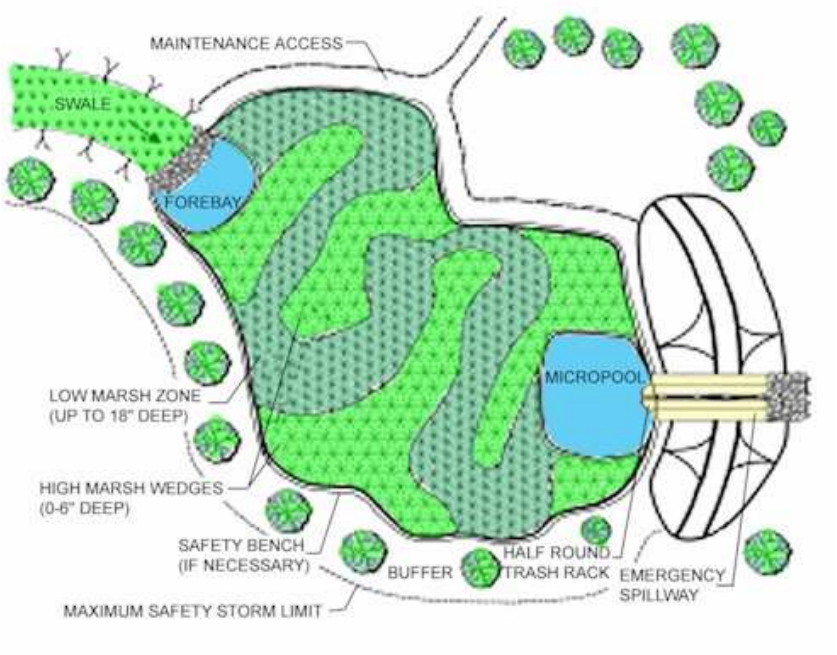
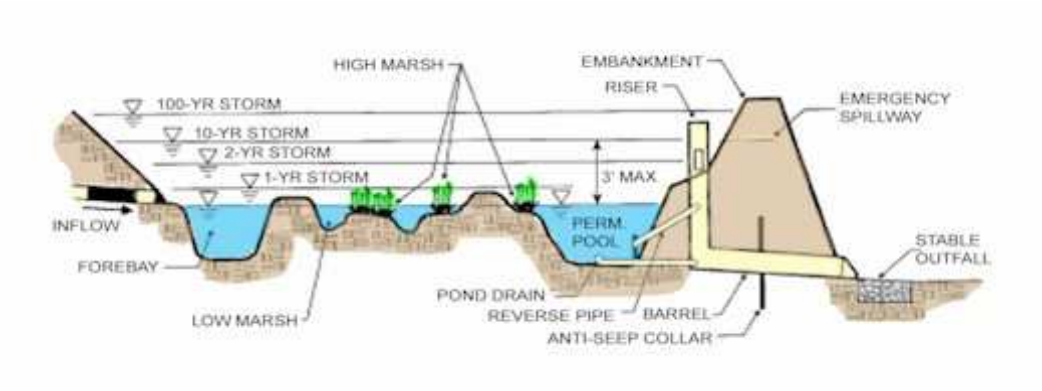
- **Pocket Wetland**





- **Offline Constructed Wetland**

- **Retrofit of existing detention basins**



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Design Considerations

1. HYDROLOGY. Constructed Wetlands must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Hydrologic calculations (or a water balance) should be performed to verify this. Shallow marsh areas can become dry at the surface but not for greater than one month, even in the most severe drought. A permanent water surface in the deeper areas of the CWs should be maintained during all but the driest periods. A relatively stable normal water surface elevation will reduce the stress on wetland vegetation. A CWs must have a drainage area of at least 10 acres (5 acres for "pocket" wetlands) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a Constructed Wetland. Pennsylvania's precipitation is generally well distributed throughout the year and is therefore suited for CWs.
2. UNDERLYING SOILS. Underlying soils must be identified and tested. Generally hydrologic soil groups "C" and "D" are suitable without modification, "A" and "B" soils may require a clay or synthetic liner. Soil permeability must be tested in the proposed Constructed Wetland location to ensure that excessive infiltration will not cause the CWs to dry out. If necessary, CWs should have a highly- compacted subsoil or an impermeable liner to minimize infiltration.
3. PLANTING SOIL. Organic soils should be used for Constructed Wetlands. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species.
4. SIZE AND VOLUME. The area required for a CWs is generally 3 to 5 percent of its drainage area. CWs should be sized to treat the water quality volume and, if necessary, to mitigate the peak rates for larger events.
5. VEGETATION. Vegetation is an integral part of a Wetland system. Vegetation may help to reduce flow velocities, promote settling, provide growth surfaces for beneficial microbes, uptake pollutants, prevent resuspension, provide filtering, limit erosion, prevent short-circuiting, and maintain healthy bottom sediments (Braskerud, 2001). Constructed Wetlands should have several different zones of vegetation as described in Table 6.6.1-1. The emergent vegetation zone (areas not more than 18" deep) should comprise about 60 to 65 percent of the normal water surface area, although recommendations in recent literature range from less than 50 to over 80 percent. Robust, non-invasive, perennial plants that establish quickly are ideal for CWs. The designer should select species that are tolerant of a range of depths, inundation periods, etc. Monoculture planting must be avoided due to the risk from pests and disease. Use local recommended plant lists.

Table 6.6.1-1

Vegetation Zone	Description
Open Water	Areas between 18 inches and 6 feet deep
Emergent	Areas up to 18 inches deep
Low Marsh	Portion of Emergent Zone between 6 and 18 inches deep
High Marsh	Portion of Emergent Zone up to 6 inches deep
Ephemeral Storage	Area periodically inundated during runoff events
Buffer	Area outside of maximum water surface elevation

SARB_014856



6. CONFIGURATION.
   a. General. Constructed Wetlands should be designed with a length to width ratio of at least 2:1 wherever possible. If the length to width ratio is lower, the flow pathway through the CWs should be maximized. CWs should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system. CWs should be designed so that the 10-year water surface elevation does not exceed the normal water surface elevation by more than 3 feet. Slopes in and around Constructed Wetlands should be 4:1 to 5:1 (H:V) wherever possible. Constructed wetlands should be located outside of any natural watercourse.
   b. Forebay/Inflows. Constructed Wetlands should have a forebay at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the remainder of the CWs, and minimize erosion by inflow. The forebays should contain 10 to 15 percent of the total permanent pool volume and should be 4 to 6 feet deep (at least as deep as other open water areas). They should be physically separated from the rest of the wetland by a berm, gabion wall, etc. Flows exiting the forebay should be non-erosive to the newly constructed CWs. Vegetation within forebays can increase sedimentation and reduce resuspension/erosion. The forebay bottom can be hardened to facilitate sediment removal. Forebays should be installed with permanent vertical markers that indicate sediment depth. Inflow channels should be fully stabilized. Inflow pipes can discharge to the surface or be partially submerged. CWs should be protected from the erosive force of the inflow to prevent the resuspension of previously collected sediment during large flows.



   c. Vegetation and Open Water Zones. About half of the emergent vegetation zone should be high marsh (up to 6” deep) and half should be low marsh (6” to 18” deep). Varying depths throughout the CWs can improve plant diversity and health. The open water zone (approx. 35 to 40% of the total surface area) should be between 18 inches and 6 feet deep. Allowing a limited 5-foot deep area can prevent short-circuiting by encouraging mixing, enhance aeration of water, prevent resuspension, minimize thermal

impacts, and limit mosquito growth. Alternating areas of emergent vegetation zone (up to 18 inches deep) and open water zone – as shown in Figures 6.13-2 and 6.13-4 – can also minimize short-circuiting and hinder mosquito propagation.

d. Outlet. Outlet control devices should be in open water areas 4 to 6 feet deep comprising about 5 percent of the total surface area to prevent clogging and allow the CWs to be drained for maintenance. Outlet devices are generally multistage structures with pipes, orifices, or weirs for flow control. Orifices should be at least 2.5 inches in diameter and should be protected from clogging. Outlet devices should be installed in the embankment for accessibility. It is recommended that outlet devices enable the normal water surface to be varied. This allows the water level to be adjusted (if necessary) seasonally, as the CWs accumulates sediment over time, if desired grades are not achieved, or for mosquito control. The outlet pipe should generally be fitted with an anti-seep collar. Online facilities should have an emergency spillway that can safely pass the 100-year storm with 1 foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.

e. Safety Benches. All areas that are deeper than 4 feet should have two safety benches, each 4 to 6 feet wide. One should be situated about 1 to 1.5 feet above the normal water elevation and the other 2 to 2.5 feet below the water surface.

7. CONSTRUCTED WETLAND BUFFER. To enhance habitat value, visual aesthetics, and wetland health, a 25-foot buffer should be added from the maximum water surface elevation. The buffer should be planted with trees, shrubs, and native ground covers. Existing trees within the buffer should be preserved. If soils in the buffer will become compacted during construction, soil restoration should take place to aid buffer vegetation.
8. MAINTENANCE ACCESS. Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least 9 feet wide, have a maximum slope of 15%, and be stabilized for vehicles.
9. PLAN ELEMENTS. The plans detailing the Constructed Wetlands should clearly show the CWs configuration, elevations and grades, depth/vegetation zones, and the location, quantity, and propagation methods of wetland/buffer vegetation. Plans should also include site preparation techniques, construction sequence, as well as maintenance schedules and requirements.
10. REGULATION. Constructed Wetlands that have drainage areas over 100 acres, embankments greater than 15 feet high, or a capacity greater than 50 acre-feet may be regulated as a dam by PADEP (see Title 25, Chapter 105 of the Pennsylvania Code).

Detailed Stormwater Functions

Volume Reduction Calculations

Although not typically considered a volume-reducing BMP, Constructed Wetlands can achieve some volume reduction through evapotranspiration, especially during small storms. An evapotranspiration study could be done to account for potential volume reduction credit. Hydrologic calculations that should be performed to verify that the CWs will have a viable amount of inflow can also predict the water surface elevation under varying conditions. The volume stored between the predicted water level and the lowest outlet elevation will be removed from the storm that occurs under those conditions.

Peak Rate Mitigation Calculations

Peak rate is primarily controlled in Constructed Wetlands through the transient storage above the normal water surface. See in Section 8 for Peak Rate Mitigation methodology.

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Water Quality Improvement

Constructed Wetlands improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption. Constructed Wetlands are effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, toxic organics, and petroleum products. The pollutant removal effectiveness varies by season and may be affected by the age of the wetland. It has been suggested that Constructed wetlands do not remove nutrients in the long term unless vegetation is harvested because captured nutrients are released back into the water by decaying plant material. Even if this is true, nutrients are generally released gradually and during the non-growing season when downstream susceptibility is generally low (Hammer, 1990). See in Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Separate wetland area from contributing drainage area:
    a. All channels/pipes conveying flows to the Constructed Wetland must be routed away from the wetland area until it is completed and stabilized.
    b. The area immediately adjacent to the Constructed Wetland must be stabilized in accordance with the PADEP's Erosion and Sediment Pollution Control Program Manual (2000 or latest edition) prior to construction of the wetland.

2. Clearing and Grubbing:
    a. Clear the area to be excavated of all vegetation.
    b. Remove all tree roots, rocks, and boulders.
    c. Fill all stump holes, crevices and similar areas with impermeable materials.

3. Excavate bottom of Constructed Wetland to desired elevation (Rough Grading).

4. Install surrounding embankments and inlet and outlet control structures.

5. Grade and compact subsoil.

6. Apply and grade planting soil.
a. Matching design grades is crucial because aquatic plants can be very sensitive to depth.

7. Apply geo-textiles and other erosion-control measures.

8. Seed, plant and mulch according to Planting Plan

9. Install any anti-grazing measures, if necessary.

10. Follow required maintenance and monitoring guidelines.

SARB_014859



Maintenance Issues

Constructed Wetlands must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal. During the first growing season, vegetation should be inspected every 2 to 3 weeks. During the first 2 years, CWs should be inspected at least 4 times per year and after major storms (greater than 2 inches in 24 hours). Inspections should access the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, and sediment/debris accumulation. Problems should be corrected as soon as possible. Wetland and buffer vegetation may require support – watering, weeding, mulching, replanting, etc. – during the first 3 years. Undesirable species should be removed and desirable replacements planted if necessary.

Once established, properly designed and installed Constructed Wetlands should require little maintenance. They should be inspected at least semiannually and after major storms as well as rapid ice breakup. Vegetation should maintain at least an 85 percent cover of the emergent vegetation zone. Annual harvesting of vegetation may increase the nutrient removal of CWs; it should generally be done in the summer so that there is adequate regrowth before winter. Care should be taken to minimize disturbance, especially of bottom sediments, during harvesting. The potential disturbance from harvesting may outweigh its benefits unless the CWs receives a particularly high nutrient load or discharges to a nutrient sensitive waterbody. Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 3 to 7 years.

Cost Issues

The construction cost of Constructed Wetlands can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2004 dollars range from approximately $30,000 to $65,000 per acre (USEPA Wetlands Fact Sheet, 1999). Costs are generally most dependent on the amount of earthwork and the planting. Annual maintenance costs have been reported to be approximately 2 to 5 percent of the capital costs although there is very little data available to support this.

Specifications:

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting.

The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Excavation**
    a. The area to be used for the CWs should be excavated to the required depth below the desired bottom elevation to accommodate any required impermeable liner, organic matter, and/or planting soil.
    b. The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.
2. **Subsoil Preparation**
    a. Subsoil shall be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
    b. Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
    c. Roll the subsoil under optimum moisture conditions to a dense seal layer with four to six passes of a sheepsfoot roller or equivalent. The compacted seal layer shall be at least 8 inches thick.
3. **Impermeable Liner**
    a. If necessary, install impermeable liner in accordance with manufacturer's guidelines.
    b. Place a minimum 12 inches of subsoil on top of impermeable liner in addition to planting soil.
4. **Planting Soil (Topsoil)**
    a. See Local Specifications for general Planting Soil requirements.
    b. Use a minimum of 12 inches of topsoil in marsh areas of the Wetland. If natural topsoil from the site is to be used it must have at least 8 percent organic carbon content (by weight) in the A-horizon for sandy soils and 12% for other soil types.
    c. If planting soil is being imported it should be made up of equivalent proportions of organic and mineral materials.
    d. Lime should not be added to planting soil unless absolutely necessary as it may encourage the propagation of invasive species.
    e. The final elevations and hydrology of the wetland zones should be evaluated prior to planting to determine if grading or planting changes are required.
5. **Vegetation**
    a. Plant Lists for Constructed Wetlands can be found in Appendix B. No substitutions of specified plants will be accepted without prior approval of the designer. Planting locations shall be based on the Planting Plan and directed in the field by a qualified wetland ecologist.
    b. All wetland plant stock shall exhibit live buds or shoots. All plant stock shall be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock shall be rejected. The stock shall be free of deleterious insect infestation, disease and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
    c. All stock shall be free from invasive or nuisance plants or seeds such as those listed in Appendix B.
    d. During all phases of the work, including transport and onsite handling, the plant materials shall be carefully handled and packed to prevent injuries and desiccation. During transit and onsite handling, the plant material shall be kept from freezing and shall be kept covered, moist, cool, out of the weather, and out of the wind and sun. Plants shall be watered to maintain moist soil and/or plant conditions until accepted.
    e. Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.

f. Detailed planting specifications can be found in Appendix B.

6. **Outlet Control Structure**
   a. Outlet control structures shall be constructed of non-corrodible material.
   b. Outlets shall be resistant to clogging by debris, sediment, floatables, plant material, or ice.
   c. Materials shall comply with applicable specifications (PennDOT or AASHTO, latest edition)

References

Auckland Regional Council, 2003. *Stormwater Management Devices: Design Guidelines Manual*, Auckland, New Zealand

Braskerud, B.C. "Influence of Vegetation on Sedimentation and Resuspension of Soil Particles in Small Constructed Wetlands," Journal of Environmental Quality, Vol. 30: pp. 1447-1457, 2001.

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Atlanta Regional Commission. *Georgia Stormwater Management Manual. 2004.*

Hammer, D. (Editor). Constructed Wetlands for Wastewater Treatment. Lewis Publishers, 1990.

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SARB_014863

BMP 6.6.2: Wet Pond/Retention Basin



Wet Ponds/Retention Basins are stormwater basins that include a substantial permanent pool for water quality treatment and additional capacity above the permanent pool for temporary runoff storage.

Key Design Elements

- Adequate drainage area (usually 5 to 10 acres minimum) or proof of sustained baseflow
- Natural high groundwater table
- Maintenance of permanent water surface
- Should have at least 2 to 1 length to width ratio
- Robust and diverse vegetation surrounding wet pond
- Relatively impermeable soils
- Forebay for sediment collection and removal
- Dewatering mechanism

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low
Recharge: Low
Peak Rate Control: High
Water Quality: Medium

Water Quality Functions

TSS: 70%
TP: 60%
NO3: 30%

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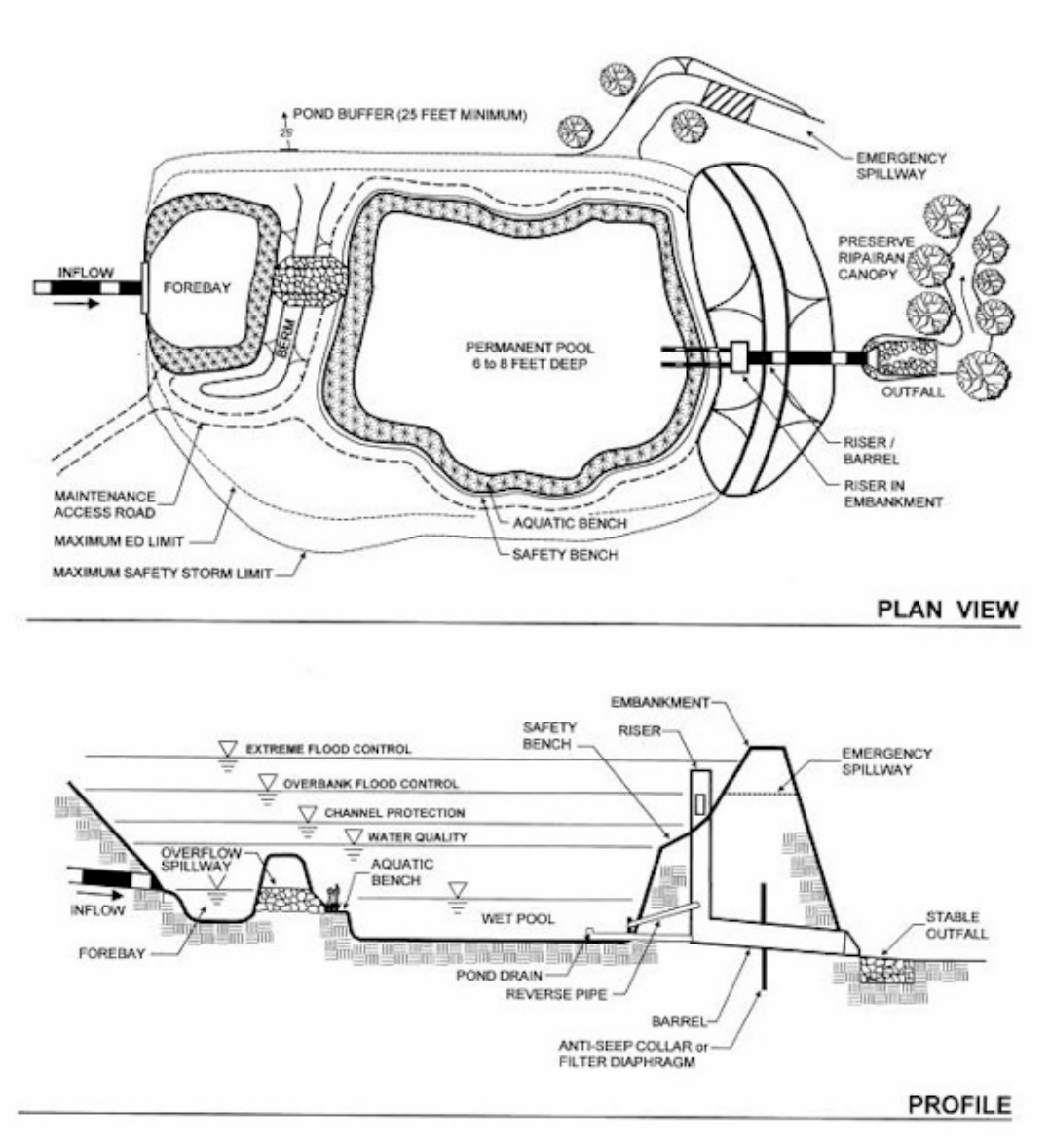
Description

Wet Detention Ponds are stormwater basins that include a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary storage. Wet Ponds should include one or more forebays that trap course sediment, prevent short-circuiting, and facilitate maintenance. The pond perimeter should generally be covered by a dense stand of emergent wetland vegetation. While they do not achieve significant groundwater recharge or volume reduction, they can be effective for pollutant removal and peak rate mitigation. Wet Ponds (WPs) can also provide aesthetic and wildlife benefits. WPs require an adequate source of inflow to maintain the permanent water surface. Due to the potential to discharge warm water, wet ponds should be used with caution near temperature sensitive waterbodies. Properly designed and maintained WPs generally do not support significant mosquito populations (O'Meara).



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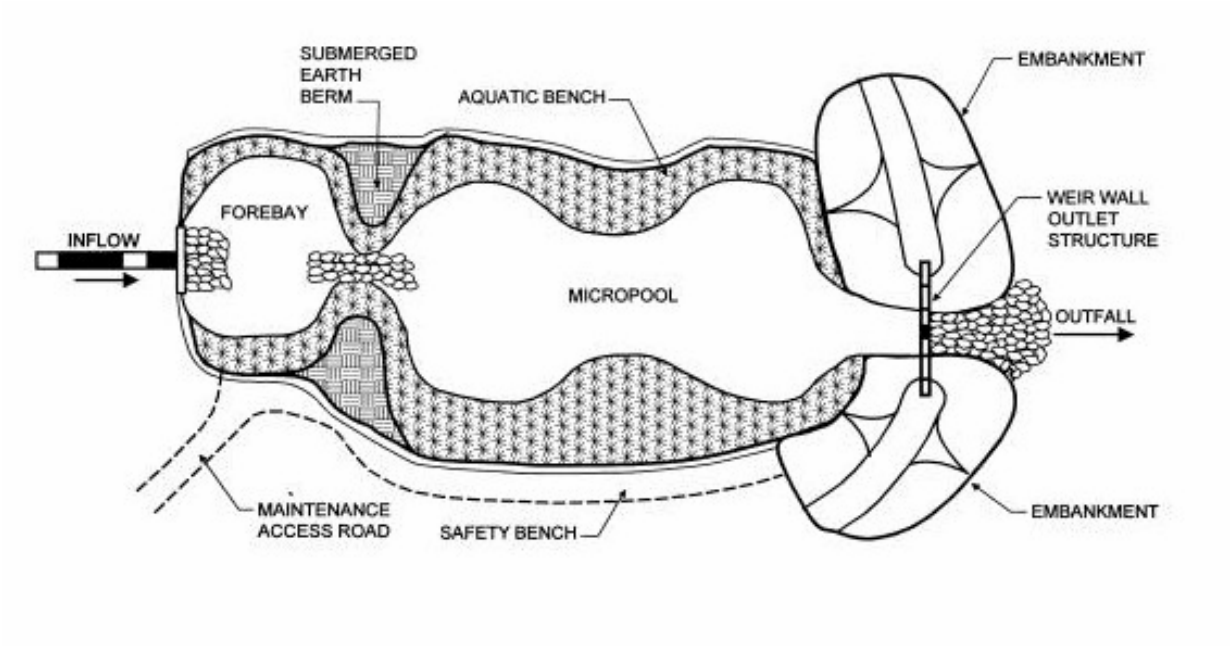
Variations

Wet Ponds can be designed as either an online or offline facilities. They can also be used effectively in series with other sediment reducing BMPs that reduce the sediment load such as vegetated filter strips, swales, and filters. Wet Ponds may be a good option for retrofitting existing dry detention basins. WPs are often organized into three groups:

- Wet Ponds primarily accomplish water quality improvement through displacement of the permanent pool and are generally only effective for small inflow volumes (often they are placed offline to regulate inflow).
- Wet Detention Ponds are similar to Wet Ponds but use extended detention as another mechanism for water quality and peak rate control.
- Pocket Wet Ponds are smaller WPs that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table to help maintain the permanent pool. They often include extended detention as well.

This BMP focuses on Wet Detention Ponds as described above because this tends to be the most common and effective type of Wet Pond. For more information on other types of wet ponds, please consult the "References and Additional Resources" list.



Applications

- **Wet Ponds**
- **Wet Detention Ponds**
- **Pocket Wet Pond**
- **Offline Wet Pond**
- **Retrofit for existing detention basins**

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Design Considerations

1. HYDROLOGY. Wet Ponds should be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. A permanent water surface in the deeper areas of the WP should be maintained during all but the driest periods. A relatively stable permanent water surface elevation will reduce the stress on vegetation in and adjacent to the pond. A WP should have a drainage area of at least 10 acres (5 acres for Pocket Wet Ponds) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a Wet Pond while discouraging mosquito growth. Pennsylvania's precipitation is generally well distributed throughout the year and is therefore suited for WPs.
2. UNDERLYING SOILS. Underlying soils must be identified and tested. Generally hydrologic soil groups "C" and "D" are suitable without modification, "A" and "B" soils may require modification to reduce permeability. Soil permeability must be tested in the proposed Wet Pond location to ensure that excessive infiltration will not cause the WP to dry out.
3. PLANTING SOIL. Organic soils should be used for shallow areas within Wet Ponds. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species.
4. SIZE AND VOLUME. The area required for a WP is generally 1 to 3 percent of its drainage area. WPs should be sized to treat the water quality volume and, if necessary, to mitigate the peak rates for larger events.
5. VEGETATION. Vegetation is an integral part of a Wet Pond system. Vegetation in and adjacent to a pond may enhance pollutant removal, reduce algal growth, limit erosion, improve aesthetics, create habitat, and reduce water warming (Mallin et al., 2002; NJ DEP, 2004; University of Wisconsin, 2000). Wet Ponds should have varying depths to encourage vegetation in shallow areas. The emergent vegetation zone (areas not more than 18" deep) generally supports the majority of aquatic vegetation and should include the pond perimeter. Robust, non-invasive, perennial plants that establish quickly are ideal for WPs. The designer should select species that are tolerant of a range of depths, inundation periods, etc. Monoculture planting should be avoided due to the risk from pests and disease. See local sources for recommended plant lists or Appendix B.

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6. CONFIGURATION.
    a. General. Wet Ponds should be designed with a length to width ratio of at least 2:1 wherever possible. If the length to width ratio is lower, the flow pathway through the WP should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation. WPs should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system. Slopes in and around Wet Ponds should be 4:1 to 5:1 (horizontal:vertical) or flatter wherever possible (10:1 max. for safety/aquatic benches, see 6.d. below). Wet Ponds should have an average depth of 3 to 6 feet and a maximum depth of 8 feet. This should be shallow enough to minimize thermal stratification and short-circuiting and deep enough to prevent sediment resuspension, reduce algal blooms, and maintain aerobic conditions. Wet ponds should not be constructed within a natural watercourse.
    b. Forebay/Inflows. Wet Ponds should have a forebay at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the remainder of the WP, and minimize erosion by inflow. The forebays should contain 10 to 15 percent of the total permanent pool volume and should be 4 to 6 feet deep. They should be physically separated from the rest of the pond by a berm, gabion wall, etc. Flows exiting the forebay should be non-erosive to the newly constructed WP. Vegetation within forebays can increase sedimentation and reduce resuspension/erosion. The forebay bottom can be constructed of hardened materials to facilitate sediment removal. Forebays should be installed with permanent vertical markers that indicate sediment depth. Inflow channels should be fully stabilized. Inflow pipes can discharge to the surface or be partially submerged. Forebays should be offline (out of the path of higher flows) to prevent resuspension of previously collected sediment during large storms.
    c. Outlet. Outlet control devices should draw from open water areas 5 to 7 feet deep to prevent clogging and allow the WP to be drained for maintenance and to provide for additional temperature benefits. Outlet devices are generally multistage structures with pipes, orifices, or weirs for flow control. A reverse slope pipe terminating 2 to 3 feet below the normal water surface, minimizes the discharge of warm surface water and is less susceptible to clogging by floating debris. Orifices, if used, should be at least 2.5 inches in diameter and should be protected from clogging. Outlet devices should be installed in the embankment for accessibility. If possible, outlet devices should enable the normal water surface to be varied. This allows the water level to be adjusted (if necessary) seasonally, as the WP accumulates sediment over time, if desired grades are not achieved, or for mosquito control. A pond drain should also be included which allows the permanent pool to be completely drained for maintenance within 24 hours. The outlet pipe should generally be fitted with an anti-seep collar through the embankment. Online facilities should have an emergency spillway that can safely pass the 100-year storm with 1 foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
    d. Safety/Aquatic Benches. All areas that are deeper than 4 feet should have two safety benches, totaling 15 feet in width. One should start at the normal water surface and extend up to the pond side slopes at a maximum slope of 10 percent. The other should extend from the water surface into the pond to a maximum depth of 18 inches, also at slopes no greater than 10 percent.
7. WET POND BUFFER. To enhance habitat value, visual aesthetics, water temperature, and pond health, a 25-foot buffer should be added from the maximum water surface elevation. The buffer should be planted with trees, shrubs, and native ground covers. Except in maintenance access areas, turf grass should not be used. Existing trees within the buffer should be preserved. If soils in the buffer will become compacted during construction, soil restoration should take place to aid buffer vegetation.

8. MAINTENANCE ACCESS. Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least 9 feet wide, have a maximum slope of 15%, and be stabilized for vehicles.
9. PLAN ELEMENTS. The plans detailing the Wet Ponds should clearly show the WP configuration, inlets and outlets, elevations and grades, safety/aquatic benches, and the location, quantity, and propagation methods of pond/buffer vegetation. Plans should also include site preparation techniques, construction sequence, as well as maintenance schedules and requirements.
10. REGULATION. Wet Ponds that have drainage areas over 100 acres, embankments greater than 15 feet high, or a capacity greater than 50 acre-feet may be regulated as a dam by PADEP (see Title 25, Chapter 105 of the Pennsylvania Code).



Detailed Stormwater Functions

Volume Reduction Calculations

Although not typically considered a volume-reducing BMP, Wet Ponds can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms. According to the International Stormwater BMP Database, wet ponds have an average annual volume reduction of 7 percent (Strecker et al., 2004). Hydrologic calculations that should be performed to verify that the WP will have a viable amount of inflow can also predict the water surface elevation under varying conditions. The volume stored between the predicted water level and the lowest outlet elevation will be removed from the that design storm.

Peak Rate Mitigation Calculations

Peak rate is primarily controlled in Wet Ponds through the transient storage above the normal water surface. See Section 8 for Peak Rate Mitigation methodology.

Water Quality Improvement

Wet Ponds improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption. WPs are relatively effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, and pathogens. The pollutant removal effectiveness varies by season and may be affected by the age of the WP. It has been suggested that this type of BMP does not provide significant nutrient removal in the long term unless vegetation is harvested because captured nutrients are released back into the water by decaying plant material. Even if this is true, nutrients are usually released gradually and during the non-growing season when downstream susceptibility is generally low (Hammer, 1990). See Section 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Separate wet pond area from contributing drainage area:
    a. All channels/pipes conveying flows to the WP should be routed away from the WP area until it is completed and stabilized.
    b. The area immediately adjacent to the WP should be stabilized in accordance with the PADEP's *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) prior to construction of the WP.

2. Clearing and Grubbing:
    a. Clear the area to be excavated of all vegetation.
    b. Remove all tree roots, rocks, and boulders.
    c. Fill all stump holes, crevices and similar areas with impermeable materials.

3. Excavate bottom of WP to desired elevation (Rough Grading).

4. Install surrounding embankments and inlet and outlet control structures.

5. Grade and prepare subsoil.

6. Apply and grade planting soil.
    a. Matching design grades is crucial because aquatic plants can be very sensitive to depth.

7. Apply erosion-control measures.

8. Seed, plant and mulch according to Planting Plan

9. Install any anti-grazing measures, if necessary.

10. Follow required maintenance and monitoring guidelines.

Maintenance Issues

Wet Ponds should have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal. During the first growing season or until established, vegetation should be inspected every 2 to 3 weeks. WPs should be inspected at least 4 times per year and after major storms (greater than 2 inches in 24 hours) or rapid ice breakup. Inspections should access the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation. The pond drain should also be inspected and tested 4 times per year. Problems should be corrected as soon as possible. Wet Pond and buffer vegetation may need support (watering, weeding, mulching, replanting, etc.) during the first 3 years. Undesirable species should be carefully removed and desirable replacements planted if necessary.

Once established, properly designed and installed Wet Ponds should require little maintenance. Vegetation should maintain at least an 85 percent cover of the emergent vegetation zone and buffer area. Annual harvesting of vegetation may increase the nutrient removal of WPs; if performed it should generally be done in the summer so that there is adequate regrowth before winter. Care should be taken to minimize disturbance, especially of bottom sediments, during harvesting. The potential disturbance from harvesting may outweigh its benefits unless the WP receives a particularly high nutrient load or discharges to a nutrient sensitive waterbody. Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 5 to 10 years.

Cost Issues

The construction cost of Wet Ponds can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2004 dollars range from approximately $25,000 to $50,000 per acre-foot of storage (based on USEPA, 1999). Costs are generally most dependent on the amount of earthwork and the planting. Annual maintenance costs have been reported to be approximately 3 to 5 percent of the capital costs although there is little data available to support this.In addition to the construction and maintenance costs, there is the cost or loss of value for the property involved.

Specifications:

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

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1. **Excavation**
    a. The area to be used for the WP should be excavated to the required depth below the desired bottom elevation to accommodate any required impermeable liner, organic matter, and/or planting soil.
    b. The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.
2. **Subsoil Preparation**
    a. Subsoil shall be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
    b. Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
    c. Roll the subsoil under optimum moisture conditions to a dense layer with four to six passes of a sheepsfoot roller or equivalent. The compacted layer shall be at least 8 inches thick.
3. **Planting Soil (Topsoil)**
    a. Use a minimum of 12 inches of topsoil in the emergent vegetation zone (less than 18" deep) of the pond. If natural topsoil from the site is to be used it must have at least 8 percent organic carbon content (by weight) in the A-horizon for sandy soils and 12% for other soil types.
    b. If planting soil is being imported it should be made up of equivalent proportions of organic and mineral materials.
    c. Lime should not be added to planting soil unless absolutely necessary as it may encourage the propagation of invasive species.
    d. The final elevations and hydrology of the vegetative zones should be evaluated prior to planting to determine if grading or planting changes are required.
4. **Vegetation**
    a. Plant Lists for WPs can be found locally. No substitutions of specified plants will be accepted without prior approval of the designer. Planting locations shall be based on the Planting Plan and directed in the field by a qualified wetland ecologist.
    b. All Wet Pond plant stock shall exhibit live buds or shoots. All plant stock shall be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock shall be rejected. The stock shall be free of deleterious insect infestation, disease and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
    c. All stock shall be free from invasive or nuisance plants or seeds.
    d. During all phases of the work, including transport and onsite handling, the plant materials shall be carefully handled and packed to prevent injuries and desiccation. During transit and onsite handling, the plant material shall be kept from freezing and shall be kept covered, moist, cool, out of the weather, and out of the wind and sun. Plants shall be watered to maintain moist soil and/or plant conditions until accepted.
    e. Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.
    f. Detailed planting specifications can be found locally, and in Appendix B.
5. **Outlet Control Structure**
    a. Outlet control structures shall be constructed of non-corrodible material.
    b. Outlets shall be resistant to clogging by debris, sediment, floatables, plant material, or ice.
    c. Materials shall comply with applicable specifications (PennDOT or AASHTO, latest edition)

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BMP 6.6.3: Dry Extended Detention Basin



A dry extended detention basin is an earthen structure constructed either by impoundment of a natural depression or excavation of existing soil, that provides temporary storage of runoff and functions hydraulically to attenuate stormwater runoff peaks. The dry detention basin, as constructed in countless locations since the mid-1970's and representing the primary BMP measure until now, has served to control the peak rate of runoff, although some water quality benefit accrued by settlement of the larger particulate fraction of suspended solids. This extended version is intended to enhance this mechanism in order to maximize water quality benefits.

The basin outlet structure must be designed to detain runoff from the stormwater quality design storm for extended periods. Some volume reduction is also achieved in a dry basin through initial saturation of the soil mantle (even when compacted) and some evaporation takes place during detention. The net volume reduction for design storms is minimal, especially if the precedent soil moisture is assumed as in other volume reduction BMPs.

Key Design Elements

- Evaluation of the device chosen should be balanced with cost
- Hydraulic capacity controls effectiveness
- Ideal in combination with other BMPs
- Regular maintenance is necessary including periodic sediment removal

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low
Recharge: None
Peak Rate Control: High
Water Quality: Low

Water Quality Functions

TSS: 60%
TP: 40%
NO3: 20%

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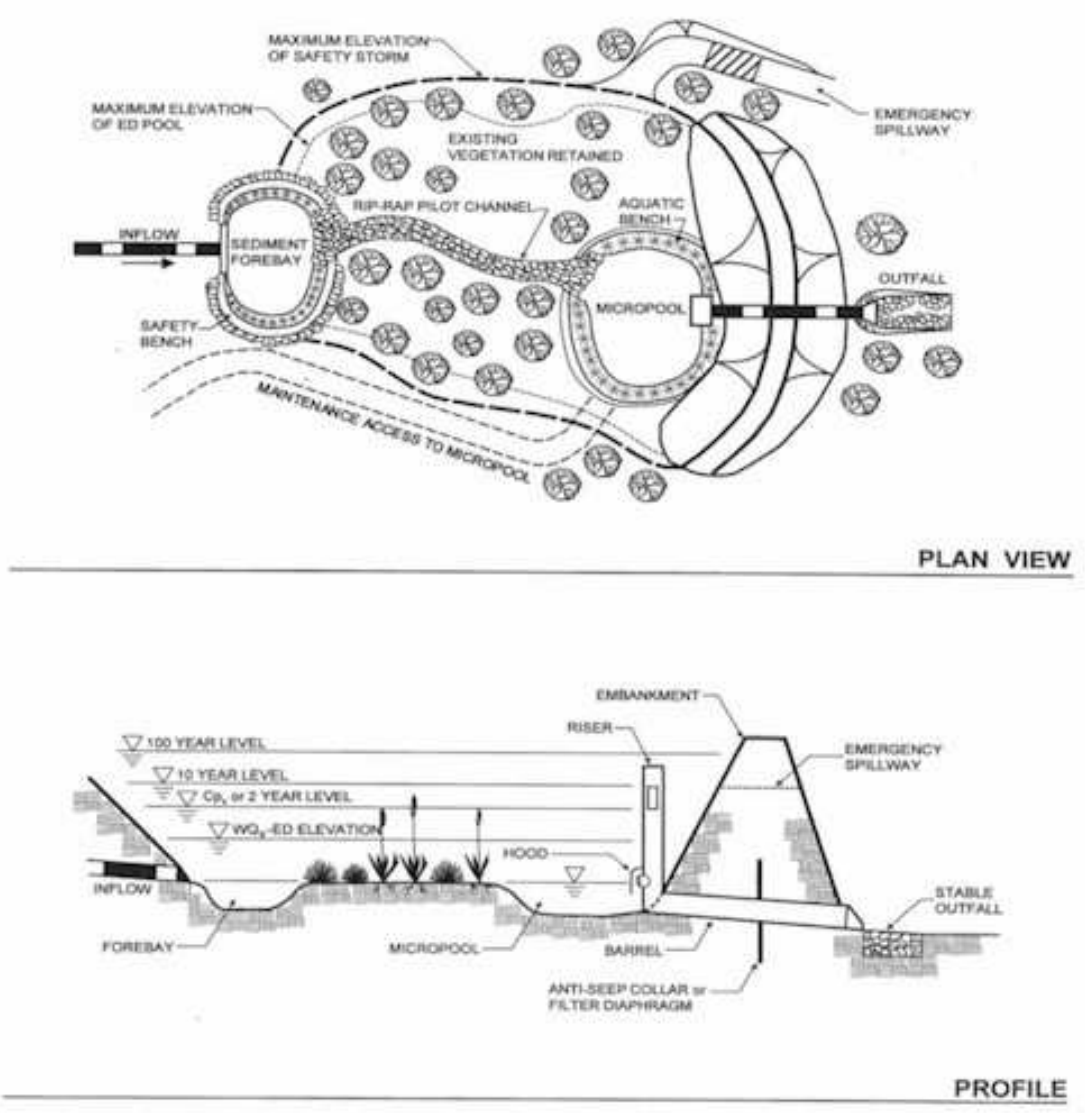
Description

Dry extended detention basins are surface stormwater structures which provide for the temporary storage of stormwater runoff to prevent downstream flooding impacts. Water quality benefits may be achieved with extended detention of the runoff volume from the water quality design storm.

- The primary purpose of the detention basin is the attenuation of stormwater runoff peaks.
    - Detention basins should be designed to control runoff peak flow rates of discharge for the 1 year through 100 year events.
    - Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event.



- Basins should be designed to provide water quality treatment storage to capture the computed runoff volume of the water quality design storm.
    - Detention basins should have a sediment forebay or equivalent upstream pretreatment. The forebay should consist of a separate cell that is offline (so as to not resuspend sediment, formed by an acceptable barrier and will need periodic sediment removal.

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- A micropool storage area should be designed where feasible for the extended detention of runoff volume from the water quality design storm.
- Flow paths from inflow points to outlets should be maximized.

Variations

Sub-surface extended detention

Extended detention storage can also be provided in a variety of sub-surface structural elements, such as underground vaults, tanks, large pipes or other structural media placed in an aggregate filled bed in the soil mantle. All such systems are designed to provide runoff peak rate mitigation as their primary function, but some pollutant removal may be included. Regular maintenance is needed, since the structure must be drained within a design period and cleaned to assure detention capacity for subsequent rainfall events. These facilities are usually intended for space-limited applications and are not intended to provide significant water quality treatment.

- Underground vaults are typically box shaped underground stormwater storage facilities constructed of reinforced concrete, while tanks are usually constructed of large diameter metal or plastic pipe. They may be situated within a building, but the use of internal space is frequently not cost beneficial.
    - Storage design and routing methods are the same as for surface detention basins.
    - Underground vaults and tanks do not provide water quality treatment and should be used in combination with a pretreatment BMP.

- Underground detention beds can be constructed by excavating a subsurface area and filling with uniformly graded aggregate for support of overlying land uses.
    - This approach may be used where space is limited but subsurface infiltration is not feasible due to high water table conditions or shallow soil mantle.
    - As with detention vaults and tanks, this facility provides minimal water quality treatment and should be used in combination with a pretreatment BMP.
    - It is recommended that underground detention facilities not be lined to allow for even minimal infiltration, except in the case where toxic contamination is possible.

Applications

- **Low Density Residential Development**
- **Industrial Development**
- **Commercial Development**
- **Urban Areas**

Design Considerations

1. **Storage Volume, Depth and Duration**

    a. Extended detention basins should be designed to mitigate runoff peak flow .rates.b. An emergency outlet or spillway which is capable of conveying the spillway design flood (SDF) should be included in the design. The SDF is usually equal to the 100-year design flood
    c. Extended detention basins should be designed to treat the runoff volume produced by the water quality design storm.

d. Extended Detention Basins are designed to achieve a specified detention time. Details on the detention time are outlined in Chapter 3.
e. The lowest elevation within an extended dry detention basin should be at least 2 feet above the seasonal high water table. If high water table conditions are anticipated, then the design of a wet pond, constructed wetland or bioretention facility should be considered.

2. **Dry Extended Detention Basin Location**

a. Extended detention basins should be located down gradient of disturbed or developed areas on the site. The basin should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.).
b. Extended detention basins should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
c. Extended detention basins should not worsen the runoff potential of the existing site by removal of trees for the purpose of installing a basin.
d. Extended detention basins should not be constructed in areas with high quality and/or well draining soils, which are adequate for the installation of BMPs capable of achieving stormwater infiltration.
e. Extended detention basins should not be constructed within jurisdictional waters, including wetlands.

3. **Basin Sizing and Configuration**

a. Basins should be shaped to maximize the length of stormwater flow pathways and minimize short-circuited inlet-outlet systems. Basins should have a minimum width of 10 feet. A minimum length-to-width ratio of 2:1 is recommended to maximize sedimentation.
b. Irregularly shaped basins are encouraged and appear more natural.
c. If site conditions inhibit construction of a long, narrow basin, baffles constructed from earthen berms or other materials can be incorporated into the pond design to "lengthen" the stormwater flow path. Care should be taken to ensure the design storage capacity is provided after baffle installation.
d. Low flow channels, if required, should always be vegetated with a maximum slope of 3 percent to encourage sedimentation. Alternatively, other BMPs may be considered such as wet ponds, constructed wetlands or bioretention.

4. **Embankments**

a. Embankments should be less than 15 feet in height and should have side slopes no steeper than 3:1 (H:V).
b. The basin should have a minimum freeboard of 1 foot above the SDF elevation.

5. **Inlet Structures**

a. Inlet structures to basin should not be submerged at the normal pool depth.
b. Erosion protection measures should be utilized to stabilize inflow structures and channels.

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6. **Outlet Design**

a. In order to meet designs storm requirements, dry extended detention basins should have a multistage outlet structure. Three elements are typically included in this design:
    1. A low-flow outlet that controls the extended detention and functions to slowly release the water quality design storm.
    2. A primary outlet that functions to attenuate the peak of larger design storms.
    3. An emergency overflow outlet/spillway
b. The primary outlet structure should incorporate weirs, orifices, pipes or a combination of these to control runoff peak rates for required design storms. Water quality storage should be provided below the invert of the primary outlet. When routing basins, the low-flow outlet should be included in the depth-discharge relationship.
c. Energy dissipaters are to be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.
d. The orifice should typically be no smaller than 2.5 inches in diameter. However, the orifice diameter may be reduced to 1 inch if adequate protection from clogging is provided.
e. The hydraulic design of all outlet structures should consider any tailwater effects of downstream waterways.
f. The primary and low flow outlet should be protected from clogging by an external trash rack.

7. **Sediment Forebay**

a. Forebays should be incorporated into the extended detention design. The forebay storage volume is included for the water quality volume requirement.
b. Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays are typically constructed as shallow marsh areas and should adhere to the following design criteria:
    1. It is recommended that forebays have a minimum length of 10 feet.
    2. Storage should be provided to trap the anticipated sediment volume produced over a period of 2 years.
    3. Forebays should be protected from the erosive force of the inflow to prevent resuspension of previously collected sediment during large storms (typically constructed offline).



8. **Vegetation and Soils Protection**
    a. Care should be taken to prevent compaction of in situ soils in the bottom of the extended detention basin in order to promote healthy plant growth and to encourage infiltration. If soils compaction is not prevented during construction, soils should be restored as discussed in BMP 6.7.3 – Soils Amendment & Restoration.
    b. It is recommended that basin bottoms be vegetated in a diverse native planting mix to reduce maintenance needs, promote natural landscapes, and increase infiltration potential. Vegetation may include trees, woody shrubs and meadow/wetland herbaceous plants.
    c. Woody vegetation should not be planted on the embankments or within 25 feet of the emergency overflow spillway.
    d. Meadow grasses or other deeply rooted herbaceous vegetation is recommended on the interior slope of embankments.
    e. Fertilizers and pesticides should not be used.

9. **Special Design Considerations**
    a. Ponds that have embankments higher than 15 feet, have a drainage of more than 100 acres or will impound more that 50 acre-feet of runoff during the high-water condition will be regulated as dams by PADEP. The designer shall consult Pennsylvania Chapter 105 to determine which provisions may apply to the specific project in question.
    b. Extended detention ponds should not be utilized as recreation areas due to health and safety issues. Design features that discourage access are recommended.

Detailed Stormwater Functions

Peak Rate Mitigation

Inflow and discharge hydrographs should be calculated and routed for each design storm. Hydrographs should be based on a 24-hour rainfall event.

Water Quality Improvement

Water quality mitigation is partially achieved by retaining the runoff volume from the water quality design storm for a minimum prescribed period as specified in Chapter 3. Sediment forebays should be incorporated into the design to improve sediment removal. The storage volume of the forebay may be included in the calculated storage of the water quality design volume.

Construction Sequence

1. Install all temporary erosion and sedimentation controls.
    a. The area immediately adjacent to the basin must be stabilized in accordance with the PADEP's *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) prior to basin construction.
2. Prepare site for excavation and/or embankment construction.
    a. All existing vegetation should remain if feasible and should only be removed if necessary for construction.
    b. Care should be taken to prevent compaction of the basin bottom.
    c. If excavation is required, clear the area to be excavated of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area
3. Excavate bottom of basin to desired elevation (if necessary).
4. Install surrounding embankments and inlet and outlet control structures.
5. Grade subsoil in bottom of basin, taking care to prevent compaction. Compact surrounding embankment areas and around inlet and outlet structures.
6. Apply and grade planting soil.
7. Apply geo-textiles and other erosion-control measures.
8. Seed, plant and mulch according to Planting Plan
9. Install any anti-grazing measures, if necessary.

Maintenance Issues

Maintenance is necessary to ensure proper functionality of the extended detention basin and should take place on a quarterly basis. A basin maintenance plan should be developed which includes the following measures:

- All basin structures expected to receive and/or trap debris and sediment should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than 1 inch.
    - Structures include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment removal should be conducted when the basin is completely dry. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and revegetated.
- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus should be removed from the basin.
    - Vegetated areas should be inspected annually for erosion.
    - Vegetated areas should be inspected annually for unwanted growth of exotic/invasive species.
    - Vegetative cover should be maintained at a minimum of 95 percent. If vegetative cover has been reduced by 10%, vegetation should be reestablished.

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Cost Issues

The construction costs associated with dry extended detention basins can range considerably. One recent study evaluated the cost of all pond systems (Brown and Schueler, 1997). Before adjusting for inflation from 1997, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

Where:

C = Construction, Design and Permitting Cost
V = Volume needed to control the 10-year storm (cubic feet)
Using this equation, a typical construction costs (1997) are:
$ 41,600 for a 1 acre-foot pond
$ 239,000 for a 10 acre-foot pond
$ 1,380,000 for a 100 acre-foot pond

Dry extended detention basins utilizing highly structural design features (rip-rap for erosion control, etc.) are more costly than naturalized basins. There is an installation cost savings associated with a natural vegetated slope treatment which is magnified by the additional environmental benefits provided. Long-term maintenance costs are reduced when more naturalized approaches are utilized due to the ability of native vegetation to adapt to local weather conditions and a reduced need for maintenance, such as mowing and fertilization.

Normal maintenance costs can be expected to range form 3 to 5 percent of the construction costs on an annual basis.

These costs don't include the cost or value of the property.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Site Preparation**
    a. All excavation areas, embankments, and where structures are to be installed shall be cleared and grubbed as necessary, but trees and existing vegetation should be retained and incorporated within the dry detention basin area where possible.
    b. Where feasible, trees and other native vegetation should be protected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow construction.
    c. Any cleared material should be used as mulch for erosion control or soil stabilization.
    d. Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

2. **Earth Fill Material & Placement**
    a. The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than 6 inches, or other

objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.

b. Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum 8-inch lifts. The principal spillway should be installed concurrently with fill placement and not excavated into the embankment.

c. The movement of the hauling and spreading equipment over the site should be controlled. For the embankment, each lift should be compacted to 95% of the standard proctor. Fill material should contain sufficient moisture so that if formed in to a ball it will not crumble, yet not be so wet that water can be squeezed out.

3. **Embankment Core**

a. The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1 to 1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.

4. **Structure Backfill**

a. Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.

b. Structure backfill may be flowable fill meeting the requirements of the PADOT Standard Specifications for Construction. Material should be placed so that a minimum of 6 inches of flowable fill should be under (bedding), over and, on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits. Average slump of the fill material should be 7 inches to assure flowability of the mixture. Adequate measures should be taken (sand bags, etc.) to prevent floating the pipe. When using flowable fill all metal pipe should be bituminous coated. Adjoining soil fill should be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment.

c. Refer to Chapter 220 0f PennDot Pub. 408 (2000).

5. **Rock Riprap**

a. Rock riprap should meet the requirements of Pennsylvania Department of Transportation Standard Specifications.

6. **Stabilization**

a. All borrow areas should be graded to provide proper drainage and left in a sightly condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms should be stabilized by seeding, planting and mulching.

7. **Operation and Maintenance**

a. An operation and maintenance plan in accordance with Local or State Regulations will be prepared for all basins. As a minimum, a dam and inspection checklist should be included as part of the operation and maintenance plan and performed at least annually.

References

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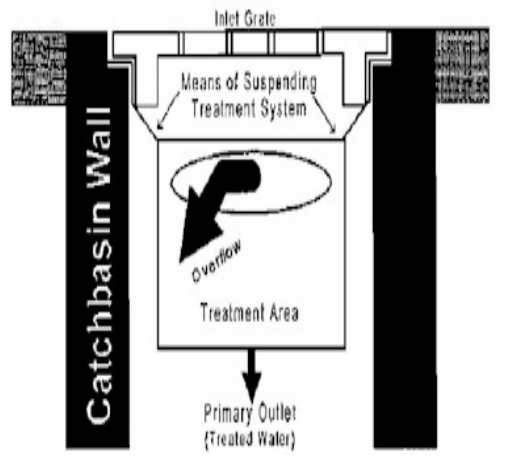
BMP 6.6.4: Water Quality Filters & Hydrodynamic Devices



A broad spectrum of BMPs have been designed to remove non point source pollutants from runoff as a part of the runoff conveyance system. These structural BMPs vary in size and function, but all utilize some form of settling and filtration to remove particulate pollutants from stormwater runoff, a difficult task given the concentrations and flow rates experienced. Regular maintenance is critical for this BMP. Many water quality filters, catch basin inserts and hydrodynamic devices are commercially available. They are generally configured to remove particulate contaminants, including coarse sediment, oil and grease, litter, and debris.

Key Design Elements

- Choose a device that (collectively) has the hydraulic capacity to treat the design storm
- Evaluation of the device chosen should be balanced with cost
- Hydraulic capacity controls effectiveness
- Most useful in small drainage areas (< 1 Acre)
- Ideal in combination with other BMPs
- Regular maintenance is necessary

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: None
Recharge: None
Peak Rate Control: None
Water Quality: Medium

Water Quality Functions

TSS: 60%
TP: 50%
NO3: 20%

Other Considerations

- See Manufacturers specifications for estimated pollutant removal efficiencies.

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Description

Water Quality Inlets are stormwater inlets that have been fitted with a proprietary product (or the proprietary product replaces the catch basin itself). They are designed to reduce large sediment, suspended solids, oil and grease, and other pollutants, especially pollutants conveyed with sediment transport. They can provide "hotspot" control and reduce sediments loads to infiltration devices. They are commonly used as pretreatment for other BMPs. The manufacturer usually provides the mechanical design, construction, and installation instructions. Selection of the most appropriate device and development of a maintenance plan should be carefully considered by the Designer.

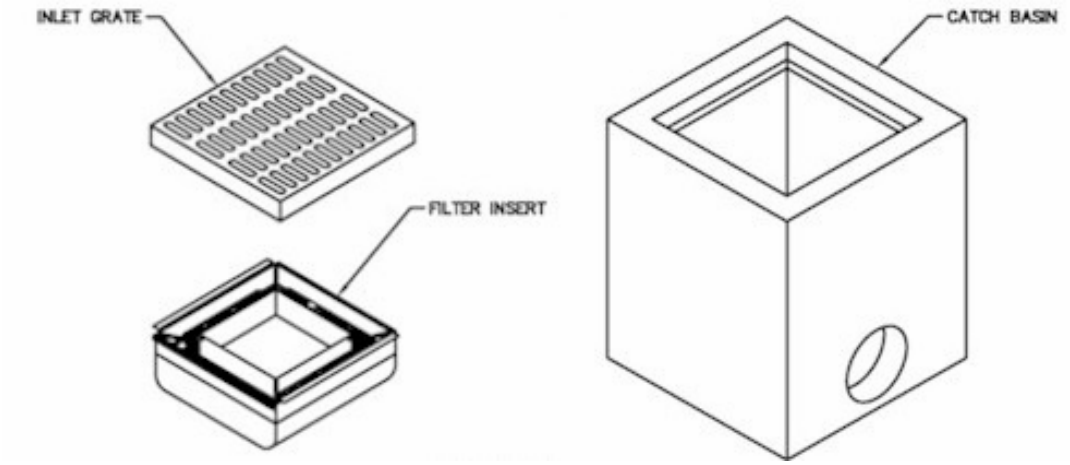
The size of a water quality inlet limits the detention time and the hydraulic capacity influences the effectiveness of the water quality insert. Most products are designed for an overflow in large storm events, which is necessary hydraulically and still allows for a "first flush" treatment.

Regular maintenance according to application and manufacturer's recommendations is essential for continued performance.

Variations

Tray types

Allows flow to pass through filter media that is contained in a tray located around the perimeter of the inlet. Runoff enters the tray and leaves via weir flow under design conditions. High flows pass over the tray and into the inlet unimpeded.



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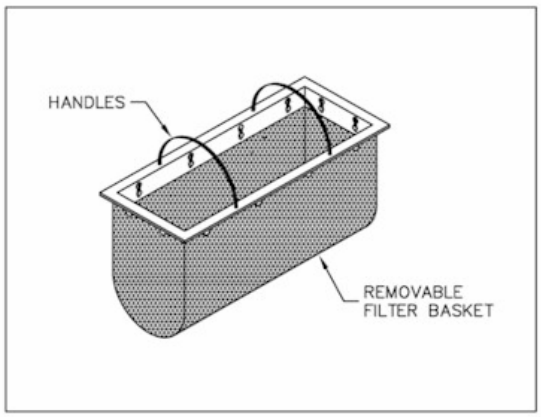
Bag types

Insert is made of fabric and is placed in the drain inlet around the perimeter of the grate. Runoff passes through the bag before discharging into the drain outlet pipe. Overflow holes are usually provided to pass larger flows without causing a backwater at the grate. Certain manufactured products include polymers intended to increase pollutant removal effectiveness.





Basket types

The insert consists of “basket type” insert that sets into the inlet and has a handle to remove basket for maintenance. Small orifices allow small storm events to weep through, while larger storms overflow the basket. Primarily useful for debris and larger sediment, and requires consistent and frequent maintenance.



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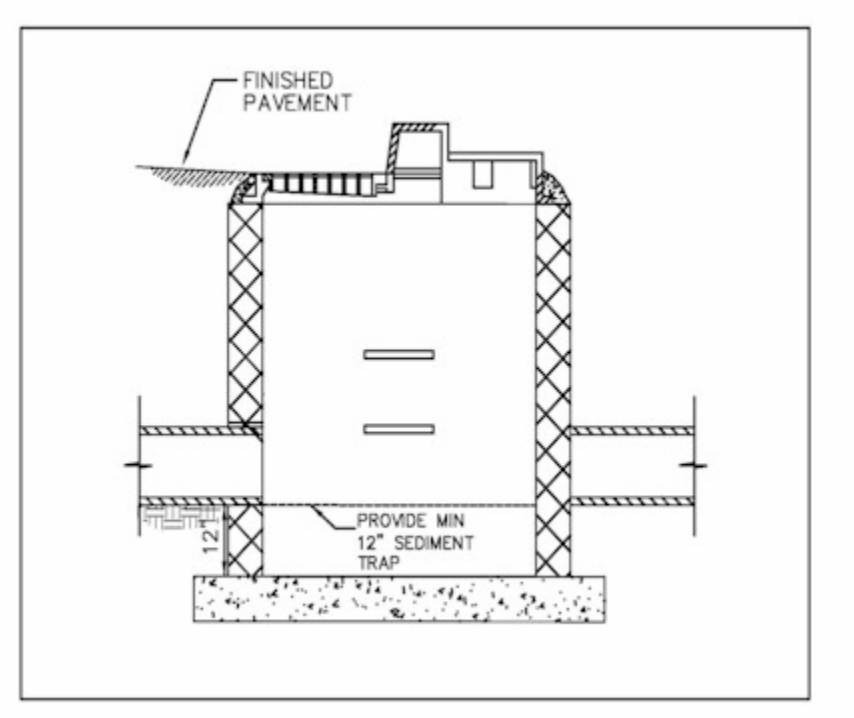
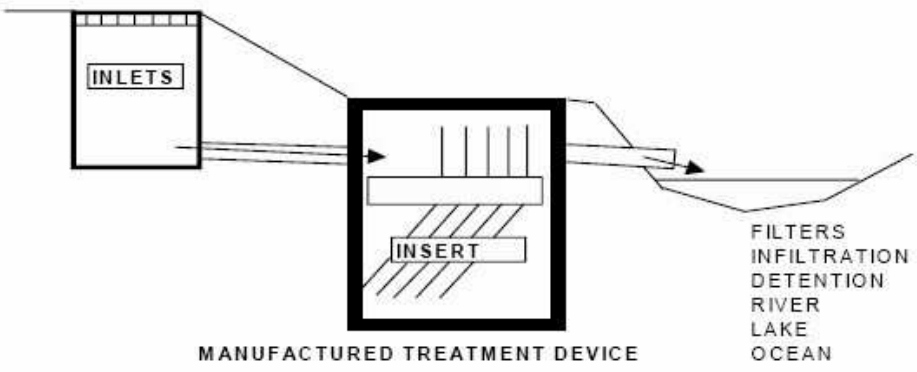
Simple, "sumps" in inlets

Space created in inlets below the invert of the pipes for sediment and debris to deposit, usually leaving 6-inches to 12-inches at the bottom of an inlet. Small weep holes should be drilled into the bottom of the inlet to prevent standing water for long periods of time. Regular maintenance is required.



Description - Hydrodynamic Devices

Hydrodynamic Devices are not truly inserts, but separate flow through devices designed to serve in concert with inlets and storm sewer. A variety of products are available from different manufacturers. The primary purpose is to use various methods to remove sediments and pollutants. These methods include baffle plate design, vortex design, tube settler design, inclined plate settler design or a combination of these. Ideally, the flow through device should remove litter, oil, sediment, heavy metals, dissolved solids and nutrients. Removal ability varies as a result of loading rate and design. Clays and fine silts do not easily settle out unless they are coagulated with some kind of chemical addition or polymer. These devices work most effectively in combination with other BMPs, either as a pre-treatment or as a final treatment at the end of a pipe.



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Applications

Any existing or proposed inlet where the contributing runoff may contain significant levels of sediment and debris, for example: parking lots, gas stations, golf courses, streets, driveways, industrial or commercial facilities, and municipal corporation yards. Commonly used as pretreatment before other stormwater BMPs.

Design Considerations

1. Match site considerations with manufacturer's guidelines/specifications (i.e. land use will determine specific pollutants to be removed from runoff).

2. Prevent re-suspension of particles by using small drainage areas and good maintenance.

3. Retrofits should be designed to fit existing inlets.

4. Placement should be accessible to maintenance.

5. If used as part of Erosion & Sedimentation Control during construction, insert should be reconfigured (if necessary) per manufacture's guidelines.

6. Overflow should be designed so that storms in excess of the device's hydraulic capacity bypass the treatment and is treated by another quality BMP.

Detailed Stormwater Functions

Volume Reduction Calculations
N/A

Peak Rate Mitigation Calculations
N/A

Water Quality Improvement
See manufacturers specifications and tests.

Construction Sequence

1. Stabilize all contributing areas before installing and connecting pipes to these inlets.

2. Follow manufacturer's guidelines for installation. Do not use water quality inserts during construction unless product is designed primarily for sediment removal. (Some products have adsorption components that should be installed post-construction.)

Maintenance Issues

Follow the manufacturer's guidelines for maintenance, also taking into account expected pollutant load and site conditions. Inlets should be inspected weekly during construction. Post-construction, they should be emptied when over half full of sediment (and trash) and cleaned at least twice a year. They

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should also be inspected after runoff events. Maintenance is crucial to the effectiveness of this BMP. The more frequent a water quality insert is cleaned, the more effective it will be. One study (Pitt, 1985) found that WQI's can store sediment up to 60% of its sump volume, and after that, the inflow resuspends the sediments into the stormwater. Some sites have found keeping a log of sediment amount date removed helpful in planning a maintenance schedule. Environmental Technology Verification (ETV) Program and the Technology Acceptance and Reciprocity Partnership (TARP) may be available to assist with the development of a monitoring plan. These programs are detailed in Section 6.3.



Disposal of removed material will depend on the nature of the drainage area and the intent and function of the water quality insert. Material removed from water quality inserts that serve "Hot Spots" such as fueling stations or that receive a large amount of debris should be handling according to DEP regulations for that type of solid waste, such as a landfill that is approved by DEP to accept solid waste. Water quality inserts that primarily catch sediment and detritus from areas such as lawns may reuse the waste on site.

Vactor trucks may be an efficient cleaning mechanism.

Winter Concerns: There is limited data studying cold weather effects on water quality insert effectiveness. Freezing may result in more runoff bypassing the treatment system. Salt stratification may also reduce detention time. Colder temperatures reduce the settling velocity of particles, which can result in fewer particles being "trapped". Salt and sand are significantly increased in the winter, and may warrant more frequent maintenance. Sometimes freezing makes accessing devices for maintenance difficult

Cost Issues

Check with manufacturers for current prices.

Specifications

Follow manufacturer's instructions and specific specifications.

References

Brzozowski, C., 2003. "Inlet Protection – Strategies for Preserving Water Quality," Stormwater magazine.

Lee, F. "The Right BMPs? Another Look at Water Quality." Stormwater magazine.

New Hampshire Watershed Management Bureau, Watershed Assistance Section, 2002. "Innovative Stormwater Treatment Technologies BMP Manual."

Pitt, R. *Characterizing and Controling Urban Runoff through Street and Sewerage Cleaning.* US EPA, June 1985.

6.7 Restoration BMPs

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BMP 6.7.1: Riparian Buffer Restoration



A riparian buffer is a permanent area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands. Riparian forests are the most beneficial type of buffer for they provide ecological and water quality benefits. Restoration of this ecologically sensitive habitat is a responsive action to past activities that may have eliminated any vegetation.

Key Design Elements

- Reestablish buffer areas along perennial, intermittent, and ephemeral streams
- Plant native, diverse tree and shrub vegetation
- Buffer width is dependant on project preferred function (water quality, habitat creation, etc.)
- Minimum recommended buffer width is 35' from top of stream bank, with 100' preferred.
- Create a short-term maintenance and long-term maintenance plan
- Mature forest as a vegetative target
- Clear, well-marked boundary

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Medium
Recharge: Medium
Peak Rate Control: Low/Med.
Water Quality: Med./High

Water Quality Functions

TSS: 65%
TP: 50%
NO3: 50%

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Description

The USDA Forest Service estimates that over one-third of the rivers and streams in Pennsylvania have had their riparian areas degraded or altered. This fact is sobering when one considers the important stormwater functions that riparian buffers provide. The non-structural BMP, Riparian Forest Buffer Protection, addresses the importance of protecting the three-zone system of existing riparian buffers.

The values of riparian buffers – economic, environmental, recreational, aesthetic, etc. – are well documented in scientific literature and numerous reports and thus will not be restated here in this BMP sheet. Rather, this BMP serves to provide a starting point for the designer that seeks to restore the riparian buffer. Important reports are cited consistently throughout this section and should be mentioned upfront as sources for additional information to a designer seeking to restore a riparian buffer. The first, the *Chesapeake Bay Riparian Handbook: a Guide for Establishing and Maintaining Riparian Forest Buffers* was prepared by the US Department of Agriculture (USDA) Forest Service for the Chesapeake Bay Program in 1997. The second, the *Pennsylvania Stream ReLeaf Forest Buffer Toolkit* was developed by the Alliance for the Chesapeake Bay specifically for the Pennsylvania streams in 1998. A third and often-referenced report, is the *Riparian Forest Buffers* series written by Robert Tjaden for the Maryland Cooperative Extension Service in 1998.

Riparian buffers are scientifically proven to provide a number of economic and environmental values. Buffers are characterized by high species density, high species diversity, and high bio-productivity as a transition between aquatic and upland environments. Project designers should take into account the benefits or services provided by the buffer and apply these to their project goals. Priorities for riparian buffer use should be established early on in the planning stages. Some important considerations when establishing priorities are:

- **Habitat** – Restoring a buffer for habitat enhancement will require a different restoration strategy than for restoring a buffer for increased water quality.
- **Stream Size** – A majority of Pennsylvania's stream miles is comprised of small streams (first, second, and third order), which may be priority areas to reduce nutrients. Establishing riparian buffers along these headwater streams will reduce the high nutrient loads relative to flow volumes typical of small streams.
- **Continuous Buffers** - Establishing continuous riparian forest buffers in the landscape should be given a higher priority than establishing larger but fragmented buffers. Continuous buffers provide better stream shading and water quality protection, as well as corridors for the movement of wildlife.
- **Degree of Degradation** – Urban streams are usually buried or piped. Streams in areas without forests, such as pastures, may benefit the most from buffer restoration, as sources of headwater streams. Highly urbanized/altered streams may not be able to provide high levels of pollution control.
- **Loading Rates** - The removal of pollutants may be highest where nutrient and sediment loading are the highest.
- **Land Use** – Adjacent land uses will influence Buffer Width and Vegetation types used to establish a riparian buffer. While the three-zone riparian-forested buffers described earlier are the ideal, they may not always be feasible to establish, especially in urban situations.

Preparation of a *Riparian Buffer Restoration Plan* is critical to ensuring long-term success of the project and should be completed before any planting is to occur. It is essential that site conditions are well understood, objectives of the landowner are considered, and the appropriate plants chosen for the site, tasks that are completed in the planning stages. Below is a summary of the nine steps that are recommended for the planning stages of a buffer restoration project.

1. Obtain Landowner Permission and Support

Landowner commitment is essential for the success of the project. Landowners must be aware of all maintenance activities that will occur once buffer is planted.

2. Make Sure Site is Suitable for Restoration

If streambanks are extensively eroded, consider an alternative location. Rapidly eroding streambanks may undermine seedlings. Streambank restoration may need to occur prior to riparian buffer restoration. Obtain professional help in evaluating the need for streambank restoration.

3. Analyze Site's Physical Conditions

The most important physical influence of the site is the soil, which will control plant selection. Evaluate the soil using the County soil survey book to determine important soil characteristics such as flooding potential, seasonal high water table, topography, soil pH, soil moisture, etc. Also, a simple field test can suffice, with direct observation of soil conditions.

4. Analyze Site's Vegetative Features

Existing vegetation present at the restoration site should be examined to determine the strategy for buffer establishment. Strategies will differ for various pre-restoration conditions such as pasture, overgrown abandoned field, mid-succession forest, etc.

- *Identify Desirable Species*: Native tree and shrub species that thrive in riparian habitats in Pennsylvania should be used. These species should be identified in the restoration site and protected for their seed bank potential. Several native vines and shrubs (blackberry, Virginia creeper, and spicebush) can provide an effective ground cover during establishment of the buffer, though they should be selectively controlled to minimize herbaceous competition.
- *Identify Undesirable Species:* Consider utilizing undesirable species such as the black locust for their shade function during buffer establishment. Consider controlling invasive plants prior to buffer planting.
- *Identify Sensitive Species*: Since riparian zones are rich in wildlife habitat and wetland plant species to be aware of any rare, threatened or endangered plant (or animal) species.

5. Draw a Map of the Site (Data collection)

Prepare a sketch of the site that denotes important existing features, including stream width, length, streambank condition, adjacent land uses and stream activities, desired width of buffer, discharge pipes, obstructions, etc.

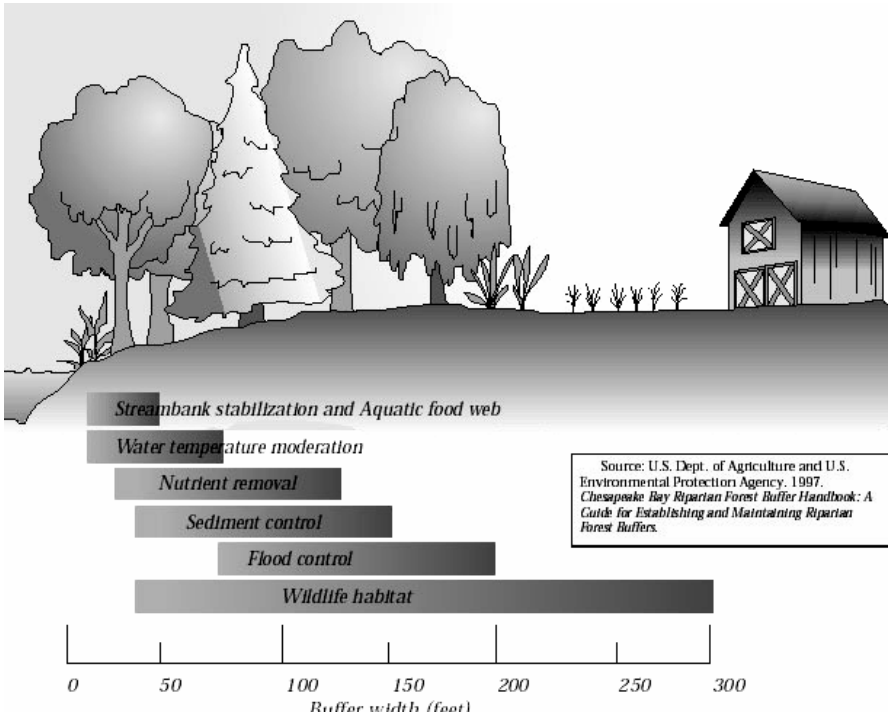
6. Create a Design that Meets Multiple Objectives

Ideally, the three-zone system should be incorporated into the design, in a flexible manner to obtain water quality and landowner objectives.

- *Consider landowner objectives*: Consider the current use of the buffer by the landowner, especially if the buffer will be protected in perpetuity. Consider linking the buffer to an existing (or planned trail system).
- *Buffer width*: Riparian buffer areas do not have a fixed linear boundary, but vary in shape, width, and vegetative type and character. The function of the buffer (habitat, water quality, etc) is the overriding criterion in determining buffer width (Figure 1). Many factors including slope, soil type, adjacent land uses, floodplain, vegetative type, and

water shed condition influence what can be planted. The most commonly approved minimum buffer widths for water quality and habitat maintenance are 35 –100 feet. Buffers less than 35 feet do not protect aquatic resources long term.

Figure 1



- *Consider costs:* The planting design (density, type, mix, etc.) will ultimately be based on the financial constraints of the project. See discussion below for estimating direct costs for planting and maintenance.
- *Choose the appropriate plants:* This manual encourages the use of native plants in stormwater management facilities. Since they are best suited to our local climate, native species have distinct genetic advantages over non-native species. Ultimately using native plants translates into greater survivorship with less replacement and maintenance which is a cost benefit to the landowner. Please refer to the plant list in Appendix B for a comprehensive list of native trees and shrubs available for stormwater management facility planting.

Plant Size: Choice of planting stock (seeds, container seedling, bare-root seedlings, plugs, etc.) is ultimately determined by funding resources. Larger material will generally cost more, although it will usually establish more rapidly.

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7. Draw a Planting Plan

Planting Density: Trees should be planted at a density sufficient to provide 320 trees per acre at maturity. To achieve this density, approximately 436 (10 x 10 feet spacing) to 681 (8 x 8 feet spacing) trees per acre should be planted initially. Some rules of thumb for tree spacing and density based on plant size at installation:

Seedlings	6-10 feet spacing (~700 seedlings / acre)
Bare Root Stock	14-16 feet spacing (~200 plants / acre)
Larger & Container	16 – 18 feet spacing (~150 plants/acre)

Formula for Estimating Number of Trees and Shrubs:
Plants = length x width of corridor (ft) / 50 square feet

This formula assumes each tree will occupy an average of 50 sq. ft., random placement of plants approximately 10 feet apart, and mortality rate of up to 40% that can be absorbed by the growing forest system.

Alternatively, the adjacent table can be utilized to estimate the number of trees per acre needed for various methods of spacing.

Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)
2x2	10,890	7x9	691	12x15	242
3x3	4,840	7x10	622	12x18	202
4x4	2,722	7x12	519	12x20	182
4x5	2,178	7x15	415	12x25	145
4x6	1,815	8x8	681	13x13	258
4x7	1,556	8x9	605	13x15	223
4x8	1,361	8x10	544	13x20	168
4x9	1,210	8x12	454	13x25	134
4x10	1,089	8x15	363	14x14	222
5x5	1,742	8x25	218	14x15	207
5x6	1,452	9x9	538	14x20	156
5x7	1,245	9x10	484	14x25	124
5x8	1,089	9x12	403	15x15	194
5x9	968	9x15	323	15x20	145
5x10	871	10x10	436	15x25	116
6x6	1,210	10x12	363	16x16	170
6x7	1,037	10x15	290	16x20	136
6x8	908	10x18	242	16x25	109
6x9	807	11x11	360	18x18	134
6x10	726	11x12	330	18x20	121
6x12	605	11x15	264	18x25	97
6x15	484	11x20	198	20x20	109
7x7	889	11x25	158	20x25	87
7x8	778	12x12	302	25x25	70

Planting Layout: Given planting density and mix, drawing the planting plan is fairly straightforward. The plan can vary from a highly technical drawn to scale plan, or a simple line drawing of the site. Any plan must show the site with areas denoted for trees and shrub species with notes for plant spacing and buffer width.

8. Prepare Site Ahead of Time

Existing site conditions will determine the degree of preparation needed prior to planting. Invasive infestation and vegetative competition are extremely variable, and therefore must be considered in the planning stages. Site preparation should begin in the fall prior to planting. Enlist professional to determine whether use of chemical controls are necessary to prepare site for planting. Eliminate undesired species with either herbicide application (consult a professional) or physical removal. If utilizing a highly designed planting layout, mark site ahead of time with flags, spray paint, or other markers so that the appropriate plant is put in the right place.

9. Determine Maintenance Needs

An effective buffer restoration project should include management and maintenance guidelines, including a description of the allowable uses in the various zones of the buffer. Buffer

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boundaries should be well defined with clear signs or markers. Weed control is essential for the survival and rapid growth of trees and shrubs, and can include any of the following:

- Organic mulch
- Weed control fabrics
- Shallow cultivation
- Pre-emergent herbicides
- Mowing

Non-chemical weed control methods are preferred since chemicals can easily enter the water system. If possible, avoid working in the riparian area between April 15 and August 15, the mating and newborn period for local wildlife.

Variations

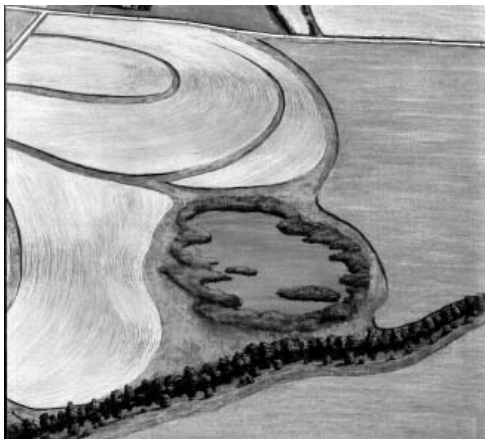
See Applications

Applications

- **Forested Landscape**



- **Agricultural Landscape**



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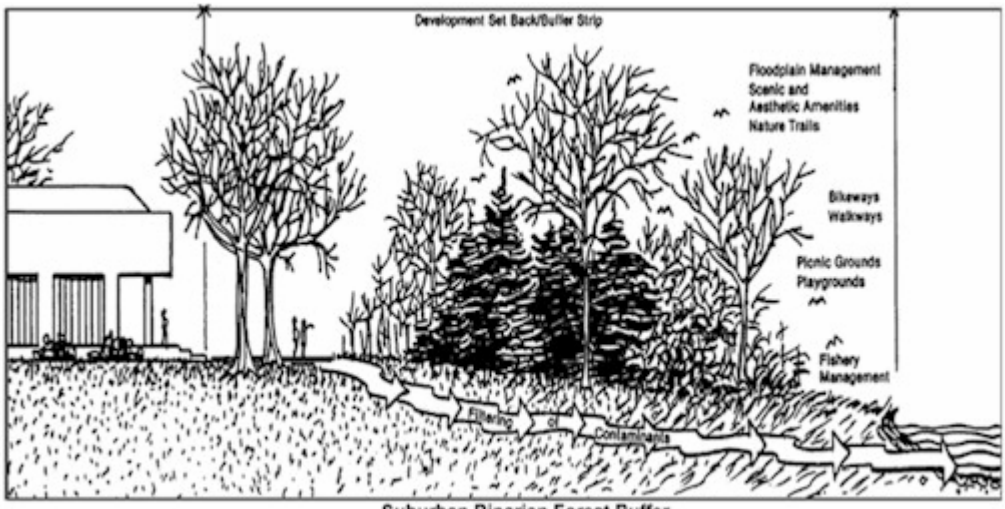
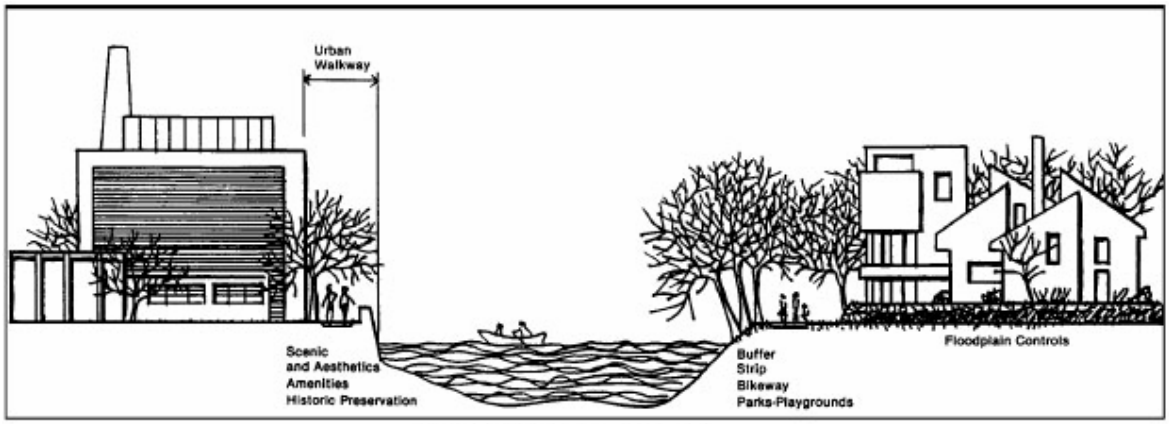
- **Suburban / Developing Landscape**



Suburban Riparian Forest Buffer

- **Urban Landscape**





Urban Riparian Forest Buffer

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Design Considerations

The considerations listed below should all be taken into account during the planning stage. There are many potential threats to the long-term viability of riparian plant establishment and with proper foresight, these problems can be eliminated or addressed.

1. Deer Control

    a. Look for signs of high deer densities, including an overgrazed understory with a browse line 5-6 feet above the ground.

2. Tree Shelters

    a. Recommended for riparian plantings where deer predation or human intrusion may be a problem.
    b. Plastic tubes that fit over newly planted trees that are extremely successful in protecting seedlings.
    c. Protect trees from accidental strikes from mowing or trimming
    d. Create favorable microclimate for seedlings
    e. Secure with wooden stake and place netting over top of tree tube
    f. Remove tree shelters 2 to 3 years after plants emerge

3. Stream Buffer Fencing

    a. Deer can jump fences up to 10 feet high, preferring to go under barriers.
    b. Farm animals cause greatest damage to stream banks – consider permanent fencing like high-tensile smooth wire fencing or barbed fencing.
    c. The least expensive is 8 foot plastic fencing, which are effective against deer and easily repaired.

4. Vegetation

    a. Consider using plants that are able to survive frequent or prolonged flooding conditions. Plant trees that can withstand high water table conditions. Figure 5 shows tree species that fit into the moisture conditions of a streamside area.
    b. Soil disturbance can result in unanticipated infestation by invasive plants.

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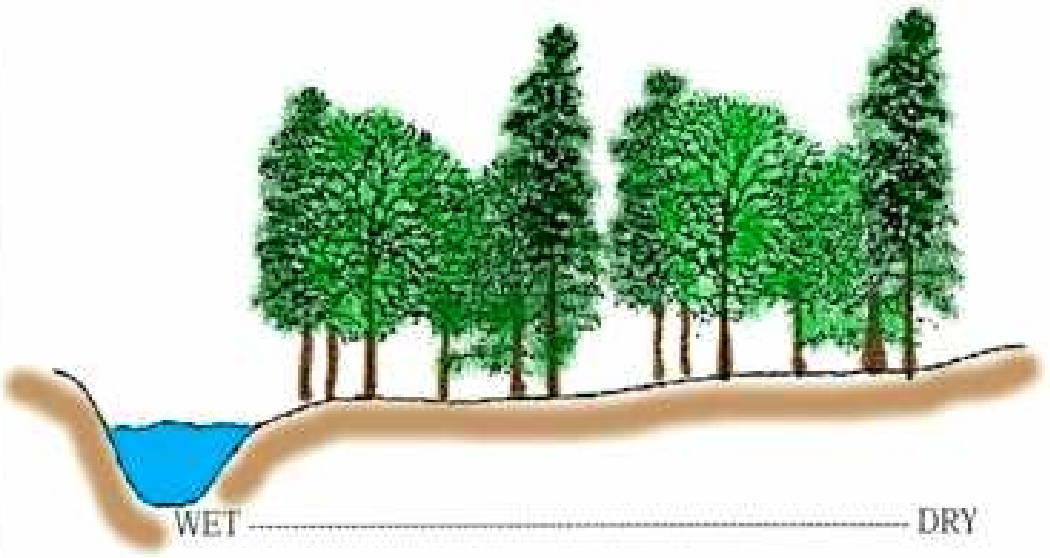
Figure 5. Sample Planting Recommendations According to Moisture Conditions



TREES

Silver Maple
Box Elder
Persimmon →
Black Ash
Red Ash
Pawpaw →
Sweet-bay Magnolia
Sycamore →
Cottonwood
Swamp White Oak
Oak,Willow →
Willow, Sandbar & Black

SMALL TREES/SHRUBS

River Birch
Smooth Alder
Chokeberry, Red
Chokeberry, Black →
Groundselbush
Dogwood, Red Osier & Silky
Summersweet →
Winterberry →
Inkberry →
Swamp Rose
Swamp Azalea
Meadowsweet →
Highbush Blueberry →
Witherod →
N. Arrowwood

TREES

← Maple, Red →
Bitternut Hickory →
← Redbud →
Hackberry →
American Beech →
← Ash, White →
← Honey Locust →
Kentucky Coffee Tree →
← Sweet-gum
Tuliptree →
Black-gum →
← Large-toothed Aspen →
← Oak, Pin →

SMALL TREES/SHRUBS

← Black/Sweet Birch →
Mountain Laurel →
← Hornbeam →
Yellow Birch →
← Shadbush (A.arborea & canadensis) →
← Dogwood, Gray & Flowering →
Fringe Tree →
American Hazelnut →
← Black Huckleberry
← Common Spicebush →
← Rosebay Rhododendron
← Southern Arrowwood
← Ninebark
← American Elder →
Bayberry →
← Highbush Cranberry →
Red Elm

TREES

White Pine
Black Cherry
Sassafras
Canada Hemlock
Oak, White
← Oak, Red
Oak, Chestnut
Hickory, Shagbark
Maple, Sugar
Black Walnut

SMALL TREES/ SHRUBS

Hop-hornbeam
Witchhazel
Staghorn Sumac
Nannyberry
Blackhaw

Arrows denote that certain species can tolerate either a wetter or drier environment.

Construction Sequence

The PA Stream ReLeaf project provides a checklist that can substitute for a construction sequence for riparian buffer restoration. A slightly modified version follows:

1. SELECT SITE

    - Confirm site is suitable for restoration
    - Obtain landowner permission

2. ANALYSE SITE

    - Evaluate site's physical conditions (soil attributes, geology, terrain)
    - Evaluate site's vegetative features (desirable and undesirable species, native species, sensitive habitats)
    - Sketch or map site feature

3. DESIGN BUFFER

    - Consider landowner objectives in creating buffer design
    - Determine desired functions of buffer in determining buffer width
    - Match plant species to site conditions (hardiness zone, moisture, soil pH)
    - Match plant Species to objectives of buffer functions (water quality, wildlife, recreation, etc.)
    - Match plant sizes to meet budget limitations
    - Develop sketch of planting plan

4. PREPARE SITE

    - Eliminate undesirable species ahead of planting date
    - Mark planting layout at the site
    - Purchase plants and planting materials (mulch, tree shelters)

5. SITE PLAN SHOULD INCLUDE:

    - Site map with marked planting zones
    - Plant species list
    - Planting directions (spacing, pattern of planting)
    - Equipment/tool list
    - Site preparation directions
    - Maintenance schedule

6. PLANTING DAY

    - Keep plants moist and shaded
    - Provide adequate number of tools
    - Document with photos of site during planting

7. SITE MAINTENANCE (additional information below)

    - Assign responsibilities watering, weeding, mowing, and maintenance
    - Monitor site regularly for growth and potential problems

Maintenance Issues

The riparian buffer is subject to many threats, including:

- Browsing
- Invasion by exotic species
- Competition for nutrients by adjacent herbaceous vegetation
- Human disturbance

Proper awareness of these issues is critical to ensure the long-term effectiveness of a restored riparian buffer.

The most critical period during buffer establishment is maintenance of the newly planted trees during canopy closure, typically the first 3 to 5 years. Ongoing maintenance practices are necessary for both small seedlings and larger plant materials. Maintenance and monitoring plans should be prepared for the specific site and caretakers need to be advised of required duties during the regular maintenance period.

Maintenance measures that should be performed regularly:

Watering

- Plantings need deep regular watering during the first growing season, either natural watering via rainfall, or planned watering, via caretaker.
- Planting in the fall increases the likelihood of sufficient rain during planting establishment.

Mulching

- Mulch will assist in moisture retention in the root zone of plantings, moderate soil temperature, provide some weed suppression, and retard evaporation
- Use coarse, organic mulch that is slow to decompose in order minimize repeat application
- Apply 2-4 inch layer, leaving air space around tree trunk to prevent fungus growth.
- Use combination of woodchips, leaves, and twigs that are stockpiled for six months to a year.

Weed control

- Weed competition limits buffer growth and survival, therefore weeds should be controlled by either herbicides, mowing, or weed mats:

    Herbicides

    This is a short-term maintenance technique (2-3 years) that is generally considered less expensive and more flexible than mowing, and will result in a quicker establishment of the buffer. Herbicide use is regulated by the PA Department of Agriculture. Proper care should be taken to ensure that proximity to water features is considered.

Mowing

Mowing controls the height of the existing grasses, yet increases nutrient uptake, therefore competition for nutrients will persist until the canopy closure shades out lower layers. A planting layout similar to a grid format will facilitate ease of mowing yet yield an unnaturally spaced community. Mowing may result in strikes on the trunk unless protective measures are utilized. Mowing should occur twice each growing season. Mower height should be set between 8 –12 inches.

Weed Mats

Weed mats are geo-textile fabrics that are used to suppress weed growth around newly planted vegetation by providing shade and preventing seed deposition. Weed mats are installed after planting, and should be removed once the trees have developed a canopy that will naturally shade out weeds.

Deer damage

- Deer will browse all vegetation within reach, generally between 5-6 feet above the ground
- Approaches to minimize damage include: 1) selecting plants that deer do not prefer (ex. Paper Birch, Beech, Ash, Common Elderberry) 2) homemade deer repellants 3) tree shelters

Tree shelters

- Repair broken stakes
- Tighten stake lines
- Straighten leaning tubes
- Clean debris from tube
- Remove netting as tree grows
- Remove when tree is approximately 2 inches wide

Invasive Plants

- Monitor restoration sight regularly for any signs of invasive plants.
- Appendix B contains common invasive plants found in Pennsylvania.
- Choice of control method is based on a variety of considerations, but falls into three general categories:
    - Mechanical
    - Mechanical with application of herbicide
    - Herbicide

Special Maintenance Considerations

Riparian buffer restoration sites should be monitored to maximize wildlife habitat and water quality benefits, and to discover emerging threats to the project. During the first four years, the new buffer should be monitored four times annually (February, May, August, and November are recommended) and inspected after any severe storm. Repairs should be made as soon as possible.
Depending on restoration site size, the buffer area should be sampled to approximate survival rate. Data derived should consider survival of the planted material and natural regeneration to determine if in-fill planting should occur to supplement plant density.

Survival rates of at least 70% are deemed to be successful. Calculate percent survival by the following equation:

(# of live plants / # of installed plants) 100 = % survival

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Cost Issues

Establishment and maintenance costs should be considered up front in the riparian buffer plan design. Installing a forest riparian buffer involves site preparation, tree planting, second year reinforcement planting, and additional maintenance. Both the USDA Riparian Handbook and the PADEP/PADCNR Stream ReLeaf Forest Buffer Toolkit utilize a basic outline for estimating costs for establishment and maintenance:

Costs may fluctuate based on numerous variables including whether or not volunteer labor is utilized, whether plantings and other supplies are donated or provided at a reduced cost.

Specifications

The USDA Forest Service developed a riparian forest buffer specification, which outlines three distinct zones and establishes the minimally acceptable requirements for reforestation by landowners.

Definition

An area of trees and other vegetation located in areas adjoining and upgradient from surface water bodies and designed to intercept surface runoff, wastewater, subsurface flow, and deeper groundwater flows from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and ground water recharge areas.

Scope

This specification establishes the minimally acceptable requirements for the reforestation of open lands, and renovation of existing forest to be managed as Riparian Forest Buffers for the purposes stated.

Purpose

To remove nutrients, sediment, animal-derived organic matter, and some pesticides from surface runoff, subsurface flow, and near root zone groundwater by deposition, absorption, adsorption, plant uptake, denitrification, and other processes, thereby reducing pollution and protecting surface water and groundwater quality.

Conditions Where Practice Applies

Subsurface nutrient buffering processes, such as denitrification, can take place in the soil wherever carbon energy, bacteria, oxygen, temperature, and soil moisture is adequate. Nutrient uptake by plants occurs where the water table is within the root zone. Surficial filtration occurs anywhere surface vegetation and forest litter are adequate.

The riparian forest buffer will be most effective when used as a component of a sound land management system including nutrient management and runoff, and sediment and erosion control practices. Use of this practice without other nutrient and runoff, sediment and erosion control practices can result in adverse impacts on buffer vegetation and hydraulics including high maintenance costs, the need for periodic replanting, and the carrying of excess nutrients and sediment through the buffer by concentrated flows.

This practice applies on lands:

1. adjacent to permanent or intermittent streams which occur at the lower edge of upslope cropland, grassland or pasture;

2. at the margins of lakes or ponds which occur at the lower edge of upslope cropland, grassland or pasture;

3. at the margin of any intermittent or permanently flooded, environmentally sensitive, open water wetlands which occur at the lower edge of upslope cropland, grassland or pasture;

4. on karst formations at the margin of sinkholes and other small groundwater recharge areas occurring on cropland, grassland, or pasture.

Note: In high sediment production areas (8-20 in./100 yrs.), severe sheet, rill, and gully erosion must be brought under control on upslope areas for this practice to function correctly.

Riparian Buffer Installation Costs - Estimation per Acre

			Cost, ea.	Number	Cost, Total
Phase 1: Establishment					
Preparation					
	Light site preparation (mow, disking)		-	-	$ 12.00
Planting					
	Tree Seedlings (12" - 18" Hardwoods)		$ 1.15	430	$ 494.50
	Tree Shelters	(optional)	$ 5.00	430	$ 2,150.00
	Fencing (1 ac = 282 ft)	(optional)			$ 564.00
		Subtotal			**$ 3,220.50**
Phase 2: Maintenance					
Reinforcement Planting					
	Tree Seedlings in Year 2		$ 1.15	50	$ 57.50
	Herbicide Treatment	(optional)			$ 54.00
	Mowing	(optional)			$ 12.00
		Subtotal			**$ 123.50**
Total Costs, no options					**$ 564.00**
Total Costs, with options					**$ 3,344.00**

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Design Criteria

Riparian Forest Buffers

Riparian forest buffers will consist of three distinct zones and be designed to filter surface runoff as sheet flow and downslope subsurface flow, which occurs as shallow groundwater. For the purposes of these buffer strips, shallow groundwater is defined as: saturated conditions which occur near or within the root zone of trees, and other woody vegetation and at relatively shallow depths where bacteria, oxygen, and soil temperature contribute to denitrification. Streamside Forest Buffers will be designed to encourage sheet flow and infiltration and impede concentrated flow.

Zone 1

Location
Zone 1 will begin at the top of the streambank and occupy a strip of land with a fixed width of fifteen feet measured horizontally on a line perpendicular to the streambank.

Purpose
The purpose of Zone 1 is to create a stable ecosystem adjacent to the water's edge, provide soil/water contact area to facilitate nutrient buffering processes, provide shade to moderate and stabilize water temperature encouraging the production of beneficial algal forms, and to contribute necessary detritus and large woody debris to the stream ecosystem.

Requirements
Runoff and wastewater to be buffered or filtered by Zone 1 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 1. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipes or tile, thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer, or treated elsewhere in the system prior to entering the surface water.

Dominant vegetation will be composed of a variety of native riparian tree and shrub species and such plantings as necessary for streambank stabilization during the establishment period. A mix of species will provide the prolonged stable leaf fall and variety of leaves necessary to meet the energy and pupation needs of aquatic insects.

Large overmature trees are valued for their detritus and large woody debris. Zone 1 will be limited to bank stabilization and removal of potential problem vegetation. Occasional removal of extreme high value trees may be permitted where water quality values are not compromised. Logging and other overland equipment shall be excluded except for stream crossings and stabilization work.

Livestock will be excluded from Zone 1 except for designed stream crossings.

Zone 2

Location
Zone 2 will begin at the edge of Zone 1 and occupy an additional strip of land with a minimum width of 60 feet measured horizontally on a line perpendicular to the streambank. Total minimum width of Zones 1 & 2 is therefore 75 feet. Note that this is the minimum width of Zone 2 and that the width of Zone 2 may have to be increased as described in the section "Determining the Total Width of Buffer" to create a greater combined width for Zones 1 & 2.

Purpose
The purpose of Zone 2 is to provide necessary contact time and carbon energy source for buffering processes to take place, and to provide for long term sequestering of nutrients in the form of forest trees. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipe or tile, thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer, or treated elsewhere in the system prior to entering the surface water.

Requirements
Runoff and wastewater to be buffered or filtered by Zone 2 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 2.

Predominant vegetation will be composed of riparian trees and shrubs suitable to the site, with emphasis on native species, and such plantings as necessary to stabilize soil during the establishment period. Nitrogen-fixing species should be discouraged where nitrogen removal or buffering is desired. Species suitability information should be developed in consultation with state and federal forestry agencies, Natural Resources Conservation Service, and USDI Fish and Wildlife Service.

Specifications should include periodic harvesting and timber stand improvement (TSI) to maintain vigorous growth and leaf litter replacement, and to remove nutrients and pollutants sequestered in the form of wood in tree boles and large branches. Management for wildlife habitat, aesthetics, and timber are not incompatible with riparian forest buffer objectives as long as shade levels and production of leaf litter, detritus, and large woody debris are maintained. Appropriate logging equipment recommendations shall be determined in consultation with the state and federal forestry agencies.

Livestock shall be excluded from Zone 2 except for necessary designed stream crossings.

Zone 3

Location
Zone 3 will begin at the outer edge of Zone 2 and have a minimum width of 20 feet. Additional width may be desirable to accommodate land-shaping and mowing machinery. Grazed or ungrazed grassland meeting the purpose and requirements stated below may serve as Zone 3.

Purpose
The purpose of Zone 3 is to provide sediment filtering, nutrient uptake, and the space necessary to convert concentrated flow to uniform, shallow, sheet flow through the use of techniques such as grading and shaping, and devices such as diversions, basins, and level lip spreaders.

Requirements
Vegetation will be composed of dense grasses and forbs for structure stabilization, sediment control, and nutrient uptake. Mowing and removal of clippings are necessary to recycle sequestered nutrients, promote vigorous sod, and control weed growth.

Vegetation must be maintained in a vigorous condition. The vegetative growth must be hayed, grazed, or otherwise removed from Zone 3. Maintaining vigorous growth of Zone 3 vegetation must take precedence and may not be consistent with wildlife needs.

Zone 3 may be used for controlled intensive grazing when conditions are such that earthen water control structures will not be damaged.

Zone 3 may require periodic reshaping of earth structures, removal or grading of accumulated sediment, and reestablishment of vegetation to maintain effectiveness of the riparian buffer.

Determining Need For Protection
Buffers should be used to protect any body of water which will not be:

- treated by routing through a natural or artificial wetland determined to be adequate treatment;

- treated by converting the flow to sheet flow and routing it through a forest buffer at a point lower in the watershed.

Determining Total Width of the Buffer
Note that while not specifically addressed, slope and soil permeability are components of the following buffer width criteria.

Each of the following criteria is based on methods developed, or used by persons conducting research on riparian forests.

Streamside Buffers

The minimum width of streamside buffer areas can be determined by any number of methods suitable to the geographic area.

1. Based on soil hydrologic groups as shown in the county soil survey report, the width of Zone 2 will be increased to occupy any soils designated as Hydrologic Group D and those soils of Hydrologic Group C which are subject to frequent flooding. If soils of Hydrologic Groups A or B occur adjacent to intermittent or perennial streams, the combined width of Zones 1 & 2 may be limited to the 75 foot minimum.

2. Based on area, the width of Zone 2 should be increased to provide a combined width of Zones 1 & 2 equal to one third of the slope distance from the streambank to the top of the pollutant source area. The effect is to create a buffer strip between field and stream which occupies approximately one third of the source area.

3. Based on the Land Capability Class of the buffer site as shown in the county soil survey, the width of Zone 2 should be increased to provide a combined width of Zones 1 & 2 as shown below.

Capability Class	Buffer Width
Cap. I, II e/s, V	75'
Cap. III e/s, IV e/s	100'
Cap. VI e/s, VII e/s	150'

Pond and Lake-Side Buffer Strips

The area of pond or lake-side buffer strips should be at least one-fifth the drainage area of the cropland and pastureland source area. The width of the buffer strip is determined by creating a uniform width buffer of the required area between field and pond. Hydrologic Group and Capability Class methods of determining width remain the same as for streamside buffers. Minimum widths apply in all cases.

Environmentally Sensitive Wetlands

Some wetlands function as nutrient sinks. When they occur in fields or at field margins, they can be used for renovation of agricultural surface runoff and/or drainage. However, most wetlands adjoining open water are subject to periodic flushing of nutrient-laden sediments and, therefore, require riparian buffers to protect water quality.

Where open water wetlands are roughly ellipsoid in shape, they should receive the same protection as ponds.

Where open water wetlands exist in fields as seeps along hillslopes, buffers should consist of Zones 1, 2 & 3 on sides receiving runoff and Zones 1 & 3 on the remaining sides. Livestock must be excluded from Zones 1 & 2 at all times and controlled in Zone 3. Where Zones 1 & 3 only are used, livestock must be excluded from both zones at all times, but hay removal is desirable in Zone 3.

Vegetation Selection

Zone 1 & 2 vegetation will consist of native streamside tree species on soils of Hydrologic Groups D and C and native upland tree species on soils of Hydrologic Groups A and B.

Deciduous species are important in Zone 2 due to the production of carbon leachate from leaf litter which drives bacterial processes that remove nitrogen, as well as, the sequestering of nutrients in the growth processes. In warmer climates, evergreens are also important due to the potential for nutrient uptake during the winter months. In both cases, a variety of species is important to meet the habitat needs of insects important to the aquatic food chain.

Zone 3 vegetation should consist of perennial grasses and forbs.

Species recommendations for vegetated buffer areas depend on the geographic location of the buffer. Suggested species lists should be developed in collaboration with appropriate state and federal forestry agencies, the Natural Resources Conservation Service, and the USDI Fish and Wildlife Service. Species lists should include trees, shrubs, grasses, legumes, forbs, as well as site preparation techniques. Fertilizer and lime, helpful in establishing buffer vegetation, must be used with caution and are not recommended in Zone 1.

Maintenance Guidelines

General
Buffers must be inspected annually and immediately following severe storms for evidence of sediment deposit, and erosion, or concentrated flow channels. Prompt corrective action must be taken to stop erosion and restore sheet flow.

The following should be avoided within the buffer areas: excess use of fertilizers, pesticides, or other chemicals; vehicular traffic or excessive pedestrian traffic; and removal or disturbance of vegetation and litter inconsistent with erosion control and buffering objectives.

Zone 1 vegetation should remain undisturbed except for removal of individual trees of extremely high value or trees presenting unusual hazards such as potentially blocking culverts.

Zone 2 vegetation, undergrowth, forest floor, duff layer, and leaf litter shall remain undisturbed except for periodic cutting of trees to remove sequestered nutrients; to maintain an efficient filter by fostering vigorous growth; and for spot site preparation for regeneration purposes. Controlled burning for site preparation, consistent with good forest management practices, could also be used in Zone 2.

Zone 3 vegetation should be mowed and the clippings removed as necessary to remove sequestered nutrients and promote dense growth for optimum soil stabilization. Hay or pasture uses can be made compatible with the objectives of Zone 3.

Zone 3 vegetation should be inspected twice annually, and remedial measures taken as necessary to maintain vegetation density and remove problem sediment accumulations.

Stable Debris
As Zone 1 reaches 60 years of age, it will begin to produce large stable debris. Large debris, such as logs, create small dams which trap and hold detritus for processing by aquatic insects, thus adding energy to the stream ecosystem, strengthening the food chain, and improving aquatic habitat. Wherever possible, stable debris should be conserved.

Where debris dams must be removed, try to retain useful, stable portions which provide detritus storage.

Deposit removed material a sufficient distance from the stream so that it will not be refloated by high water.

Planning Considerations

1. Evaluate the type and quantity of potential pollutants that will be derived from the drainage area.

2. Select species adapted to the zones based on soil, site factors, and possible commercial goals such as timber and forage.

3. Plan to establish trees early in the dormant season for maximum viability.

4. Be aware of visual aspects and plan for wildlife habitat improvement if desired.

5. Consider provisions for mowing and removing vegetation from Zone 3. Controlled grazing may be satisfactory in Zone 3 when the filter area is dry and firm.

References

Natural Resources Conservation Service. 1997. USDA Natural Resources Conservation Practice Standard Riparian Forest Buffer. USDA Natural Resources Conservation Service.

Palone, R.S. and A.H. Todd (editors.) 1997. Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. USDA Forest Service. NA-TP-02-97. Radnor, PA. http://www.chesapeakebay.net/pubs/subcommittee/nsc/forest or *order from: U.S. EPA Chesapeake Bay Program. 410 Severn Ave. Suite 109. Annapolis, MD. 1-800-968-7229*.

PA Department of Environmental Protection. 1998. *Pennsylvania Stream ReLeaf – Forest Buffer Toolkit*, http://www.dep.state.pa.us/dep/deputate/watermgt/WC/Subjects/StreamReLeaf/default.htm

Tjaden, R.L. and G.M. Weber. 1997. An Introduction to the Riparian Forest Buffer. Maryland Cooperative Extension Fact Sheet 724. College Park, MD. 2 pages. http://www.riparianbuffers.umd.edu/PDFs/FS724.pdf.

Tjaden, R.L. and G.M. Weber. 1997. Riparian Buffer Systems. Maryland Cooperative Extension Fact Sheet 733. College Park, MD. 2 pages. http://www.riparianbuffers.umd.edu/PDFs/FS733.pdf.

BMP 6.7.2: Landscape Restoration



Landscape Restoration is the general term used for actively sustainable landscaping practices that are implemented outside of riparian (or other specially protected) buffer areas. Landscape Restoration includes the restoration of forest (i.e. reforestation) and/or meadow and the conversion of turf to meadow. In a truly sustainable site design process, this BMP should be considered only after the areas of development that require landscaping and/or revegetation are minimized. The remaining areas that do require landscaping and/or revegetation should be driven by the selection and use of vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides..

Key Design Elements

- Minimize traditional turf lawn area
- Maximize landscape restoration area planted with native vegetation
- Protect landscape restoration area during construction
- Prevent post-construction erosion through adequate stabilization
- Minimize fertilizer and chemical-based pest control programs
- Creates and maintains porous surface and healthy soil.
- Minimize mowing (two times per year)
- Reduced maintenance cost compared to lawn

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Low/Med.
Water Quality: Very High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 50%

Other Considerations

- Soil investigation recommended
- Soil restoration may be necessary

Description



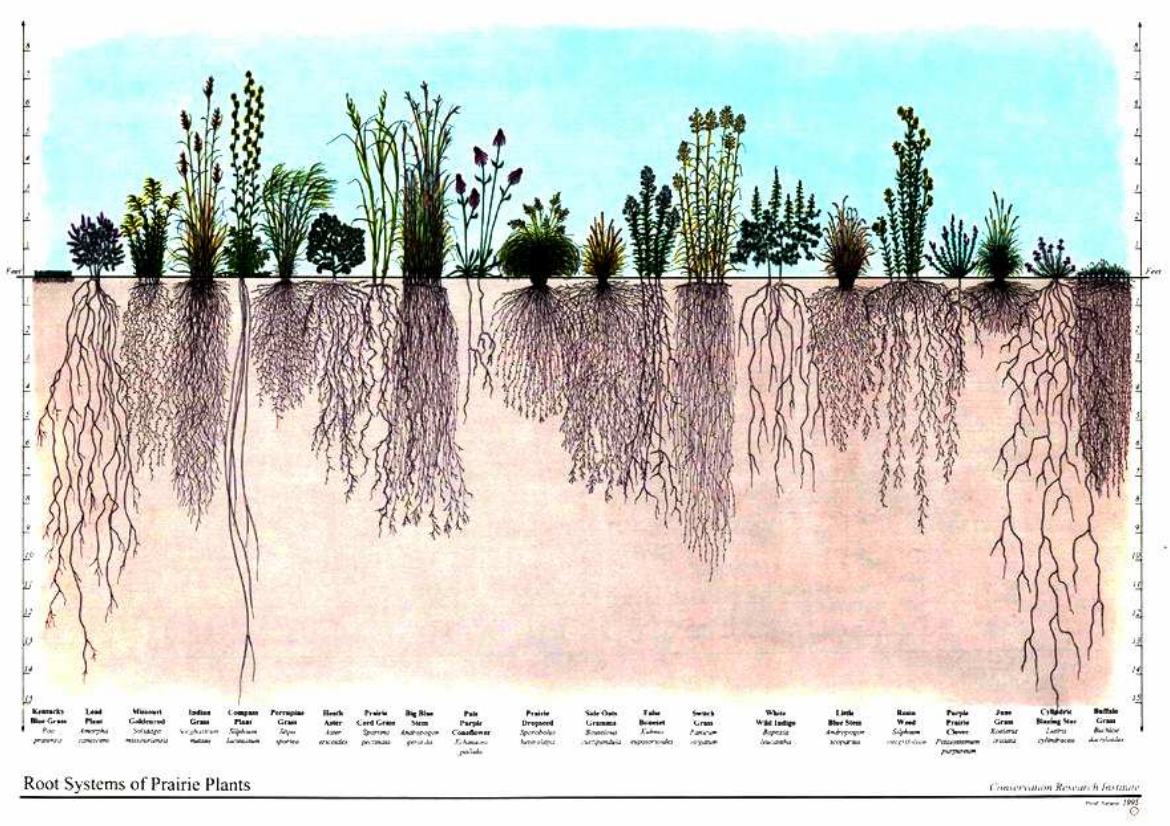
In an integrated stormwater management plan, the landscape is a vital factor, not only in sustaining the aesthetic and functional resources of a site, but also in mitigating the volume and rate of stormwater runoff. Sustainable landscaping, or Landscape Restoration, is an effective method of improving the quality of site runoff. This often overlooked BMP includes the restoration of forest and/or meadow or the conversion of turf to meadow.

Landscape Restoration involves the careful selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides. Implicit in this BMP is the assumption that native species have the greatest tolerance and resistance to pests and require less fertilization and chemical application than do nonnative species. Furthermore, since native grasses and other herbaceous materials often require less intensive maintenance efforts (i.e. mowing or trimming), their implementation on a site results in less biomass produced.

Native species are customarily strong growers with stronger and denser root and stem systems, thereby generating less runoff. If the objective is revegetation with woodland species, the longer-term effect is a significant reduction in runoff volumes, with increases in infiltration, evapotranspiration, and recharge, when contrasted with a conventional lawn planting. Peak rate reduction also is achieved. Similarly, meadow reestablishment is also more beneficial than a conventional lawn planting, although not so much as the woodland landscape. Again, these benefits are long term in nature and will not be forthcoming until the species have had an opportunity to grow and mature (one advantage of the meadow is that this maturation process requires considerably less time than a woodland area). Native grasses also tend to have substantially deeper roots and more root mass than turf grasses, which results in:

- A greater volume of water uptake (evapotranspiration)
- Improved soil conditions through organic material and macropore formation
- Provide for greater infiltration

Landscape architects specializing in the local plant community are usually able to identify a variety of species that meet these criteria. Other sources of advice may be county conservation districts, watershed associations and other conservation groups. As the selection of such materials begins at the conceptual design stage, where lawns are eliminated or avoided altogether and landscaping species selected, Landscape Restoration can generally result in a site with reduced runoff volume and rate, as well as significant nonpoint source load reduction/prevention.



Landscape Restoration can improve water quality by minimizing application of fertilizers and pesticides/herbicides. Given the high rates of chemical application which have been documented at newly created lawns for both residential and nonresidential land uses, eliminating the need for chemical application is important for water quality. Of special importance here is the reduction in fertilization and nitrate loadings. For example, Delaware's *Conservation Design for Stormwater Management* lists multiple studies that document high fertilizer application rates, including both nitrogen and phosphorus, in newly created landscapes in residential and nonresidential land developments. Expansive lawn areas in low density single-family residential subdivisions as well as large office parks typically receives intensive chemical application, both fertilization and pest control, which can exceed application rates being applied to agricultural fields. Avoidance of this nonpoint pollutant source is an important water quality objective.

Variations

- Meadow
- No-mow lawn area
- Woodland restoration
- Removal of existing lawn to reduce runoff volume
- Buffers between lawn areas and wetlands or stream corridors
- Replacement of "wet" lawn areas difficult to mow
- Replacement of hard to maintain lawns under mature trees

Applications

- Forested Landscape/Restoration
- Suburban / Developing Landscape
- Urban Landscape
- Meadow Restoration
- Conversion of Turf to Meadow

Design Considerations

1. The recommended guidelines for Landscape Restoration are very closely related to those of Riparian Buffer Restoration (RBR) (BMP 6.7.1). Specifically, Landscape Restoration overlaps with the guidelines for Zones 2 and 3 in typical RBR. As with RBR, it is essential for successful Landscape Restoration that site conditions be well understood, objectives of the landowner considered, and the appropriate plants chosen for the site. These are all tasks that should be completed in the early planning stages of a project. For a summary of the nine steps recommended for the planning stages of a restoration project, see BMP 6.7.1- Riparian Buffer Restoration. Included in this nine-step process are: analysis of site soils/natural vegetative features/habitat significance/topography/etc., determination of restoration suitability, and site preparation.

2. In those sites where soils have been disturbed or determined inadequate for restoration (based on analysis), soil amendments are needed. Soil amendment and restoration is the process of restoring compromised soils by subsoiling and/or adding a soil amendment, such as compost, for the purpose of reestablishing its long-term capacity for infiltration and pollution removal. For more information on restoring soils, see BMP 6.7.3 Soil Amendments and Restoration.

3. “Native species” is a broad term. Different types of native species landscapes may be created, from meadow to woodland areas, obviously requiring different approaches to planting. A native landscape may take several forms in Pennsylvania, ranging from reestablishment of woodlands with understory plantings to reestablishment of meadow. It should be noted that as native landscapes grow and mature, the positive stormwater benefits relating to volume control and peak rate control increase. So, unlike highly maintained turf lawns, these landscapes become much more effective in reducing runoff volumes and nonpoint source pollutants over time.

4. Minimizing the extent of lawn is one of the easiest and most effective ways of improving water quality. Typical (i.e. compacted) lawns on gentle slopes can produce almost as much runoff as pavement. In contrast to turf, “natural forest soils with similar overall slopes can store up to 50 times more precipitation than neatly graded turf.” (Arendt, Growing Greener, pg. 81)
   The first step in sustainable site design is to limit the development footprint as much as possible, preserving natural site features, such as vegetation and topography. If lawn areas are desired in certain areas of a site, they should be confined to those areas with slopes less than 6%.

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5. Meadow restoration may be used alone or in combination with a forest restoration. The native meadow landscape provides a land management alternative that benefits stormwater management by reducing runoff volume and nonpoint source pollutant transport. Furthermore, meadow landscapes vastly reduce the need for maintenance, as they do not require frequent mowing during the growing season. Because native grasses and flowers are almost exclusively perennials, properly installed meadows are a self-sustaining plant community that will return year after year.

   Meadows can be constructed as a substitute to turf on the landscape, or they can be created as a buffer between turf and forest. In either situation, the meadow restoration acts to reduce runoff as well as reduce erosion and sedimentation. Meadow buffers along forests also help reduce off-trail pedestrian traffic in order to avoid creating paths which can further concentrate stormwater.

   The challenge in restoring meadow landscapes is a lack of effective establishment and maintenance methods. Native grasses and flowers establish more slowly than weeds and turf grass. Therefore, care must be taken when creating meadow on sites where weed or other vegetative communities are well established. It may take a year or more to prepare the site and to get weeds under control before planting. Erosion prone sites should be planted with a nurse crop (such as annual rye) for quick vegetation establishment to prevent seed and soil loss. Steep slopes and intermittent water courses should be stabilized with erosion blankets, selected to mitigate expected runoff volumes and velocities. Additionally, seed quality is extremely important to successful establishment. There is tremendous variation among seed suppliers, seeds should be chosen with a minimum percent of non-seed plant parts.



6. Conversion of turf grass areas to meadow is relatively simple and has enormous benefits for stormwater management. Though turf is inexpensive to install, the cost of maintenance to promote an attractive healthy lawn is high (requiring mowing, irrigation, fertilizer, lime and

herbicides) and its effects are detrimental to water quality. Turf areas are good candidates for conversion to meadow as they typically have lower density of weed species. The conversion of turf to meadow requires that all turf be eliminated before planting, and care must be taken to control weed establishment prior to planting.

7. Forest restoration includes planting of appropriate tree species (small saplings) with quick establishment of an appropriate ground cover around the trees in order to stabilize the soil and prevent colonization of invasive species. Reforestation can be combined with other volume control BMPs such as retentive berming, vegetated filter strips and swales.

   Plant selection should mimic the surrounding native vegetation and expand on the native species composition already found on the site. A mixture of native trees and shrubs is recommended and should be planted once a ground cover is established.



8. In terms of woodland areas, DCNR's *Conservation Design for Stormwater Management* states, "…a mixture of young trees and shrubs is recommended…. Tree seedlings from 12 to 18 inches in height can be used, with shrubs at 18 to 24 inches. Once a ground cover crop is established (to offset the need for mowing), trees and shrubs should be planted on 8-foot centers, with a total of approximately 430 trees per acre. Trees should be planted with tree shelters to avoid browse damage in areas with high deer populations, and to encourage more rapid growth." (p.3-50). Initial watering and weekly watering during dry periods may be necessary during the first growing season. As tree species grow larger, both shrubs and ground covers recede and yield to the more dominant tree species. The native tree species mix of small inexpensive saplings should be picked for variety and should reflect the local forest communities. Annual mowing to control invasives may be necessary, although the quick establishment of a strong-growing ground cover can be effective in providing invasive control. Native meadow planting mixes also are available. A variety of site design factors may influence the type of vegetative community that is to be planned and implemented. In so many cases, the "natural" vegetation of Pennsylvania's communities is, of course, woodland.

9. Ensure adequate stabilization. Adequate stabilization is extremely important as native grasses, meadow flowers, and woodlands establish more slowly than turf. Stabilization can be achieved for forest restoration by establishing a ground cover before planting of trees and shrubs. When creating meadows, it may be necessary to plant a fast growing nurse crop with meadow seeds for quick stabilization. Annual rye can be planted in the fall or spring with meadow seeds and will establish quickly and usually will not present a competitive problem. Erosion prone sites should be planted with a nurse crop and covered with weed-free straw mulch, while steep slopes and areas subject to runoff should be stabilized with erosion control blankets suitable for the expected volume and velocity of runoff.

Volume Reduction Calculations and Peak Rate Mitigation
Areas designated for landscape restoration should be considered as "Meadow, good condition" in stormwater calculations.

Water Quality Improvement
See Section 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

Forest restoration installation follows closely the procedure outlined in BMP 6.7.1- Riparian Buffer Restoration. Refer to BMP 6.7.1 for detailed information, with the understanding that species selection for upland forest restoration will differ from that for riparian restoration.

Meadow installation should proceed as follows:

1. SELECT SITE
- Confirm site is suitable for restoration, should be sunny, open and well-ventilated. Meadow plants require at least a half a day of full sun.
- Obtain landowner permission

2. ANALYZE SITE
- Evaluate site's physical conditions (soil attributes, geology, terrain)
- Evaluate site's vegetative features (desirable and undesirable species, native species, sensitive habitats). Good candidates for meadow plantings include areas presently in turf, cornfields, soybean fields, alfalfa fields and bare soils from new construction.
- Areas with a history of heavy weed growth may require a full year or longer to prepare for planting.
- Beware of residual herbicides that may have been applied to agricultural fields. Always check the herbicide history of the past 2-3 years and test the soils if in doubt.

3. PLANT SELECTION
- Select plants that are well adapted to the specific site conditions. Meadow plants must be able to out compete weed species in the first few years as they become established.

4. PREPARE SITE
- All weeds or existing vegetation must be eliminated prior to seeding.
- Perennial weeds may require year long smothering, repeated sprayings with herbicides, or repeated tillage with equipment that can uproot and kill perennial weeds.

5. PLANTING DAY
- Planting can take place from Spring thaw through June 30 or from September 1 through soil freeze-up ("dormant seeding")
- Planting in July and August is generally not recommend due to the frequency of drought during this time.
- Seeding can be accomplished by a variety of methods: no-till seeder for multi-acre planting; broadcast seeder; hand broadcast for small areas of one acre or less.
- Seed quality is critical and a seed mix should be used with a minimum percentage of non-seed plant parts.

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6. SITE MAINTENANCE (additional information below)

- Assign responsibilities for watering, weeding, mowing, and maintenance
- Monitor site regularly for growth and potential problems

Maintenance Issues

Meadows and Forests are low maintenance but not "no maintenance". They usually require more frequent maintenance in the first few years immediately following installation.

Forest restoration areas planted with a proper cover crop can be expected to require annual mowing in order to control invasives. Application of a carefully selected herbicide (Roundup or similar glyphosate herbicide) around the protective tree shelters/tubes may be necessary, reinforced by selective cutting/manual removal, if necessary. This initial maintenance routine is necessary for the initial 2 to 3 years of growth and may be necessary for up to 5 years until tree growth and tree canopy begins to form, naturally inhibiting weed growth (once shading is adequate, growth of invasives and other weeds will be naturally prevented, and the woodland becomes self-maintaining). Review of the new woodland should be undertaken intermittently to determine if replacement trees should be provided (some modest rate of planting failure is usual).

Meadow management is somewhat more straightforward; a seasonal mowing or burning may be required, although care must be taken to make sure that any management is coordinated with essential reseeding and other important aspects of meadow reestablishment. In the first year weeds must be carefully controlled and consistently mowed back to 4-6 inches tall when they reach 12 inches in height. In the second year, weeds should continue to monitored and mowed and rhizomatous weeds should be hand treated with herbicide. Weeds should not be sprayed with herbicide as the drift from the spray may kill large patches of desirable plants, allowing weeds to move in to these new open areas. In the beginning of the third season, the young meadow should be burned off in mid-spring. If burning is not possible, the meadow should be mowed very closely to the ground instead. The mowed material should be removed from the site to expose the soil to the sun. This helps encourage rapid soil warming which favors the establishment of "warm season" plants over "cool season" weeds.

Cost Issues

Landscape restoration cost implications are minimal during construction. Seeding for installation of a conventional lawn is likely to be less expensive than planting of a "cover" of native species, although when contrasted with a non-lawn landscape, "natives" often are not more costly than other nonnative landscape species. In terms of woodland creation, somewhat dated (1997) costs have been provided by the *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*:

$860/acre trees with installation
$1,600/acre tree shelters/tubes and stakes
$300/acre for four waterings on average

In current dollars, these values would be considerably higher, well over $3,000/acre for installation costs. Costs for meadow reestablishment are lower than those for woodland, in part due to the

elimination of the need for shelters/tubes. Again, such costs can be expected to be greater than installation of conventional lawn (seeding and mulching), although the installation cost differences diminish when conventional lawn seeding is redefined in terms of conventional planting beds.

Cost differentials grow greater when longer term operating and maintenance costs are taken into consideration. If lawn mowing can be eliminated, or even reduced significantly to a once per year requirement, substantial maintenance cost savings result, often in excess of $1,500 per acre per year. If chemical application (fertilization, pesticides, etc.) can be eliminated, substantial additional savings result with use of native species. These reductions in annual maintenance costs resulting from a native landscape reestablishment very quickly outweigh any increased installation costs that are required at project initiation. Unfortunately, because developers pay for the installation costs and longer term reduced maintenance costs are enjoyed by future owners, there is reluctance to embrace native landscaping concepts.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Vegetation – See Appendix B

References

Bowman's Hill Wildflower Preserve, Washington Crossing Historic Park, PO Box 685, New Hope, PA 18938-0685, Tel (215) 862-2924, Fax (215) 862-1846, Native plant reserve, plant sales, native seed, educational programs, www.bhwp.org

Morris Arboretum of the University of Pennsylvania; 9414 Meadowbrook Avenue, Philadelphia, PA 19118, Tel (215) 247-5777, www.upenn.edu/morris, PA Flora Project Website: Arboretum and gardens (some natives), educational programs, PA Flora Project, www.upenn.edu/paflora

Pennsylvania Department of Conservation and Natural Resources; Bureau of Forestry; PO Box 8552, Harrisburg, PA 17105-8552, Tel (717)787-3444, Fax (717)783-5109, Invasive plant brochure; list of native plant and seed suppliers in PA; list of rare, endangered, threatened species.

Pennsylvania Native Plant Society, 1001 East College Avenue, State College, PA 16801 www.pawildflower.org

Western Pennsylvania Conservancy; 209 Fourth Avenue, Pittsburgh, PA 15222, Tel (412) 288-2777, Fax (412) 281-1792, www.paconserve.org

Conservation Design for Stormwater Management (DNREC and EMC)

Stream ReLeaf Plan and Toolkits

The Once and Future Forest – Leslie Sauer

Forestry Best Management Practices for Water Quality – Virginia Department of Forestry

Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers (1997)

Arendt, R. *Growing Greener.* Island Press, November 1999.

Diboll, Neil. Five Steps to Successful Prairie Meadow Establishment. Windstar Wildlife Institute.

Penn State College of Agricultural Sciences, Agricultural Research and Cooperation Extension. " Pennsylvania Wildlife No. 12: Warm-season Grasses and Wildlife" and "Pennsylvania Wildlife No. 5: Meadows and Prairies: Wildlife-friendly Alternatives to Lawn"

BMP 6.7.3: Soil Amendment & Restoration



Soil amendment and restoration is the process of improving disturbed soils and low organic soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil's long-term capacity for infiltration and pollution removal.

Key Design Elements

- Existing soil conditions should be evaluated before forming a restoration strategy.
- Physical loosening of the soil, often called subsoiling, or tilling, can treat compaction.
- The combination of subsoiling and soil amendment is often the more effective strategy.
- Compost amendments increase water retention.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Medium
Water Quality: Medium

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 50%

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Problem Description

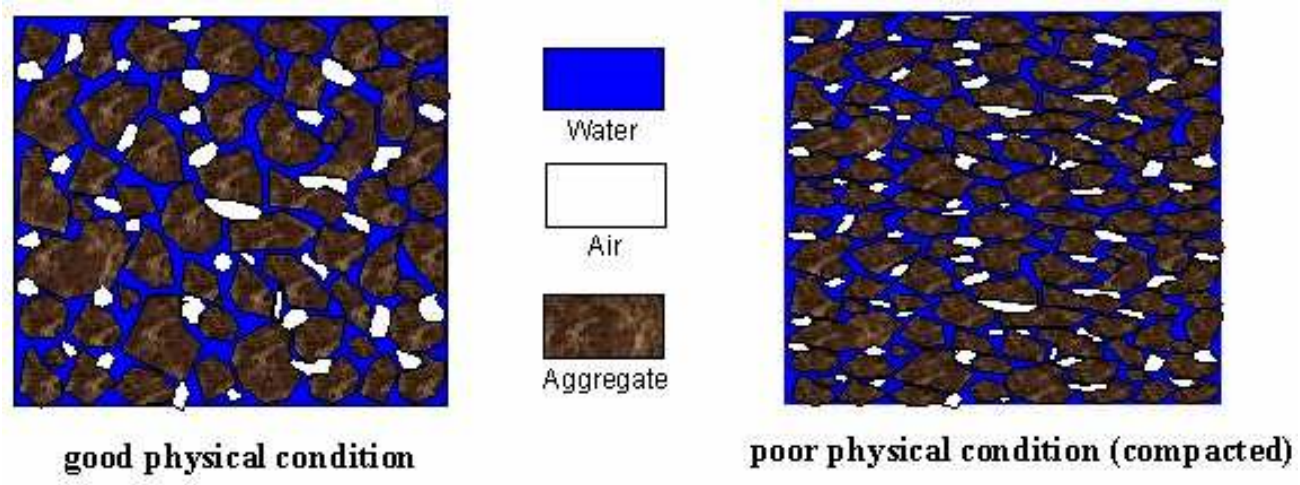
Animals, farm equipment, trucks, construction equipment, cars, and people cause compaction. Wet soil compacts easier than dry soil. Natural compaction occurs due to special chemical or physical properties, and these occurrences are called “hard pans”. A typical soil after compaction has strength of about 6,000 kPa, while studies have shown that root growth is not possible beyond 3,000 kPa.



Different Types of Compaction

1) Minor Compaction – surface compaction within 8-12” due to contact pressure, axle load > 10 tons can compact through root zone, up to 1’ deep

2) Major Compaction – deep compaction, contact pressure and total load, axle load > 20 tons can compact up to 2’ deep (usually large areas compacted to increase strength for paving and foundation with overlap to “lawn” areas)



In general, compaction problems occur when airspace drops to 10-15% of total soil volume. Compaction affects the infiltrating and water quality capacity of soils. When soils are compacted, the soil particles are pressed together, reducing the pore space necessary to move air and water throughout the soil. This decrease in porosity causes an increase in bulk density (weight of solids per unit volume of soil). The greater the bulk density, the lower the infiltration and therefore the larger volume of runoff.

Different types of soils have bulk density levels at which compaction starts to limit root growth. When root growth is limited, the uptake of water and nutrients by vegetation is reduced.

Soil organisms are also affected by compaction; biological activity is greatly reduced, decreasing their ability to intake and release nutrients.

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The best soil restoration is the complete revegetation of woodlands, as "A mature forest can absorb as much as 14 times more water than an equivalent area of grass." (DNREC and Brandywine Conservancy, 1997) (See Structural BMP 6.7.2 Landscape Restoration and use in combination with this BMP)

Soil Restoration Methodology

Soil restoration is a technique that can be used to restore and enhance compacted soils or soils low in organic content by physical treatment and/or mixture with additives such as compost. Soil restoration has been shown to alter soil properties known to affect water relations of soils, including water holding capacity, porosity, bulk density and structure. Two methods have been shown to restore some of the characteristics of soils that are damaged by compaction; tilling and addition of amendments such as compost or other materials.

One of the options for soil amendment is compost, which has many benefits. It improves the soil structure, creating and enhancing passageways in the soil for air and water that have been lost due to compaction. This recreates a better environment for plant growth. Compost also supplies a slow release of nutrients to plants, specifically nitrogen, phosphorous, potassium, and sulfur. Using compost reuses natural resources, reducing waste and cost.

Soil amendment with compost has been shown to increase nutrients in the soil, such as phosphorus and nitrogen, which provides plants with needed nutrients, reducing or eliminating the need for fertilization. This increase in nutrients results in an aesthetic benefit as turf grass and other plantings establish and proliferate more quickly, with less maintenance requirements. Soil amendment with compost increases water holding and retention capacity, improves infiltration, reduces surface runoff, increases soil fertility, and enhances vegetative growth. Compost also increases pollutant-binding properties of the soil properties, which improves the quality of the water passing through the soil mantle and into the groundwater.

The second method is tilling, which involves the digging, scraping, mixing, and ripping of soil with the intent of circulating air into the soil mantle in various layers. Compaction down to 20 inches often requires ripping for soil restoration. Tilling exposes compacted soil devoid of oxygen to air and recreates temporary air space.

Bulk density field tests may be used to determine the compaction level of soils.

Soil Texture	Ideal Bulk densities	Bulk densities that may afffect root growth	Bulk densities that restrict root growth
	g/cm3	g/cm3	g/cm3
Sands, loamy sands	<1.60	1.69	1.8
Sandy loams, loams	<1.40	1.63	1.8
Sandy clay loams, loams, clay loams	<1.40	1.6	1.75
Slilt, silt loams	<1.30	1.6	1.75
Silt loams, silty clay loams	<1.10	1.55	1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	1.58
Clays (>45% clay)	<1.10	1.39	1.47
Source: Protecting Urban Soil Quality, USDA-NRCS			

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Variations

- Soil amendment media can include compost, sand, and manufactured microbial solutions.
- Seed can be included in the soil amendment to save application time.

Applications

- **New Development (Residential, Commercial, Industrial)** – new lawns can be amended with compost and not heavily compacted before planting, to increase the porosity of the soils.

- **Urban Retrofits** - Tilling of soils that have been compacted before it is converted into meadow, lawn, or a stormwater facility is recommended.

- **Detention Basin Retrofits** – The inside face of detention basins is usually heavily compacted, and tilling the soil mantle on surfaces beyond the constructed embankment will encourage infiltration to take place. Tilling may be necessary to establish better vegetative cover.

- **Landscape Maintenance** – compost can substitute for dwindling supplies of native topsoil in urban areas.

- **Golf Courses** – Using compost as part of the landscaping upkeep on the greens has been shown to alleviate soil compaction, erosion, and turf disease problems.

Design Considerations

1. Treating Compaction by **Soil Restoration**
   a) Soil amendment media usually consists of compost, but can include mulch, manures, sand, and manufactured microbial solutions.
   b) Compost should be added at a rate of 2:1 (soil:compost). If a proprietary product is used, the manufacturer's instructions should be followed in terms of mixing and application rate.
   c) Soil restoration should not be used on slopes greater than 30%. In these areas, deep-rooted vegetation can be used to increase stability.
   d) Soil restoration should not take place within the drip line of a tree to avoid damaging the root system.
   e) On-site soils with an organic content of at least 5 percent can be properly stockpiled (to maintain organic content) and reused.
   f) Procedure: rototill, or rip the subgrade, remove rocks, distribute the compost, spread the nutrients, rototill again.
   g) Add 6 inches compost / amendment and till up to 8 inches for minor compaction.
   h) Add 10 inches compost / amendment and till up to 20 inches for major compaction.

2. Treating Compaction by **Ripping / Subsoiling / Tilling / Scarification**
   a) Subsoiling is only effective when performed on dry soils.
   b) Ripping, subsoiling, or scarification of the subsoil should be performed where subsoil has become compacted by equipment operation, dried out and crusted, or where necessary to obliterate erosion rills.
   c) Ripping (Subsoiling) should be performed using a solid-shank ripper and to a depth of 20 inches, (8 inches for minor compaction).

d) Should be performed before compost is placed and after any excavation is completed.
e) Subsoiling should not be performed within the drip line of any existing trees, over underground utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design.

Subsoiling should not be performed with common tillage tools such as a disk or chisel plow because they are too shallow and can compact the soil just beneath the tillage depth.

3. Other methodologies:
   a) Irrigation Management – low rates of water should be applied, as over-irrigation wastes water and may lead to environmental pollution from lawn chemicals, nutrients, and sediment.
   b) Limited mowing – higher grass corresponds to greater evapotranspiration.
   c) Compost can be amended with bulking agents, such as aged crumb rubber from used tires or weed chips. This can be a cost-effective alternative that reuses waste materials.
   d) In areas where compaction is less severe (not as a result of heavy construction equipment), planting with deep-rooted perennials can treat compaction, however restoration takes several years.

Table 2. Mean runoff from unvegetated test plots during a 30 minute high-intensity (~ 4 in/hr) rain storm

	Biosolids	Yard Trimmings	Bio-industrial	Compacted Subsoil	Topsoil
Geometric mean runoff (mm) during 30-minute rainfall	0.13[a]	<0.01[a]	0.08[a]	26.22[b]	15.54[b]

Values with different letters are significantly different statistically ($p<0.05$) from one another.

Table 3. Mean time to initiate runoff from unvegetated test plots

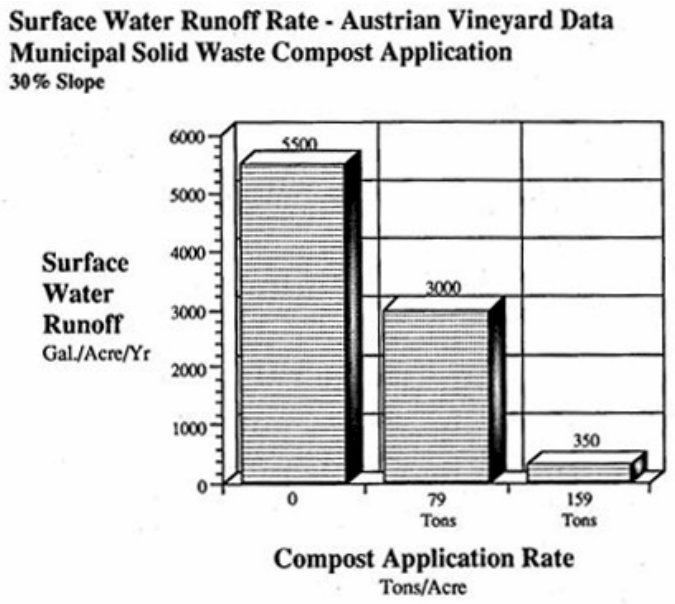
	Biosolids	Yard Trimmings	Bio-industrial	Compacted Subsoil	Topsoil
Mean time (min)	31.08[c]	56.92[d]	32.17[c,d]	4.67[a]	7.83[b]

Values with different letters are significantly different statistically ($p<0.05$) from one another.

SARB_014926

Detailed Stormwater Functions

Infiltration Area (If needed)
The infiltration area will be the entire area restored, depending on the existing soil conditions, and the restoration effectiveness.



Volume Reduction Calculations
Soil Amendments can reduce the need for irrigation by retaining water and slowly releasing moisture, which encourages deeper rooting. Infiltration is increased; therefore the volume of runoff is decreased.

Compost amended soils can significantly reduce the volume of stormwater runoff. For soils that have either been compost amended according to the recommendations of their BMP, or subject to restoration such that the field measured bulk densities meet the Ideal Bulk Densities of Table 1, the following volume reduction may be applied:

Amended Area (ft^2) x 0.50in x 1/12 = Volume (cf)

Peak Rate Mitigation
See Section 8 for peak rate mitigation.

Water Quality Improvement
See Section 8 for water quality improvement.

Table 4. Adsorbed Mass of Nutrients and Metals in Unvegetated Plot Runoff From 30-Minute, High-Intensity (100-mm/hr.) Rainstorm

	Compost Treatments			Conventional Treatments	
	Biosolids	Yardwaste	Bioindustrial Compost	Compacted Subsoil	Topsoil
Element	Geometric Mean (mg)				
Chromium	0.01[b]	<0.01[a]	<0.01[b]	0.92[c]	0.76[c]
Copper	0.02[b]	<0.01[a]	0.01[b]	1.03[c]	0.66[c]
Nickel	<0.01[b]	<0.01[a]	<0.01[b]	0.96[c]	0.67[c]
Lead	0.01[b]	<0.01[a]	<0.01[b]	1.82[c]	0.95[c]
Zinc	0.10[b]	<0.01[a]	0.03[b]	6.55[c]	3.99[c]
Nitrogen	0.47[b]	<0.01[a]	0.09[a,b]	266.65[c]	211.87[c]
Phosphorus	0.45[b]	<0.01[a]	0.09[a,b]	36.47[c]	29.07[c]
Potassium	0.17[b]	<0.01[a]	0.09[a,b]	103.94[c]	71.57[c]

Means within the same row with different letter designations are significantly different ($p<0.05$).

Highest Medium Lowest

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Construction Sequence

1. All construction should be completed and stabilized before beginning soil restoration.

Maintenance Issues

The soil restoration process may need to be repeated over time, due to compaction by use and/or settling. (For example, playfields or park areas will be compacted by foot traffic.)

Cost Issues

Tilling costs, including scarifying sub-soils, range from $800/ac to $1000/ac.

Compost amending of soil ranges in cost from $860/ac to $1000/ac.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. SCOPE

    a. This specification covers the use of compost for soil amendment and the mechanical restoration of compacted, eroded and non-vegetated soils. Soil amendment and restoration is necessary where existing soil has been deemed unhealthy in order to restore soil structure and function, increase infiltration potential and support healthy vegetative communities.

    b. Soil amendment prevents and controls erosion by enhancing the soil surface to prevent the initial detachment and transport of soil particles.

2. COMPOST MATERIALS

    a. Compost products specified for use in this application are described in Table 1. The product's parameters will vary based on whether vegetation will be established on the treated slope.

    b. Only compost products that meet all applicable state and federal regulations pertaining to its production and distribution may be used in this application. Approved compost products must meet related state and federal chemical contaminant (e.g., heavy metals, pesticides, etc.) and pathogen limit standards pertaining to the feedstocks (source materials) in which it is derived.

    c. Very coarse compost should be avoided for soil amendment as it will make planting and crop establishment more difficult.

d. **Note 1** - Specifying the use of compost products that are certified by the U.S. Composting Council's Seal of Testing (STA) Program (www.compostingcouncil.org) will allow for the acquisition of products that are analyzed on a routine basis, using the specified test methods. STA participants are also required to provide a standard product label to all customers, allowing easy comparison to other products.

3. SUB-SOILING TO RELIEVE COMPACTION

a. Before the time the compost is placed and preferably when excavation is completed, the subsoil shall be in a loose, friable condition to a depth of 20 inches below final topsoil grade and there shall be no erosion rills or washouts in the subsoil surface exceeding 3 inches in depth.

b. To achieve this condition, subsoiling, ripping, or scarification of the subsoil will be required as directed by the owners s representative, wherever the subsoil has been compacted by equipment operation or has become dried out and crusted, and where necessary to obliterate erosion rills. Sub-soiling shall be required to reduce soil compaction in all areas where plant establishment is planned. Sub-soiling shall be performed by the prime or excavating contractor and shall occur before compost placement.

c. Subsoiled areas shall be loosened to less than 1400 kPa (200 psi) to a depth of 20 inches below final topsoil grade. When directed by the owner's representative, the Contractor shall verify that the sub-soiling work conforms to the specified depth.

d. Sub-soiling shall form a two-directional grid. Channels shall be created by a commercially available, multi-shanked, parallelogram implement (solid-shank ripper). The equipment shall be capable of exerting a penetration force necessary for the site. No disc cultivators chisel plows, or spring-loaded equipment will be allowed. The grid channels shall be spaced a minimum of 12 inches to a maximum of 36 inches apart, depending on equipment, site conditions, and the soil management plan. The channel depth shall be a minimum of 20 inches or as specified in the soil management plan. If soils are saturated, the Contractor shall delay operations until the soil will not hold a ball when squeezed. Only one pass shall be performed on erodible slopes greater than 1 vertical to 3 horizontal. When only one pass is used, work should be at right angles to the direction of surface drainage, whenever practical.

e. Exceptions to sub-soiling include areas within the drip line of any existing trees, over utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design (abutments, footings, or in slopes), and on inaccessible slopes, as approved by the owner's representative. In cases where exceptions occur, the Contractor shall observe a minimum setback of 20 feet or as directed by the owner's representative. Archeological clearances may be required in some instances.

4. COMPOST SOIL AMENDMENT QUALITY

a. The final, resulting compost soil amendment must meet all of the mandatory criteria in Table 4.

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5. COMPOST SOIL AMENDMENT INSTALLATION

    a. Spread 2-3 inches of approved compost on existing soil. Till added soil into existing soil with a rotary tiller that is set to a depth of 6 inches. Add an additional 4 inches of approved compost to bring the area up to grade.

    b. After permanent planting/seeding, 2-3 inches of compost blanket will be applied to all areas not protected by grass or other plants

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SARB_014931

BMP 6.7.4: Floodplain Restoration

Floodplain restoration tries to mimic the interaction of groundwater, stream base flow, and root systems – key components of a stream corridor under pre-settlement (pre-1600s) conditions. Under pre-settlement conditions, typically the roots of the riparian vegetation on the floodplain were directly linked to the base flow elevation of the stream. Groundwater frequently interacted with the root zones and the stream's base flow. Where the groundwater was lower than the stream's base flow, the gravel-lined streams and permeable floodplains frequently reduced surface flows through infiltration. The interaction among the stream's base flow, groundwater, permeable floodplain soils, and riparian root zones provides multiple benefits, including the filtering of sediments and nutrients through retention of frequent high flows onto the floodplain, removal of nitrates from groundwater, reduction of peak flow rates, groundwater recharge/infiltration, and increase of storage and reduction of flood elevations during higher flows. As a result of historical and recent human impacts, many stream networks have little interaction among the groundwater, stream base flow, and the root systems of floodplain vegetation. Frequently, recently deposited floodplain soils are cohesive, separating the root zones from base flow and allowing only minimal infiltration from the surface flow through the porous pre-settlement soils and gravels. Floodplain restoration as a BMP should be considered where there is minimal interaction among the key components. Other benefits of this BMP include thermal cooling of the stream base-flow, improved benthic community species diversity and habitat, re-establishment and significant increases of wetland areas and native plant species on the floodplain, reduction of invasive plant species, and increased aquatic habitat and riparian areas.

Key Design Elements

- A natural, system-based BMP that uses native vegetation, soils, and other natural elements
- Can be easily integrated into the initial site planning process Can prevent riparian problems from getting worse or can fix problems caused by historical practices
- Can address numerous problems, from the site level to the watershed level
- Provides multiple benefits of restoring a fluvial and riparian system to a fully functioning level of interaction
- Re-connection of stream channel to functional floodplain
- Incorporation of an aquatic and riparian system that interacts with the groundwater and/or stream base flow.
- Reattachment of root systems of floodplain vegetation/riparian areas connected to groundwater and/or base flow.
- Removal of "legacy sediments" and associated nutrients stored within the stream corridors prior to release through bank erosion.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: N/A
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/High
Recharge: Low/High
Peak Rate Control: Medium
Water Quality: Med/High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: >30%

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Description

Floodplain restoration as a BMP is an effective tool to meet water quality and quantity requirements, prevent riparian problems from getting worse, and fix current problems caused by historical practices. The interaction and connection of the groundwater, stream base flow, riparian vegetation root system, and permeable floodplain soils and gravels immediately reduce downstream sedimentation by stopping or greatly reducing stream bank and channel erosion. The “legacy sediments” stored in stream valleys create unnaturally high stream banks and floodplains that frequently contain massive amounts of nutrients, which are released during erosion. Additionally, high banks separate plant root zones from the nitrates in the stream base flow and groundwater. Thus, instead of nitrogen being removed by the plants, groundwater and base flow continue to transport nitrates to receiving waters. Floodplain restoration directly removes a significant source of phosphorus and sediments and creates a riparian/aquatic environment to provide effective denitrification. Additionally, a restored floodplain and stream may greatly enhance infiltration and storage of surface flow in the floodplain, which reduces flood flow stages, volumes, and peak discharges. Floodplain restoration is an effective technique to meet stormwater management initiatives. One of the great advantages of this technique is that it can address numerous problems, from the site-specific to the watershed-level. Floodplain restoration can prevent or substantially mitigate the full range of stormwater impacts in one BMP. It is a natural, system-based BMP that uses native vegetation, soil, and other natural features. Floodplain restoration reconnects a number of key components within a stream corridor so that their interaction protects the stability of the bed and channel while the system receives, holds, infiltrates, and filters sediment and nutrients from overland flow. These components include:

- a floodplain that receives more routine flows, thereby reducing erosive flow forces in the channel and allowing existing sediments and nutrients to remain in storage;
- a floodplain that allows vegetative root systems to interact with the base flow and/or groundwater, providing frequent removal of nitrates and effective stabilization of the stream banks and floodplain;
- a floodplain wide and flat along the valley bottom, consisting of the proper earthen materials to absorb surface flows and increase infiltration to groundwater;
- a plant community adapted to frequent inundation that will provide suitable habitat for riparian wildlife and whose root systems will provide nitrate and phosphate removal from surface and/or groundwater; and
- increased and improved habitat for aquatic resources.

Traditional on-site BMPs focus on the development site itself, while floodplain restoration can focus not only on the development site but also on the receiving streams. Adding floodplain restoration to the toolbox also increases the flexibility to address onsite BMP limitations such as steep slopes, shallow bedrock, or property limitations.

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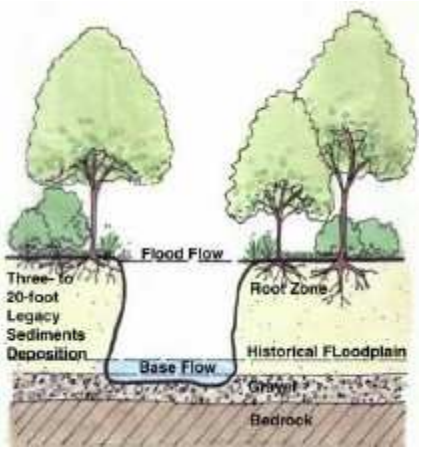
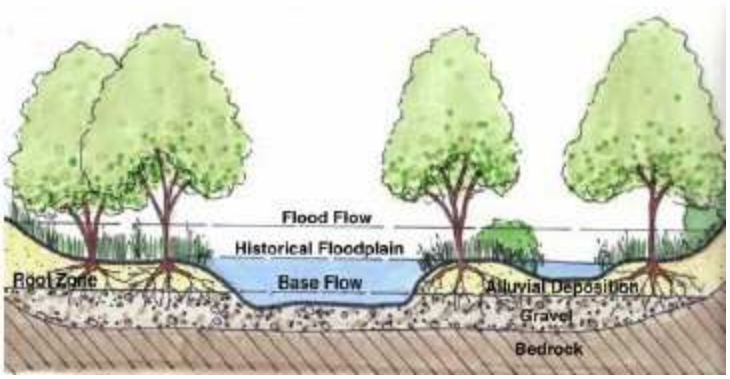


Existing Conditions: Stream channels are eroding or have eroded back down through sediments that collected behind mill dams, leaving their alluvial terraces high above the current base flow water elevation, and disconnecting riparian root systems from groundwater flows. The processes of frequent floodplain inundation, which relieves in-channel stresses; groundwater infiltration through porous floodplain material, and nitrogen removal from groundwater through root systems are lost under these conditions that are prevalent today throughout the Piedmont region of the United States.

Pre-settlement / Restored Conditions: Stable, pre-settlement stream and floodplain systems were characterized by: a low floodplain in close contact with surface water in the stream channel, allowing for frequent inundation of the floodplain during high flows; riparian vegetation with roots zones in contact with groundwater that enabled ground-water denitrification through root uptake; and a channel bed composed of cobble and gravel, which helped protect the underlying bedrock from erosive flow forces.









Santo Domingo Creek, Lititz Run Watershed, Lancaster County, Pa.
Top Left: Existing conditions.
Top Right: Restored conditions
Right: Riparian Wetland adjacent to channel.

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Variations

When implementing a Floodplain Restoration BMP, existing site constraints can influence the opportunity or potential to achieve all the benefits. Impacts to natural channels often create streambeds that are perched above the historical bed that existed prior to the 1600s. This is especially the case when historical milldams, creating significant backwater influences upstream of the physical dam, caused natural channels to fill with fine alluvial sediments from hillside erosion during the widespread land-clearing of the post-settlement era. When current streambeds are perched, it is often the case that the groundwater elevation is below the streambed. In this case, base flow, whether intermittent or perennial, flows on the perched streambed and has little interaction with the groundwater elevation below the streambed. The fine alluvial sediments that washed from the hillsides often act as a barrier, keeping the in-channel base flow and groundwater separated.

As a ***first priority***, the design of a Floodplain Restoration BMP should attempt to establish the proposed streambed so that the base flow in the channel is connected to the pre-settlement streambed gravels and, typically, the groundwater elevation. This scenario provides the greatest benefit for nutrient uptake, because the newly established, active, vegetated root zone will be highly attached to the groundwater and base flows in the new active channel. Where cohesive soils or clays separate the top of the floodplain from the underlying porous material, these cohesive materials should be replaced with more porous soils. On sites where vertical constraints from existing infrastructure, such as roadway crossings, culverts, and utility crossings, prevent lowering the restored streambed to its historical pre-settlement elevation that would, in many cases, have been attached to the groundwater elevation, then a ***second priority*** to the Floodplain Restoration BMP should be utilized. The second priority shall be utilized where site constraints do not allow for the reconnection of the restored streambed to the groundwater elevation. In this case, the restored channel should be established such that the base flow or, in the case of an intermittent stream, the streambed is highly attached to the stream bank vegetated root zone, meaning that the established root zone extends down to the streambed elevation.

Applications

On-Site: When a stream is located within or immediately adjacent to a proposed development site, the Floodplain Restoration BMP can be directly tied into the site development stormwater management plan, given the stream is in need of restoration as a stand-alone BMP or as a supplemental BMP to other stormwater BMP needs. **Off-Site:** On development projects that do not have a stream on or adjacent to the site, the Floodplain Restoration BMP may be implemented on the downstream receiving stream or within the watershed. Existing watershed prioritization studies may be useful in identifying appropriate sites for off-site applications of this BMP. In areas where existing wetlands or mature riparian forests or vegetation exist, this practice may not be applicable. The benefits of the practice must be weighed against the impact to determine if this method is acceptable.

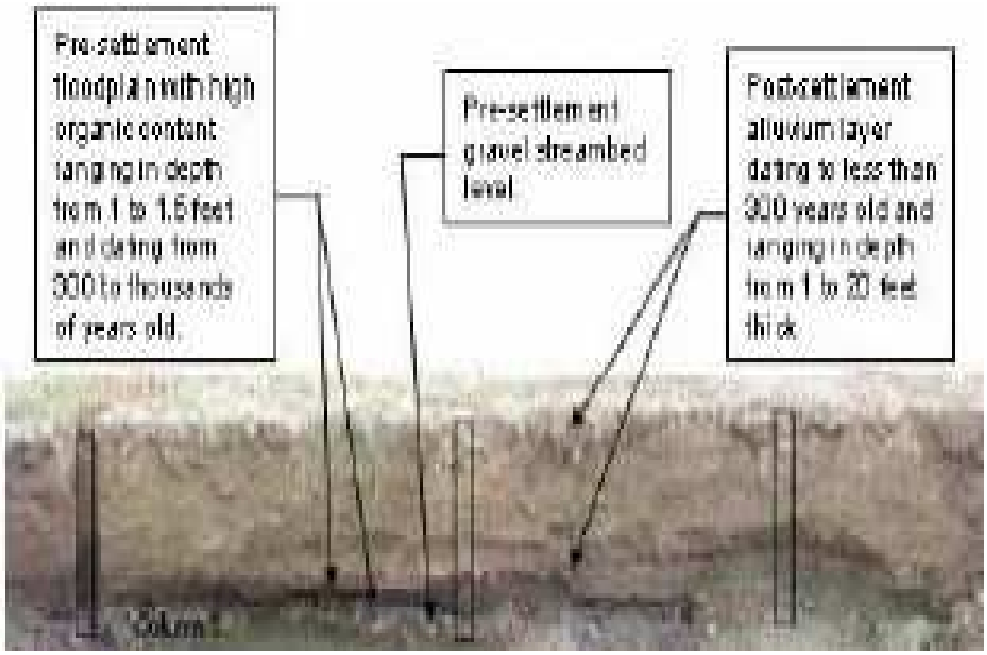
Design Considerations

The goal of floodplain restoration is to re-establish the natural interaction of a stream system, including surface flow; groundwater; porous, organic floodplain soils; and vegetative roots systems by re-establishing the stream channel and adjacent floodplain in their natural valley-flat location such that it functions similarly to the pre-settlement conditions. Any restoration required for the stream channel itself should follow the guidelines established by the Keystone Stream Team in *Guidelines For Natural Stream Channel Design for Pennsylvania Waterways*.

General design procedures:

1. Determine if the vegetative root zone is connected to the base flow and groundwater or, in the case of an ephemeral stream, the stream bed. A simplified way to determine root zone connection is to examine the root depth of the vegetation on the floodplain or out-of-bank level along the active stream banks. If the base of the active root zone extends into the base flow or channel bed region, then the floodplain is likely to be attached to the active stream channel.

2. Excavate a trench(es) or perform geo probes along the existing floodplain to determine pre-settlement floodplain and streambed elevations. Typically, the buried pre-settlement floodplain consists of dark peat and organic material.



Trench excavated across the existing floodplain reveals the pre-settlement streambed and floodplain levels currently buried under post-settlement alluvium and facilitates soil layer analyses, including various dating procedures.

3. Identify any vertical constraints or limitations that may prevent the floodplain restoration from providing the interconnection of the key components described above.

4. If the channel bed exists at the groundwater or pre-settlement bed elevation, then lower the floodplain and re-establish the appropriate vegetation where the rooting depth is connected to the base flow and/or groundwater.

5. If downstream constraints such as utility crossings or culverts will not allow lowering the floodplain and stream bed to its pre-settlement elevation, and floodplain soils are porous, excavate the existing

floodplain soils to an elevation that allows the floodplain vegetative root systems to be connected to the base flow elevation.

6. If downstream constraints such as utility crossings or culverts will not allow lowering the floodplain and stream bed to its pre-settlement elevation, and floodplain soils are cohesive and non-porous, remove the clays and replace with more porous materials to an elevation that allows the floodplain vegetative root systems to be connected to the base flow elevation.

7. Hydrologic/hydraulic studies may be necessary as required.

8. Obtain federal, state, and local permits and coordinate with local floodplain regulations.

9. Accommodate multiple uses, such as greenways, trails, and other stormwater BMPs as pre-treatment or energy dissipation measures.

10. Based on preceding design procedures, excavate floodplain to proper elevation and provide vegetative stabilization of the restored floodplain area. Vegetation establishment is an integral part of a floodplain restoration. Vegetation will help reduce flow velocities, promote settling, provide nutrient uptake, provide filtering, limit erosion along streambanks, and prevent active channel short-circuiting in the floodplain. Robust, non-invasive, perennial plants that establish quickly are ideal for floodplain restoration. The designer should select native species that are tolerant of a range of conditions, such as those accustomed to saturated conditions, emergent and upland areas.

Detailed Stormwater Functions

Volume Reduction Calculations: Floodplain restoration can achieve increased flood storage. Floodplain wetlands can attenuate smaller flows until the capacity of these wetlands is exceeded. The volume of soils removed as part of the floodplain restoration is now available for storage of flood flows and is capable of conveying flood flows at lower elevations, thus reducing water surface elevations and nuisance flooding.

Peak Rate Mitigation Calculations: Peak rate is primarily controlled through the infiltration of runoff and additional storage from runoff and receiving waters in the floodplain. Also, the shallow depth and high floodplain roughness can increase the travel time, reducing downstream peak rates.

Water Quality Improvements: Floodplain restoration will reduce the sediment load through the reduction of streambank erosion and the reconnection of the stream channel to a functional floodplain. A floodplain also promotes deposition of fine sediments and filtering of nutrients. Root zones attached to the base flow and groundwater remove nutrients during low flow or drought periods. The floodplain also acts as a riparian buffer or a vegetated filter strip filtering nutrients and sediment from overland runoff prior to waters entering the stream channel.

Recharge: The wide and flat area of the floodplain along the valley bottom should typically be porous, providing a large area for infiltration. In many “karst” or limestone areas, the channel bed may be significantly higher than the groundwater elevation. The channel and floodplain in these areas can provide significant groundwater recharge even during drought conditions. The floodplain/channel bed must consist of the proper earthen materials to absorb surface flows, increase infiltration to groundwater**,** and promote groundwater recharge.

Construction Sequence

The Pennsylvania Keystone Stream Team has developed *Guidelines For Natural Stream Channel Design for Pennsylvania Waterways*, and Construction Considerations are discussed specifically in Chapter 8.

Maintenance Issues

Floodplain restoration projects must have a maintenance plan that will address the condition of the channel and floodplain through the monitoring of the survivability of the riparian plan implemented with the restoration project. As discussed in the design considerations, vegetation establishment is paramount to the stability of streambanks and the floodplain. Vegetation established along the streambanks and within the floodplain should maintain a minimal 85 percent survival rate, which should be documented through the implementation of a monitoring plan.

Monitoring of the floodplain restoration should coincide with the regulatory requirements established by state and federal regulatory agencies. These monitoring requirements are typically established as a condition of the issuance of a permit to authorize the floodplain restoration activities.

Weed and Invasive Plant Control

Weeds and invasive plants limit buffer growth and survival of native plants; therefore, weeds and invasive plants should be controlled by either herbicides, mowing, or weed mats. These techniques may need to be implemented after the first growing season and may need to continue into the fourth year after the implementation of the floodplain restoration.

Herbicides

This is a short-term (two to three years) maintenance technique that is generally less expensive and more flexible than mowing and will result in a quicker establishment of the buffer. Herbicide use is regulated by the Pennsylvania Department of Agriculture. Proper care should be taken to ensure that proximity to water features is considered.

Mowing

Mowing controls the height of the existing grasses yet increases nutrient uptake; therefore, competition for nutrients will persist until the canopy closure shades out lower layers. Mowing could occur twice each growing season. Mower height should be set between eight and 12 inches.

Weed Mats

Weed mats are geo-textile fabrics that are used to suppress weed growth around newly planted vegetation by providing shade and preventing seed deposition. Weed mats are installed after planting, and should be removed once the trees have developed a canopy that will naturally shade out weeds. Once established, the floodplain restoration project should require little to no long-term maintenance.

Cost Issues

The Pennsylvania Keystone Stream Team has developed preliminary cost ranges associated with the assessment, design, permitting, and implementation of floodplain restoration projects. They can be found at the Keystone Stream Team website: http://www.keystonestreamteam.org/.

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Specifications

Floodplain restoration designs need to accommodate the sediment loads of the watershed without aggrading or degrading. Guidelines for floodplain restoration projects can be found in the Keystone Stream Team's *Guidelines for Natural Stream Channel Design for Pennsylvania's Waterways* (March 2003).

References

Guidelines For Natural Stream Channel Design for Pennsylvania Waterways, Chapter 8, Keystone Stream Team, March 2003.

Cost Ranges Outline, Keystone Stream Team website: www.keystonestreamteam.org
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6.8 Other BMPs and Related Measures

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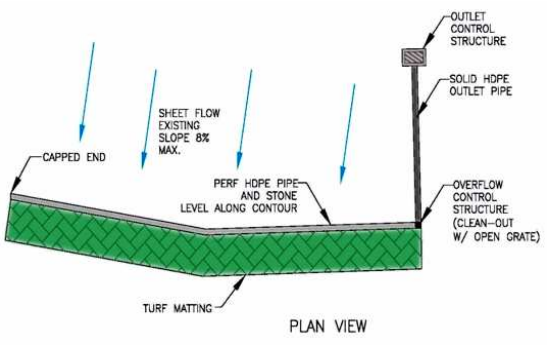
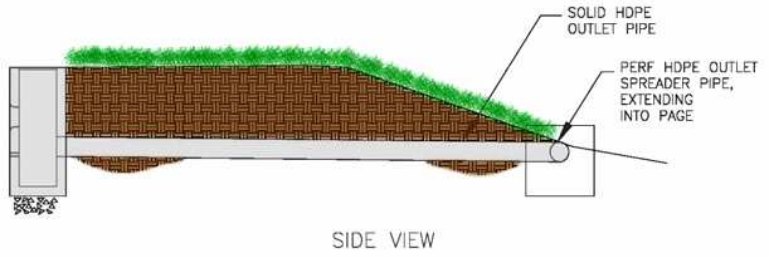
BMP 6.8.1: Level Spreader



Level Spreaders are measures that reduce the erosive energy of concentrated flows by distributing runoff as sheet flow to stabilized vegetative surfaces. Level Spreaders, of which there are many types, may also promote infiltration and improved water quality.



Key Design Elements

- Level spreaders must be level.
- Specific site conditions, such as topography, vegetative cover, soil, and geologic conditions must be considered prior to design; level spreaders are not applicable in areas with easily erodible soils and/or little vegetation.
- Level spreaders should safely diffuse at least the 10-year storm peak rate; bypassed flows should be stabilized in a sufficient manner.
- Length of level spreaders is dependent on influent flow rate, pipe diameter (if applicable); number and size of perforations (if applicable), and downhill cover type.
- It is always easier to keep flow distributed than to redistribute it after it is concentrated; multiple outfalls/level spreaders are preferable to a single outfall/level spreader.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low
Recharge: Low
Peak Rate Control: Low
Water Quality: Low

Water Quality Functions

TSS: 20%
TP: 10%
NO3: 5%

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Description

Ensuring distributed, non-erosive flow conditions is an important consideration in any stormwater management strategy and particularly critical to the performance of certain BMPs (e.g. filter strips). Level spreading devices diffuse flows (both low and high), promote infiltration, and improve water quality by evenly distributing flows over a stabilized vegetated surface. There are many different types and functions of level spreaders. Examples include concrete sills (or lips), curbs, earthen berms, and level perforated pipes.

For the purposes of the Manual, there are essentially two categories of level spreaders. The first type of level spreader (Inflow) is meant to evenly distribute flow entering into another structural BMP, such as a filter strip, infiltration basin, or vegetated swale. Examples of this type of level spreader include concrete sills (or lips), curbs, and earthen berms. The second type of level spreader (Outflow) is intended to reduce the erosive force of low to moderate flows while at the same time enhancing natural infiltration opportunities. Examples of this second type include a level, perforated pipe in a shallow aggregate trench (similar to an Infiltration Trench) and earthen berms. While the first type of level spreader can be a very effective measure, it is already discussed in some detail as a design consideration in other structural BMPs and particularly in BMP 6.4.10 Infiltration Berms. This section therefore, focuses primarily on the second category of level spreaders.

Outflow level spreaders are often used in conjunction with other structural BMPs, such as BMP 6.4.2 Infiltration Basins and BMP 6.4.3 Subsurface Infiltration Bed. However, in certain situations, they can be used as “stand alone” BMPs to dissipate runoff from roofs or other impervious areas. In either case, level spreaders might account for some level of volume and rate reduction, the degree to which depends on the specific design, natural infiltration rate of the soil, amount of influent runoff, vegetation density and slope of downhill area, and extent (length of level spreader). Specific credit, as defined in BMPs 5.8.1 and 5.8.2, is given to stand alone level spreaders for impervious areas greater than 500 square feet.

A typical level spreader that is used in conjunction with another structural BMP is a level perforated pipe in a shallow aggregate trench. Though the actual design will vary, a “level spreader pipe” should be designed to at least distribute to the 10-year storm. Depending on the computed flow rate and available space, the designer may provide enough length of pipe to distribute the 100-year storm (see Design Considerations). If space is limited, then flows above the 10-year storm may be allowed to bypass the level spreader. The level spreader pipe must be installed evenly along a contour at a shallow depth in order to ensure adequate flow distribution and discourage channelization. In some cases, a level spreader pipe may be “upgraded” to an Infiltration Trench if additional volume and rate reduction is required (see BMP 6.4.4, Infiltration Trench).

The condition of the area downhill of a level spreader should be considered prior to installation. For instance, the slope, density and condition of vegetation, natural topography, and length (in the direction of flow) will all affect the effectiveness of a distributed flow measure. Areas immediately downhill from a level spreader may need to be stabilized, especially if they have been recently disturbed. Erosion control matting and/or compost blanketing are the recommended measures for achieving permanent downhill stabilization. Permanent vegetative stabilization should be in place prior to placing the level spreader into operation. Manufacturer’s specifications should be followed for chosen stabilization measure.

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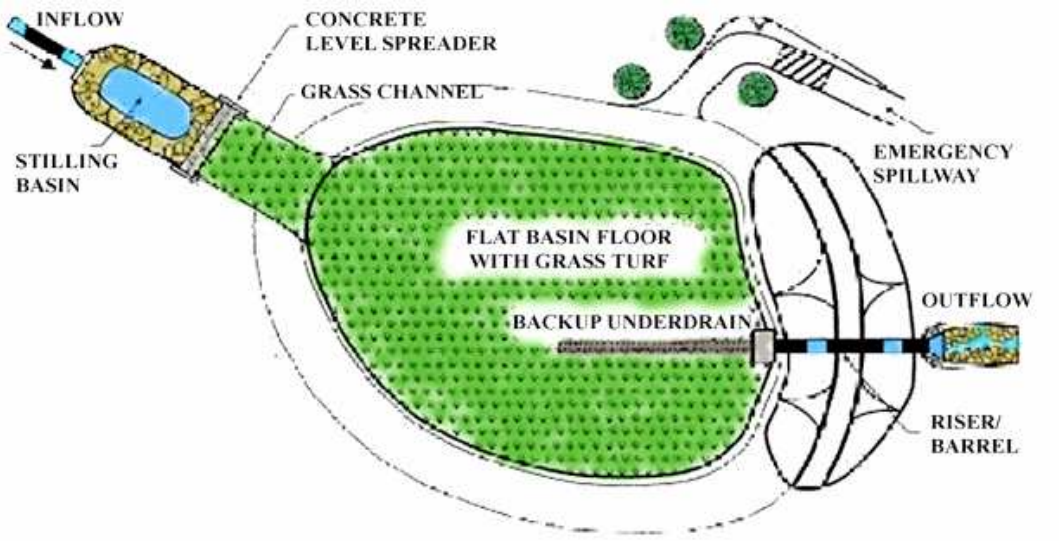
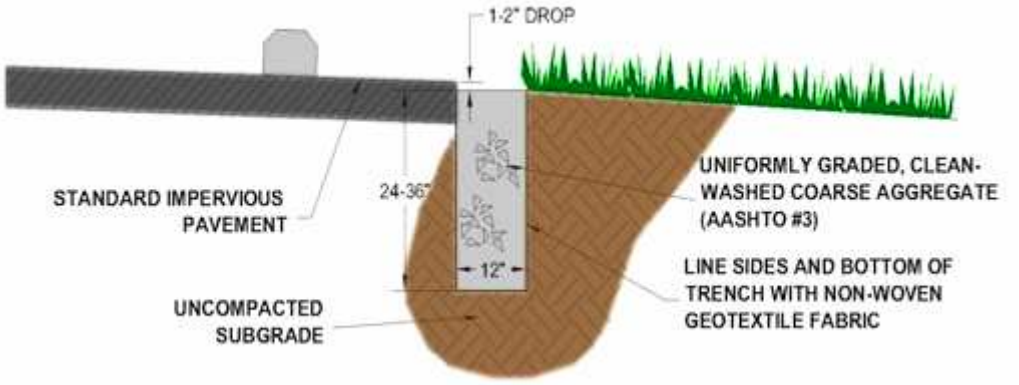
Variations

- **Inflow Level Spreaders**
  Evenly distribute flow entering into another structural BMP, such as a filter strip or infiltration basin. Examples include concrete sills (or lips), curbs, concrete troughs, ½ pipes, short standing PVC-silt fence, aggregate trenches, and earthen berms (see Infiltration Berms and Filter Strips). To ensure even distribution of flow, it is critical that these devices be installed as levelly as possible. More rigid structures (concrete, wood, etc.) are often preferable to earthen berms, which have the potential to erode.





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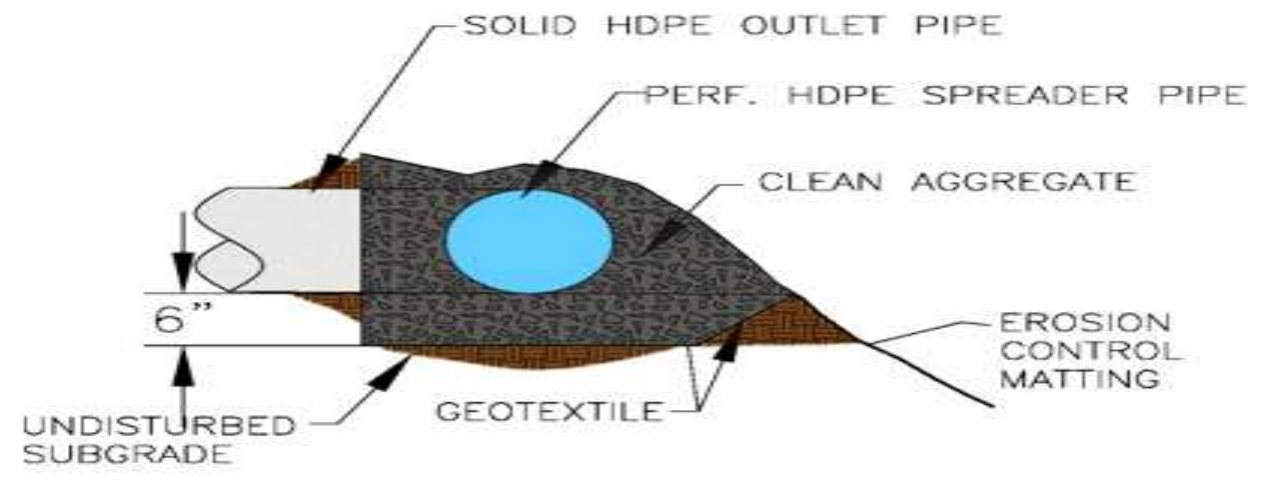
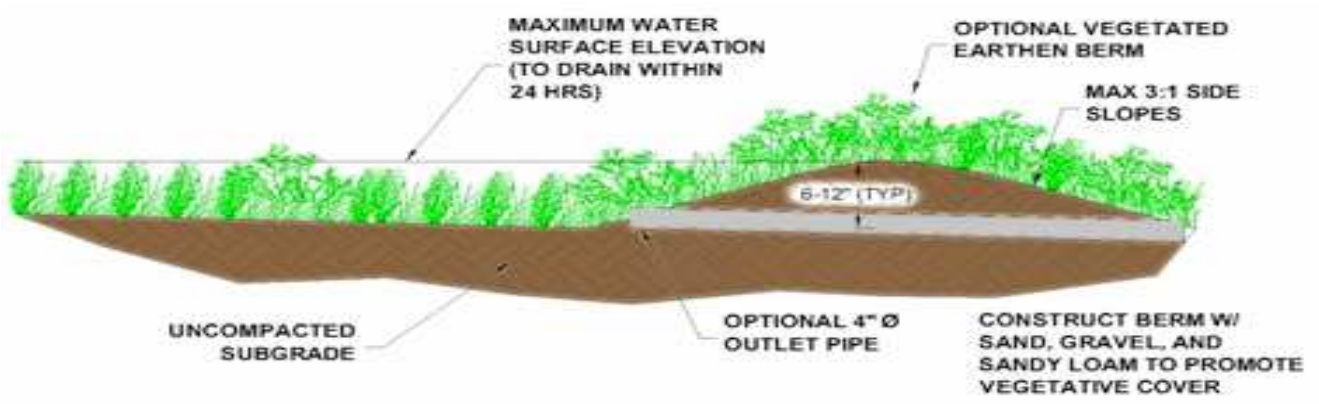
- **Outflow Level Spreaders (in conjunction with structural BMP)**
  Reduces the erosive force of low to moderate flows while at the same time enhancing natural infiltration opportunities. Examples include a level perforated pipe in a shallow aggregate trench (similar to an Infiltration Trench) and earthen berms.





- **Outflow Level Spreader (stand alone)**
  Distribute runoff from roofs or other impervious areas of 500 square feet or less. Unless modified to approximate an Infiltration Trench, stand-alone level spreaders do not usually account for substantial volume or rate reductions. However, if designed and installed properly, they still represent effective flow diffusion devices with some water quality benefits.



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Applications

- **Ultimate outlet from structural BMPs not discharging directly to a receiving stream**
- **Roof downspout connections (roof area < 500sf)**
- **Inlet connections (impervious area < 500sf)**
- **Inflow to structural BMP, such as filter strip, infiltration basin**

Design Considerations

1. It is usually preferable to not initially concentrate stormwater and provide as many outfalls as possible. This can reduce or even eliminate the need for devices to provide even distribution of flow.

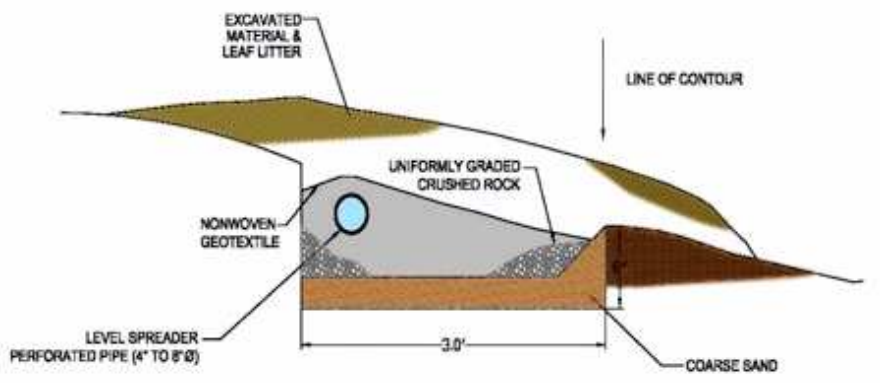
2. Receiving soils and land cover should be undisturbed or stabilized with vegetation or other permanent erosion-resistant material prior to receiving runoff. Level spreaders are not applicable in areas with easily erodable soils and/or little vegetation. The slope below the level spreader should be relatively smooth in the direction of flow to discourage channelization. The minimum flow length of the receiving area should be 75 feet.

3. For design considerations of earthen berm level spreaders refer to BMP 6.4.10 Infiltration Berm.

4. Level spreaders should not be located in constructed fill. Virgin soil is much more resistant to erosion than fill.

5. Level spreaders should not be used for sediment removal. Significant sediment deposition in a level spreader will render it ineffective.

6. A perforated pipe level spreader may range in size from 4 to 12 inches in diameter. The pipe should be laid in an envelope of AASHTO #57 stone, the thickness of which is based upon the desired volume reduction. A deeper trench will provide additional volume reduction and should be included in the calculations (see BMP 6.4.4 Infiltration Trench). Non-woven geotextile should be placed below the aggregate to discourage clogging by sediment.



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7. The length of level spreaders is primarily a function of the calculated influent flow rate. The level spreader should be long enough to freely discharge the calculated peak flow rate. At a minimum, the peak flow rate shall be that resulting from a 10-year/24-hour design storm. This flow rate should be safely diffused without the threat of failure (i.e. creation of erosion gullies or rills). Diffusion of the storms greater than the 10-year/24-hour storm is permissible if space permits. Generally, level spreaders should have a minimum length of ten feet and a maximum length of 200 feet.

   Conventional level spreaders designed to diffuse all flow rates should be sized based on the following:

   For grass or thick ground cover vegetation:

   a) 13 linear feet of level spreader for every 1 cfs flow
   b) Slopes of 8% or less from level spreader to toe of slope

   For forested areas with little or no ground cover vegetation:

   a) 100 linear feet of level spreader for every 1 cfs flow
   b) Slopes of 6% or less from level spreader to toe of slope

   Determining the perforation discharge per linear foot of pipe may further refine the length of a perforated pipe level spreader. A level spreader pipe shall safely discharge in a distributed manner at the same rate of inflow. Perforated pipe manufacturers' specifications provide the discharge per linear foot of pipe, though it is typically based on the general equation for flow through an orifice. Manufacturer's specifications can be used to find the right combination of length and size of pipe. If the number of perforations per linear foot (based on pipe diameter) and average head above the perforations are known, then the flow can be determined by the following equation:

   $$L \text{ (length of level spreader pipe)} = Q / Q_L$$

   Q_L (discharge per linear foot) = Q_O * # of perforations per linear foot of pipe (provided by manufacturer, based on perforation diameter)

   Q_O (perforation flow rate) = $C_d * A * (2 * g * H)^{0.5}$

   Q_O = the free outfall flow rate through one perforation (ft^3/sec)
   C_d = Coefficient of discharge (typically 0.60)
   A = Cross sectional area of one perforation (ft^2)
   g = 32.2 ft/sec^2
   H = head, average height of water above perforation (ft) (provided by manufacturer)

   For example, the 10- and 100-year design flows for a site were determined to be 2 and 5 cfs, respectively. Assuming a 12-in diameter pipe with thirty-six 0.375-in. diameter perforations per linear foot and an H value of 0.418 feet, the discharge per linear foot is calculated at 0.086 cfs/ft. When the two design flows are divided by the discharge per linear foot, the resulting required lengths are 24 and 59 feet, respectively.

This calculation assumes a free flow condition. Since the level spreader pipe is encased in aggregate (which is around 40% void space) this assumption is usually acceptable. However, for this reason and to account for the potential for clogging of perforations over time, the length of pipe should be multiplied by minimum factor of safely of 1.1.

8. Flows (> 10-year storm peak rate) may bypass a level spreader in a variety of ways, including an overflow structure or up-turned ends of pipe. (The ends of the perforated pipe could be turned uphill at a 45-degree angle or more with the ends screened.) Cleanouts/overflow structures with open grates can also be installed along longer lengths of perforated pipe. The designer shall provide stabilization measures for bypassed flows in a manner consistent with the Pennsylvania Erosion and Sedimentation Pollution Control Program Manual.

9. Erosion control matting or compost blanketing is recommended immediately downhill and along the entire length of the level spreader, particularly in those areas that are unstable or have been recently disturbed by construction activities. Generally, low flows that are diffused by a level spreader do not require additional stabilization on an already stabilized and vegetated slope. The installation requirements for erosion control methods will vary according to the manufacturer's specifications.

   There are a variety of permanent erosion control alternatives to riprap currently on the market. Turf/reinforcement matting is a manufactured product that combines vegetative growth and synthetic materials to reduce the potential for soil erosion on slopes. It is typically made of synthetic materials that will not biodegrade and will create a foundation for plant roots to take hold, extending the viability of grass beyond its natural limits.

   Compost blankets are an emerging technology that serves a similar function to permanent erosion control matting. When compost is applied as a "blanket" over a disturbed area, it encourages a thicker, more permanent vegetative cover due to its ability to improve the infrastructure of the soil. Compost blankets reduce runoff volume by holding water in its pores and improve water quality by binding and degrading specific chemical contaminants.





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Detailed Stormwater Functions

Volume Reduction Calculations

In general, level spreaders do not substantially reduce runoff volume. However, for level spreaders designed similar to Infiltration Trenches, a volume reduction can be achieved. Also, for level spreaders serving as stand-alone BMPs (for contributing impervious up to 500 square feet), volume reduction credits, as discussed in BMPs 5.8.1 and 5.8.2, can be achieved for runoff disconnection. The true amount of volume reduction will depend on the length of level spreader, the density of vegetation, the downhill length and slope, the soil type of the receiving area, and the design runoff. Large areas with heavy, dense vegetation will absorb some flows, while barren or compacted areas will absorb limited amounts of runoff. See Section 9 for detailed calculation methodologies.

Peak Rate Mitigation Calculations

The influent peak rate to a level spreader will be diffused (or dissipated) over the length of the level spreader; the number of perforations in a level spreader pipe will essentially divide the concentrated flow into many smaller flows. To be conservative, and to allow for the possibility of re-convergence, the peak rate should be taken prior to diffusion from the level spreader. See Section 9 for detailed calculation methodologies.

Water Quality Improvement

Water quality improvements occur if the area down gradient of the level spreader is vegetated, stabilized, and minimally sloped. See Section 9 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Level spreaders are considered a permanent part of a site's stormwater management system. Therefore, the uphill development should be stabilized before diverting runoff to any dispersing flow techniques. If the level spreader is used as an erosion and sedimentation control measure, it must be reconfigured (flush perforated pipe, clean out all sediment), to its original state before use as a permanent stormwater feature.

2. All contributing stormwater elements (infiltration beds, inlets, outlet control structures, pipes, etc) should be installed.

3. Perforated pipe should be installed along a contour, with care taken to construct a level bottom. The pipe can be underground in a shallow infiltration trench (see Infiltration Trench for design guidance), or closer to the surface and covered with a 12-inch thick layer of AASHTO #57 stone. If the perforated pipe is in a trench, excavate to the design dimensions. If the pipe is to be at or near the surface, some minor excavation or filling may be necessary to maintain a level bottom.

4. If necessary, install erosion control matting along the length of the level spreader and to a distance downhill, as specified by the manufacturer/supplier. Cover the pipe with AASHTO #57 stone.

5. For construction sequence of earthen berms, see BMP 6.4.10 Infiltration Berm.

Maintenance Issues

Compared with other BMPs, level spreaders require only minimal maintenance efforts, many of which may overlap with standard landscaping demands. The following recommendations represent the minimum maintenance effort for level spreaders:

- Catch Basins and Inlets draining to a level spreader should be inspected and cleaned on an annual basis.

- The receiving land area should be immediately restored to design conditions after any disturbance. Vegetated areas should be seeded and blanketed.

- It is critical that even **sheet flow conditions** are sustained throughout the life of the level spreader, as their effectiveness can deteriorate due to lack of maintenance, inadequate design/location, and poor vegetative cover.

    - **Inspection** - The area below a level spreader should be inspected for clogging, density of vegetation, damage by foot or vehicular traffic, excessive accumulations, and channelization. Inspections should be made on a quarterly basis for the first two years following installation, and then on a semiannual basis thereafter. Inspections should also be made after every storm event greater than 1-inch.

    - **Removal** - Sediment and debris should be routinely removed (but never less than semiannually), or upon observation, when buildup occurs in the clean outs. Regrading and reseeding may be necessary in the areas below the level spreader. Regrading may also be required when pools of standing water are observed along the slope. (In no case should standing water be allowed for longer than 72 hours.)

    - **Vegetation** - Maintaining a vigorous vegetative cover on the areas below a level spreader is critical for maximizing pollutant removal efficiency and erosion prevention. If vegetative cover is not fully established within the designated time, it may need to be replaced with an alternative species. (It is standard practice to contractually require the contractor to replace dead vegetation.) Unwanted or invasive growth should be removed on an annual basis. Biweekly inspections are recommended for at least the first growing season, or until the vegetation is permanently established. Once the vegetation is established, inspections of health, diversity, and density should be performed at least twice per year, during both the growing and non-growing season. Vegetative cover should be sustained at 85% and replaced if damage greater than 50% is observed.

Cost Issues

As there are various types of level spreaders, their associated costs will vary. Per foot material and equipment cost will range from $5 to $20 depending on the type of level spreader desired. Concrete level spreaders may cost significantly more than perforated pipes or berms. (For more detailed cost information in BMP 6.4.4 Infiltration Trenches and BMP 6.4.10 Infiltration Berms.)

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Stone** shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids ³ 35% as measured by ASTM-C29.

2. **Non-Woven Geotextile** shall consist of needled non-woven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) ³ 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) ³ 225 psi
   c. Flow Rate (ASTM-D4491) ³ 95 gal/min/ft^2
   d. UV Resistance after 500 hrs (ASTM-D4355) ³ 70%
   e. Heat-set or heat-calendared fabrics are not permitted
   Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. **Topsoil** amend with compost (See BMP 6.7.3, Soil Amendment & Restoration)

4. **Pipe** shall be solid or continuously perforated, smooth interior, with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

5. **Vegetation** see Native Plant List in Appendix B.

References

Maine Department of Transportation, 1992. *Maine Department of Transportation BMP Manual for Erosion and Sedimentation Control*.

NC Division of Water Quality. *Level Spreader Design Suggestions.* October 10, 2001.

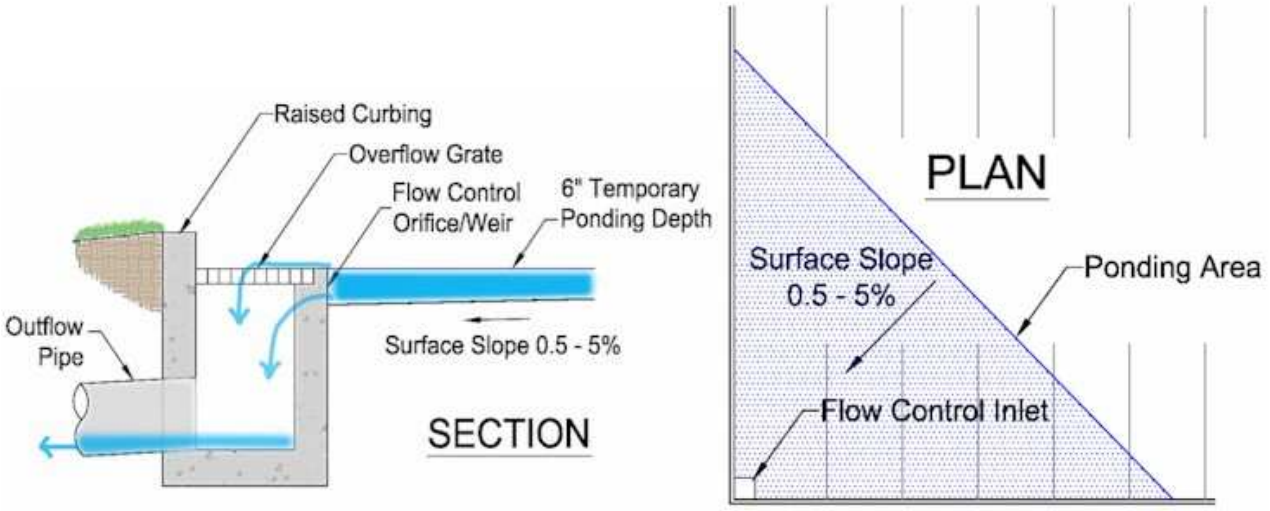
Idaho Department of Environmental Quality. *Idaho Catalog of Stormwater BMPs.*

Auckland Regional Council, 2003. *Stormwater Management Devices: Design Guidelines Manual*, Auckland, New Zealand

US EPA, NPDES, *Construction Site Storm Water Runoff Control – Permanent Diversions*

Designing Level Spreaders to Treat Stormwater Runoff (W.F. Hunt, D.E. Line, R.A. McLaughlin, N.B. Rajbhandari, R.E. Sheffield; North Carolina State University, 2001.)

BMP 6.8.2: Special Detention Areas – Parking Lot, Rooftop



Areas such as parking lots and rooftops that are primarily intended for other uses but that can be designed to temporarily detain stormwater for peak rate mitigation.

Key Design Elements

- Almost entirely for peak rate control
- Water quality and quantity are not addressed
- Short duration storage; rapid restoration of primary uses
- Minimize safety risks, potential property damage, and user inconvenience
- Emergency overflows
- Maximum ponding depths
- Flow control structures
- Adequate surface slope to outlet
- Waterproofing (rooftop storage)

Potential Applications

Residential: Limited
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Very Low
Recharge: Very Low
Peak Rate Control: Med./Low
Water Quality: Low

Water Quality Functions

TSS: 0%
TP: 0%
NO3: 0%

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Description

Special Detention Areas are places such as parking lots and rooftops that are primarily intended for other uses but that can be designed to temporarily detain stormwater for peak rate mitigation. Generally detention is achieved through the use of a flow control structure that allows runoff to temporarily pond. In most cases, ponding depths should be kept less than one foot. Special Detention Areas can be very effective at reducing peak rates of runoff but do little in terms of water quality and almost nothing to reduce the volume of runoff. Therefore, Special Detention Areas should be combined with other BMPs that address water quality, quantity, and groundwater recharge.

Variations

Special Detention is especially suited for:

- Large gently-sloping parking lots



- Flat rooftops



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- Recessed plazas



- Athletic fields



Applications

Detention areas can be created in parking lots in depressed areas or along curbs by controlling flow at stormwater inlets and/or using raised curbing. Rooftop runoff storage can be achieved by restricting flow at scuppers, drains, parapet wall openings, etc. Recessed plazas and athletic fields can be designed with detention through the use of flow control structures and/or berms (for fields). Special Detention Areas can be used effectively to attenuate flows reaching other BMPs and thereby increase their performance; they can also be used to meet release rate requirements from Act 167 plans or municipal ordinances.

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Design Considerations

1. General

    a. Emergency overflows should be designed to prevent excessive depths from occurring during extreme events or if the primary flow control structures are clogged. Emergency overflows should be designed to safely convey flows downstream.
    b. Storage areas should be adequately sloped towards outlets to ensure complete drainage after storm events.
    c. Flow control structures should be designed to discharge stored runoff in a timely manner so that the primary use of the area can be restored.
    d. Care should be taken to ensure against ice build-up in the pooled area.

2. Parking Lot Storage

    a. Locate storage in areas so that ponding will not significantly disrupt typical traffic or pedestrian flow. Remote areas of large commercial parking lots, overflow parking areas, and other under-utilized parking areas are prime locations.
    b. Minimize potential safety risks and property damage due to ponding. Detention areas should be identified with signage or pavement markings or their use should be restricted during storms.
    c. Storage depths must be no greater than 1 foot.
    d. The area used for detention should be sloped towards the flow control structure at a least 0.5% to ensure adequate drainage after storms. Slopes greater than 5% tend to be inefficient because storage volume is much lower for a given ponding depth.

3. Rooftop Storage

    a. The roof structure must be able to support the additional load created by ponded water. Most roofs designed for snow load will be able to support runoff storage.
    b. Ponding depths should generally be less than 6 inches and stored water should not cause damage to any HVAC equipment on the roof.
    c. The areas utilized for storage must have adequate waterproofing.
    d. Emergency overflows can be provided by openings in the parapet wall or by additional drains.

Detailed Stormwater Functions

Volume Reduction Calculations

Special Detention Areas generally do not achieve significant volume reduction.

Peak Rate Mitigation Calculations

Peak rate of runoff is reduced in Special Detention Areas through the transient storage provided. See in Section 9 for Peak Rate Mitigation methodology.

Water Quality Improvement

Although they may provide some quality improvement through settling, Special Detention Areas do not appreciably address water quality.

Construction Sequence

Not applicable.

Maintenance Issues

Special Detention Areas generally require little maintenance. Maintenance activities should include semiannual inspection and cleaning of flow control structures, clearing debris/sediment from detention areas (as necessary), and inspecting waterproofing in rooftop storage areas.

Cost Issues

Special Storage Areas can be a very economical means of reducing peak rates of runoff because they require little additional material and take up no additional space on a site.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. Flow Control Structures

    a. Flow control structures shall be constructed of non-corrodible material.
    b. Structures shall be resistant to clogging by debris, sediment, floatables, plant material, or ice.
    c. Materials shall comply with applicable specifications (PennDOT or AASHTO, latest edition)

2. Waterproofing

    a. Waterproofing shall prevent all water migration into the building.
    b. Waterproofing must comply with applicable state and local building codes.
    c. Waterproofing shall have an expected service life of at least 25 years.

References

2001, Georgia Stormwater Management Manual; Volume Two: Technical Handbook

2003, Ontario Stormwater Management Planning & Design Manual

Iowa Statewide Urban Design Standards Manual

1992, Michigan - Index of Individual BMPs

Pennsylvania Stormwater Best Management Practices Manual

Chapter 7

Special Management Areas

(Brownfields, Highways and Roads, Karst Areas, Mined Lands, Water Supply Well Areas, Surface Water Supplies and Special Protection Waters)



363-0300-002 / December 30, 2006

SARB_014960

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Special Management Areas (Brownfields, Highways and Roads, Karst Areas, Mined Lands, Water Supply Well Areas, Surface Water Supplies and Special Protection Waters)

7.1 Introduction

The non-structural and structural BMPs described in the preceding Chapters provide measures that mitigate the additional volume, pollutant load and increased rate of runoff produced by land development. Some land surfaces, however, will not be compatible with the application of certain BMPs. Successful compliance with the Control Guidelines described in Chapter 3 should still be possible for most new land development sites, but the range of measures available may be limited. In fact, some types of BMPs may be totally unsuitable for consideration in these special land areas and should be excluded from application.

The land use types considered as "Special Management Areas" are very different from each other, but all are places where land disturbance can alter the original natural environment. This land use type, past or present, above or below the surface, will dictate which BMPs are suitable.

7.2 Brownfields



Brownfields are real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of hazardous substances, pollutants, or contaminants. Cleaning up and reinvesting in these properties takes development pressures off of undeveloped, open land, and both improves and protects the environment. (Source: http://www.epa.gov/brownfields/)

Pennsylvania encourages private cleanups of contaminated properties and the return of those sites to productive use. It has developed programs such as the Act 2 – Land Recycling Program, which was envisioned as an integral part of a sound land use policy that would help prevent the needless development of prime farmland, open space areas and natural areas; and the Brownfield Action Team, which expedites the remediation, reclamation, reuse and redevelopment of brownfield lands. It is important to point out that this section of the manual is applicable to all cleanup sites, not just those that enter the Act 2 Program – which is a voluntary program.

Smart growth encourages the redevelopment of brownfield properties as pedestrian friendly, transit-accessible properties, built compactly with a mixture of land uses, and with access to public spaces, parks or plazas. Use of smart growth principles in brownfield redevelopment can create greater benefits from the reuse of infill sites, reduce demand for land for development on the urban fringe, and improve the air and water quality of the regions in which they are applied. Brownfield redevelopment is an essential component of smart growth, as both seek to return abandoned and underutilized sites to their fullest potential as community and economic assets.

Brownfield sites have a wide range of complexity, primarily dependent on previous, existing and proposed land use. Land development at brownfield sites normally occurs in two stages: (1) site remediation and (2) redevelopment. Planning, design and construction work associated with these two stages typically involve separate consultants and/or contractors. There are very few practitioners who perform both stages of work. This bifurcation of responsibility can potentially lead to miscommunication, mistakes and problems. It is critical that both parties coordinate and are mutually agreeable to the proposed activities at the site.

When applying for permits for a brownfield site (for either stage), it is imperative that the applicant provide full disclosure, including but not limited to the following information:

1. Existing and previous land uses
2. Potential pollutants, along with a summary of sampling data.
3. Source and location of the potential pollutant(s) on the Erosion and Sediment Control (E&S) Plan drawings,
4. A description of what measures are proposed to manage and control discharges of these pollutants to eliminate the potential for pollution to surface waters of the Commonwealth.

7.2.1 Site Remediation (i.e. Cleanup)

The site remediation stage does not typically generate new impervious surfaces. In fact, remediation may reduce impervious area through the demolition of buildings and other impermeable surfaces. These areas, along with other earthmoving related to the cleanup, are usually temporarily stabilized until the site is redeveloped. As a result, this stage of land recycling does not typically require structural infiltration stormwater BMPs. The focus of site remediation routinely involves earthmoving to address soil and groundwater contamination. The stormwater management portion of this work is normally limited to non-structural BMPs, consisting of detailed construction sequencing or other measures to prevent the transport of contaminated runoff from the site.

How stormwater is managed on brownfield sites depends largely on how the site was remediated. Contaminated soil can be completely removed from the site, contaminated soil can be isolated and capped, or contaminated soil can be blended with clean soil so that it meets state standards for public health and safety. For more information on site remediation, go to: www.depweb.state.pa.us.

7.2.2 Site Redevelopment

Most of the site improvements occur in the redevelopment stage. It is imperative that this stage of the project does not disturb any completed work from the site remediation stage (e.g. a cap or other cleanup remedy). Conflicts most frequently arise during the foundation work or utility work phases of a project. Utility lines, in particular, are often overlooked and can have a major impact by opening new preferential pathways for contaminants to migrate. Each stage should be considered independently; ideally, the remediation work should be completed prior to commencing redevelopment work.

The redevelopment stage is where any net increase of impervious area would be expected to occur; thereby leading to increases in the rate and volume of stormwater runoff. Even where there is no net increase in impervious area, the existing site is usually devoid of any notable stormwater management BMPs. This is the stage where post-construction stormwater management must be addressed.

All stormwater management options are available for use on brownfield sites where the contaminated soil has been completely removed from the site. Emphasis should be placed on minimizing the amount of earth disturbance area and soil compaction, minimizing the creation of impervious area, maximizing stormwater infiltration, and dispersing runoff to a number of BMPs scattered around the site rather than conveying and concentrating runoff to just a few locations.

For the less severe cases, a brownfield redevelopment can follow the same track as a conventional land development project, provided that certain precautions are taken. To facilitate this process, the applicant should clearly identify on their plan drawings where "hot spot" areas are known to exist and any associated remediation that may have occurred. The project consultants should prepare this vital information during the site remediation stage. Except for structural stormwater infiltration BMPs, the stormwater management options listed in this manual are also available for use on brownfield sites where contaminated soil is isolated and sealed, or the contaminated soil was blended with clean soil. Since soil contaminants are still present at these sites, the use of structural stormwater infiltration BMPs should be used only if the residual soil contaminants are non-soluble pollutants.

Precipitation and some runoff can be infiltrated through lawn and landscaped areas. These areas should be designed to have a layer of topsoil at least 8 inches thick. The topsoil should contain sufficient decomposed organic material (10 percent by dry weight is recommended in the Stormwater Management Manual for Western Washington) to provide cation exchange capacity to remove pollutants.

Bio-retention provides good options for water quality BMPs on all sites, including brownfield sites. Bio-retention coupled with infiltration should be considered on brownfield sites where all soil contaminants have been removed during remediation, or where only non-soluble contaminants remain. On brownfields where soluble contaminants are still present in the soil, bio-retention BMPs should be designed so that all water passing through the planting soil is directed to an overflow and not permitted to infiltrate.

Vegetated roofs can be used effectively on brownfield sites to retain much of the rainwater that falls on the roof. This BMP is very effective in areas where subsurface systems are not feasible. Stormwater can also be retained in basins or landscaped ponds and allowed to evaporate.

Cisterns and vertical storage units can be placed in corners of structured parking lots, inside buildings, on the outside walls of buildings, in adjacent alleys, alongside elevator shafts, and other locations deemed feasible by the designer. Vertical storage is particularly applicable to urban areas where space is at a premium. The shape and location of this BMP requires very little land area. Water collected this way can be re-used for things such as fire suppression, drip irrigation, lawn sprinkling, cooling buildings, toilet flushing and recreational water.

Chapter 6 of this manual provides more detailed information on these structural BMPs.

7.3 Highways and Roads

The purpose of this section is to consider the most suitable BMPs for managing runoff from roadways. Consideration of roadway design, construction, and maintenance should be included in the selection of BMPs that minimize the rate and volume, and enhance the quality of roadway runoff.

Mitigating the impacts of runoff from highways and roads is a concern for highway managers (such as PennDOT and the PA Turnpike Commission) and for municipalities; particularly those tasked with stormwater management and NPDES Phase II responsibilities. Highways and roads face specific challenges in managing stormwater, including:

- The need to manage stormwater while maintaining safe road conditions
- Limited available space and the need to locate BMPs within the right-of-way, if possible.
- Drainage area imperviousness greater than 50 percent, and sometimes 100%.
- Areas of extensive disturbance and compaction of soils (cut and fill).
- The potential for spills of hazardous materials.
- The use of deicing chemicals and salts as well as anti-skid materials, and the need to dispose of removed snow.
- Higher concentration of pollutants as compared to many other land uses.
- Thermal impacts to receiving streams in both summer and winter.

Pennsylvania ranks eighth in the country in terms of "total road and street" miles (http://www.fhwa.dot.gov), with a total of over 120,000 road miles, including over 18,000 miles of dirt and gravel roads. The intersection of these roads with the 86,000 miles of rivers and streams in Pennsylvania warrants careful consideration by stormwater managers and roadway designers alike.

7.3.1 Roadway Runoff Quality Issues

Highway and roadway runoff has been identified as a significant source of stormwater pollutants (Bannerman, et al 1993), as well as a significant source of thermal pollution to receiving waterways (Bush, et al 1974). The chemical constituents of roadway runoff are highly variable. The Federal Highway Administration (FHWA, 1999, Ultra-urban) identifies a number of roadway runoff pollutants and possible sources (Table 7-1). The FHWA also summarizes the concentrations of typical constituents found in highway runoff as outlined in Table 7-2. In comparison to other land uses and impervious surfaces, roadway runoff tends to have higher levels of sediment and suspended solids, which must be taken into consideration when selecting BMPs. Roadway runoff may also contain salts, deicing materials, and metals that can affect both receiving waters and vegetation and must be considered in BMP selection.

In addition to the chemical water quality issues associated with roadway runoff, exaggerated temperatures may also affect water quality. Roadway systems may deliver large amounts of warm or cold water directly and rapidly to receiving streams and wetlands, resulting in significant temperature extremes that could be harmful to fish and other aquatic life. Studies have shown that the runoff from summer storm events may exceed 90 degrees F, and winter runoff may be 37 degrees F colder than the receiving stream ambient temperature (Galli, 1990, Pluhowski, 1970). Such wide temperature differentials can have profound impacts on the aquatic systems of a receiving stream, and significantly alter and reduce the native aquatic life and its diversity. Stormwater collection and conveyance systems, and stormwater BMPs, should be designed with consideration of the potential thermal impacts on receiving waters due to runoff from road surfaces. Extended detention basins, in particular, should be designed to reduce this potential as discussed below.

*Table 7-1 Constituents and Sources in Highway Runoff **

Constituent	Source
Particulates	Pavement wear, vehicles, atmospheric deposition, maintenance activities
Nitrogen, Phosphorus	Atmospheric deposition and fertilizer application
Lead	Leaded gasoline from auto exhausts and tire wear
Zinc	Tire wear, motor oil and grease
Iron	Auto body rust, steel highway structures such as bridges and guardrails, and moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear and insecticide application
Chromium	Metal plating, moving engine parts, and brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, and asphalt paving
Manganese	Moving engine parts
Cyanide	Anti-caking compounds used to keep deicing salts granular
Sodium, Calcium Chloride	Deicing salts
Sulphates	Roadway beds, fuel, and deicing salts

* From FHWA Stormwater Best Management Practices in an Ultra-Urban Setting

Table 7-2. Constituents of Highway Runoff

Parameter	Concentration (mg/L)
Total Suspended Solids (TSS)	45 - 798
Volatile Suspended Solids (VSS)	4.3 - 79
Total Organic Carbon (TOC)	24 - 77
Chemical Oxygen Demand (COD)	14.7 - 272
Biochemical Oxygen Demand (BOD)	12.7 37
Nitrate + Nitrite (NO_3 + NO_2)	0.15 - 1.636
Total Kjeldahl Nitrogen (TKN)	0.335 - 55.0
Total Phosphorus as P	0.113 - 0.998
Copper (Cu)	0.022 - 7.033
Lead (Pb)	0.073 - 1.78
Zinc (Zn)	0.056 - 0.929
Fecal coliform (organisms/100 ml)	50 - 590

7.3.2 BMP Considerations for Roadways

While many of the BMPs discussed in this manual are appropriate for use in managing roadway runoff, these BMPs should be designed and implemented with consideration to the nature of runoff from road surfaces. Specifically:

1. Roadway runoff generates higher levels of suspended solids than most other urban land uses. Roadway runoff should not be discharged directly to infiltration systems without first reducing sediment loads. Infiltration BMPs are appropriate for roadway systems but must be designed in conjunction with a measure (structural or non-structural) that reduces the amount of sediment in roadway runoff prior to infiltration. There are a variety of options that will reduce sediment loads, including:

    a. Vegetated systems such as grassed swales, filter strips, and bioretention;
    b. Structural elements such as catch basin inserts, filters, and manufactured treatment units; and
    c. Maintenance measures such as street sweeping and vacuuming.

    Using some or all of these measures before discharging to an infiltration BMP will minimize the accumulation of sediment that could lead to failure of an infiltration BMP. All measures for sediment reduction require regular maintenance.

2. Vegetative BMPs such as grassed swales and filter strips can be highly effective in reducing pollutant loads from roadways but must be properly designed in terms of slope, flow velocity, flow length, and vegetative cover (Barrett, et al, 1997). Improperly designed or maintained systems may contribute to pollutant load, rather than reduce it.

3. The potential for spills must be considered. It is cost prohibitive to design for spill containment on all sections of roadway, but the designer should certainly consider the potential for spills and the necessary action should a spill occur. Subsurface systems, infiltration systems, or vegetative systems may require replacement should a spill occur. While this may seem to be a limiting factor in the use of such systems, many existing storm sewers from roadways discharge directly to receiving streams with no opportunity to contain or mitigate a spill before discharge to a receiving stream. Therefore, while BMP restoration may be required after a spill, the potential for a direct stream discharge of the contaminated substance will be greatly reduced or eliminated.

4. The use of deicing materials and salts, as well as anti-skid materials, may affect vegetation, soil conditions, and water quality. Consideration should be given to the types of vegetation used in vegetative BMPs, as high chloride levels may adversely affect some vegetation as well as the soil microbial community. Proximity to water supply sources should also be considered when designing infiltration BMPs, and the potential for groundwater chloride levels to be impacted by roadway runoff should be considered. Consideration must also be given to the disposal of snow removed from roadways. This snow may ultimately be deposited in BMP areas and may contain higher concentrations of roadway salts and sediments. The potential impacts of this material on the BMP should be considered in the design process.

5. Temperature extremes of runoff from roadways can significantly affect receiving stream aquatic habitat. Roadways, especially asphalt roadways, tend to absorb heat and lack cooling vegetation. Many existing storm sewers from roads discharge directly and immediately to receiving waters. New discharges should provide mitigation for temperature impacts prior to discharge to the receiving water. This may involve:

    a. Vegetated systems and buffers to replace sections of concrete swales or pipes that impart heat to runoff. Use of multiple small drainage elements that use

vegetated swales for conveyance can help reduce the temperature impacts from roadway runoff.

b. If extended detention systems, wet ponds, or constructed wetlands are used for peak rate mitigation, the discharge from these systems should be further mitigated by the use of vegetated swales or buffers, as these impoundments may also create adverse temperature impacts (SWRCB 2002; Oberts 1997). The discharge from an extended detention system should be conveyed by a vegetated swale, or dispersed through a level spreader, wherever practicable. Discharges should not be routinely piped directly into receiving streams or wetlands.
c. Extended detention systems should include design elements (Table 7-3) to attenuate runoff temperature. Recommended techniques (FHW, Young, et al 1996) include:
    1. Designing the system with minimal permanent pool;
    2. Preserving existing shade trees and planting fast growing trees along the shoreline, but not on the constructed embankment;
    3. Aligning ponds in a north-south direction; and
    4. Avoiding excessive riprap and concrete channels that impart heat to runoff.

Table 7-3. Impacts and Mitigation Measures for use of extended detention basins (Young, et al. 1996)

Environmental Issue	Diligent Responses
Need to avoid an existing wetland	Perform wetland delineation before sitting pond.
	Select pond systems with minimal permanent pool.
	Adjust pond configuration.
	Install parallel pipe system to divert runoff around wetland to pond site sited further downstream.
	Construct ponds around the wetland.
Need to preserve mature forest or habitat area	Configure pond to minimize the removal of specimen trees.
	Limit the area of disturbance.
	Mandate tree protection measures during construction.
	Plant native trees and shrubs to replicate habitat functions lost due to pond.
Concern about the thermal impact of pond on downstream fishery	Select system with minimal permanent pool.
	Preserve existing shade trees, plant fast-growing shade trees along the shoreline.
	Align pond north-south direction.
	Avoid excessive riprapping and concrete channels that rapidly impart heat to runoff.
	Maximize detention and/or increase first flush amount to runoff greater than first 13 mm of rain.
Need to protect stream reach above pond from urban storm flows	Install parallel pipe system along the upstream reach to convey excessive storm flows.
	Install plunge-pools at terminus of storm drains to reduce runoff velocities.
	Use bioengineering techniques and check dams to stabilize the stream reach.

PENNDOT Program and Recommendations

As the primary state agency charged with construction, operation and maintenance of the major roadways in the Commonwealth, the PA Dept. of Transportation has worked to develop a strategy to address two related issues. The immediate impact created by earthwork and disturbance during new construction, considered as Erosion and Sediment Control (E&S), is the subject of the recent Manual produced by the Department (PENNDOT E&S Manual, 2004). The long-term problems of stormwater runoff, discussed here, remains as a major issue. In discussions with PADEP, a set of strategies have been developed as follows:

- Use sod-forming grasses adjacent to the roadway shoulders and for vegetated swales to serve as filters for suspended solids and metals.
- Use non-invasive native species vegetation (or plant species that are known to take up and store certain contaminants) in lawn areas, on slopes and within wetland reconstruction/banking areas to enhance water uptake and the storage of certain pollutants in plant tissue.
- Limit the use of curb-gutter sections as much as practical for filtering and temperature considerations.
- Limit the use of storm sewers as much as practical for filtering and temperature considerations.
- Consider bioretention capability in the design of new detention basins (Dry Extended Detention Basin design).
- Monitor the effectiveness of existing constructed wetlands, updating the current design practices as necessary.
- Consider alternative methods of energy dissipation (in-lieu of rock pads) at culvert and storm sewer outfalls for temperature considerations.
- Where practical, discharge storm sewers into wetland areas or vegetated swales instead of discharging directly to streams for filtering and temperature considerations.
- Consider vegetated islands in-lieu of concrete islands (where practical for maintenance considerations) for filtering and temperature considerations.
- Consider the inclusion of infiltration berms and retentive grading in areas that are down slope of the roadway.
- Continue efforts to monitor and minimize the volume of winter maintenance materials utilized to minimize pollutant loadings within the runoff and into the groundwater.
- Continue efforts to protect all salt storage and loading areas from weather influences in efforts to minimize pollutant loadings.

- Consider practices to dilute flows where high concentrations of salts are anticipated to minimize pollutant loadings.
- Consider porous pavement and other subsurface infiltration methodologies on Department park-and-ride sites and for Department building site parking areas.
- Consider dry wells and other subsurface infiltration methodologies for Department building roof drains.

7.3.3 Specific BMP Considerations:

Limited Access Highways, Interstates and Turnpikes (Principal Arterials)

Highways are usually designed with shoulders and often include vegetated medians, presenting prime areas for BMP implementation. Infiltration opportunities may be limited due to compaction and fill, as the right-of-way is often subject to significant grading changes to meet highway design standards. However, infiltration should not be precluded, and should be considered on a case-by-case basis.

The use of vegetated swales and buffer strips is highly recommended to reduce sediment loads from highways, but the possible impact on sight distances and roadway visibility must be considered, with planting design sensitive to this height issue. Vegetated swales and buffer strips can be combined with subsurface infiltration trenches or small infiltration/bioretention basins for volume reduction and temperature mitigation. For example, strips of vegetated swales that are underlain by infiltration trenches can provide both quality treatment and volume reduction, and replace concrete channels and pipe systems. Numerous small bioretention systems can provide peak rate mitigation and be incorporated into the right-of-way.

New Streets and Residential Roads

New streets and roads in residential and commercial developments provide the greatest opportunity to incorporate both non-structural and structural BMPs to address road runoff. Non-structural BMPs include:

- Reduced street widths
- Reduction or elimination of curbs and gutters
- Reduction of storm sewer infrastructure

Structural residential road systems include:

- Vegetated swales and infiltration trenches along the right-of-way
- Bioretention areas along the roadway
- Bioretention or bio-infiltration in cul-de-sacs
- Porous pavement
- Infiltration trenches along the contour that are perpendicular to the road
- Catch basin inserts or treatment devices

In new development, the roads and driveways often comprise the greatest amount of impervious area, sometimes as much as 70% of the total impervious area. Techniques that seek to manage the roadway runoff where it is generated, and reduce piping and conveyance of stormwater, should be implemented to the greatest extent possible.

Bridges

Grit and oil removal BMP's should be considered for addressing stormwater discharging from scuppers serving bridge decks. If the inclusion of grit and oil removal BMP's is not feasible due to design constraints, more frequent "street cleaning" of the bridge deck should be made part of the project's Operation and Maintenance plan.

7.3.4 Dirt and Gravel Roads

A significant portion of the state is served by unpaved roadways constructed of various types of gravel base, constructed over time and with locally available materials. While not constructed with AC impervious pavement, theses roadways serve as stormwater conveyance pathways, creating significant erosion in the process and requiring constant maintenance to restore shoulders.

Pennsylvania has over 18,000 miles of unpaved roads. These roads consist of dirt and or gravel, and have historically been undermaintained compared to paved roads. These roads are frequently a source of pollution to streams and rivers in a drainage area, especially for sediment. This pollution occurs as precipitation carries sediment eroded from these roads and adjacent banks along the road surface and into open water. Statewide, while runoff from these roads is not the major source of pollution in streams, close proximity of rural roads to high quality streams is common, and these roads often parallel streams and discharge directly into them. Others have culverts that convey large amounts of water before discharging at high rates, following long downhill grades to a stream crossing. Adequate drainage is essential to the longevity of these roads, but environmentally sensitive practices for discharge of this drainage will benefit the health of the surrounding environment.

Pennsylvania's Dirt & Gravel Road Pollution Prevention Program was formed in 1997 to "fund environmentally sound maintenance of unpaved roadways that have been identified as sources of dust and sediment pollution." This program strives to reduce erosion, sediment, and dust pollution by using improved maintenance techniques that benefit both dirt and gravel roads and the environment. This program is centered on using local control as a method of stopping pollution. To date, at least 1400 projects have been completed under this program, and over 3,500 people have participated in the program's two day "Environmentally Sensitive Maintenance." Training course. Eligible dirt and gravel road sections are those identified by County Conservation District personnel as having a sediment source from the road polluting a stream.

Program initiatives include identifying and replacing pipes running beneath unpaved roads that are undersized and contribute to "ponding" on the road. The program also has developed a GIS (Geographical Information Systems) database, which tracks the location and status of all the dirt and gravel roads in PA, and allows the local entities to submit electronic reports directly to the State Conservation Commission. In 2000, data from over 17,000 miles of unpaved roads was compiled and resulted in over 11,000 verified pollution sites found. In addition to this, the

program is undergoing an aggregate study in Centre County, PA to determine the most economical and durable stone for gravel roads.

Local Municipalities and state agencies have jurisdiction of over 90% of dirt and gravel roads, and because the cost of paving these roads is often too high for the road owner, there are several best maintenance practices that can be employed to maintain an unpaved road in an environmentally sensitive manner. Recommendations include:

- Working with the natural landscape in the design of roads (minimize cut and fill)
- Identifying existing drainage patterns and designing to minimize disturbance
- Crowning the road to drain the water away from the center
- Using graders with scarified blades as preferred equipment to reshape a road
- Sizing roadside ditches appropriately and outletting appropriately within an infiltration design
- Driving Surface Aggregate mix should have increased abrasion resistance, be angular on the surface with increased fines to provide stability and facilitate compaction (stone quality matters)
- Vegetating roadside banks to prevent erosion
- Using snowplow shoes when clearing snow and re-shaping the road after snow season
- Preserving soil stabilizing vegetation in ditches and observing appropriate roadside vegetation management practices along road corridors
- Limiting driving speeds

Reduced road maintenance costs (grading, regrading, & re-graveling), and reduced sedimentation in water affecting aquatic life and drinking water reservoirs, should result from the implementing these measures, and are consistent with the various BMPs discussed in this manual. A detailed listing of technical bulletins and further information on “Environmentally Sensitive Maintenance” practices for dirt and gravel roads is available from the Center for Dirt and Gravel Road Studies at Penn State University (www.dirtandgravelroads.org).

7.4 Karst Areas

7.4.1 The Nature of Karst

Surface-Water Interaction: Water is a key to sinkhole collapses. Taking water away from where it was or putting a new, concentrated source of water where it wasn’t before can speed the development of sinkholes. Examples of new sources of water could be drainage from rain gutters, pavement, collection ditches and ponds. Treatment basins or lagoons must be diligently lined in karst to prevent a sudden drainage out of the bottom and into the groundwater. Leaky water and sewer pipes can cause the soil underneath to wash away and are often the trigger for sinkholes. However, an existing sinkhole under a pipe can cause the initial leak. The greater the volume of water and the faster it moves into the karst system, the more soft material is washed from the voids. Weather events can also trigger sinkholes. In Pennsylvania, sinkholes can “pop” when a heavy rain event comes after a prolonged drought.

Karst areas present problems to those attempting to work with conventional hydrologic models. Typically, modeling of a karst site or watershed via SCS or other traditional methods provides poor representation of runoff rates, with regard to both flooding and over-design of conduits and stormwater management facilities. This is largely because standard hydrologic modeling methods lack allowances for losses into sinkholes, fractures, crevices or caves that may exist in the

carbonate units. Neither do models typically account for the stormwater that joins surface runoff as “interflow” when the collective capacity of interconnected conduits and cavities in the subsurface is exceeded. (Source: **Technical Bulletin No. 2** Virginia Department of Conservation and Recreation - Hydrologic Modeling and Design in Karst)

Karst loss is a term given to surface runoff loss into bedrock strata in areas underlain by limestone formations. Unlike other calculation factors, such as curve numbers (which deal with characteristics of the land surface), a karst loss factor is intended to depict projected losses into bedrock. The determination of karst potential in any given area may be simplified by the observation of noticeable indicators such as caves, crevices, limestone outcrops, sink holes, ponds that appear to lack sufficient contributing area, and disappearing streams. In other cases, karst infiltration areas may be difficult to identify since definitive karst features are not always obvious. Generally, a lack of natural drainage way erosion or inadequately sized drainage ways (for the size of the contributing area) may be clues to karst loss. Other observations may include undersized drainage conduits that never run full.

Thick sequences of carbonate bedrock (limestone and dolomite) underlie a sizeable area in - central and southeastern Pennsylvania. Folding and faulting have extensively fractured this bedrock. Over millions of years, chemical weathering of the deformed carbonate units by weakly acidic water along points of weakness has produced a subdued, but deeply developed karst (Wilshusen and Kochanov, 1999). The process of carbonate bedrock dissolution results in a distinct landscape called karst topography. Karst topography includes features such as sinkholes, surface depressions, and caves. Other notable characteristics are significant changes in the depth to bedrock or groundwater table within a short distance and “losing” streams that disappear into the subsurface.

Karst development is a water-driven system; whereby the enlargement of fractures creates a natural system of “pipes and drains” that serves to transport groundwater, surface water and surficial material. Karst drains are typically covered with a mantle of soil. Surface and/or groundwater can mobilize these sediments into subsurface voids, resulting in sinkholes or closed depressions. Variations in the volume of water entering the karst system can increase the rate at which sinkholes develop.

Karst aquifers are vulnerable to contamination when the natural filtration capability of soil is bypassed due to thin soils, sinkholes or subsurface open fractures and voids. Contaminants can enter the karst system and travel long distances over a relatively short period of time.

When addressing stormwater management issues, **the complexities of a karst system demand a more rigorous scrutiny than other geologic settings**. In areas that undergo land-use changes, stormwater, which once had established infiltration routes into the ground, may then be captured and redirected into a variety of artificial drainage ways and catchment areas. This change creates an imbalance that can result in increased subsidence and sinkhole activity, potential groundwater contamination, and could affect the quantity and quality of the karst aquifer system (Knight, 1971; Newton, 1987; White and others, 1986).

7.4.2 Infiltration vs. non-infiltration

A decision must be made to either promote infiltration at a karst site (recommended, but may not be feasible in all areas) or eliminate infiltration altogether as an attempt to curb sinkholes or contamination liability. This decision must be based on a sound site assessment and

consideration of potential contaminants that can be introduced by the proposed project. The worst scenario is to ignore karst features entirely and thus significantly increase the potential for costly delays, repairs, catastrophes and legal proceedings.

Stormwater control plans that utilize infiltration in karst are more common in areas such as Kentucky (Crawford, 1989) and Tennessee (McCann & Smoot, 1999) but have generally been avoided by hesitant or inexperienced developers in Pennsylvania. Non-infiltration plans may seem safer and more economical even with the increased cost, but, an additional, long-term "cost" is associated – lowering of the groundwater table, reducing the potential groundwater resources of an area, and increasing the risk of a sudden, catastrophic ground collapse (via a failed impoundment, swale, retention structure, etc.). Use of infiltration BMPs, especially watershed-wide, is the best method for stormwater control in most karst areas. (Crawford, 1989)(McCann & Smoot, 1999) Future research in this area should identify additional innovative solutions to these stormwater management challenges.

7.4.3 Basic Principles

Successful stormwater management in karst areas can be achieved by developing a strategy for the site that will be best suited to function within the tolerance limits of the natural system. Every effort should be made to maintain the pre-development hydrologic regime and utilize existing karst drainage features in a safe way. The risk of sinkholes, subsidence problems and potential groundwater contamination issues should be of utmost consideration. As previously noted in Chapter 3, watershed-wide stormwater planning that considers and incorporates the existing karst drainage will achieve the best overall results.

The following basic principles must be considered in karst areas:

Identification, understanding and consideration of geologic information are crucial.

- An initial site assessment is critical to identify karst and existing drainage features. It is recommended that a broader area be reviewed to spot regional trends in geology and drainage. A thorough site assessment should include, but not be limited to, the following:
    - Review of aerial photographs, geologic literature, sinkhole maps, borings (if available), existing well data, and municipal wellhead or aquifer protection plans.
    - Site reconnaissance, including a thorough field examination for features such as limestone pinnacles, sinkholes, closed depressions, fracture traces, faults, springs and seeps. Special attention should be paid to confirmation of features located during literature review.
    - Drilling of boreholes.
    - Determination of groundwater elevations, especially with respect to the bedrock surface, and flow direction. To assess seasonal changes, it is necessary to obtain groundwater measurements over several months to a year.
    - Geophysical surveys to locate subsurface anomalies. Consult a professional experienced in geophysical methods and karst areas before conducting these tests.
- Observe the site under different weather conditions especially during heavy rain events and through different seasons. Identify and map the natural drainageways.
- A site design in karst areas should be supported by a geotechnical or hydrogeologic report conducted by a qualified and/or licensed professional (i.e., soil scientist, geologist, hydrogeologist, geotechnical engineer, etc.). The report should include:
    - Site reconnaissance discussion.

- Identification and mapping of karst features and hydrogeologic conditions of the site.
- Identification and mapping of existing drainage patterns and features.
- Discussion of groundwater hydrology.
- Survey of soil characteristics and thickness and analysis of the site's capability for infiltrating stormwater.
- A discussion of how infiltration will be handled to avoid contamination of the groundwater aquifer.
- A plan view drawing of the site, noting the locations of important features. This plan should delineate areas available for infiltration, areas not suitable for infiltration and areas where development should not occur.
- A contingency plan to be used if unexpected conditions or unmapped karst features are encountered during site excavation.

Refer to the Case Studies in karst areas contained in Chapter 9 for examples. More information is available from Virginia DCR Technical Bulletin No. 2, Memon and others, 1999 and Ralston, and others, 1999)

Maintain natural conditions within the stormwater plan to the maximum extent possible.

- Maintain the natural water balance for surface flows and groundwater recharge. (See also section 5.4.3). Existing drainage patterns and features, both natural and artificial, should be taken into consideration. Use these pre-development drainage ways to the maximum extent possible. Avoid building on or adjacent to these drainage features.
- Maintain groundwater levels and hydrostatic pressure to the maximum extent possible – avoid large groundwater withdrawals, elimination of recharge areas or concentrated injection (in reference to time as well as location). Fluctuating groundwater levels will undermine the structural stability of the subsurface.
- Establish a buffer zone around karst features that are not used for infiltration - areas of historic or active sinkholes or surface depressions and related geologic features such as fracture zones and faults - grading water away from these features. Establish filter berms (with gabions or vegetation, for example), etc. to prevent contamination from overland flow and discourage access to these areas. (McCann & Smoot, 1999)
- Designate aquifer recharge areas. Promote safe infiltration. Direct recharge into groundwater aquifers without proper filtration of sediments and pollutants is prohibited. *Improved* sinkholes may be utilized as injection wells, but must be properly constructed. Casing must be firmly seated into competent bedrock and grouted into place. Sediment and pollution controls must be incorporated. EPA categorizes these structures as Class 5 Underground Injection Wells. With adequate planning and design, these infiltration structures can be used successfully in karst areas (McCann & Smoot, 1999, case studies). A permit from EPA must be obtained to construct and operate a Class 5 Underground Injection Well.
- Replicate natural hydrologic loading rates as much as possible when designing infiltration BMPs. Minimize impervious surfaces. Drastically increasing or decreasing the loading rate may promote or accelerate sinkhole development. (Loading rate is the ratio of drainage area to infiltration area.)

Avoid Concentrating Water.

- Employ methods to reduce runoff volumes and velocity.

- Implement numerous infiltration BMPs throughout the site instead of just one.
- Stormwater should not be conveyed into concentrated runoff flow paths. Broad and shallow flow dispersion is most effective. Minimizing impervious surfaces should aid in decreasing runoff, in general. (Virginia DCR)
- Impounded water causes soil saturation and loss of cohesion, and produces stress from the weight of the water. Differences in hydraulic head and steep hydraulic gradients can result in sinkhole development. For these reasons, shallow basins with overflow channels are preferred over one large, deep basin. Basins, if they must be used, must have synthetic liners to prevent failure and sudden loss of water into a subsurface drain.

Diligence and site maintenance can influence the ultimate success of the stormwater plan.

- Seal all exploratory boreholes to eliminate surface water entry.
- Minimize earth disturbance when installing stormwater structures. Disturbing the upper, cohesive soils can lead to subsidence and future collapses. (Newton, 1987)
- Management of stormwater structures usually ends after construction. In karst, however, BMPs need to be inspected, cleaned, maintained, and possibly repaired. Sinkholes should be promptly and properly repaired. Inspection and maintenance schedules must be addressed in the plans.
- Pay specific attention to the integrity of piping of all types. Evidence of pipe leakage or sagging should be immediately addressed because these areas quickly become the focus for soil loss into subsurface voids that leads to subsidence and sinkhole collapse.
- All stormwater management designs for karst areas must include details for sinkhole repair during and after construction. The sinkhole repair plan should appear on the construction drawings and also be made a part of the site's Operation and Maintenance Plan. The sinkhole repair plan should be flexible to accommodate a variety of failure modes and locations. A qualified individual should oversee the repair work.

7.4.4 BMP Considerations

The conventional stormwater BMPs presented for traditional development activities are generally applicable and effective in karst areas. However, these are not necessarily the *most* effective or appropriate. (McCann & Smoot, 1999) (Virginia DCR) The following are some conventional examples of karst area BMPs:

Increased storage

- Dry detention pond
- Wet retention with lined settling ponds
- Shallow detention ponds
- Vegetated Roof

Increased infiltration

- Runoff spreaders
- Porous pavement
- Improved sinkholes / Class V injection well (See Crawford, 1989, Chapter 3)
- Perforated pipes
- Bioretention cells / rain gardens

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Decreased velocity

- Increased vegetation density / vegetated swales
- Terraced slopes
- Rip rap (preferably using carbonate rock)

Pollution control/water quality

- Filter berms
- Gravel or sand filtration systems
- Peat moss or activated carbon filtration
- Constructed wetlands (lined)
- Increased vegetation density / rain gardens
- Rip rap
- Compost

7.5 Mined Lands

Disturbed lands that have been strip or surface mined, or are underlain by deep mine excavations, are one of the most difficult areas on which to apply stormwater BMPs. The drainage of rainfall that has percolated through residual mine wastes on the land surface, or infiltrated the existing land surface and drained into deep mines and subsequently found its way to the surface from mine tunnels, has produced one of the most severe water quality conditions in Pennsylvania. Thousands of miles of streams within the state are devoid of aquatic life because of the extreme acidity of surface waters that are polluted by abandoned mine discharges. This condition is considered by most experts to be the single greatest pollution issue in the state, simply because it has no obvious or easy solution.

Since this acid drainage from abandoned mines begins as rainfall on the surface, the obvious solution would seem to be to redirect any rainfall away from any surface materials containing mine wastes, and assure that as little infiltration as possible took place above deep mine layers.

The exclusion of all infiltration BMPs in these areas would negate many of the BMPs described in Chapter 6, other than the vegetated roof systems and the capture/reuse measures. One important consideration is that the use of vegetation to remove or change the chemical form of pollutants in acid mine drainage could also include the pollutant load from new impervious surfaces where suitable. A great deal of research has been directed toward the use of wetland systems as passive AMD treatment technologies (PADEP, 2005). These systems form part of a larger strategy for abandoned mine reclamation (PADEP, 1998) in those watersheds where the problem is widespread.

All of this very important water quality research does not address the specific problem created by new development or redevelopment on mined lands. Where the potential exists for runoff from new development to come into contact with mine wastes, then surface drainage design should convey runoff to surface swales and channels free of any mine waste residual. If detention basins are used for rate mitigation, they should be lined if situated on surface mined lands or over deep mines. Water quality measures will need to rely on intensive maintenance programs for new development, and control of pollutant application, especially fertilizers, herbicides and pesticides. If porous pavements are designed, the sub-surface beds must be lined, so that the primary function will be detention rather than volume reduction by infiltration. Finally, the land development plan should place special emphasis on protection of existing vegetation and

restoration of new woodlands, because they offer the best method of healing and restoring these damaged lands.

7.6 Stormwater Management Near Water Supply Wells

Pennsylvania ranks third in the nation for the total number of public water supply wells, and nearly half of Pennsylvania's 12 million residents get drinking water directly from ground water sources. It is critical that stormwater BMPs be designed to remove pollutants from stormwater that is to be infiltrated in close proximity to public or private water supply wells, and be sufficiently isolated from ground water supply sources.

Water supply wells in Pennsylvania generally pump water from two types of aquifers, unconsolidated aquifers and consolidated rock or fractured-bedrock aquifers. Unconsolidated aquifers are composed of sands, silts and gravel. They are generally unconfined and close to the surface, have high porosity and a high measure of permeability. Water moves into and through unconsolidated aquifers readily. These aquifers are generally limited to major stream valleys, the Atlantic Coastal Plain and the glaciated northeast and northwest regions of the state. Fractured-bedrock aquifers are the most widespread and commonly exploited aquifers in the state. They may be bedrock layers composed of sandstone, shale, or carbonate rocks such as limestone and dolomite but they can also be layered or irregular bodies of crystalline rocks such as gneiss, schist, granite and diabase. Ground water in bedrock aquifers can occur in either unconfined or confined conditions. Fractured-bedrock aquifers have low primary porosity and ground water is mainly stored in openings between rock layers and in fractures throughout the rock. Water moves into and through these aquifers much more slowly than in unconsolidated aquifers. Exceptions occur in limestone and dolomite where dissolution of the rock increases the size and frequency of the fractures and therefore increases secondary porosity and permeability. Some Pennsylvania public water supply wells in limestone and dolomite aquifers produce larger volumes of water than do wells in unconsolidated aquifers.

Stormwater infiltration BMPs near water supply wells

Pennsylvania's Safe Drinking Water Regulations (25 Pa. Code § 109) establish a three-tiered approach to wellhead protection of public ground water supplies. Zone I is the innermost protective zone surrounding a well, spring or infiltration gallery that may range from a radius of 100 to 400 feet depending on site-specific source and aquifer characteristics. The water supplier must own this area or substantially control activities within the zone that could potentially harm quality or quantity of the source. Zone II is the capture zone that encompasses the portion of the aquifer through which water is diverted to a well or flows to a spring or infiltration gallery. Zone II is defined as a one-half mile radius around the source unless a more rigorous hydrogeologic delineation is performed. Zone III is the area beyond the capture zone that contributes significant recharge to the aquifer within the capture zone. For more detailed information about protecting underground drinking water supplies, please refer to the Department's Source Water Protection Program.

Infiltration BMPs should not be located within Zone I wellhead protection areas. In addition, extreme caution must be exercised when planning stormwater infiltration BMPs for use in delineated Zone II areas or for use in areas within one half mile of public water supply wells. This is especially important where the water supply wells are in unconsolidated aquifers or bedrock aquifers of fractured limestone of dolomite. These easily recharged aquifers can become

contaminated through stormwater infiltration BMPs unless adequate stormwater pre-treatment occurs first. It is also essential that local government officials be contacted early when planning infiltration BMPs within Zone II wellhead protection areas. Some municipalities have specific ordinances that address land use within rigorously delineated Zone II areas.

To ensure that privately owned wells and ground water sources serving non-community water supply systems are adequately protected, a minimum isolation distance of 50 feet must be observed between the ground water source and all infiltration BMPs.

As always, the basic tenets of stormwater management should be applied:

- All efforts should be taken to minimize the amount of impervious area on the site; and
- Stormwater management should be designed to disperse runoff to a number of BMPs scattered around the site rather than conveying and concentrating runoff to just a few locations.

One of the most effective ways to pre-treat stormwater for infiltration is to pass the stormwater through a layer of compost or a compost/soil mixture before allowing it to infiltrate into the ground. (Compost is meant to be decomposed or composted organic material, not mulch.) EPA and others report that organic materials in the compost and compost/soil mixtures have demonstrated pollutant removal rates of over 90 percent for sediments, metals, bacteria and petroleum hydrocarbons, and as high as 75 percent for total phosphorous. Pollutant removal effectiveness increases with the amount of compost/soil mixture the stormwater has to pass through. Compost or soil/compost mixtures are not effective in removing chlorides such those found in deicing salt. The post-construction stormwater operation and maintenance plan should include limited use of deicing salts in areas draining to infiltration BMPs. Sand or other inert antiskid materials should be used in parking lots or roadways if stormwater infiltration is being used near water wells to minimize water quality impacts from stormwater/melt water runoff.

Use compost or compost/soil mixtures in vegetated swales, bio-retention areas, and infiltration trenches and basins so that stormwater must first pass through 18 to 36 inches of compost or a compost/soil mixture before percolating into the ground. The type of vegetation planted in the compost or compost/soil layer should be selected, in part, for its ability to replenish organic matter through seasonal leaf fall, root die back etc. It is important to maintain a high percentage of organic material in the soil because it is the organic material (compost) that has the cation exchange capacity necessary to capture pollutants in stormwater.

Porous pavement and other sub-surface stormwater infiltration BMPs are not recommended for use in areas close to water supply wells. These BMPs generally cannot be designed to allow stormwater to percolate through 18 to 36 inches of compost or soil/compost mixture.

Non-infiltration BMPs near water supply wells

Non-infiltration type stormwater BMPs can be used in areas close to water supply wells. As with all stormwater BMPs, they should be planned so that the stormwater runoff is spread throughout a number of locations rather than conveyed and concentrated in just a few places. Stormwater conveyance systems for loading docks, gas stations and other areas that have an increased likelihood of hazardous spills should be designed with an emergency shutoff to contain spills if there is an accident or release.

Appropriate BMPs

Some appropriate BMPs to consider for stormwater management in areas within one half mile of a water supply well are discussed below. These BMPs are detailed more thoroughly in Chapters 5 and 6.

Reduce Parking Imperviousness: Parking areas should be kept to the minimum allowed by the municipality. Excess parking area increases the volume of runoff that must be managed.

Rooftop Disconnection: Roof leaders (gutters) in residential and urban areas can be re-configured to drain into Rain Barrels, or flow onto lawn areas. Multiple, smaller stormwater elements placed around the home/structure can be combined to form a flexible design applicable to confined areas. Larger, commercial buildings may have internal drainage systems, which can still be disconnected into larger stormwater elements such as cisterns, planters, vertical storage or infiltration BMPs. Roof runoff can often be routed directly to an infiltration BMP. Roof runoff is generally cleaner than street and parking lot runoff and may not require as much pre-treatment before infiltrating into the soil.

Vegetated Roof: A vegetated roof is one of the most effective (both cost and stormwater – wise) methods to manage stormwater in an urban environment. Many buildings in urban areas have large flat roofs that can be converted into vegetated roofs.

Rain Garden/Bioretention: Rain Gardens are excellent applications for use around water supply wells and can be designed to fit areas of various shapes and sizes. Common locations are parking lot islands, landscaped areas around buildings, and plantings adjacent to streets. Runoff can be directed into these areas either by a “bubbler” inlet or by graded surfaces. Curb cuts can be utilized in parking areas and along roads to convey stormwater to these systems. Rain gardens and bio-retention areas should contain 18 to 36 inches of compost or compost/soil mixture. The pollutant removal capability of the BMP increases with the depth of the compost or compost/soil mixture used.

Infiltration Trench: Infiltration trenches can pick up runoff from parking areas and roads. A variation of this theme is the planting of trees and other vegetation in the trench along sides of roads, between the road and the sidewalk. This system promotes tree growth and facilitates the evapotranspiration of stormwater through tree and plant uptake. Infiltration trenches must be constructed with a layer of 18 to 36 inches of compost or compost/soil mixture for pollutant removal. The efficiency of the BMP improves with the depth of the compost or compost/soil mixture used.

Capture & Reuse of Rooftop Runoff: Rain barrels can be used to capture runoff originally coming from roof leaders. They are small enough to fit in yards and can easily be employed in urban residential neighborhoods. Cisterns and vertical storage units can be placed in corners of structured parking lots, inside buildings, on the outside walls of buildings, in adjacent alleys, alongside elevator shafts, and other locations deemed feasible by the designer. Vertical storage is well suited for use in urban areas where space is at a premium; the shape and location of this BMP requires very little horizontal land area.

Wet ponds: Monitored performance of well constructed and maintained wet ponds has documented efficiencies of greater than 90 percent removal for suspended solids, and ranges of 60 – 70 percent removal for nutrients and 60 – 95 percent removal for heavy metals. Wet ponds can also be used to pre-treat stormwater before it is conveyed to infiltration and bio-retention BMPs.

Vegetated swales: Vegetated swales are excellent applications to attenuate stormwater volume and provide effective pollutant removal while conveying and dispersing stormwater runoff. The swales should contain 18 to 36 inches of compost or compost/soil mixture to remove pollutants from any stormwater infiltrating through the swale.

De-icing alternatives: Sand or other inert antiskid materials should be used in parking lots or roadways in areas near water supply wells or upstream of surface-water intakes to minimize water quality degradation from stormwater or melt water runoff.

7.7 Surface Water Supplies and Special Protection Waters

Antidegradation requirements for special protection waters (High Quality and Exceptional Value) and for surface water supply (Potable Water Supply) will be met if the post-construction stormwater infiltration volume equals or exceeds the pre-construction stormwater infiltration volume, and that any post-construction stormwater discharge is pre-treated and managed so that it will not degrade the physical, chemical or biological characteristics of the receiving stream. Please refer to the Department's *Water Quality Antidegradation Implementation Guidance* (document number 391-0300-002) for more information.

The project should be designed to minimize the amount of impervious area. Any resultant stormwater should be infiltrated to the maximum extent possible. Water quality treatment BMPs should be employed for all stormwater that is discharged. Stormwater BMPs should be planned so that the stormwater is spread out to a number of locations rather than conveyed and concentrated in just a few places. Finally, the volume and rate of any stormwater discharge must be managed to prevent the physical degradation of the receiving water, such as scour, and stream bank destabilization.

Stormwater infiltration near surface water supplies and Special Protection waters

Care must be taken when planning stormwater infiltration BMPs for use in areas within two miles * on either side of special protection waters or surface waters used for public water supply. Infiltration BMPs in these areas must be designed to encourage maximum pollutant removal before the stormwater is infiltrated into the ground or discharged to a receiving stream.

[Pennsylvania also employs a three-tiered approach - for surface water source protection. **Zone A is a 1/4 mile buffer on either side of the river or stream extending from the area 1/4 mile downstream of the intake upstream to the five hour time-of-travel (TOT). **Zone B** is a two-mile buffer on either side of the water body extending from the area 1/4 mile downstream of the intake upstream to the 25 hour TOT. **Zone C** constitutes the remainder of the basin. Please refer to the Department's Source Water Protection Program for more information.]*

One of the most effective ways to pre-treat stormwater for infiltration is to pass the stormwater through a layer of compost or a compost/soil mixture before allowing it to infiltrate into the ground. The organic materials in the compost and compost/soil mixtures have repeatedly demonstrated

pollutant removal rates of over 90 percent for sediments, metals, bacteria and petroleum hydrocarbons, and as high as 75 percent for total phosphorous. Pollutant removal effectiveness increases with the amount of compost or compost/soil mixture the stormwater has to pass through. Compost or soil/compost mixtures are not effective in removing chlorides such those found in deicing salt. The operation and maintenance plan for these BMPs should include judicious or limited use of deicing salts in areas draining to the BMP.

Vegetated swales, bio-retention areas, infiltration trenches and basins should be constructed so that stormwater must first pass through 18 to 36 inches of compost or a compost/soil mixture before percolating into the ground. The type of vegetation planted in the compost or compost/soil layer should be selected, in part, for its ability to replenish organic matter through seasonal leaf fall or root die back. Maintaining a high percentage of organic material in the soil is of utmost importance. It is the organic material (compost) that has the cation exchange capacity necessary to capture pollutants in stormwater.

What if the stormwater cannot be infiltrated?

Infiltration is not the only way to reduce stormwater runoff volumes. Vegetated roofs can be used effectively on brownfield sites to retain much of the rainwater that falls on the roof. Stormwater can also be retained in basins or landscaped ponds and allowed to evaporate. Cisterns and vertical storage units can be placed in corners of structured parking lots, inside buildings, on the outside walls of buildings, in adjacent alleys, alongside elevator shafts, and other locations deemed feasible by the designer. Vertical storage is very applicable to urban areas where space is at a premium. The shape and location of this BMP requires very little land area. Water collected this way can be re-used for things such as fire suppression, drip irrigation, lawn sprinkling, cooling buildings, toilet flushing and recreational water. Chapter 6 of this manual provides more detailed information on stormwater capture and reuse.

7.8 Urban Areas

7.8.1 Highly Impervious Urban Land

This land area of special consideration includes the most densely populated regions of the state. The intensity of land development in most urban centers has resulted in a land use pattern that could be considered fully developed, with an almost continuous impervious surface comprised of multi-story structures surrounded by pavement. Beneath these paved areas lay a complex web of; water, wastewater, stormwater, gas, electric, stream and communications infrastructure. In the most densely developed urban communities, people also move beneath the surface in trains and subways. Auto parking is largely provided in concrete boxes or below buildings. The few “green areas” remaining are isolated parks and public spaces, many of which are also underlain with auto parking levels extending 60 feet or more into the ground. Narrow planting strips along many urban corridors support “street trees” that wage a constant battle to survive in a hostile environment.

Beneath these urban landscapes lie the residue of prior development, which in older cities such as Philadelphia can form a rubble layer many feet thick, comprised of bricks, blocks, concrete, wood, and other building materials. All of these conditions severely limit the use of any BMPs that

are dependent on infiltration into the soil mantle for volume reduction, and so the use of other BMPs is necessary.

One of the few “downtown” locations suitable for volume reduction is the roof of building structures. European engineers and architects learned the importance of going “up on the roof” for stormwater management several decades ago, and it has become the primary method in most cities. In Germany local ordinances require the construction of vegetated roof systems on flat or up to 20% sloping roofs. Failure to comply with these rules result in a “stormwater tax” being levied that is sufficiently onerous to virtually assure compliance. This action was precipitated by an increased awareness of the impacts of stormwater on “combined” sewers that convey both runoff and raw sewage to the nearest stream, river or lake. Many of the German cities were reduced to rubble during World War II, and in the rebuilding process it was recognized that vegetated rooftops on all new buildings provided a solution to anticipated urban stormwater problems.
Mandatory application of this BMP in existing urban centers, such as Philadelphia and Pittsburgh, will require specific ordinances that guide both new and existing building efforts, a significant capital program for any municipality. Without the opportunity for infiltration measures, however, the available alternatives to vegetated roof systems are quite limited, and focus on various capture and reuse efforts, most of which would require a significant re-plumbing effort for existing structures.

In terms of appropriate Control Guidance for the urban center, the solution may have to be tailored to fit the hydraulic capacity of the existing conveyance system. Where combined sewers are the only drainage pipes available, the overflow and discharge from CSO outfalls is usually triggered by frequent rainfall events of an inch or less. If the volume of runoff from a 1-inch storm event can be reduced in these areas, many combined sewer overflows can be avoided and much water quality benefits can be gained. Detailed computer modeling can develop the appropriate volume control guidance for highly urban watersheds with single pipe sewers.

As development has extended out from urban centers into surrounding farmlands, the percentage of impervious surfaces within a given land parcel has generally been regulated with the assumption that less impervious cover (combined with height limitations) would result in a community that did not have the negative aspects of the more dense urban environment. This has proven not to be the case, especially for stormwater. The suburban commercial center or office park can result in a highly impervious land parcel, equal to or greater than some older communities, even though it exists on an isolated parcel. Suburban residential developments are generally comprised of far less impervious cover than the urban streets, but still produce a significant pollutant load (Bannerman et al., 1993). This suburban runoff is generated in large measure from land that has been altered and then re-vegetated. The construction process has compacted the soils in these grassed and landscaped areas such that runoff volume has increased significantly. Thus a low-density suburban residential lot could degrade water quality as severely as the row home in center city Philadelphia.

7.8.2 Urban Water Quality

Several studies (Schueler, 2003) have indicated that the amount of impervious cover in a watershed is a good indicator of degraded water quality. The impacts of urbanization on a watershed can be measured when the level of impervious cover reaches 5 percent. Water quality in the watershed is severely degraded by the time the level of impervious cover reaches 20 percent. This reduction of water quality and stream habitat occurs from the increased runoff

volumes eroding stream banks, pollutants conveyed with this runoff, and diminished stream base flow. The pattern of degradation for urban streams shows a dramatic increase in magnitude and intensity of runoff with a corresponding reduction in stream flow during much of the year, and drought periods resulting in a transition from perennial to intermittent hydrology. In older urban centers, where the impervious cover can reach 75% or more, the hydrologic cycle has been so severely altered that full restoration seems to be impossible, especially in terms of restoring any original stream networks that function as combined sewers beneath the city streets.

Physical pollutants of frequent concern in urban areas include suspended solids, bacteria, phosphorus, nitrate, hydrocarbons, and metals. The runoff from streets is a significant source of pollutants and concern in urban areas (Barrett, et al, 1995) and is the single greatest source of water quality pollutants in the urban environment. In general, rooftop runoff is an order of magnitude less in concentration for most pollutants, and only becomes a problem when it is added to the surface flows, transporting the pollutant load accumulated on pavements. Such street runoff is affected by hydrocarbon emissions including leaks from vehicles, nutrients and organics from urban vegetation, bacteria and other pollutants from pet and other animal waste, and the general mix of wastes discarded in urban environments. Street curb and gutter systems are traditionally designed to convey, not trap, the fine particles associated with street runoff, and will carry the litter and debris directly to surface inlets, the storm sewer system and finally the receiving streams.

Increased temperature is a significant water quality issue in urban areas that can quickly pollute receiving waters. Although interception or disconnection of stormwater flows (i.e., peak shaving) to pervious areas may provide some limited reduction in temperature impact, opportunities for disconnection are often limited. It should be noted that low dissolved oxygen levels in receiving streams are related to the extreme temperature variability of runoff from impervious areas (as temperature increases, dissolved oxygen levels decline with lethal consequences to aquatic life). For fish and aquatic insects, temperature ultimately can be one of the most critical pollutants, presenting especially difficult challenges in urban areas.

Many urban storm sewers are in fact buried streams, especially first and second-order streams that were enclosed and buried as the urban center expanded in the late 19th century. These buried streams still serve as storm runoff conduits with the natural movement of groundwater along and into the stream channel. In some areas, the fill material above the original channel may eventually wash away, creating subsidence problems and “cave-ins” in urban streets. In other areas, the pipes serve to convey water more rapidly than the original stream would have done, creating downstream flooding or surcharging of both the sub-surface culverts and surface outlets. Deprived of both oxygen and sunlight, the original rate and water quality buffering function of first and second-order streams has been lost.

One aggressive concept that has received considerable attention but little real implementation is the idea of “daylighting” buried streams. This means that the original riparian channel is uncovered and restored with new stream banks cut and revegetated as appropriate. While representing a dramatic measure to restore an urban stream, the reality of fill removal and possible loss of property values along the original channel alignment usually translates into an unacceptable economic impact and disruption in the urban landscape. Even where substantial redevelopment has occurred in older cities, little serious thought has been given to the restoration of buried streams.

High levels of trash and debris, including concentrated areas of pet waste, characterize many urban streets. A high degree of imperviousness, combined with a curb and gutter system

designed to flush and convey debris, makes the urban landscape a significant source of pollutants that are rapidly conveyed to receiving surface streams. The use of various devices to intercept and contain these waste materials offers some measure of pollutant reduction, if maintenance is performed on a regular basis. Street cleaning by vacuum units also presents a very efficient method of pollutant removal, but purchase cost combined with operation and maintenance makes this BMP a significant investment for any urban community. In one urban center (Santa Monica, CA), the street gutters have been formed with porous concrete and infiltrating underdrains, combined with traps at corner inlets. Less dense residential portions of the urban community may utilize a variation of this approach, where shallow infiltration can be accomplished.

Stormwater "hot spots" such as gas stations, industrial areas, vehicle service areas, and public works storage areas are commonly found in urban communities, especially in the industrial zones. Smaller facilities, such as fueling islands and dumpster pads, should be treated as separate sources of pollution, and the runoff should be prevented or segregated from surface runoff. On the larger scale, a block-by-block strategy may be appropriate in portions of the community where pollutant-producing activities are concentrated.

7.8.3 Other Urban Stormwater Management Considerations

In many urban areas, local codes and regulations may require designs that are contrary to current BMP design. For example, local codes may require that all roof leaders be connected directly to a storm sewer, or that all streets have curbs and gutters. Local code officials may not be familiar with on-going stormwater management efforts. In these instances, early review of local requirements and communication to the appropriate officials is necessary to avoid BMP construction delays or denials. Long-term, review and updating of local ordinances may be warranted, with model urban guidelines developed by PADEP.

Redevelopment in depressed or blighted communities adds an additional dimension to stormwater management. These conditions have led some states (such as New Jersey) to exclude such communities from new stormwater regulations. The imposition of stringent regulations that are not feasible may serve to direct redevelopment to undeveloped sites outside the urban center. Brownfield parcels with significant residual contamination must be designed carefully to assure that any residual pollutants are not mobilized by stormwater BMPs. Highly contaminated sites may warrant excavation and removal of materials before any BMP can be installed. Stormwater management must not be detrimental to the economic health of urban areas, because this would ultimately be more damaging to the overall water resources of an area.

Most of the BMPs described in Chapter 6 can find some application in the urban environment, but a number of seemingly small measures, not described in separate BMP sections, can have a cumulative effect if applied to hundreds or thousands of individual residences or small buildings. These types of measures include:

Reduce Parking Imperviousness - New parking lots in urban areas can follow the guidelines set out in Chapter 5 relating to reducing imperviousness, while rehabilitation of existing parking lots can be designed with some areas of pervious paving, or even re-vegetated areas if the parking spaces are under-utilized.

Rooftop Downspout Disconnection - Roof leaders (gutters) in residential, urban areas can be re-configured to drain into rain barrels or planter boxes, for example. Multiple, smaller stormwater elements placed around the home/structure can be combined to form a flexible design applicable

to confined areas. Larger, commercial buildings may have internal drainage systems, which can still be disconnected into larger stormwater elements such as cisterns, planters, or vertical storage.

Disconnect from storm sewers - Disconnecting from existing storm sewers can be accomplished by either adding another inlet slightly up-gradient from the existing inlet to intercept the runoff and redirect it into a storm water feature, or closing off the existing inlet and regrading the area to drain into a stormwater feature, such as an infiltration bed.

Street Sweeping - Streets, roads, and highways constitute large percentages of urban areas, and pollutant loadings are usually greatest from these areas. Runoff from streets may end up at a treatment plant, but is more typically discharged directly to a body of water. Actively sweeping or vacuuming these surfaces can greatly reduce the amount of pollutants entering inlets, and possibly reduce the need for other (usually more costly) water quality measures.

Rooftop Runoff Capture & Reuse Rain barrels can be used to capture runoff originally coming from roof leaders, and they are small enough to fit in yards often found in urban residential neighborhoods. Cisterns and vertical storage units can be placed in corners of structured parking lots, inside buildings, on the outside walls of buildings, in adjacent alleys, alongside elevator shafts, and other locations deemed feasible by the designer. Vertical storage is very applicable in urban areas where space is at a premium; the shape and location of this BMP requires very little horizontal land area.

Vegetated Roof: A vegetated roof is one of the most effective (both cost and stormwater – wise) methods to manage stormwater in an urban environment. Many buildings in urban areas have large flat roofs that can be converted into vegetated roofs

Water Quality Filter - Filters can be used at the end of a drainage area, or at a “hot spot” to treat pollutant filled runoff. They have urban area relevance because of their size – filters can provide substantial water quality treatment in a relatively small container. They are typically used at the end of a drainage area (before it discharges into a body of water) that did not have room up gradient for other water quality measures.

Water Quality Insert - These manufactured devices can be placed in urban area inlets to address water quality. They’re appropriate where stormwater is discharged without other treatment and where removing pollutants before they enter the conveyance system is crucial. They are not appropriate for areas with combined sewers

Use of Parking lots and rooftops, as special detention areas - Detaining runoff on impervious surfaces does not have any volume benefit, but does reduce CSO impacts by temporarily holding the runoff and slowly releasing it so that the treatment plant can properly treat it. Surface storage can also help reduce the peak rates of a drainage area by increasing the time of concentration for that specific area. This can be useful in areas that require peak rate reductions, or are subject to downstream flooding.

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Pennsylvania Stormwater Best Management Practices Manual

Chapter 8

Stormwater Calculations and Methodology



363-0300-002 December 30, 2006

SARB_014993

SARB_014994

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8.1 Introduction to Stormwater Methodologies

There have been many methodologies developed to estimate the total runoff volume, the peak rate of runoff, and the runoff hydrograph from land surfaces under a variety of conditions. This chapter describes some of the methods that are most widely used in Pennsylvania and throughout the country. It is certainly not a complete list of procedures nor is it intended to discourage the use of new and better methods as they become available.

There is a wide variety of both public and private domain computer models available for performing stormwater calculations. The computer models use one or more calculation methodologies to estimate runoff characteristics. The procedures most commonly used in computer models are the same ones discussed below.

To facilitate a consistent and organized presentation of information throughout the state, assist design engineers in meeting the recommended control guidelines, and help reviewers analyze project data; a series of Worksheets is provided in this Chapter for design professionals to complete and submit with their development applications.

8.2 Existing Methodologies for Runoff Volume Calculations and their Limitations

8.2.1 Runoff Curve Number Method

The runoff curve number method, developed by the Soil Conservation Service (now the Natural Resources Conservation Service), is perhaps the most commonly used tool for estimating runoff volumes. In this method, runoff is calculated based on precipitation, curve number, watershed storage, and initial abstraction. When rainfall is greater than the initial abstraction, runoff is given by (NRCS, 1986):

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where: Q = runoff (in.)
P = rainfall (in.)
I_a = initial abstraction (in.)
S = potential maximum retention after runoff begins (in.)

Initial abstraction (I_a) includes all losses before the start of surface runoff: depression storage, interception, evaporation, and infiltration. I_a can be highly variable but NRCS has found that it can be empirically approximated by:

$$I_a = 0.2S$$

Therefore, the runoff equation becomes:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

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Finally, S is a function of the watershed soil and cover conditions as represented by the runoff curve number (CN):

$$S = \frac{1000}{CN} - 10$$

Therefore, runoff can be calculated using only the curve number and rainfall. Curve numbers are determined by land cover type, hydrologic condition, antecedent moisture condition (AMC), and hydrologic soil group (HSG). Curve numbers for various land covers based on an average AMC for annual floods and $I_a = 0.2S$ can be found in Urban Hydrology for Small Watersheds (Soil Conservation Service, 1986) and various other references.

Often a single, area-weighted curve number is used to represent a watershed consisting of sub-areas with different curve numbers. While this approach is acceptable if the curve numbers are similar, if the difference in curve numbers is more than 5 the use of a weighted curve number significantly reduces the estimated amount of runoff from the watershed. This is especially problematic with pervious/impervious combinations: "combination of impervious areas with pervious areas can imply a significant initial loss that may not take place." (Soil Conservation Service, 1986) Therefore, the runoff from different sub-areas should be calculated separately and then combined or weighted appropriately. At a minimum, runoff from pervious and directly connected impervious areas should be estimated separately for storms less than approximately 4 inches. (NJDEP, 2004)

The curve number method is less accurate for storms that generate less than 0.5 inches of runoff and the Soil Conservation Service (1986) recommends using another procedure as a check for these situations. For example, the storm depth that results in 0.5 inches of runoff varies according to the CN; for impervious areas (CN of 98) it is a 0.7-inch storm, for "Open space" in good condition on C soils (CN of 74) it is 2.3 inches, for Woods in good condition on B soils (CN of 55) it is over 3.9 inches. An alternate method for calculating runoff from small storms is described below.

8.2.2 Small Storm Hydrology Method (SSHM)

The Small Storm Hydrology Method was developed to estimate the runoff volume from urban and suburban land uses for relatively small storm events. Other common procedures, such as the runoff curve number method, are less accurate for small storms as described previously. The CN methodology can significantly underestimate the runoff generated from smaller storm events. (Claytor and Schueler, 1996 and Pitt, 2003) The SSHM is a straightforward procedure in which runoff is calculated using volumetric runoff coefficients. The runoff coefficients, R_V, are based on extensive field research from the Midwest, the Southeastern U.S., and Ontario, Canada over a wide range of land uses and storm events. The coefficients have also been tested and verified for numerous other U.S. locations. Runoff coefficients for individual land uses generally vary with the rainfall amount – larger storms have higher coefficients. **Table 8.1** below lists SSHM runoff coefficients for seven land use scenarios for the 0.5 and 1.5 inch storms.

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Table 8.1. Runoff Coefficients for the Small Storm Hydrology Method (adapted from Pitt, 2003)

Rainfall (in.)	Volumetric Runoff Coefficients, R_v						
	Impervious Areas				Pervious Areas		
	Flat Roofs/ Large Unpaved Parking Areas	Pitched Roofs	Large Imperv. Areas	Small Imperv. Areas and Uncurbed Roads	Sandy Soils (HSG A)	Silty Soils (HSG B)	Clayey Soils (HSG C & D)
0.5	0.75	0.94	0.97	0.62	0.02	0.09	0.17
1.5	0.88	0.99	0.99	0.77	0.05	0.15	0.24

Runoff is simply calculated by multiplying the rainfall amount by the appropriate runoff coefficient. Because the runoff relationship is linear for a given storm (unlike the curve number method), a single weighted runoff coefficient can be used for an area consisting of multiple land uses. Therefore, runoff is given by:

$Q = P \times R_v$

where: Q = runoff (in.)
P = rainfall (in.)
R_v = area-weighted runoff coefficient

8.2.3 Infiltration Models for Runoff Calculations

Several computer packages offer the choice of using soil infiltration models as the basis of runoff volume and rate calculations. Horton developed perhaps the best-known infiltration equation – an empirical model that predicts an exponential decay in the infiltration capacity of soil towards an equilibrium value as a storm progresses over time. (Horton, 1940) Green-Ampt (1911) derived another equation describing infiltration based on physical soil parameters. As the original model applied only to infiltration after surface saturation, Mein and Larson (1973) expanded it to predict the infiltration that occurs up until saturation. (James et al., 2003) These infiltration models estimate the amount of precipitation excess occurring over time – excess must be transformed to runoff with other procedures to predict runoff volumes and hydrographs.

8.3 Existing Methodologies for Peak Rate/Hydrograph Estimations and their Limitations

8.3.1 The Rational Method

The Rational Method has been used for over 100 years to estimate peak runoff rates from relatively small, highly developed drainage areas (generally less than 200 acre drainage area). The peak runoff rate from a given drainage area is given by:

$Q_y = C \times I \times A$

where: Q_y = peak runoff rate (cubic feet per second)

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C = the runoff coefficient of the area (assumed to dimensionless)
I = the average rainfall intensity (in./hr) for a storm with a duration equal to the time of concentration of the area
A = the size of the drainage area (acres)

The runoff coefficient is usually assumed to be dimensionless because one acre-inch per hour is very close to one cubic foot per second (1 ac-in./hr = 1.008 cfs). Although it is a simple and straightforward method, estimating both the time of concentration and the runoff coefficient introduce considerable uncertainty in the calculated peak runoff rate. In addition, the method was developed for relatively frequent events so the peak rate as calculated above should be increased for more extreme events. (Viessman and Lewis, 2003) Because of these and other serious deficiencies, the Rational Method should be used only to predict the peak runoff rate for very small, highly impervious areas. (Linsley et. al, 1992)

The Rational Method, discussed in detail above, has been adapted to include estimations of runoff hydrographs and volumes through the Modified Rational Method. Due to the limitations of the Rational Method itself (see above) as well as assumptions in the Modified Rational Method about the total storm duration, this method should not be used to calculate water quality, infiltration, or capture volumes.

8.3.2 SCS (NRCS) Unit Hydrograph Method

In combination with the curve number method for calculating runoff depth, the National Resource Soil Conservation Service (NRCS) also developed a system to estimate peak runoff rates and runoff hydrographs using a dimensionless unit hydrograph derived from many natural unit hydrographs from diverse watersheds throughout the country (NRCS Chapter 16, 1972). As discussed below, the NRCS methodologies are available in several public domain computer models including TR-55 (WinTR-55) computer model (2003), Technical Release 20 (TR-20); Computer Program for Project Formulation Hydrology (1992), and in addition, the U.S. Army Corp of Engineers' Hydrologic Modeling System (HEC-HMS, 2003), EFH2 and the U.S. EPA's Storm Water Management Model (SWMM 5.0.003, 2004).

8.4 Computer Models

8.4.1 HEC Hydrologic Modeling System (HEC-HMS)

The U.S. Army Corp of Engineers' Hydrologic Modeling System (HEC-HMS, 2003) supersedes HEC-1 as "next-generation" rainfall-runoff simulation software. According to the Corp, HEC-HMS "is a significant advancement over HEC-1 in terms of both computer science and hydrologic engineering." (U.S. ACE, 2001) HEC-HMS was designed for use in a "wide range of geographic areas for solving the widest possible range of problems." The model incorporates several options for simulating precipitation excess (runoff curve number, Green & Ampt, etc.), transforming precipitation excess to runoff (NRCS unit hydrograph, kinematic wave, etc.), and routing runoff (continuity, lag, Muskingum-Cunge, modified Puls, kinematic wave). HEC-HMS Version 2.2.2 (May 28, 2003) can be downloaded at no cost from: http://www.hec.usace.army.mil/software/hec-hms/hechms-hechms.html.

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8.4.2 SCS/NRCS Models (WIN TR-20 and WIN TR-55)

"Technical Release No. 20: Computer Program for Project Formulation Hydrology (TR-20) is a physically based watershed scale runoff event model" that "computes direct runoff and develops hydrographs resulting from any synthetic or natural rainstorm." (NRCS, 2004) Hydrographs can then be routed through stream/channel reaches and reservoirs. TR-20 applies the methodologies found in the Hydrology section of the National Engineering Handbook (NRCS, 1969-2001), specifically the runoff curve number method and the dimensionless unit hydrograph. (NRCS, 1992) Version 2.04 was released in 1992 and can be downloaded at: http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models.html. A Beta test version for Windows, WinTR-20, was also released in 2004.

Technical Release 55 (TR-55) was originally published in 1975 as a simple procedure to estimate runoff volume, peak rate, hydrographs, and storage volumes required for peak rate control. (NRCS, 2002) TR-55 was released as a computer program in 1986 and work began on a modernized Windows version in 1998. WinTR-55 generates hydrographs from urban and agricultural areas and routes them downstream through channels and/or reservoirs. WinTR-55 uses the TR-20 model for all of its hydrograph procedures. (NRCS, 2002) WinTR-55 Version 1 was officially released in 2002 and can be downloaded at: http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models.html.

8.4.3 NRCS NEH 650 Engineering Field Handbook, Chapter 2 (EFH2)

Peak discharge is determined by procedures contained in NRCS NEH 650 Engineering Field Handbook, Chapter 2. Information needed to use this procedure include watershed characteristics (drainage area, curve number, watershed length, watershed slope) and rainfall amount and distribution.

The method applies when the:
-watershed is accurately represented by a single curve number between 40 and 98
-watershed area is between 1 and 2000 acres
-watershed hydraulic length is between 200 and 26000 feet
-average watershed slope is between 0.5 and 64 percent
-watershed requires no valley or reservoir routing
-urban land use within the watershed does not exceed 10%.

EFH2 Version 1.1.0 was released in March 2003 and can be downloaded at: http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models.html

Refer to NRCS Engineering Field Handbook, Chapter 2 for a complete discussion of the methodology and its limitations.

8.4.4 Storm Water Management Model (SWMM)

The U.S. Environmental Protection Agency (2004) describes its model as:

"a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate

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runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators.

SWMM was first developed in 1971 and has since undergone several major upgrades. It continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well. The current edition, Version 5, is a complete re-write of the previous release. Running under Windows, SWMM 5 provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats.

SWMM is a powerful model capable of simulating areas consisting of a single, uniform subcatchment to the drainage system of an entire city. Although typically not used to evaluate a single development site, the recently released Version 5 is more user-friendly and should promote an increase in use among design professionals.

Rainfall excess is calculated in SWMM by subtracting infiltration (based on Horton or Green & Ampt) and/or evaporation from precipitation. Rainfall excess is converted to runoff by coupling Manning's equation with the continuity equation. (Rossman, 2004 and James et al., 2003) The newest version of SWMM also incorporates the runoff curve number method for estimating infiltration. (Rossman, 2004)

8.5 Precipitation Data for Stormwater Calculations

In 2004 the National Weather Service's Hydrometeorological Design Studies Center published updated precipitation estimates for much of the United States, including Pennsylvania. NOAA Atlas 14 supercedes previous precipitation estimates such as Technical Memorandum NWS Hydro 35 and Technical Papers 40 and 49 (TP-40 and TP-49) because the updates are based on more recent and expanded data, current statistical techniques, and enhanced spatial interpolation and mapping procedures. (Bonnin et al., 2003 and NWS, 2004) The "Precipitation-Frequency Atlas of the United States," NOAA Atlas 14, provides estimates of 2-year through 1000-year storm events for durations ranging from 5 minutes to 60 days as shown for Harrisburg in Table 8-2 (available online at http://hdsc.nws.noaa.gov/hdsc/pfds/). Users can select precipitation estimates for Pennsylvania from over 300 observation sites, by entering latitude/longitude coordinates, or by clicking on an interactive map on the Precipitation Frequency Data Server. These new rainfall estimates are recommended for all applicable stormwater calculations.

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Table 8.2 Harrisburg precipitation estimates.

Precipitation Frequency Estimates (inches)																		
ARI* (years)	**5 min**	**10 min**	**15 min**	**30 Min**	**60 min**	**120 min**	**3 hr**	**6 hr**	**12 hr**	**24 hr**	**48 hr**	**4 day**	**7 day**	**10 day**	**20 day**	**30 day**	**45 day**	**60 day**
2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	2.1	2.5	2.9	3.4	3.78	4.42	5.07	6.83	8.42	10.6	12.6
5	0.5	0.7	0.9	1.3	1.7	1.9	2.1	2.6	3.18	3.68	4.3	4.77	5.51	6.26	8.18	9.9	12.2	14.4
10	0.5	0.8	1	1.5	1.9	2.3	2.5	3.1	3.76	4.37	5	5.63	6.46	7.26	9.28	11.1	13.5	15.8
25	0.6	0.9	1.1	1.7	2.2	2.7	3	3.7	4.64	5.44	6.2	6.93	7.89	8.75	10.9	12.8	15.3	17.8
50	0.6	1	1.2	1.8	2.5	3.1	3.4	4.3	5.42	6.41	7.3	8.09	9.16	10	12.2	14.2	16.7	19.2
100	0.7	1	1.3	2	2.7	3.6	3.9	4.9	6.29	7.53	8.5	9.41	10.6	11.4	13.6	15.7	18.2	20.7
200	0.7	1.1	1.4	2.1	3	4	4.4	5.6	7.26	8.81	9.9	10.9	12.2	13	15.1	17.3	19.6	22.2
500	0.7	1.2	1.5	2.3	3.3	4.6	5.1	6.7	8.75	10.8	12	13.2	14.7	15.3	17.2	19.5	21.6	24.3
1000	8	1.2	1.5	2.5	3.6	5.2	5.7	7.5	10.1	12.7	14	15.3	16.8	17.4	19	21.3	23.2	25.8

8.6 Stormwater Quality Management

The purpose of this section is to ensure compliance with the water quality requirements for stormwater runoff from developed sites. Unlike the approach for volume and rate control, which considers the net change in hydrology resulting from land development, water quality evaluation begins by assuming that the built site will generate pollutants from the new or disturbed surfaces, and that the various BMPs can prevent or remove these pollutants from the resultant runoff. As discussed in Chapter 2, reduction of Non-point Source (NPS) pollutants by stormwater management is the primary issue of concern. If Control Guideline 1 or Control Guideline 2 are met for volume reduction, then it follows that the first flush of NPS pollutants have passed through one or more BMPs and the resultant runoff meets the water quality criteria, except for solutes. There is no consideration of any transport of pollutants that might be generated from the site before development, and the undisturbed portions of the site are to be ignored as sources of NPS pollution.

The use of infiltration measures to meet water quality criteria as well as volume reduction has one potential constraint; solutes, specifically nitrate, cannot be assumed to be sufficiently reduced by infiltration alone. To further complicate the nitrate issue, it has been observed that the concentration of nitrate in runoff remains fairly constant over the entire hydrograph, with some reduction by dilution during the peak flow period. As a solute, this means that the nitrate is dissolved in runoff throughout the rainfall process, and continues to move throughout the entire storm. In effect, the “first flush” approach used for particulate-associated pollutants does not apply, nor does the removal efficiency of the various BMP measures.

The non-structural measures discussed in Chapter 4 offer very efficient preventive answers to this issue, such as reduced fertilization, vegetative restoration and street sweeping. For the land development projects that apply these various non-structural measures, the overall pollutant load generated should be minimized for both particulates and solutes. If a project has preserved and restored the woodland vegetation on portions of the tract as an integral part of the development program, prevented compaction or restored permeability in disturbed soils, and

kept to an absolute minimum the chemical maintenance required for new landscaping elements, the pollutant load generated should be minimal, from a water quality perspective, and should not warrant regulatory control. The determination of how successful a given site design is in meeting water quality compliance with non-structural measures will be guided by the loading data analysis described in this Chapter. The initial load estimate of NPS pollution generated by the proposed building program will provide insight into the relative impact of different built surfaces on ambient water quality in a watershed.

8.6.1 Analysis of Water Quality Impacts from Developed Land

Chapter 3 proposed criteria for three representative pollutants (Suspended Solids, Total Phosphorus and Nitrate) in terms of percent reduction of the anticipated load produced from the areas disturbed during construction. The specific values proposed for each pollutant are intended to reflect the potential efficiencies of the various BMPs considered, as well as the anticipated reduction required to sustain or restore water quality in receiving waters. The impact of NPS pollution on surface water quality is well documented, but generally in terms of the receiving water body. A reduction in ambient water quality in many major riverine, lacustrine and estuarine systems has usually been associated with changes in land use within the contributing drainage, and in some cases, specific pollutants have been identified as “key” pollutants. A study of the Lake Erie drainage basin in the mid-1960’s focused on phosphorus as the critical nutrient leading to trophic changes in the lake, and the resultant water quality strategy reduced this nutrient from both point sources and land runoff. The pattern of lake and estuary eutrophication has been repeated in countless water bodies across the US and throughout the world, and in virtually every drainage catchment, phosphorus is the limiting nutrient.

In the Chesapeake Bay drainage basin, which is largely provided by runoff from central Pennsylvania, both phosphorus and nitrate are considered limiting nutrients. These pollutants contribute to diminishing water quality and a loss of both habitat and species by enrichment of the estuary waters. A major initiative has recently been undertaken by states in the Chesapeake Bay drainage basin to significantly reduce both nutrients from wastewater effluent at over 350 treatment facilities, a process that will require an investment of hundreds of millions of dollars over the next decade (Chesapeake Bay Tributary Strategy, CEC, 8/12/04). In that program, PA must reduce nitrate by 48.2 million pounds and total phosphorus by 1.98 million pounds annually. Sediment has also played a major part in the reduction in water quality in the Bay. Therefore a dual effort of reducing nutrients and sediment from the land runoff must be included in any Bay recovery program, keeping in mind that the phosphorus is transported with the colloid fraction of sediments.

Thus all three of the selected NPS criteria are appropriate for water quality management of stormwater, not only in the Chesapeake bay drainage basin, but throughout the state. Again, these pollutants serve as surrogates for a wide range of other pollutants that occur in lesser or trace concentrations but also contribute to degraded water quality. Many of these other pollutants are also solutes, and so the focus on nitrate serves a broader function.

Table 8.3 summarizes the concentration of representative pollutants, both particulate and solute, that have been measured in the runoff from various built surfaces in a selected group of studies. In the preparation of this BMP Manual, a larger body of literature has been reviewed for comparative data, and is summarized in Appendix A. While this data is derived from numerous sources, the studies referenced were performed on very different sites, and measurement methods varied by investigator. The use of a value that represents the “mean”

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concentration of a pollutant in runoff is very dependent on the level of detail applied in the development of this data. For the purposes of evaluating the water quality impacts of land development and the benefits of a given BMP in reducing this pollution, the data were expanded to consider variations in land cover type, and are shown in Table 8.3.

It is possible that a proposed development may not conform exactly to the land cover categories shown in this Table. Independent sampling of representative stormwater chemistry from similar sites can be prepared by a developer or other interested party, if desired. It is recommended that any stormwater sampling be compiled by use of automated sampling equipment at flow measurement stations, where the record of chemical variability during runoff incidents can be gathered, and that the Department approves the program prior to initiation. These new sampling data should allow the integration of hydrographs and chemographs to formulate mass transport loads and develop flow-weighted concentrations for analysis and substitution in lieu of Table 8.3 values.

In the absence of new sampling data prepared by a developer or other applicant, the values shown in Table 8.3 will be applied to the volume of runoff estimated from new development for completion of Worksheets. The concept of "Event Mean Concentration" was explained in Chapter 2, and represents the anticipated average concentration of a given pollutant that could be scoured from a given surface during a storm event of significant magnitude to produce surface runoff. No specific rainfall amount is applied to this term, and the body of data from which it is derived reflects very different hydrologic conditions.

TABLE 8.3. EVENT MEAN CONCENTRATIONS (EMCs)

		POLLUTANT		
	LAND COVER CLASSIFICATION	**Total Suspended Solids, EMC *(mg/l)***	**Total Phosphorus, EMC *(mg/l)***	**Nitrate-Nitrite EMC *(mg/l as N)***
Pervious Surfaces	Forest	39	0.15	0.17
	Meadow	47	0.19	0.3
	Fertilized Planting Area	55	1.34	0.73
	Native Planting Area	55	0.4	0.33
	Lawn, Low-Input	180	0.4	0.44
	Lawn, High-Input	180	2.22	1.46
	Golf Course Fairway/Green	305	1.07	1.84
	Grassed Athletic Field	200	1.07	1.01
Impervious Surfaces	Rooftop	21	0.13	0.32
	High Traffic Street / Highway	261	0.4	0.83
	Medium Traffic Street	113	0.33	0.58
	Low Traffic / Residential Street	86	0.36	0.47
	Res. Driveway, Play Courts, etc.	60	0.46	0.47
	High Traffic Parking Lot	120	0.39	0.6
	Low Traffic Parking Lot	58	0.15	0.39

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8.6.2 Analysis of Water Quality Benefits from BMPs

Unlike the traditional approach to wastewater, the implementation of stormwater quality criteria is intended to change development practices and land management concepts, rather than to establish a series of treatment or pollutant removal methodologies. As a general rule, the removal of pollutants, both particulate and dissolved, from stormwater is a difficult and inefficient process. Because the rate of flow from a developed site, as well as the concentration of many pollutants, varies greatly during a storm, the use of traditional wastewater "unit operation" technologies is inappropriate. The intermittent nature of runoff also complicates the pollutant removal process. NPS pollution is produced in concentrated "slugs" of runoff, and not contained in a uniform flow that can be applied to a microbial based process in a medium or structure, such as a sewage treatment plant. Finally, the form of NPS pollutant, particulate or solute, determines the potential for removal by any physical BMP.

The BMPs described in detail in Chapters 5 and 6 represent a variety of measures that, generally speaking, have not been broadly applied during the past twenty-five years for water quality mitigation on land development projects throughout the state. A number of wet extended detention basins have been built, as a variation on the conventional detention basin, but most of these have not been subject to detailed monitoring that would quantify water quality benefits. Infiltration BMPs have also seen limited application in PA, but again virtually none have had thorough scientific monitoring measures included in their design. Several dozen porous pavement systems have been built since 1981, largely in the southeast area of the state, but even these systems have had little water quality monitoring data developed, simply because the site owner declined to participate in and support such a program. Other infiltration measures, including trenches, rain gardens and cisterns, have been built on a limited number of sites, but these have also not been designed to provide sample collection from the unsaturated zone or groundwater beneath the BMP. Thus the scientific basis for pollutant removal efficiency is derived from other relevant literature, especially the soil sciences and agriculture.

The most complete record of pollutant removal efficiency for BMPs is based on surface detention basins, as modified to include standing water, vegetation, multiple pond systems and the like. While simple detention structures can provide significant reduction of Suspended Solids, especially the larger particulate fraction, the NPS pollutant removal process is greatly enhanced by these modifications. For the other BMPs, the evaluation process is largely a work in progress. A review of the available literature, included in Appendix A, suggests a range of benefits from BMPs, including their relative efficiency of pollutant reduction, removal or prevention, as summarized in Appendix A.

The available water quality data demonstrates that the roof areas of structures will not contribute a significant fraction of the total pollutant load, and can generally be ignored, since much of the pollution washed from rooftops is comprised of atmospheric deposition. For "big box" projects this may not necessarily be true because of the relative size and proportion, and the potential loading analysis should guide the designer in this step. The estimate of NPS pollution produced by a built site can be simplified by ignoring rooftop runoff and undisturbed land areas as NPS sources. The analysis effectively limits the contributing surfaces to two major categories; impervious pavements and chemically maintained landscapes. Both of these types of surfaces can vary in their pollutant contribution, as illustrated by Table 8.3. In many if not most new developments, the evaluation and reduction of pollutant impacts will focus on these two types of sources.

All infiltration BMPs shown in Table 8.4 assume the NPS pollutant removal efficiency for both TSS and TP is 85%, although an efficiency of close to 100% is reasonable for all infiltrated runoff. Any runoff greater than the design storms of Volume Control Guidelines 1 and 2 probably will overflow or bypass these BMPs, and so some NPS load during major storms will discharge to surface waters. For the situation where an infiltration BMP is in close proximity to a potable water supply source, the potential for contamination by solutes must be considered, and additional BMPs applied if the site conditions warrant (e.g., groundwater concentration exceeds 10 mg/l).

Compliance with Volume Control Guidelines 1 and 2 requires the site plan to optimize runoff capture, ideally with distributed BMPs. If they consist of a single measure or multiple measures distributed across the site, the first question is the amount of total built surface that drains to one or more BMP. This "capture efficiency" of the stormwater management system determines not only hydraulic capacity of any given measure, but also how much of the site is controlled in terms of pollutant containment. It is recognized that most site designs do not allow total capture of all runoff, no matter how flat the parcel may be. Completion of the Worksheets for either volume control guideline will result in a design capacity for the selected BMPs, which usually can be aggregated by type for analysis of water quality impacts. That is, multiple small measures such as rain gardens in a residential development can be treated as a single measure in terms of pollutant reduction.

The removal efficiency of BMPs connected either in series or in parallel may be computed using the two equations provided below. Figures 8-1 and 8-2 below illustrate BMPs connected in series and in parallel.

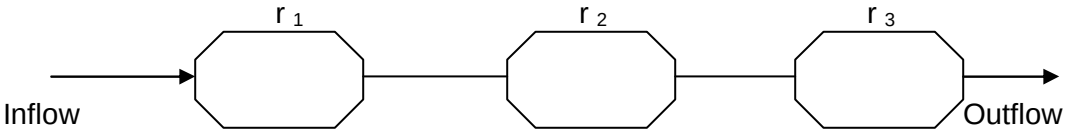

Fig. 8-1. BMPs Connected in Series

Equation for removal efficiency of BMPs in series:

$$R = 1 - \prod_{i=1}^{n} (1 - r_i)$$

R = Removal efficiency of n BMPs in series.

r_i = Removal efficiency of BMP_i

The removal efficiency R of the above three BMPS in series is,

$$R = 1 - \{(1 - r_1) * (1 - r_2) * (1 - r_3)\}$$

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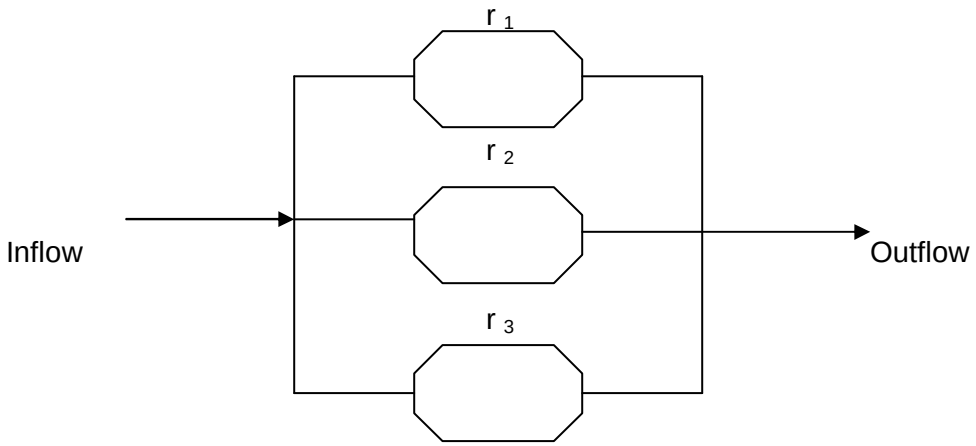

Fig. 8-2. BMPs Connected in Parallel

Equation for removal efficiency of BMPs in connected in parallel:

$$R = 1 - \frac{\sum_{i=1}^{n} C_i Q_i (1 - r_i)}{\sum_{i=1}^{n} C_i Q_i}$$

R = Removal efficiency of n BMPs in parallel.

Q_i = Rate of flow i passing through BMP_i.

C_i = Concentration of pollutant in flow i.

r_i = Removal efficiency of BMP_i.

The removal efficiency R for the three BMPs shown in **Fig. 8-2** is,

$$R = \frac{C_1 Q_1 (1 - r_1) + C_2 Q_2 (1 - r_2) + C_3 Q_3 (1 - r_3)}{C_1 Q_1 + C_2 Q_2 + C_3 Q_3}$$

8.6.3 Water Quality Analysis

Confirmation that the BMP program has been successful in meeting the water quality criteria assumes that either Volume Control Guideline 1 or 2 have been met, and that at least 90% of the disturbed area is conveyed or mitigated by a BMP (Flow Chart D – page 40). Compliance with the volume criteria assumes that the major portion of particulate pollutants have been removed from runoff by one or more BMP, and so the only additional demonstration required for compliance with water quality criteria is to confirm that one or more of the BMPs that are most effective in solute reduction have been included in the stormwater management program.

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Worksheet 10 is a simple checklist of those measures, and is divided into two categories, primary and secondary. Without performing a detailed loading analysis, the inclusion of a combination of these measures should provide adequate demonstration that the site design has considered this issue and incorporated the best feasible solution.

Worksheet 11 is intended for those sites where volume reduction cannot be met. This form estimates the total pollutant load produced from all built surfaces, so that the designer can appreciate the relative magnitude of the problem created by the proposed design. Where the site design provides insufficient capture by BMPs, the designer should revisit the overall program and apply additional measures to meet water quality criteria. That is, even if site constraints prevent compliance with Volume Control Guideline 1 and 2, water quality criteria should still be met.

In many site designs where NPS reduction is a concern, it is usually obvious that the greatest pollutant impact is from two surfaces; impervious pavements and fertilized landscapes. As designers focus attention on the uncontrolled runoff from streets and fertilized landscapes and revisit the water quality impacts, the value of non-structural measures, including street sweeping and the use of native plantings for landscape design, should become apparent.

Worksheets 12 and 13 indicate the uncontrolled load from built surfaces and gives credit for load reduction and source omissions by using the full array of non-structural and structural BMPs. It is likely that if compliance with Volume Control Guideline 1 and 2 is not feasible, no additional structural measures can be included without major site plan redesign. That option is not excluded, but if non-structural measures can be incorporated, then the answer is simple, and additional structural measures may not be required. The designer can turn to land management measures that can be incorporated in the finished building program without any structural alterations. Clearly, it will require creative design to meet the recommended water quality goals, but it is well within the capabilities of the BMPs described in this Manual.

8.7 Guidance for Stormwater Calculations for Volume Control Guideline 1 and Volume Control Guideline 2

Stormwater management in Pennsylvania has historically focused on flow rate control for large storm events. Stormwater management has traditionally required that there be no increase in the rate of runoff from development as compared to the rate of runoff before development for storm events ranging from the 2-year, 24-hour event to the 100-year, 24-hour event. The *Pennsylvania Stormwater Best Management Practices Manual* is recommending that stormwater management be expanded to include:

- Rate of flow
- Volume of flow
- Groundwater recharge
- Water quality
- Stream channel protection

Volume Control Guideline 1 and Volume Control Guideline 2 provide recommended guidelines to achieve these stormwater management elements.

It should be noted that control of the rate of flow of stormwater runoff remains an important part of stormwater management. This criteria is generally based on larger storm events of limited frequency (i.e., the 1-year through the 100-year storm events).

By contrast, the additional elements of stormwater management – volume, groundwater recharge, water quality, and stream channel protection – are based on the smaller, more frequent storm events. Effective stormwater management includes rate control and the additional elements of volume, groundwater recharge, water quality, and stream channel protection.

Engineers and regulatory officials are familiar with the engineering methods and models used to evaluate the rate of runoff for large storm events. There is general consistency in the calculation methodologies used across the state, with the Cover Complex Method or the Rational Method being the two most common methodologies applied to estimate rate of runoff.

To manage stormwater for volume, ground water recharge, quality, and channel protection, additional or expanded analytical methods are needed. The following sections provide guidance on recommended procedures and methodologies to improve stormwater management, and include worksheets and flow charts intended to assist in this process.

8.7.1 Stormwater Calculation Process

Flow Chart A (page 31) is provided to guide the user in the first step of the stormwater calculation process (*Stormwater Calculation Process Non-structural BMPs*).

- Step 1: Provide General Site information (Worksheet 1).

- Step 2: Identify sensitive natural resources, and if applicable, identify which areas will be protected (Worksheet 2).

- Step 3: Incorporate Non-structural BMPs into the stormwater design. Quantify the volume benefits of Non-structural BMPs (Worksheet 3).

Proceed to either Flow Chart B, Volume Control Guideline 1 or Flow Chart C, Volume Control Guideline 2.

8.7.1.1 For Volume Control Guideline 1 (Flow Chart B)

- Step 4: Estimate the increased volume of runoff for the 2-Year storm event, using the Cover Complex Curve Number method. **Combining Curve Numbers for land areas proposed for development with Curve Numbers for areas unaffected by the proposed development into a single weighted curve number is NOT acceptable.** Runoff volume should be calculated based on land use and soil types (Worksheet 4).

- Step 5: Design and incorporate Structural and Non-Structural BMPs that provide volume control for the 2-Year volume increase indicated on Worksheet 4. Provide calculations and documentation to support the volume estimate provided by BMPs. For Non-structural BMPs, provide Non-structural BMP checklists to demonstrate that BMPs are appropriate. Indicate the volume reduction provided by BMPs (Worksheet 5). *Note: if the designer is unable to incorporate the 2-year volume increase after all feasible BMP*

options have been considered, the designer proceeds to Volume Control Guideline 2.

- Step 6: Determine if the site is exempt from peak rate calculations (Worksheet 6).

- Step 7: If the site is NOT exempt from peak rate calculations, provide detailed routing analysis to demonstrate peak rate control for the 1-year through 100-year storm events. This routing should consider the benefits of BMPs. Provide additional detention capacity if needed.

  Proceed to Flow Chart D, Water Quality Calculations

8.7.1.2 For Volume Control Guideline 2 (Flow Chart C)

This guideline integrates water quality, stream channel protection, and groundwater recharge requirements into a simplified statement that can be implemented with relatively easy computations. The guideline uses runoff depth rather than precipitation to compute required capture volumes. The total capture volume of 2 inches corresponds roughly to the state-wide average runoff produced by a 1-year 24-hour storm on an impervious surface. One-half of the captured volume may be released slowly, one-fourth is recommended for reuse, and one-fourth is recommended for groundwater recharge. These recommended values are based on a generalized water budget analysis. During the development of watershed-based stormwater management plans, the analysis can be re-computed to derive values that reflect local watershed conditions more accurately (e.g. Act 167 plans). The generalized version of Volume Control Guideline 2 is as follows:

- Step 4: Capture the first 2 inches of runoff from all contributing impervious surfaces. The first 1-inch of runoff should be permanently removed and not be released to the Surface Waters of the Commonwealth. The other 1inch of runoff should be detained. Compute Runoff Volumes using **Worksheet 7**.

- Step 5: Design and incorporate Structural and Non-Structural BMPs that provide permanent removal for the PRV and extended detention. The removal options for PRV include reuse, evaporation, transpiration, and infiltration. Infiltration for the first 0.5 inch is encouraged. Documentation to support the computations for volumes can be provided using Worksheet 8. For Non-structural BMPs, checklists can be used to demonstrate that selected BMPs are appropriate. Indicate the volume reduction provided by BMPs on **Worksheet 8**.

- Step 6: Provide detailed routing analysis to demonstrate peak rate control for the 2-year through 100-year storm events. This routing should consider the benefits of BMPs.

Proceed to Water Quality Calculations (Flow Chart D), Step 8.

8.7.2 Water Quality Calculations (Flow Chart D)

- Step 8: Determine if the stormwater management design complies with either Volume Control Guideline 1 or 2 . If volume compliance is achieved under either of these guidelines, proceed to Step 9. If compliance is not achieved, proceed to Step 11.

- Step 9: Determine if at least 90% of the disturbed site area is controlled by a BMP (maximum disturbed, uncontrolled area of 10%). To be considered "controlled" by a BMP, the disturbed area must either drain to a structural BMP (or series of BMPs) or be off-set by a preventive BMP, such as reduced imperviousness or landscape restoration. If at least 90% of the disturbed area is controlled, proceed to Step 10; else proceed to Step 12.

- Step 10: TSS and TP requirements are considered met. Demonstrate use of specific nitrate prevention/reduction BMPs (Worksheet 10). If the required BMPs (2 primary or 4 secondary or 1 primary and 2 secondary) are proposed within the stormwater management plan, then the water quality requirement for nitrate is achieved. If the required BMPs are not proposed, proceed to Step 11.

- Step 11: If neither Control Guideline is met for volume control, demonstrate use of specific BMPs for pollutant prevention (Worksheet 11).

- Step 12: Estimate pollutant load from disturbed areas of the site, excluding preventive measures (if proposed). (Worksheet 12).

- Step 13: Calculate pollutant load reductions with the proposed structural BMPs (**Worksheet 13**). If target load reductions are achieved for TSS, TP, and nitrate, then the water quality requirements are met.

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8.8 Non-Structural BMP Credits

The use of Non-structural BMPs is an important part of a project's stormwater management system. However, the BMPs must be correctly implemented to be effective.

For the Non-Structural BMPs applied, use the appropriate checklists to demonstrate that BMPs are applicable to project.

Worksheet 3 determines the amount of Volume credit or Peak Rate credit associated with Non-structural BMPs.

The following BMPs are "self-crediting" in that the use of these BMPs automatically provides a reduction in impervious area and a corresponding reduction in stormwater impacts. Additionally, the use of these BMPs may be regulated by local ordinances. Local governments and reviewing agencies are encouraged to promote the use of these BMPs where feasible:

BMP 5.5.1 Cluster Uses
BMP 5.5.2 Concentrate Uses through Smart Growth
BMP 5.7.1 Reduce Street Imperviousness
BMP 5.7.2 Reduce Parking Imperviousness

The following BMPs provide a quantitative runoff volume reduction:

BMP 5.4.1 Protect Sensitive/Special Value Features
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas
BMP 5.4.3 Protect/Utilize Natural Flow Pathways
BMP 5.6.1 Minimize Disturbed Area
BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas
BMP 5.8.1 Rooftop Disconnection
BMP 5.8.2 Disconnection from Storm Sewers

References that support the quantitative BMP volume reduction are provided at the end of this chapter. **No more than 25% of the Volume Reduction may be met through Non-Structural BMP credits**.

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Criteria and Credits for BMP 5.4.1 Protect Sensitive/Special Value Features

To receive credit, the proposed areas:

- ☐ Shall include natural areas of floodplains, mapped wetlands, mapped woodlands, and natural slopes over 15% and 25%.
- ☐ May include other areas of significant natural resources that the applicant demonstrates are of special natural value.
- ☐ Shall not be disturbed during project construction (i.e., cleared or graded) except for temporary impacts associated with mitigation and reforestation efforts. Utility disturbance is discouraged and should be kept to a minimum.
- ☐ Shall be protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Shall be located within an acceptable land preservation/protection agreement or other enforceable instrument, such as a deed restriction, that ensures perpetual protection of the proposed areas. The preservation agreement shall clearly specify how the natural area shall be managed and boundaries will be marked with permanent survey markers.
- ☐ Managed turf is not considered an acceptable form of vegetation management.
- ☐ Shall be located on the development project.

CREDITS

Volume and Quality

Protected Area is not to be included in Runoff Volume calculation

Stormwater Management Area = (Total Area – Protected Area)

Peak Rate and Channel Protection

Runoff from the Protected Area may be excluded from Peak Rate calculations and Channel Protection calculations for rate control, provided that the runoff from the protected area is not conveyed to and/or through stormwater management control structures. If necessary, runoff from Protected Areas should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainage ways.

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Criteria and Credits for BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas

To receive credit, the Riparian Buffer Protection areas:

- ☐ Shall include a minimum width of 25 feet from each streambank for Zone 1. Smaller widths do not receive credit.
- ☐ Shall include a minimum width of 75 feet from each streambank for Zone 2. Smaller widths do not receive credit.
- ☐ Shall not be disturbed during project construction (i.e., cleared or graded) except for temporary impacts associated with mitigation and afforestation efforts. Utility disturbance is discouraged and should be kept to a minimum.
- ☐ Areas disturbed for stream crossings (temporary or permanent) do not receive credit.
- ☐ Shall be protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Shall be located within an acceptable land preservation/protection agreement or other enforceable instrument, such as a deed restriction, that ensures perpetual protection of the proposed areas. The preservation agreement shall clearly specify how the Riparian Buffer shall be managed and boundaries will be marked with permanent survey markers.
- ☐ Managed turf is not considered an acceptable form of vegetation management within Zone 1 or Zone 2.
- ☐ Zone 1 shall not be subject to point discharges for the entire length of Zone 1. Zone 2 shall not be subject to point discharges unless the use of a level spreader or similar device is implemented.
- ☐ Shall be located on the development project.
- ☐ Forested Buffers are encouraged. See BMP 5.6.3 for Tree Planting Credit.

CREDITS

Volume and Quality

Protected Area in Zone 1 and/or Zone 2 is not to be included in Runoff Volume calculation or Water Quality volume

Mitigation Area = (Total Area – Protected Area)

Peak Rate and Channel Protection

Runoff from the Protected Area may be excluded from Peak Rate calculations and Channel Protection calculations for rate control, provided that the runoff from the protected area is not conveyed to and/or through stormwater management control structures. If necessary, runoff from Protected Areas should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainage ways.

SARB_015015

Criteria and Credits for BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

To receive credit, the proposed natural Drainage Features:

- ☐ Shall include natural swales and drainage pathways that existed prior to development and that will receive runoff from developed areas, including intermittent drainage areas and intermittent wetland depressions. Manmade drainage features are not included.
- ☐ May use check dams, low berms, native vegetation, and limited grading to improve natural drainage features.
- ☐ Shall be designed to receive runoff such that flows after development are non-erosive. Care must be taken to maintain the non-erosive conditions and natural systems should not be overloaded.
- ☐ Shall be protected from compaction or unintended disturbance during construction by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Shall be noted on stormwater management plans as part of stormwater management system and included in any municipal easement requirements for stormwater systems. Such areas shall be noted on parcel deeds and protected from future encroachment or disturbance by deed restrictions.
- ☐ Shall be located on the development project.
- ☐ May not include perennial streams.
- ☐ Does not include Constructed Vegetated Swales and Vegetated Filter Strips

CREDITS

Volume and Quality

A Volume Reduction may be credited based upon the area of the Natural Drainage Feature that is vegetated.

Volume Reduction (ft^3) = Area x ¼-inch runoff
= Vegetated Area of Natural Drainage Feature (ft^2) x ¼" / 12

Note: A greater volume credit may be requested by the applicant if calculations support a greater numerical value to Minimizing Soil Compaction.

Peak Rate and Channel Protection

The Peak Rate is reduced by a longer travel time of runoff through Natural Drainage Features. The Time of Travel (Tt) after development may be considered the same as the Tt before development for flows through Natural Drainage Features.
When calculating flow rates:

$Tt_{BEFORE} = Tt_{AFTER}$

SARB_015016

Criteria and Credits for BMP 5.6.1 Minimize Total Disturbed Area - Grading

To receive credit, areas of Minimized Disturbance/Grading must meet the following criteria:

- ☐ Area shall not be subject to grading or movement of existing soils.
- ☐ Existing native vegetation in a healthy condition may not be removed.
- ☐ Invasive non-native vegetation may be removed.
- ☐ Pruning or other required maintenance of vegetation is permitted. Additional planting is permitted.
- ☐ Area shall be protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ The area not subject to grading shall be clearly delineated on the Stormwater Management Plan. If future grading or disturbance of this area occurs, subsequent stormwater management must be provided to address disturbance.
- ☐ Shall be located on the development project.

CREDITS

Volume and Quality

Protected Area is not to be included in Runoff Volume calculation or Water Quality volume

Mitigation Area = (Total Area – Protected Area)

Peak Rate and Channel Protection

Runoff from the Protected Area (area not subject to grading) may be excluded from Peak Rate calculations and Channel Protection calculations for rate control, provided that the runoff from the protected area is not conveyed to and/or through stormwater management control structures. If necessary, runoff from Protected Areas should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainage ways.

SARB_015017

Criteria and Credits for BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas

To receive credit, areas of Minimal Soil Compaction must meet the following criteria:

- ☐ Area shall NOT be stripped of existing topsoil.
- ☐ Area shall not be subject to excessive equipment movement. Vehicles movement, storage, or equipment/material laydown shall not be permitted in areas of Minimized Disturbance/Grading.
- ☐ The area shall be protected by having the limits of disturbance and access clearly shown on the Stormwater Management Plan, all construction drawings and delineated in the field.
- ☐ The use of soil amendments and additional topsoil is permitted. Light grading may be done with tracked vehicles that prevent compaction.
- ☐ Lawn and turf grass are acceptable uses. Planted Meadow is an encouraged use.
- ☐ Area shall be located on the development project.

CREDITS

Volume and Quality

A Volume Reduction may be credited based upon the area of Minimal Soil Compaction.

For Lawn Areas:
Volume Reduction (ft^3) = Area of Min. Soil Compaction (ft^2) x ¼" / 12

For Meadow Areas:
Volume Reduction (ft^3) = Area of Min. Soil Compaction (ft^2) x 1/3" / 12

Note: The applicant may request a greater volume credit if calculations support a greater numerical value to Minimizing Soil Compaction.

Peak Rate and Channel Protection

The Peak Rate for flood protection and channel protection will be reduced by the reduction in runoff volume provided above.

SARB_015018

Criteria and Credits for BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species

This BMP includes both Protection of Existing Trees and Re-forestation:

Part 1 Protect Existing Trees

To receive credit for protecting existing trees **NOT** located within Sensitive/Special Value areas, the following criteria must be met:

- ☐ Trees shall be protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Protection during construction shall entail minimizing disruption of the root system; construction shall not encroach within a space measured 10 feet outside of the drip line to the tree trunk.
- ☐ Trees credited for stormwater management shall be clearly labeled on the construction drawings and recorded on Record Plan for project.
- ☐ Trees shall be maintained and protected for the life of the project (50 years) or until redevelopment occurs.
- ☐ No more than 25% of the runoff volume can be mitigated through the use of trees.
- ☐ Pruning or other required maintenance of existing vegetation is permitted for safety purposed only, unless near a building.
- ☐ Escrow shall be provided for the replacement of any protected trees used for stormwater credit that die within 5 years of construction. Dead trees shall be replaced within 6 months.
- ☐ Shall be located on the development project.
- ☐ Existing tree canopy must be within 100 feet of impervious surfaces to gain credit.
- ☐ Only applies for trees outside Sensitive/Special Value areas.
- ☐ Applies to existing trees of 4-inch caliper or larger. Non-native species are not applicable.

CREDITS

Volume and Quality

A Volume Reduction may be credited based upon the existing tree canopy.

For Trees within 100 feet of impervious cover:
Volume Reduction (ft^3) = Existing Tree Canopy (ft^2) x 1/2" / 12

Peak Rate and Channel Protection

The Peak Rate for flood protection and channel protection will be reduced by the reduction in runoff volume provided above.

SARB_015019

Part 2 Revegetate and Reforest

To receive credit for planting trees, the following criteria must be met:

- ☐ Trees must be native species (see Appendix), minimum 2" caliper. Minimum tree height is 6 feet.
- ☐ Trees shall be adequately protected during construction.
- ☐ Trees credited for stormwater management shall be clearly labeled on the construction drawings and recorded on Record Plan for project.
- ☐ Trees shall be maintained and protected for the life of the project (50 years) or until redevelopment occurs.
- ☐ No more than 25% of the runoff volume can be mitigated through the use of trees.
- ☐ Escrow shall be provided for the replacement of any protected trees used for stormwater credit that die within 5 years of construction. Dead trees shall be replaced within 6 months.
- ☐ Shall be located on the development project.
- ☐ May be applied for trees required under Street Tree or Landscaping requirements.
- ☐ May be applied for trees planted as part of Riparian Buffer improvement.
- ☐ Non-native species are not applicable.

CREDITS
Volume and Quality

A Volume Reduction may be credited based upon the existing tree canopy.

For Deciduous Trees:
Volume Reduction (ft^3) = 6 ft^3

For EvergreenTrees:
Volume Reduction (ft^3) = 10 ft^3

Peak Rate and Channel Protection

The Peak Rate for flood protection and channel protection will be reduced by the reduction in runoff volume provided above.

SARB_015020

Criteria and Credits for BMP 5.8.1 Rooftop Disconnection

To receive credit, Rooftop Disconnection Areas must meet the following criteria:

- ☐ Roof leaders are directed to a pervious area where runoff can either infiltrate into the soil or filter over it.
- ☐ Shall be located on the development project.
- ☐ The use of soil amendments and additional topsoil is permitted.
- ☐ Lawn and turf grass are acceptable uses. Planted Meadow is an encouraged use.
- ☐ Shall be noted on stormwater management plans as part of stormwater management system and included in any municipal easement requirements for stormwater systems.
- ☐ Rooftop cannot be within a designated hotspot.
- ☐ Disconnection shall not cause basement seepage.
- ☐ The contributing rooftop area to each disconnection point shall be 500 sf or less. For greater areas, see BMP 6.20 Level Spreader.
- ☐ The length of the disconnection shall be 75 feet or greater.
- ☐ Dry wells, french drains, recharge gardens, infiltration trenches/beds, or other similar storage devices may be utilized to compensate for areas with disconnection lengths less than 75 feet. (Do not credit BMP 5.11)
- ☐ In residential development applications, disconnections will only be credited for lot sizes greater than 6000 sf.
- ☐ The entire vegetated “disconnection” area shall have a maximum slope of 5%.
- ☐ The disconnection must drain continuously through a vegetated swale or filter strip to the property line or BMP.
- ☐ Roof downspouts shall be at least 10 feet away from the nearest impervious surface to discourage “re-connections”
- ☐ For rooftops draining directly to a buffer, only the rooftop disconnection credit of the buffer credit may be used, not both.

CREDITS
Volume and Quality

Volume Reduction (ft^3) = Contributing Rooftop Area (ft^2) x 1/4” / 12

Note: The applicant may request a greater volume credit if calculations support a greater numerical value to Minimizing Soil Compaction.

Peak Rate and Channel Protection

The Peak Rate for flood protection and channel protection will be reduced by the reduction in runoff volume provided above.

SARB_015021

Criteria and Credits for BMP 5.8.2 Disconnection from Storm Sewers

To receive credit, the following must be met:

- ☐ Runoff from the non-rooftop impervious cover shall be directed to pervious areas where it is infiltrated into the soil.
- ☐ May include Vegetated Swales as outlined in BMP 6.8.
- ☐ May include check dams, low berms, native vegetation, and limited grading to improve natural drainage features.
- ☐ Shall be designed such that flows after development are non-erosive.
- ☐ Shall be protected from compaction or unintended disturbance during construction by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Shall be noted on stormwater management plans as part of stormwater management system and included in any municipal easement requirements for stormwater systems.
- ☐ Shall be located on the development project.
- ☐ Runoff cannot originate from a designated hotspot.
- ☐ The maximum contributing impervious flow path length shall be 75 feet.
- ☐ The disconnection shall drain continuously through a vegetated swale or filter strip, or planted area to the property line or BMP.
- ☐ The length of the disconnection area must be at the least the length of the contributing area.
- ☐ The entire vegetated “disconnection” area shall have a maximum slope of 5%.
- ☐ The contributing impervious area to any one discharge point shall not exceed 1000 ft^2.
- ☐ Disconnections are encouraged on relatively well-draining soils (HSG A & B).
- ☐ If the site cannot meet the required disconnect length, a level-spreading device, recharge garden, infiltration trench, or other storage device may be needed for compensation.

CREDITS
Volume and Quality

Volume Reduction (ft^3) = Contributing Impervious Area (ft^2) x 1/4” / 12

Note: A greater volume credit may be requested by the applicant if calculations support a greater numerical value to Minimizing Soil Compaction.

Peak Rate and Channel Protection

The Peak Rate for flood protection and channel protection will be reduced by the reduction in runoff volume provided above.

SARB_015022

Supporting Documentation

Natural Drainage Swales (BMP 5.4.3)

"Headwater streams and wetlands have a particularly important role to play in recharge. These smallest upstream components of a river network have the largest surface area of soil in contact with available water, thereby providing the greatest opportunity for recharge of groundwater. Moreover, water level in headwater streams is often higher than the water table, allowing water to flow through the channel bed and banks into soil and groundwater. Such situations occur when water levels are high, such as during spring snowmelt or rainy seasons." "Headwaters can be intermittent streams that flow briefly when snow melts or after rain, but shrink in dry times to become individual pools filled with water…wetlands are depressions in the ground that hold water whether from rainwater, snowmelt, or groundwater welling up to the surface."

The scientific Imperative for Defending Small streams and Wetlands Judy L. Meyer, PhD, et al, American Rivers, September 2003

Trees (BMP 5.6.3)

"Besides taking in carbon dioxide and putting out oxygen, trees have an enormous impact on temperature. As much as 90 percent of the solar energy is absorbed. Trees also cool by transpiration, the evaporation of water from their leaves. A medium sized tree can move more than 500 gallons of water into the air on a hot day, thereby reducing air temperature."

The Natural Habitat Garden by Ken Druse with Margaret Roach, Timber Press 2004.

500 gal = 66.8 cf

Volume Credits (BMPs 5.4.3; 5.6.2; 5.8.2)

Protect natural drainage ways, avoiding compaction, and disconnecting impervious areas all contribute to a reduction in the volume of runoff and the rate of runoff. The amount of reduction will vary depending on the site-specific conditions, including soil type, cover, etc. The designer may request additional volume credit by providing supporting calculations. The following table compares the difference in runoff volume for protected versus disturbed area for three storm events (1.5-inch, 2.7-inch, and 3.3-inch) for different soil types using the Cover Complex Method.

For 1.5" Rainfall

	A soil	B soil	C soil	D soil
Runoff Before	0	0.00	0.10	0.23
Runoff After	0.00	0.07	0.26	0.41
Difference	***0.00***	***0.07***	***0.16***	***0.18***

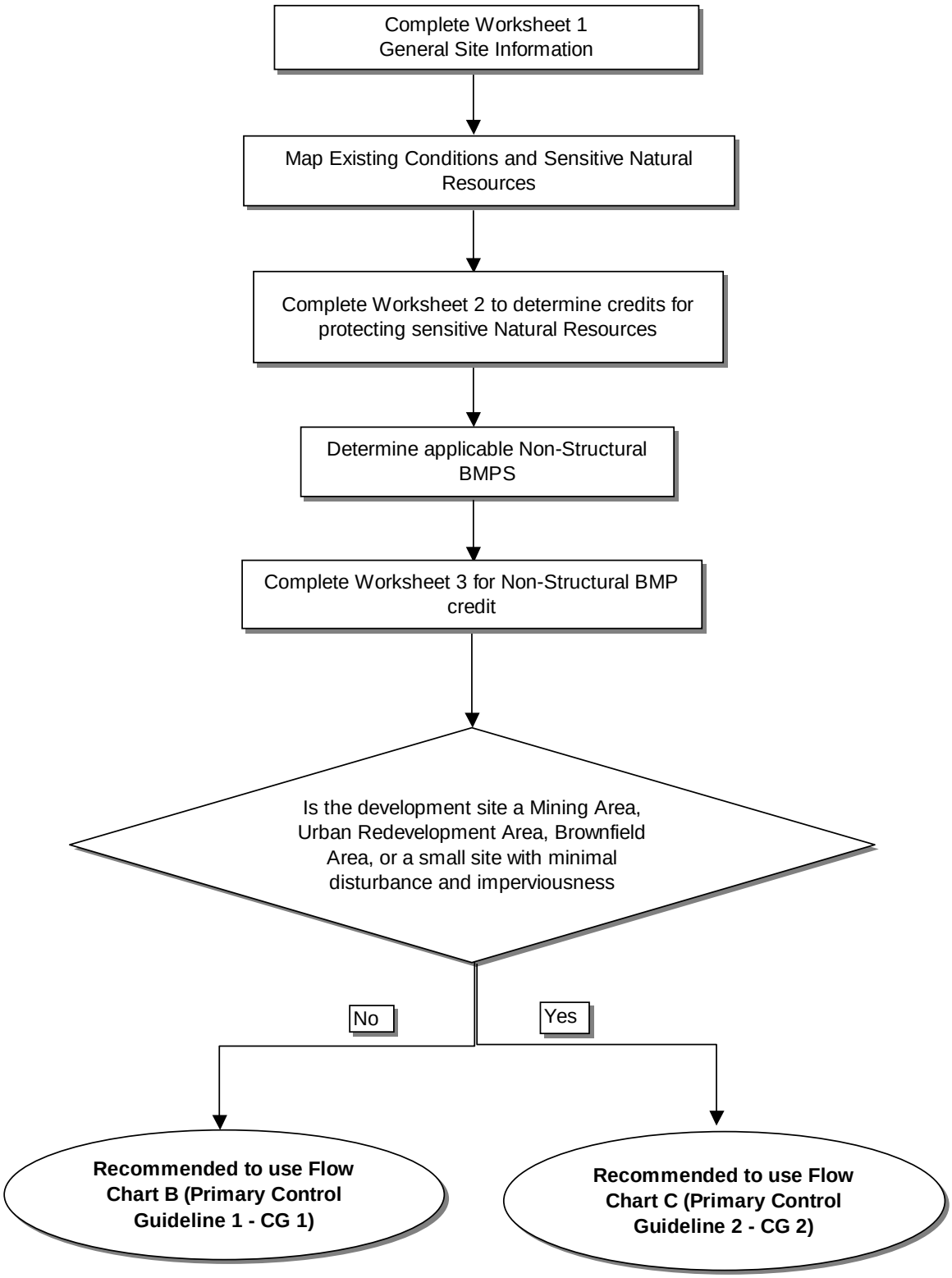
For 2.7" Rainfall

	A soil	B soil	C soil	D soil
Runoff Before	0	0	0.59	0.92
Runoff After	0.03	0.52	0.97	1.27
Difference	***0.03***	***0.52***	***0.38***	***0.35***

For 3.3" Rainfall

	A soil	B soil	C soil	D soil
Runoff Before	0	0.38	0.94	1.35
Runoff After	0.13	0.84	1.41	1.77
Difference	***0.13***	***0.46***	***0.47***	***0.42***

SARB_015023


Complete Worksheet 1
General Site Information
Map Existing Conditions and Sensitive Natural Resources
Complete Worksheet 2 to determine credits for protecting sensitive Natural Resources
Determine applicable Non-Structural BMPS
Complete Worksheet 3 for Non-Structural BMP credit
Is the development site a Mining Area, Urban Redevelopment Area, Brownfield Area, or a small site with minimal disturbance and imperviousness
No
Yes
Recommended to use Flow Chart B (Primary Control Guideline 1 - CG 1)
Recommended to use Flow Chart C (Primary Control Guideline 2 - CG 2)

SARB_015024

Worksheet 1. General Site Information

INSTRUCTIONS: Fill out Worksheet 1 for each watershed

Date: _____

Project Name: _____

Municipality: _____

County: _____

Total Area (acres): _____

Major River Basin: _____

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm#newtopics

Watershed: _____

Sub-Basin: _____

Nearest Surface Water(s) to Receive Runoff: _____

Chapter 93 - Designated Water Use: _____

http://www.pacode.com/secure/data/025/chapter93/chap93toc.html

Impaired according to Chapter 303(d) List? Yes ☐ No ☐

http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/303d-Report.htm

List Causes of Impairment:

Is project subject to, or part of:

Municipal Separate Storm Sewer System (MS4) Requirements? Yes ☐ No ☐

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralPermits/default.htm

Existing or planned drinking water supply? Yes ☐ No ☐

If yes, distance from proposed discharge (miles): _____

Approved Act 167 Plan? Yes ☐ No ☐

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/Approved_1.html

Existing River Conservation Plan? Yes ☐ No ☐

http://www.dcnr.state.pa.us/brc/rivers/riversconservation/planningprojects/

SARB_015025

Worksheet 2. Sensitive Natural Resources

INSTRUCTIONS:

1. Provide Sensitive Resources Map according to non-structural BMP 5.4.1 in Chapter 5. This map should identify wetlands, woodlands, natural drainage ways, steep slopes, and other sensitive natural areas.

2. Summarize the existing extent of each sensitive resource in the Existing Sensitive Resources Table (below, using Acres). If none present, insert 0.

3. Summarize Total Protected Area as defined under BMPs in Chapter 5.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once.

EXISTING NATURAL SENSITIVE RESOURCE	MAPPED? yes/no/n/a	TOTAL AREA (Ac.)	PROTECTED AREA (Ac.)
Waterbodies			
Floodplains			
Riparian Areas			
Wetlands			
Woodlands			
Natural Drainage Ways			
Steep Slopes, 15% - 25%			
Steep Slopes, over 25%			
Other:			
Other:			
TOTAL EXISTING:			

SARB_015026

Worksheet 3. Nonstructural BMP Credits

PROTECTED AREA

1.1 Area of Protected Sensitive/Special Value Features (see WS 2) _____ **Ac.**

1.2 Area of Riparian Forest Buffer Protection _____ **Ac.**

3.1 Area of Minimum Disturbance/Reduced Grading _____ **Ac.**

TOTAL _____ **Ac.**

Site Area	*minus*	Protected Area	=	Stormwater Management Area
	-		=	

This is the area that requires stormwater management

VOLUME CREDITS

3.1 Minimum Soil Compaction

Lawn _____ ft^2 x 1/4" x 1/12 = _____ **ft^3**

Meadow _____ ft^2 x 1/3" x 1/12 = _____ **ft^3**

3.3 Protect Existing Trees

For Trees within 100 feet of impervious area:

Tree Canopy _____ ft^2 x 1/2" x 1/12 = _____ **ft^3**

5.1 Disconnect Roof Leaders to Vegetated Areas

For runoff directed to areas protected under 5.8.1 and 5.8.2

Roof Area _____ ft^2 x 1/3" x 1/12 = _____ **ft^3**

For all other disconnected roof areas

Roof Area _____ ft^2 x 1/4" x 1/12 = _____ **ft^3**

5.2 Disconnect Non-Roof impervious to Vegetated Areas

For Runoff directed to areas protected under 5.8.1 and 5.8.2

Impervious Area _____ ft^2 x 1/3" x 1/12 = _____ **ft^3**

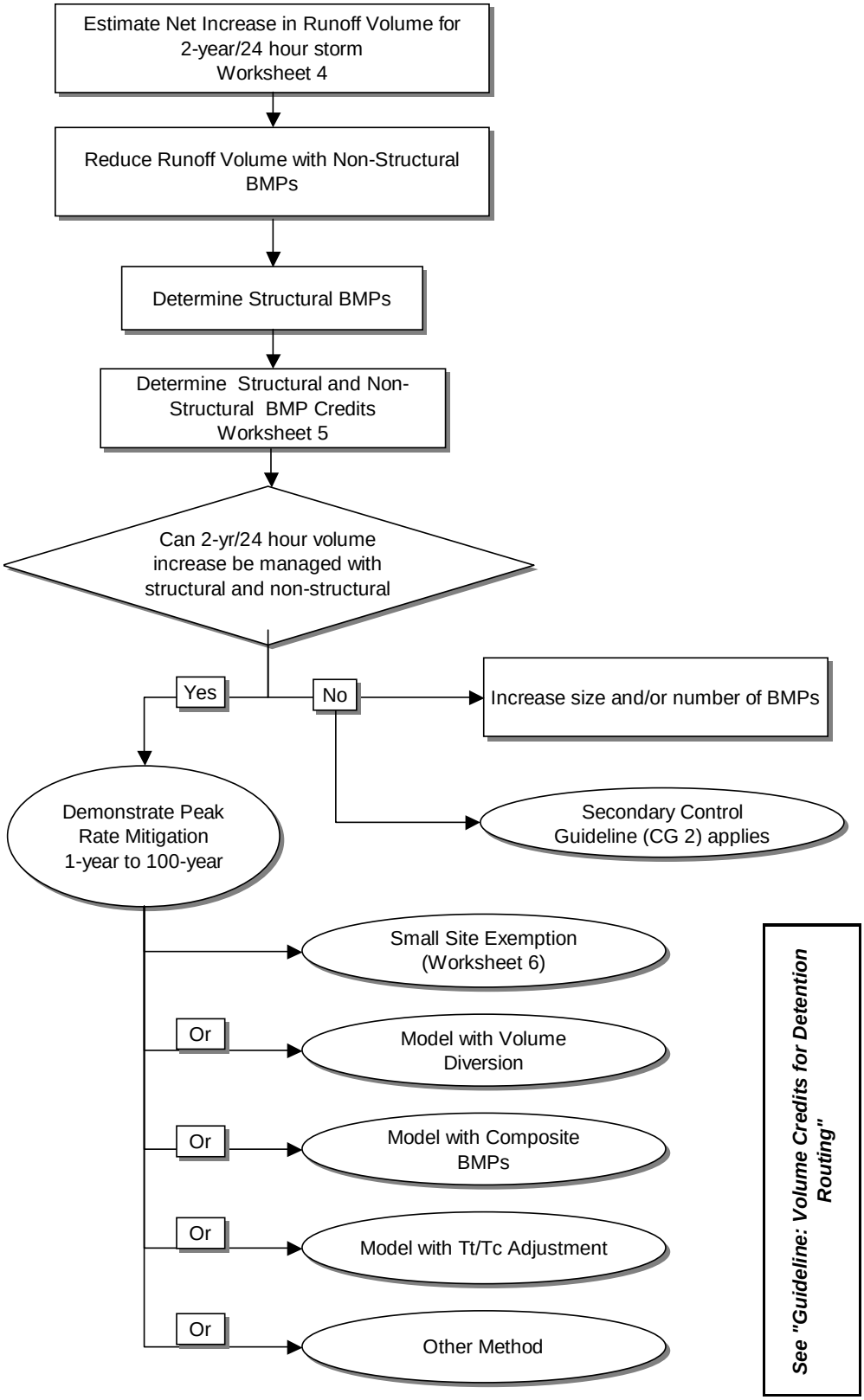
For all other disconnected roof areas

Impervious Area _____ ft^2 x 1/4" x 1/12 = _____ **ft^3**

TOTAL NON-STRUCTURAL VOLUME CREDIT* _____ **ft^3**

** For use on Worksheet 5*

FLOW CHART B
Control Guideline 1 Process



SARB_015028

WORKSHEET 4 . CHANGE IN RUNOFF VOLUME FOR 2-YR STORM EVENT

PROJECT: _____
Drainage Area: _____
2-Year Rainfall: _____ **in**

Total Site Area: _____ **acres**
Protected Site Area: _____ **acres**
Managed Area: _____ **acres**

Existing Conditions:

Cover Type/Condition	Soil Type	Area (sf)	Area (ac)	CN	S	Ia (0.2*S)	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Woodland								
Meadow								
Impervious								
TOTAL:								

Developed Conditions:

Cover Type/Condition	Soil Type	Area (sf)	Area (ac)	CN	S	Ia (0.2*S)	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
TOTAL:								

2-Year Volume Increase (ft3):

2-Year Volume Increase = Developed Conditions Runoff Volume - Existing Conditions Runoff Volume

1. Runoff (in) = $Q = (P - 0.2S)^2 / (P + 0.8S)$ where

P = 2-Year Rainfall (in)

S = (1000/ CN)-10

2. Runoff Volume (CF) = Q x Area x 1/12

Q = Runoff (in)

Area = Land use area (sq. ft)

Note: Runoff Volume must be calculated for EACH land use type/condition and HSGl. The use of a weighted CN value for volume calculations is not acceptable.

SARB_015029

WORKSHEET 5 . STRUCTURAL BMP VOLUME CREDITS

PROJECT: _____

SUB-BASIN: _____

Required Control Volume (ft^3) - *from Worksheet 4*: _____

Non-structural Volume Credit (ft^3) - *from Worksheet 3*: - _____

Structural Volume Reqmt (ft^3) _____

(Required Control Volume minus Non-structural Credit)

Proposed BMP		Area (ft^2)	Storage Volume (ft^3)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench		
6.4.5	Rain Garden/Bioretention		
6.4.6	Dry Well / Seepage Pit		
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			

Total Structural Volume (ft^3): _____

Structural Volume Requirement (ft^3): _____

DIFFERENCE _____

SARB_015030

WORKSHEET 6 . SMALL SITE / SMALL IMPERVIOUS AREA EXCEPTION FOR PEAK RATE MITIGATION CALCULATIONS

The following conditions must be met for exemption from peak rate analysis for small sites under CG-1:

_____ The 2-Year/24 Hour Runoff Volume increase must be met in BMPs designed in accordan with Manual Standards

_____ Total Site Impervious Area may not exceed **1 acre.**

_____ Maximum Development Area is : is **5 Acres**

_____ Maximum site impervious cover is 50%.

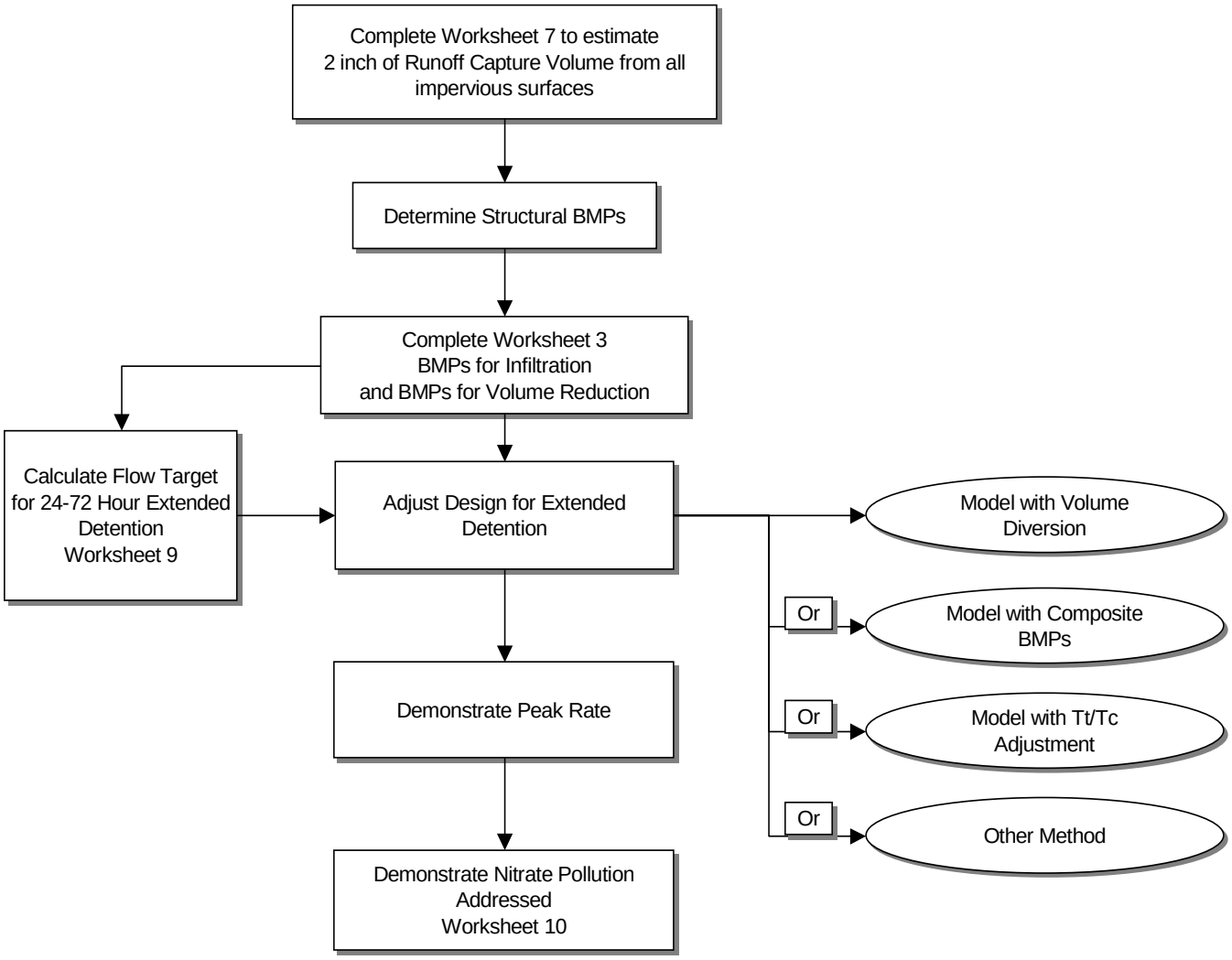
_____ No more than 25% Volume Control can be in Non-structural BMPs

_____ Infiltration BMPs must have an infiltration of at least 0.5 in/hr.

Site Area	Percent Impervious	Total Impervious
5 acre	20%	1 acre
2 acre	50%	1 acre
1 acre	50%	0.5 acre
0.5 acre	50%	0.25 acre

SARB_015031

FLOW CHART C
Control Guideline 2 Process



SARB_015032

WORKSHEET 7. CALCULATION OF RUNOFF VOLUMES (PRV and EDV) FOR CG-2 ONLY

PROJECT: _____

DRAINAGE AREA:

Total Site Area: acres

Protected Site Area: _____ acres

Managed Area: acres

Total Impervious Area acres

2 Inch Runoff - Multiply Total Impervious Area by 2 inch

Cover Type	Area (ac)	Runoff Capture Volume (ft^3)
Roof		
Pavement		
Other Impervious		
TOTAL:		

1 Inch Rainfall -

Cover Type	Area (sf)	Area (ac)	Runoff (in)	Runoff Volumes (ft^3)
TOTAL:				

1. Total Runoff Capture Volume (ft^3) =Total Impervious Area (ft^2) x 2 inch x 1/12

2. PRV (ft^3) = Total Impervious Area (ft^2) x 1 inch x 1/12

3. EDV (ft^3) = Total Impervious Area (ft^2) x 1 inch x 1/12

Water quality volume requirements for land areas with existing cover consisting of meadow, brush, wood-grass combination, or woods proposed for conversion to any other non-equivalent type of pervious cover shall be sized for one-half (1/2) the volume required for impervious surfaces as mentioned in this worksheet and calculated in items 1 through 3 above

SARB_015033

WORKSHEET 8 . STRUCTURAL BMP VOLUME CREDITS

PROJECT: _____

SUB-BASIN: _____

Required Control Volume (ft^3) - *from Worksheet 7*: _____

Non-structural Volume Credit (ft^3) - *from Worksheet 3*: - _____

Structural Volume Reqmt (ft^3) _____

(Required Control Volume minus Non-structural Credit)

Proposed BMP*		Area (ft^2)	Storage Volume (ft^3)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench		
6.4.5	Rain Garden/Bioretention		
6.4.6	Dry Well / Seepage Pit		
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			

Total Structural Volume (ft^3): _____

Structural Volume Requirement (ft^3): _____

DIFFERENCE _____

SARB_015034

1) Volume Diversion. Many computers models have components that allow a "diversion" or "abstraction". The total volume reduction provided by the applicable structural and non-structural BMPs can be diverted or abstracted from the modeled runoff before it is routed to the detention system(s). This approach is very conservative because it does not give any credut to the increased time of travel, ongoing infiltration, etc. associated with the BMPs.

2) Composite BMPs. For optimal stormwater management, this manual suggests widely distributed BMPs for volume, rate, and quality control. This approach, however, can be very cumbersome to evaluate in detail with common computer models. To facilitate modeling, similar types of BMPs can be combined within the model. For modeling purposes, the storage of the combined BMP is simply the sum of the BMP capacities that it represents. A stage-storage-discharge relationship can be developed for the combined BMP based on the configuration of the individual systems. The combined BMPs can then be routed normally and the results submitted.

3) Travel Time/ Time of Concentration Adjustment. The use of widely-distributed, volume-reducing BMPs can significantly increase the post-development runoff travel time and therefore decrease the peak rate of discharge. The Delaware Urban Runoff Management Model (DURMM) calculates the extended travel time through storage elements, even at flooded depths, to adjust peak flow rates (Lucas, 2001). The extended travel time is essentially the residence time of the storage elements, found by dividing the total storage by the 2-year peak flow rate. This increased travel timecan be added to the time of concentration of the area to account for the slowing effect of the volume-reducing BMPs. This can reduce the amount of detention storage required for peak rate control.

4) Other Methods. Other methods, such as adjusting runoff curve numbers based on the runoff volume left after BMP application, or reducing net precipitation based on the volume captured, can be applied as appropriate.

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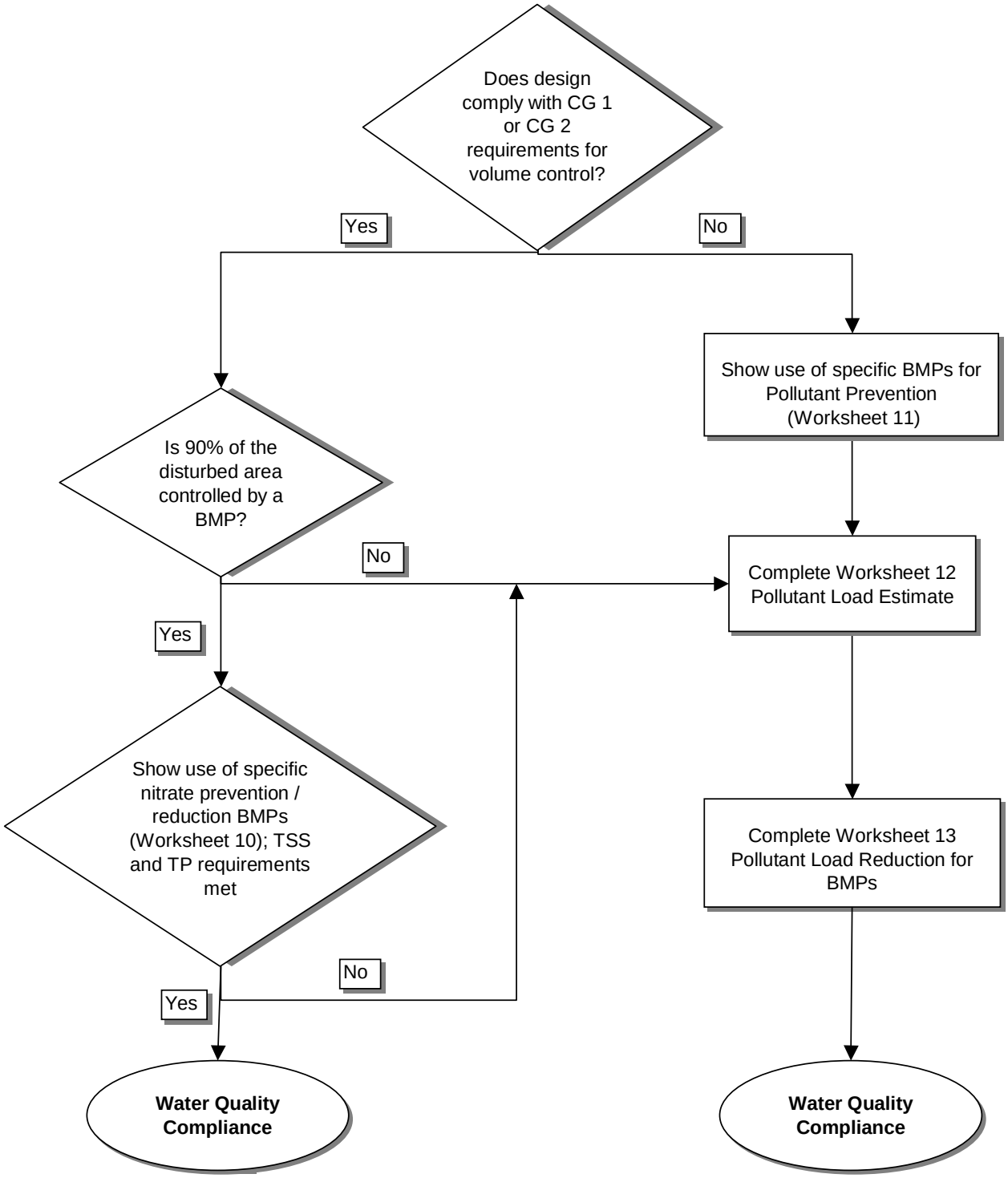
Flow Chart D
Water Quality Process



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WORKSHEET 10. WATER QUALITY COMPLIANCE FOR NITRATE

Does the site design incorporate the following BMPs to address nitrate pollution? A summary "yes" rating is achieved if at least 2 Primary BMPs for nitrate are provided across the site or 4 secondary BMPs for nitrate are provided across the site (or the

PRIMARY BMPs FOR NITRATE:

	YES	NO
NS BMP 5.4.2 - Protect / Conserve / Enhance Riparian Buffers		
NS BMP 5.5.4 - Cluster Uses at Each Site		
NS BMP 5.6.1 - Minimize Total Disturbed Area		
NS BMP 5.6.3 - Re-Vegetate / Re-Forest Disturbed Areas (Native Species)		
NS BMP 5.9.1 - Street Sweeping / Vacuuming		
Structural BMP 6.7.1 - Riparian Buffer Restoration		
Structural BMP 6.7.2 - Landscape Restoration		

SECONDARY BMPs FOR NITRATE:

NS BMP 5.4.1 - Protect Sensitive / Special Value Features		
NS BMP 5.4.3 - Protect / Utilize Natural Drainage Features		
NS BMP 5.6.2 - Minimize Soil Compaction		
Structural BMP 6.4.5 - Rain Garden / Bioretention		
Structural BMP 6.4.8 - Vegetated Swale		
Structural BMP 6.4.9 - Vegetated Filter Strip		
Structural BMP 6.6.1 - Constructed Wetland		
Structural BMP 6.7.1 - Riparian Buffer Restoration		
Structural BMP 6.7.2 - Landscape Restoration		
Structural BMP 6.7.3 - Soils Amendment/Restoration		

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WORKSHEET 11. BMPS FOR POLLUTION PREVENTION

Does the site design incorporate the following BMPs to address nitrate pollution? A summary "yes" rating is achieved if at least 2 BMPs are provided across the site. "Provided across the site" is taken to mean that the specifications for that BMP set forward in Chapters 5 and 6 are satisfied.

BMPs FOR POLLUTANT PREVENTION:

	YES	NO
NS BMP 5.4.1 - Protect Sensitive / Special Value Features		
NS BMP 5.4.2 - Protect / Conserve / Enhance Riparian Buffers		
NS BMP 5.4.3 - Protect / Utilize Natural Flow Pathways in Overall Stormwater Planning and Design		
NS BMP 5.5.1 - Cluster Uses at Each Site; Build on the Smallest Area Possible		
NS BMP 5.6.1 - Minimize Total Disturbed Area - Grading		
NS BMP 5.6.2 - Minimize Soil Compaction in Disturbed Areas		
NS BMP 5.6.3 - Re-Vegetate / Re-Forest Disturbed Areas (Native Species)		
NS BMP 5.7.1 - Reduce Street Imperviousness		
NS BMP 5.7.2 - Reduce Parking Imperviousness		
NS BMP 5.8.1 - Rooftop Disconnection		
NS BMP 5.8.2 - Disconnection from Storm Sewers		
NS BMP 5.9.1 - Street Sweeping		
Structural BMP 6.7.1 - Riparian Buffer Restoration		
Structural BMP 6.7.2- Landscape Restoration		
Structural BMP 6.7.3- Soils Amendment and Restoration		

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WORKSHEET 12. WATER QUALITY ANALYSIS OF POLLUTANT LOADING FROM ALL DISTURBED AREAS

TOTAL SITE AREA (AC)	
TOTAL DISTURBED AREA (AC)	
DISTURBED AREA CONTROLLED BY BMPs (AC)	

TOTAL DISTURBED AREAS:

		POLLUTANT					POLLUTANT LOAD		
	LAND COVER CLASSIFICATION	**TSS EMC *(mg/l)***	**TP EMC *(mg/l)***	**Nitrate-Nitrite EMC *(mg/l as N)***	**COVER (Acres)**	**RUNOFF VOLUME (AF)**	**TSS** (LBS)**	**TP** (LBS)**	**NO_3 (LBS)**
Pervious Surfaces	Forest	39	0.15	0.17					
	Meadow	47	0.19	0.3					
	Fertilized Planting Area	55	1.34	0.73					
	Native Planting Area	55	0.40	0.33					
	Lawn, Low-Input	180	0.40	0.44					
	Lawn, High-Input	180	2.22	1.46					
	Golf Course Fairway/Green	305	1.07	1.84					
	Grassed Athletic Field	200	1.07	1.01					
Impervious Surfaces	Rooftop	21	0.13	0.32					
	High Traffic Street / Highway	261	0.40	0.83					
	Medium Traffic Street	113	0.33	0.58					
	Low Traffic / Residential Street	86	0.36	0.47					
	Res. Driveway, Play Courts, etc.	60	0.46	0.47					
	High Traffic Parking Lot	120	0.39	0.60					
	Low Traffic Parking Lot	58	0.15	0.39					
						TOTAL LOAD			
						REQUIRED REDUCTION (%)	**85%**	**85%**	**50%**
						REQUIRED REDUCTION (LBS)			

* Pollutant Load = [EMC, mg/l] X [Volume, AF] X [2.7, Unit Conversion]

** TSS and TP calculations only required for projects not meeting CG1/CG2 or not controlling less than 90% of the disturbed area

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WORKSHEET 13. POLLUTANT REDUCTION THROUGH BMP APPLICATIONS*

** FILL THIS WORKSHEET OUT FOR EACH BMP TYPE WITH DIFFERENT POLLUTANT REMOVAL EFFICIENCIES. SUM POLLUTANT REDUCTION ACHIEVED FOR ALL BMP TYPES ON FINAL SHEET.*

BMP TYPE: _____

DISTURBED AREA CONTROLLED BY THIS BMP TYPE (AC)	

DISTURBED AREAS CONTROLLED BY THIS BMP TYPE:

		POLLUTANT					POLLUTANT LOAD**		
	LAND COVER CLASSIFICATION	TSS EMC *(mg/l)*	TP EMC *(mg/l)*	Nitrate-Nitrite EMC *(mg/l as N)*	COVER (Acres)	RUNOFF VOLUME (AF)	TSS*** (LBS)	TP*** (LBS)	NO_3 (LBS)
Pervious Surfaces	Forest	39	0.15	0.17					
	Meadow	47	0.19	0.3					
	Fertilized Planting Area	55	1.34	0.73					
	Native Planting Area	55	0.40	0.33					
	Lawn, Low-Input	180	0.40	0.44					
	Lawn, High-Input	180	2.22	1.46					
	Golf Course Fairway/Green	305	1.07	1.84					
	Grassed Athletic Field	200	1.07	1.01					
Impervious Surfaces	Rooftop	21	0.13	0.32					
	High Traffic Street / Highway	261	0.40	0.83					
	Medium Traffic Street	113	0.33	0.58					
	Low Traffic / Residential Street	86	0.36	0.47					
	Res. Driveway, Play Courts, etc.	60	0.46	0.47					
	High Traffic Parking Lot	120	0.39	0.60					
	Low Traffic Parking Lot	58	0.15	0.39					
						TOTAL LOAD TO THIS BMP TYPE			
						POLLUTANT REMOVAL EFFICIENCIES FROM TABLE 9-3 (%)			
						POLLUTANT REDUCTION ACHIEVED BY THIS BMP TYPE (LBS)			

POLLUTANT REDUCTION ACHIEVED BY ALL BMP TYPES (LBS)			
REQUIRED REDUCTION FROM WS12 (LBS)			

** Pollutant Load = [EMC, mg/l] X [Volume, AF] X [2.7, Unit Conversion]
*** TSS and TP calculations only required for projects not meeting CG1/CG2 or not controlling less than 90% of the disturbed area

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Pennsylvania Stormwater Best Management Practices Manual

Chapter 9

Case Studies: Innovative Stormwater Management Approaches and Practices



Chapter 9 Case Studies: Innovative Stormwater Management Approaches and Practices

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Case Studies: Innovative Stormwater Management Approaches and Practices

9.1 Introduction

Although examples of BMPs have been included throughout all chapters of this manual with a considerable number of illustrations, in most cases these examples have been necessarily condensed and highly summarized. Most examples have not been able to do justice to all aspects of the site development program and the site design and stormwater management plans that have been developed. Consequently, early in the process of developing this new manual, the decision was made to include a chapter that highlights functioning projects in Pennsylvania communities that have successfully incorporated many of the Non-Structural and Structural BMPs that are described in this manual. Clearly, seeing is believing – there is great value in being able to visit and view firsthand successful applications of the many different BMPs which have been presented.

This chapter is a work in progress, where PADEP hopes to increase its file of successful case studies over time. In particular, the hope is to add many more successful applications from all regions of the state. Many of the innovative projects that have been undertaken have occurred in projects in southeastern and southcentral Pennsylvania, to some extent reflecting the greater amount of land development activity occurring in that region of Pennsylvania.
A Self-Guided Stormwater Best Management Practices Tour has been developed recently by the Chester County Conservation District and funded by the PADEP Growing Greener Grant Program. The Tour ingeniously features 21 different sites that include a variety of both non-structural and structural BMPs applied in residential, commercial, and recreational land use settings. The entire Tour and all of the written and photographic material which describes the sites and stormwater practices is available on line through the Chester County Conservation District website. Several of the BMPs included in the tour are featured in this chapter. Many other County Conservation Districts have also installed demonstration BMPs at their office locations, including Westmoreland, Adams, Dauphin and Erie Counties.

The case studies that have been included in this chapter are designed to focus on successful BMP application - what works. Over time, this case study discussion will be expanded to include lists of what to avoid – what doesn't work – as well. PADEP invites all interested stormwater stakeholders to submit case study information in the future for additional projects. Section 9.2 is a list of information and data items that case study descriptions should address, although it is recognized that some data gaps may exist.

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9.2 Outline of Information Needed for Case Studies

PADEP Stormwater Manual Case Study
Outline of Needed Information/Data

Name of Project:
Address of Project:
- Street
- Municipal/county
- Year constructed
- Developer/builder/owner (name and contact information, if available)

Natural Site Features:
Water Resources
Major Watershed/minor watershed
- Stream classification
- Special: water supply source? TMDL? Impaired streams?
- Streams, ponds, lakes?

Drainage features on the site
- Wetlands? Floodplains? Riparian areas?
- Wells (existing and future)? Zone of contribution? Zone of influence? Groundwater protected area?

Geology
- Rock/aquifer type?
- Special? Limestone? Subsidence potential? Fracture/fault traces? Lineaments?

Soils Hydrologic Soil Group A thru D?
- Soil testing performed?
- Thickness?
- Other?

Slopes?
Vegetation
- Existing at site?
- Extent of vegetation disturbed/removed?
- Re-vegetation?

Proposed Use/Building Program
- How much?
- Of what?
- Total site area?
- Total disturbed area?
- Total impervious area?
- Costs of development?

Proposed Stormwater BMPs
- Structurals?
  - Design specs, calculations, etc.
- Non-Structurals?
  - Design specs, calculations, etc.
- Maintenance issues?
- Other special issues?
- Costs of site work and stormwater elements?

9.3 Case Studies

The following case studies present examples of a range of structural and nonstructural BMPs that have been successfully implemented across the state. The information provided has been assembled from contributing Conservation Districts within Pennsylvania. Each case study has been developed to include a high level of detail from the information provided, however data gaps do exist. For further information, the reader is encouraged to contact the conservation district in the county where the project is located.

Case Study 1: Penn State University - Centre County Visitor Center, Centre County

- **Porous Asphalt Parking Lots underlain with Subsurface Infiltration Beds**
- **Porous Concrete Sidewalks**
- **Subsurface Infiltration Trenches**
- **Vegetated Infiltration Bed**
- **Several Rain Gardens / Bioretention areas**

Project Background

The Penn State University/Centre County Visitor Center in State College was constructed in 1999 on a site underlain by the Nittany Formation. The Visitor's Center incorporates a number of stormwater infiltration techniques, shown in Figure 9-1, and was designed to imitate the natural hydrologic system that existed at the site before development.

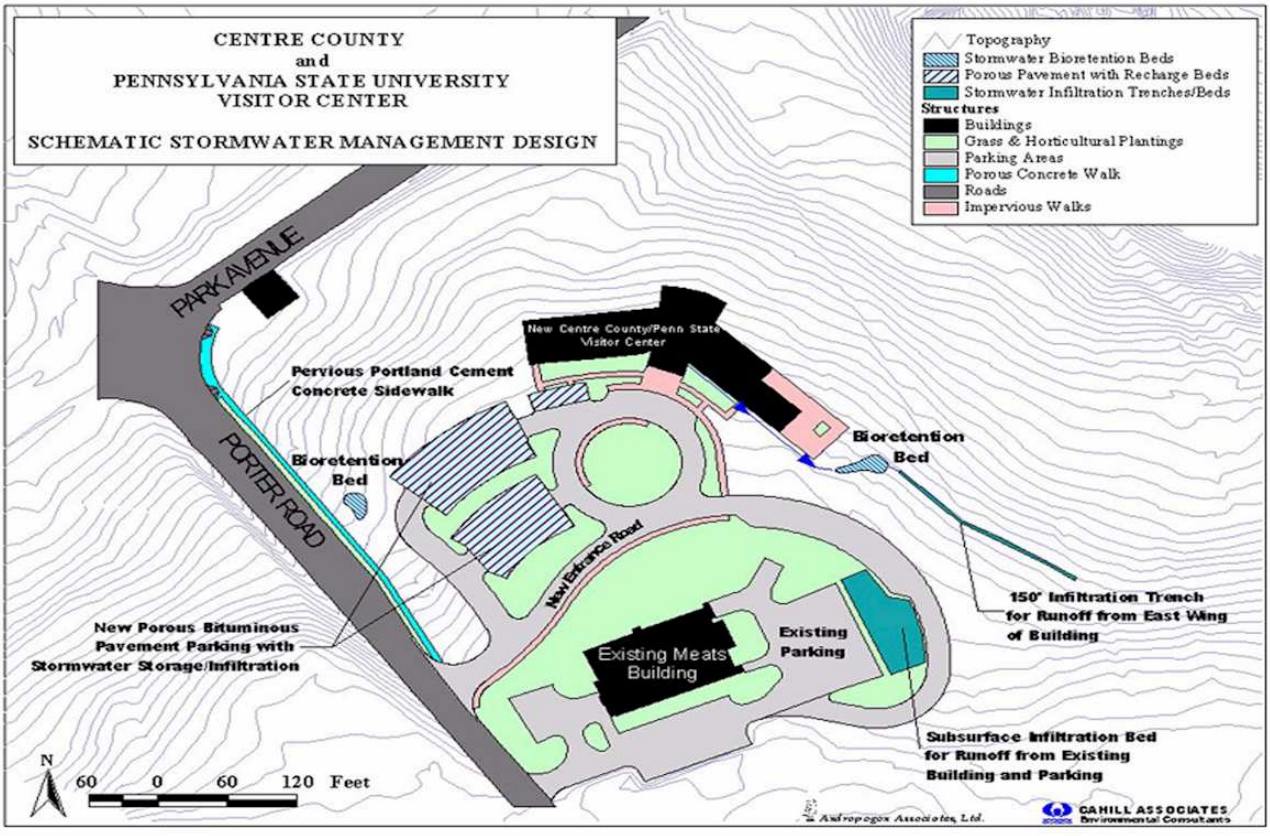

Figure 9-1. Stormwater Management System at PSU Visitor's Center in Centre County, PA.

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According to the soil survey, the soil at this site was classified as the Hagerstown Series, well-drained soils that formed in limestone residuum. Typically, the surface layer was dark-brown silt loam about eight (8) inches thick. The subsoil consisted of yellowish-red and reddish-brown silty clay, clay, and silty-clay loam approximately 37 inches thick. The substratum was generally yellowish-brown clay loam to a depth of about 75 inches. The entire 5-acre site was underlain by the same soil series.

This information indicated several important characteristics of this site, even before detailed testing was completed. The soil was well-drained with probably at least 5 to 6 feet of soil above the weathered bedrock. Some clay was contained in the soils, which was a positive element since some mix of clay would prevent water from draining excessively rapidly and would serve to remove pollutants.

The underlying geology was classified as the Nittany Formation according to the Department of Environmental Resources, Bureau of Topographic and Geologic Survey (1982). This formation consists of light to dark gray, finely to coarsely crystalline dolomite with alternating beds of sandy, cherty dolomite. The rock is moderately resistant to weathering and is slightly weathered to a shallow depth. The development of joint and solution channel openings in the rock is common. Bedrock pinnacles are also common in the interface between the rock and soil mantle, which can make excavation of the rock difficult. No specific geologic features (i.e. fracture traces) are indicated for this site.

Again, this information was crucial to developing a more detailed site investigation program. The presence of pinnacles required a field investigation that can provide a site-specific understanding of the pinnacle locations. In addition, the tendency for joint and solution channel openings to form indicates a strong need to disperse stormwater and avoid concentrated points of storage or infiltration.

One additional piece of important information is that several University water supply wells are located approximately 1/2-mile downstream of this site, indicating the importance of maintaining groundwater recharge and water quality.

Site Testing: Geotechnical Investigation for Building Structure

The initial field investigation involved the excavation of five test borings, two groundwater-monitoring wells, and four test pits. The initial tests were all installed as part of the geotechnical investigation for the proposed building (independent of SWM), but provided useful and valid information for the stormwater system as well. In other words, the stormwater design engineer should make use of all available data developed at the site.

This information included the following findings:
Groundwater was not encountered in any of the borings or test pits.
Auger refusals were encountered at depths ranging from 2 feet to 8.7 feet – very shallow.
Refusal materials were encountered in three of the four test pits ranging from 3.1 to 4.8 feet.
The dolomitic limestone rock cores were weathered and fractured near the surface.
The rock contained interbedded clay seams.
No evidence of subsurface activity associated with sinkholes was encountered.

Site Testing: Geotechnical Investigation for Stormwater Management

The information from the building geotechnical investigation confirmed that bedrock depth was variable and could be quite shallow. Based on this information, a more detailed geotechnical investigation was developed that included a grid of shallow core borings, to a depth of ten feet or refusal, approximately 25 feet on-center. The shallow augers confirmed that there was considerable variation in the top of rock reflecting the pinnacle nature of the underlying bedrock.

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Seven additional test pits were also excavated at the same time that the borings were undertaken. These test pits were a critical part of the investigation and provided direct physical observation of the soil layers and geology, confirming the soil survey series designations (which may or may not be correct for the site). In this situation the test pits indicated the considerable variability in the top of rock; even within a distance of eight feet (the length of the test pit), the surface of the bedrock could vary by two to three feet. At the same time, simple percolation tests were also conducted at the test pits to provide an estimate of the infiltration capabilities of the soil.

Compilation of Data: Cross Section Development

Before any design of the site and stormwater system takes place, the engineer should understand the data in relation to the proposed use of the site. The most effective way to understand this information is to incorporate it into the site plans. The location of the test borings and test pits is indicated on Figure 9-2, which also indicates the proposed site layout. Next to each test boring, the depth to bedrock is indicated. This is the first step in laying out the stormwater components. The engineer should strive to integrate the information on a single sheet that helps the engineer visualize and determine feasible areas for infiltration systems. At the Penn State Visitor Center, the area of the parking lots had been generally proposed. The next step in design was to develop a profile of this information. Several cross sections of the site were developed in the area of the proposed parking lots. On each profile, the existing surface topography, the depth to bedrock and any other relevant information was plotted.

Stormwater Management Design: Fit to Site and Close to Source

Using these profiles, the parking bays and infiltration beds were “fit” into the hillside, stepping down the hillside with two parking bays, and adjusting the bottoms of the infiltration beds to “step down” as well. This is shown in Figure 9-3.

Several items in design should be noted. Because the rock was shallow in places, the existing soil was not excavated. Instead, the beds were “built up” using berms to avoid soil excavation, and only the organic layer was removed. Where rock was very shallow, infiltration was limited to what would naturally fall or drain to the area before development, and no attempt was made to convey additional stormwater to the area. Instead, the pre-development balance (or Loading Rate) was carefully maintained.

Development of cross sections can be an extremely useful element in design of infiltration systems on carbonate rock. Because the beds must be carefully set with adequate soil mantle, the cross sections provide the design engineer with the information necessary for the layout. Additionally, cross sections provide the Contractor with the necessary information to build the system. In the same manner that profiles are required for utility pipe design (i.e., water, wastewater, and stormwater pipes), profiles are an important component of design of infiltration BMPs in carbonate rock.

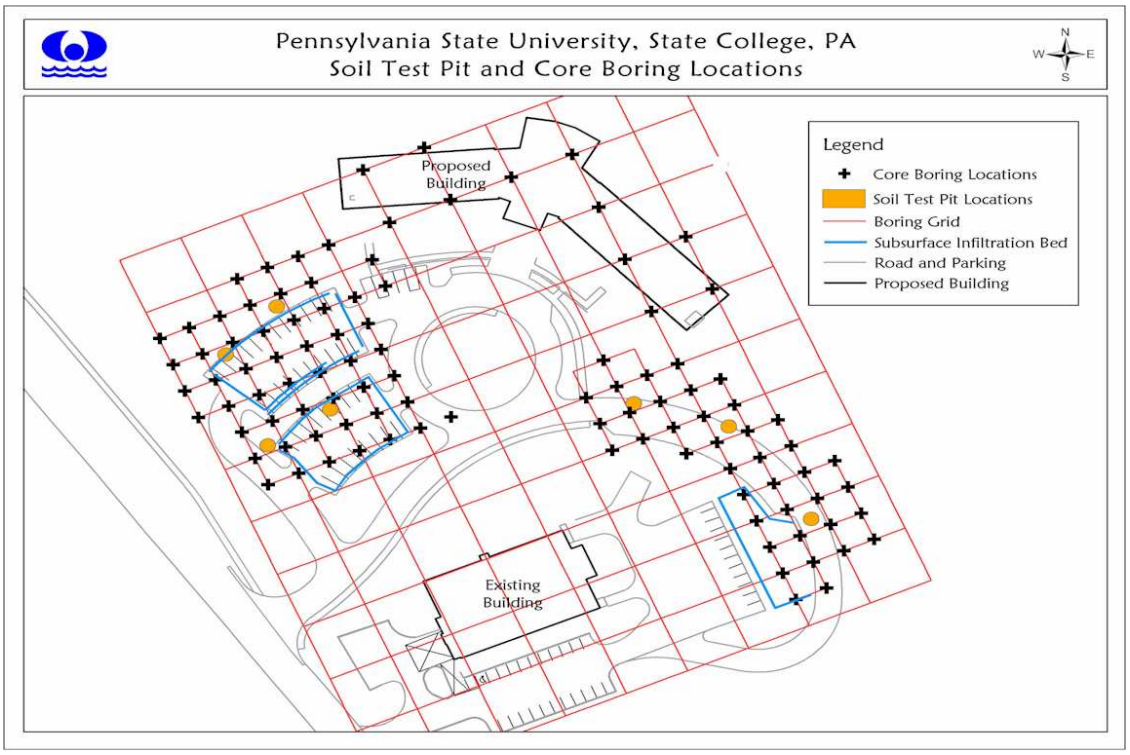

Figure 9-2. Core Boring and Soil Test Pit Locations at the PSU Visitor's Center, Centre County.

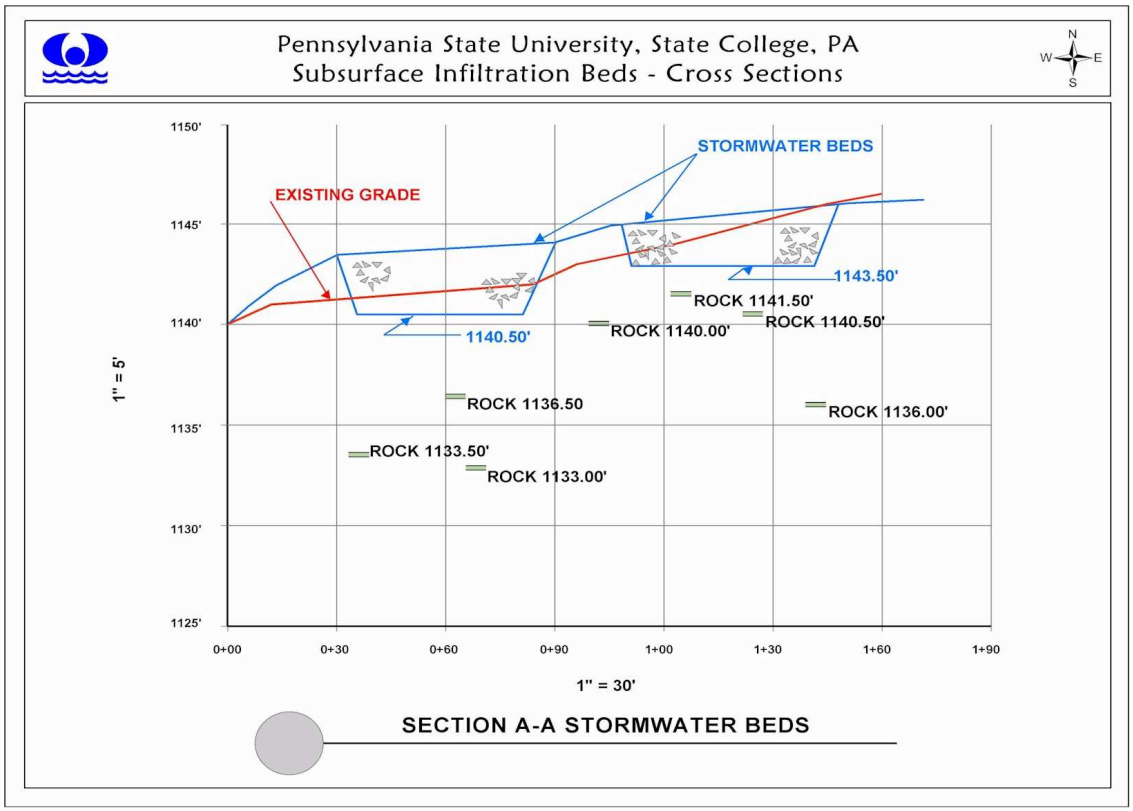

Figure 9-3. Cross-section view showing bedrock pinnacles, existing grade, and proposed stormwater infiltration beds with elevations.

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Finally, and most importantly, it was recognized at the Visitor Center that any attempt to convey stormwater from one portion of the site to another would result in stormwater pipes that would be placed in the bedrock. Given the pinnacled nature of the site, it would be inevitable that any length of pipe would be forced to traverse bedrock. To avoid this situation, stormwater is managed as close to the source as possible and a variety of measures are incorporated:

Runoff from the roof of the eastern side of the building is conveyed to a Rain Garden and then to a subsurface Infiltration Trench located on contour.

The Infiltration Trench (Figure 9-4) intercepts a portion of the entrance road runoff. To compensate for the remainder, a vegetated subsurface Infiltration Bed (Figure 9-5) was located immediately adjacent to an existing, uncontrolled parking lot.

The runoff from the western portion of the building is conveyed to the parking lot immediately adjacent to the building where the soil mantle is suitable and the top of bedrock was much deeper (Figure 9-6). In several key locations where stormwater management was needed, small Rain Gardens (Figure 9-7), designed to infiltrate, were incorporated to avoid installing stormwater pipes.

Porous concrete sidewalks were constructed to manage the rainfall incident to them (Figure 9-8).



Figure 9-4. Infiltration trench located on contour, State College, Centre County.

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Figure 9-5. Vegetated infiltration bed, State College, Centre County.



Figure 9-6. Porous asphalt parking lot, State College, Centre County.



Figure 9-7. Rain Garden, State College, Centre County.

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Figure 9-8. Porous concrete sidewalks, State College, Centre County.

Engineering Plans

The final and critical element to stormwater infiltration system design was to provide the Contractor the required information to build the systems. The subsurface grading of the stormwater infiltration beds was critical to their success. In addition to the cross sections provided, each system should indicate the subsurface contours. An example from the Visitor Center is provided in Figure 9-9. This grading information allowed the earthwork contractor to construct the bed as designed. Because this information is "sub-surface," it would not normally be part of a site-grading plan. However, adding this grading information to the stormwater plan was critical.

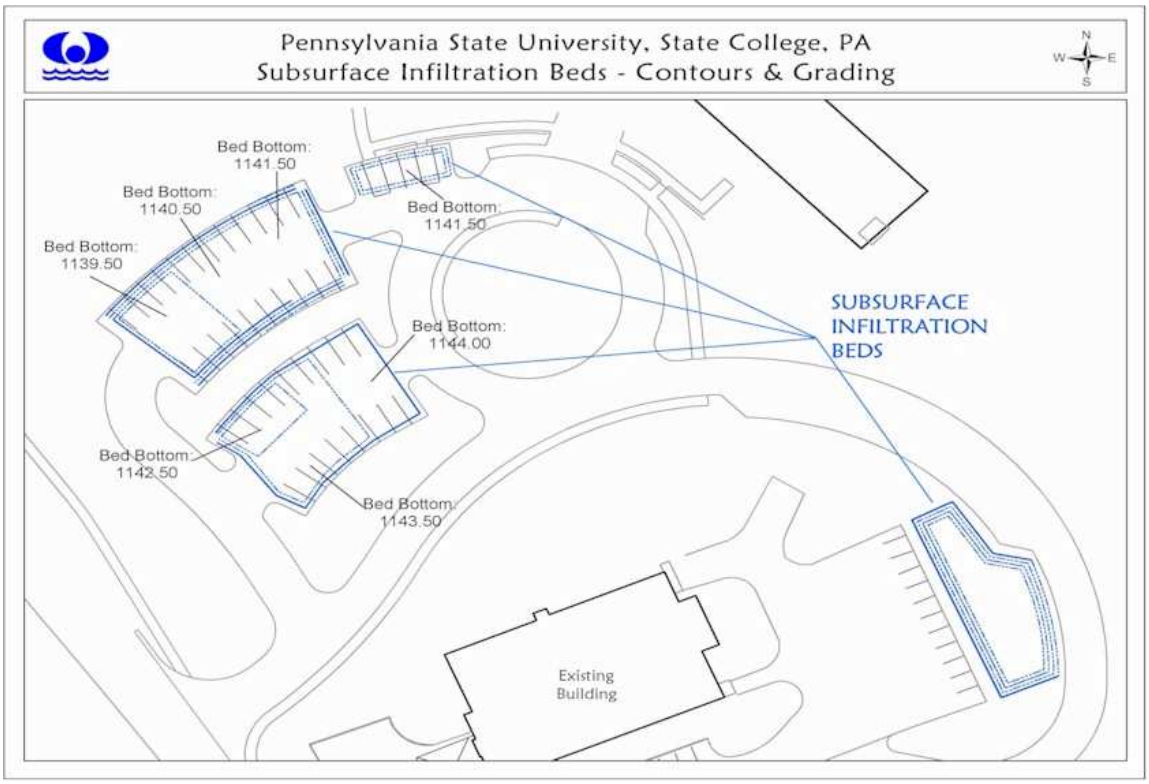

Figure 9-9. Subsurface contours and grading for the infiltration beds at PSU Visitor's Center, Centre County.

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Case Study 2: Dennis Creek Streambank Restoration, Franklin County

- **Riparian Buffer Reestablishment**
- **Wetland Restoration**
- **Monitoring**

Partnership began with the Franklin County Watershed Association, an informal cooperative group of landowners, farmers, municipal authorities, and other local officials

Part of the Potomac River Basin, the watershed originates in Hamilton Township, Franklin County, near Chambersburg, PA in the pristine headwaters in of the Kittatinny Mountain Ridge. However, nutrient runoff and the presence of cattle in the stream have degraded both the macro-invertebrate life living within the stream as well as the streambanks themselves.

Historically, the watershed and forestland was cleared as fuel for the iron industries, causing severe erosion problems. As the iron industry gave way to the agricultural industry, erosion problems continued and were exacerbated by overgrazing, cattle waste pollution, and unprotected streambanks.

A first step to restore Dennis Creek was to install several miles of streambank fencing to keep cattle out of the stream itself and allow for revegetation of the riparian buffer. This practice alone provided immediate water quality and macro-invertebrate community improvements. Fences are maintained through the local partnership

Because many riparian areas had no trees or vegetation, another task in this project included the streambank planting of trees and native warm season grasses, as well as the restoration of wetlands for stormwater runoff quality control. A newly restored marsh provides animal habitat and water quality improvement in the intensely farmed watershed

A water quality-monitoring program involving government agencies, school students and others has been implemented to measure the project success.

Important project points:

- Total watershed area is 14 square miles
- Resulted in improved hunting and fishing opportunities for community and an educational opportunity for students
- Video located on the web:

http://www.greentreks.org/watershedstv/more_information/featuredtopic_denniscreek.asp



Figure 9-10. Dennis Creek Watershed in Franklin County, PA.

SARB_01857

Case Study 3: Commerce Plaza III, Lehigh County

- **Vegetated infiltration basin**
- **Concrete level spreader**
- **Vegetated swale**

Project Background

Commerce Plaza III, in Upper Macungie Township and South Whitehall Township in Lehigh County, PA is a mid-rise office complex that was proposed for a 49-acre site. A major concern during the design phase was to locate elements of the site stormwater management system away from limestone formations to avoid potential sinkhole problems. The site, historically in agricultural use before subdivision, had a pre-existing sinkhole located near the area slated for stormwater management.

Figure 9-11. Vegetated infiltration basin in Lehigh County.



BMP Description

The vegetated infiltration basin (Figure 9-11) collects stormwater runoff from one parking lot and one building, and mitigates runoff from two additional buildings nearby. The basin was designed with a high loading rate of impervious surface runoff to BMP area. Stormwater runoff sheet flows from the inlet to a concrete level spreader (Figure 9-12) into the infiltration basin. The surface of the infiltration basin was graded with extreme care, creating an even basin surface elevation to receive stormwater. Figure 9-13 shows the vegetated swale inflow to the infiltration basin.



Figure 9-12. Level spreader distributes stormwater into the infiltration basin.



Figure 9-13. Vegetated swale

Soils: Figure 9-14 shows the Commerce Plaza office location along with the corresponding soil series. The infiltration basin at Commerce Plaza III is located within the Washington soil series. Washington soils found in Lehigh County are deep, well-drained soils, whose underlying material is glacial till, or frost-churned material weathered from limestone.

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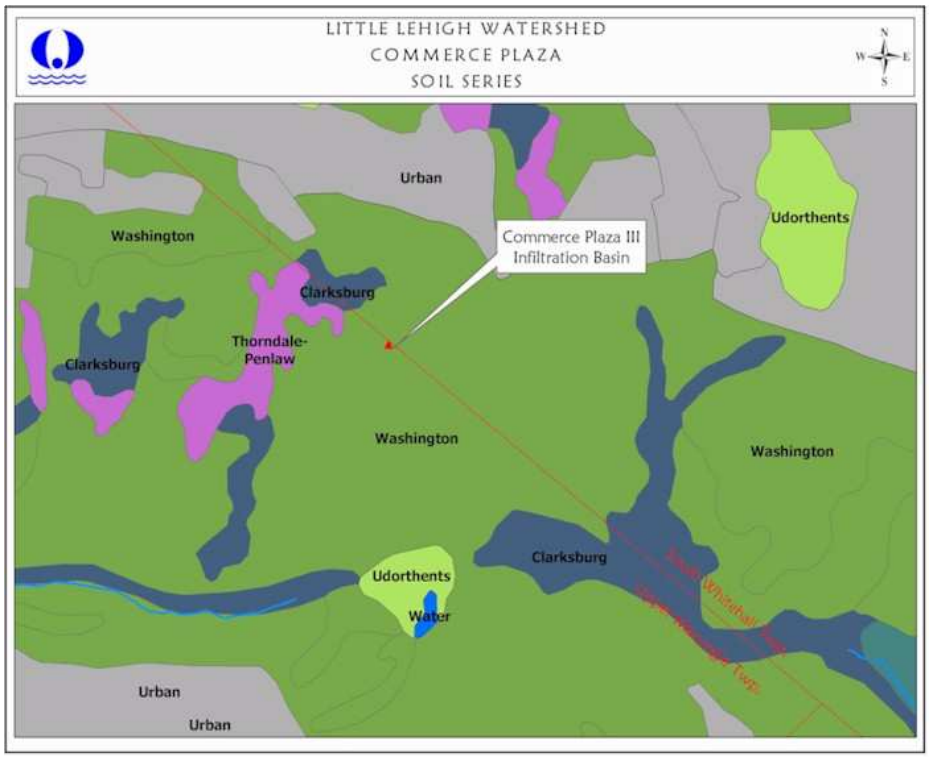

Figure 9-14. Commerce Plaza soils, NRCS.

Geology: Figure 9-15 shows the BMP location along with the corresponding surficial geologic formations. The site is located on the Epler Formation of the Beekmantown Group. The Epler Formation dates from the Lower Ordovician and is a medium to dark-medium gray, finely crystalline, silty limestone interbedded with some thin- to thick-bedded cryptocrystalline dolomite.

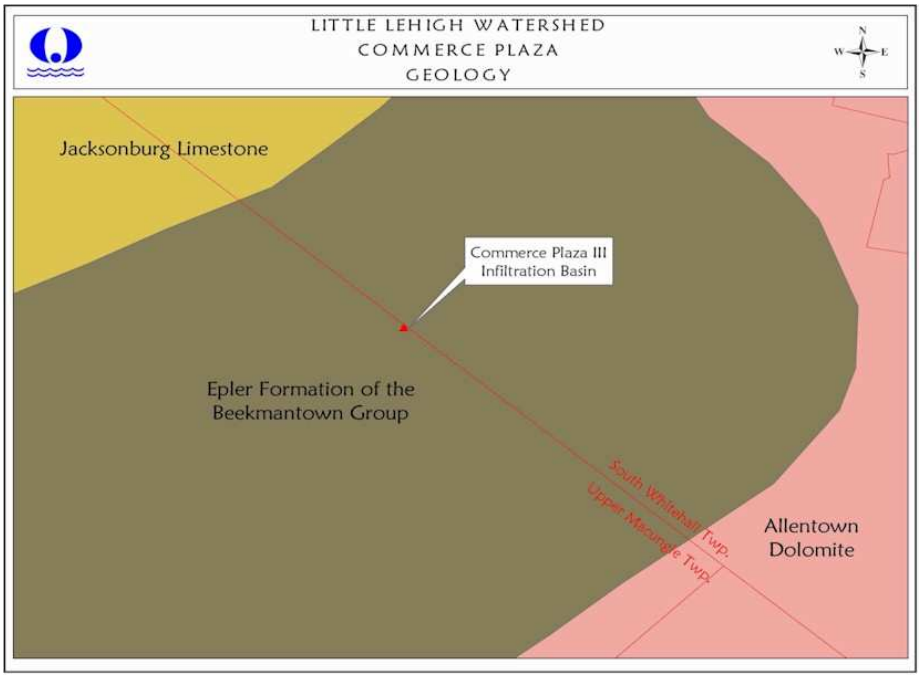

Figure 9-15. Commerce Plaza in Lehigh County is located on limestone geology.

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Case Study 4: Flying J. Truck Plaza for Welsh Oil of Indiana Truck Refueling Terminal, Cumberland County

- **Subsurface Infiltration Bed**
- **Perimeter Trench Drain**
- **Treatment Wetlands**
- **Vegetated Infiltration Filters**
- **Curb Cuts with Filter Strips**

Project Background

In 1993, Flying J Truck Plaza, a truck refueling facility in Middlesex Township, Cumberland County, Pennsylvania, was faced with complying with municipal open space requirements and the site area needed for their development program. Conventional stormwater detention basins exceeded site area limits required, and as a result, the use of groundwater recharge beds for stormwater management was proposed. Subsurface infiltration beds, located beneath the truck parking facility itself, provided additional space for parking.

Situated over a carbonate formation, the possibility of sinkholes was thoroughly investigated utilizing ground-penetrating radar to map the underlying bedrock. By designing recharge beds to distribute the infiltrating stormwater over a large area where the soil mantle was sufficiently thick, the development of solution channels in the carbonate was minimized. Use of a recharge design for stormwater management for a facility serving as many as 1,500 heavy trucks per day in a sensitive carbonate context had to be coupled with special water quality measures. A two-stage pretreatment system was designed, including a settling unit and vegetated filtration system to remove first flush pollutants from stormwater runoff before entering the groundwater.



Figure 9-16. Perimeter trench drain.



Figure 9-17. Vegetated infiltration filters.

Site Description

Soils: The primary soils found on the site include Duffield silt loam (DuA and DuB), Hagerstown silt loam (HaB), and Huntington silt loam (HuA); with Berks shaley silt loam and Blairton silt loam found primarily around the site perimeter.

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Design Images and Details

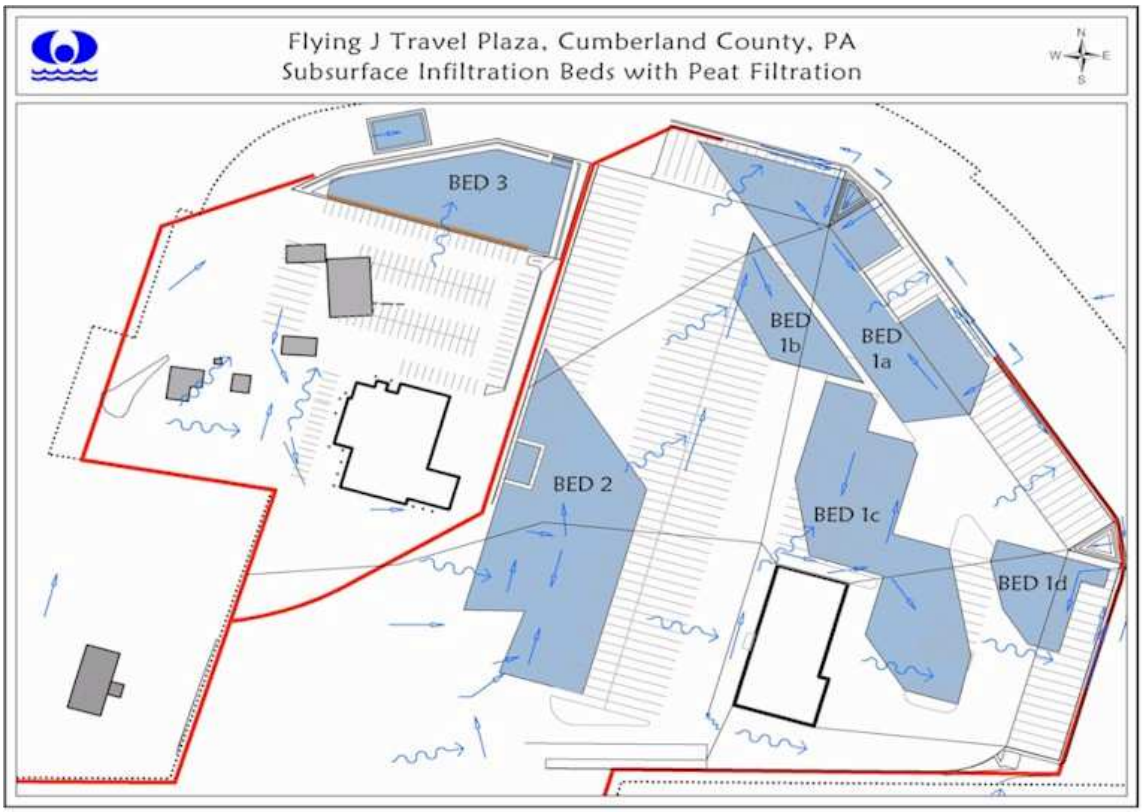

Figure 9-18. Stormwater flow path for the Travel Plaza stormwater management system.

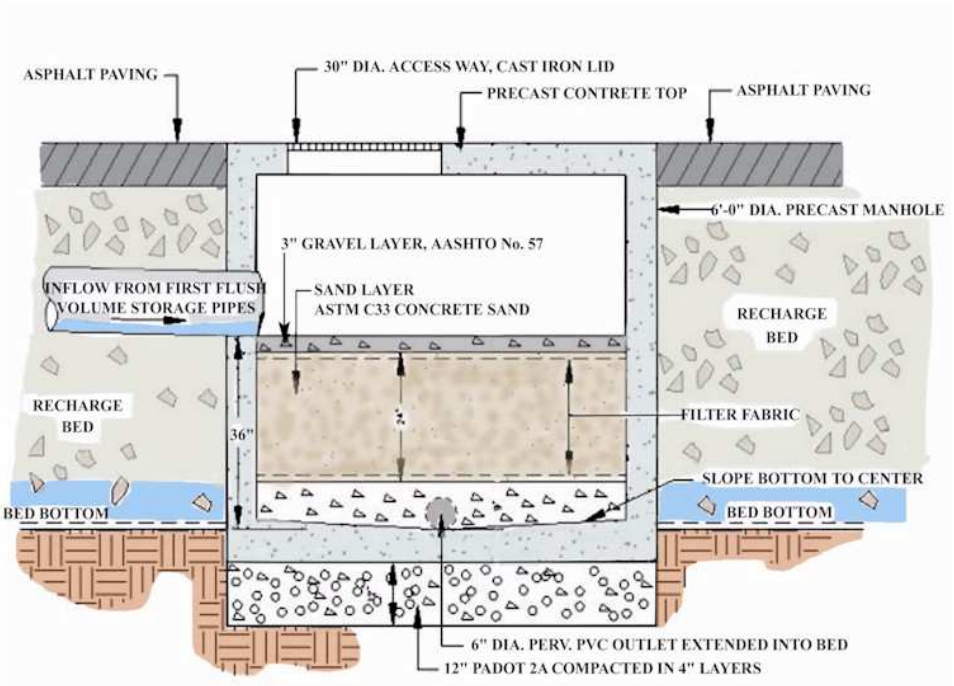

Figure 9-19. Shows the construction design detail for the filter station at the Truck Plaza.

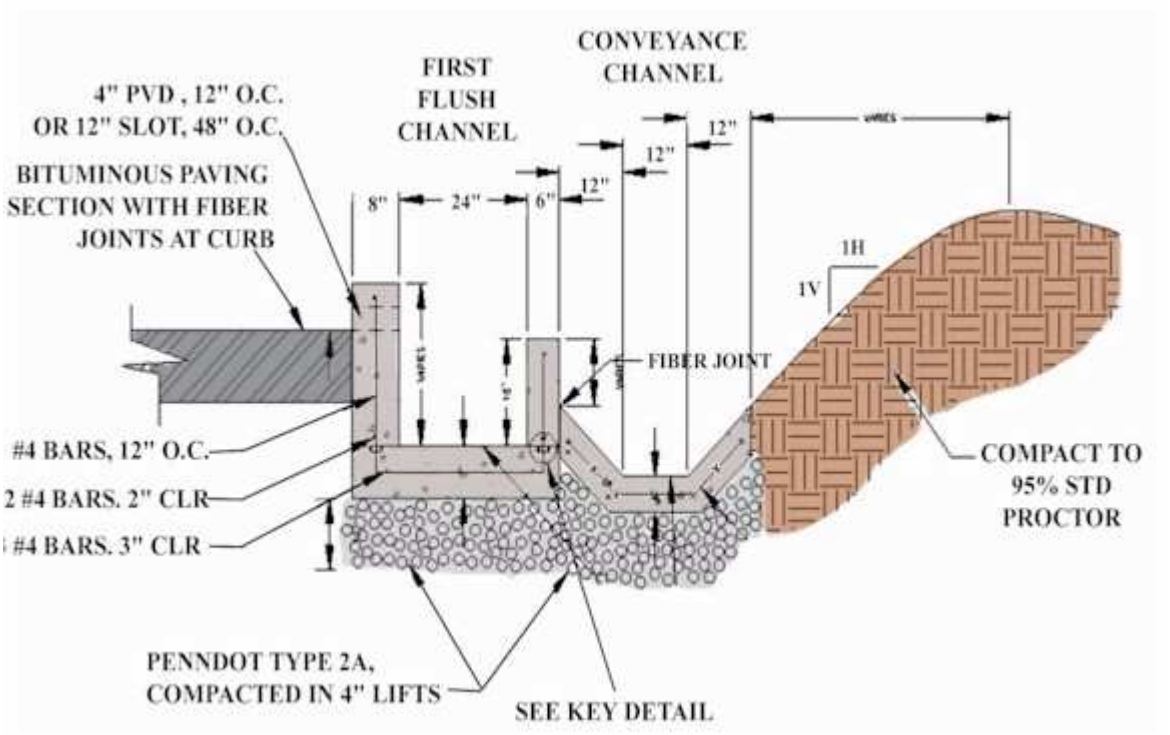

Figure 9-20. Shows the construction design detail for the perimeter channel section.

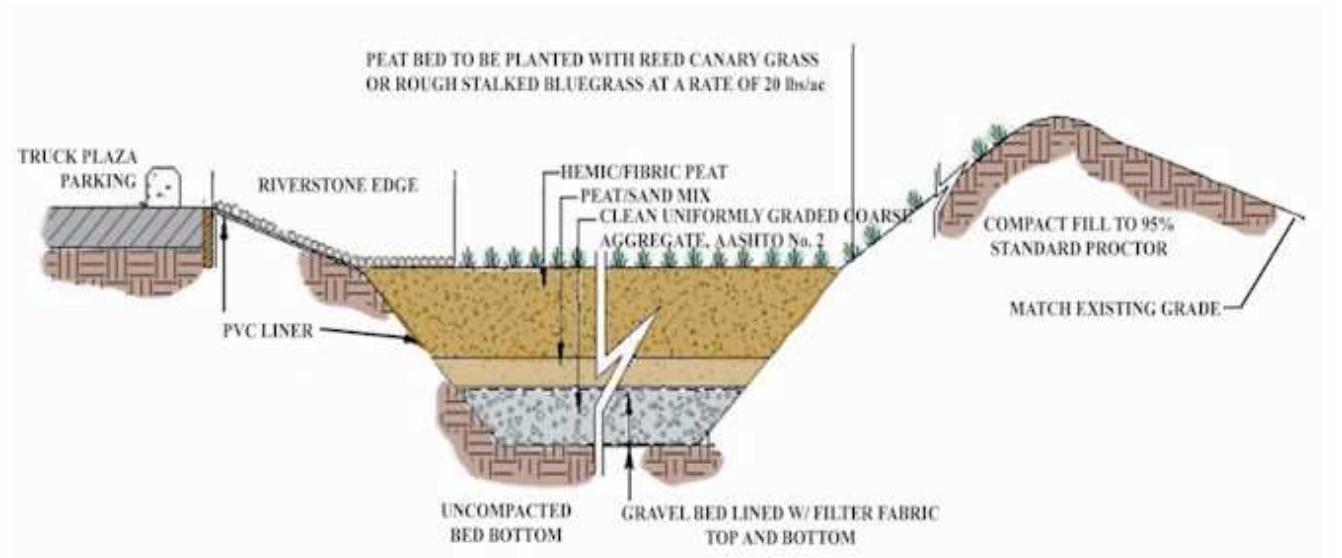

Figure 9-21. Illustrates the peat infiltration bed that is adjacent to the truck parking lot.

Case Study 5: Ephrata Performing Arts Center, Lancaster County

- **Porous Asphalt parking lot**
- **Vegetated Swale**

Site Address
Ephrata Performing Arts Center
Cocalico Road
Ephrata, PA 17522

Project Background
The Ephrata Performing Arts Center is located in the existing Grater Park, and includes the Ephrata Playhouse, American Legion, other miscellaneous buildings and associated parking facilities. The project was proposed in coordination with a planned expansion and remodeling of the existing playhouse that required new parking facilities to support the additional use.

The new porous parking lot consists of two rows on each end of the existing lot. A total of 9,200 square feet of porous parking area was installed, providing 40 new parking spaces on the site. The new parking was installed in an existing lawn area and vegetated bioretention swales were included in the design. The project was completed in September 2004.

Site Description
The site is located within the Cocalico Creek Watershed. The stream is classified WWF (Warm Water Fishery) and is on the 303(d) list of impaired streams for siltation/sediment. The site is bordered to the north by Cocalico Creek.

The site is underlain by the Snitz Creek (CsC) Formation, which is a Cambrian Age Dolomite and Sandstone. All BMPs were installed within the Hagerstown Urban Soil Complex, which is classified as Hydrologic Soil Group "C". Percolation tests were conducted on the underlying soils and infiltration rates observed were ½ inch per hour or greater. There was no disturbance of steep slopes involved in the project; all construction occurred on slopes of 6 percent or less.

BMP Description
The porous parking is underlain by a stone infiltration bed with various benches ranging in depth from 18 to 48 inches and receives runoff from surrounding impervious driveways and parking areas. The bed connected to the northernmost parking row is designed to overflow to a flat grassed area, and the bed under the southern row discharges to a vegetated bioretention swale. As part of the design, a portion of the existing impervious parking area was removed and a bioretention bed was installed to promote the additional infiltration of runoff conveyed by the existing parking areas.

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Figure 9-22. Construction of porous asphalt parking area to compliment building expansion.



Figure 9-23. Completed porous asphalt parking lot at Ephrata Performing Arts Center.

Case Study 6: Lebanon Valley Agricultural Center, Lebanon County

- **Porous Asphalt parking lot**

Site Address:
Lebanon Valley Agricultural Center
2120 Cornwall Road
Lebanon, PA 17042

Project Background
The porous parking lot at the Lebanon Valley Agricultural Center was installed to provide additional parking at the existing site. The completed lot provides 58 new spaces, 40 of which are porous. The center drive lane is conventional asphalt with porous pavement limited to the parking bays. The porous parking installation was completed in July 2003.

Site Description
The Lebanon Valley Agricultural Center is located within the Snitz Creek Watershed, which is classified TSF (Trout Stocking Fishery). The site contains no wetlands, floodplains or riparian zones. Bedrock on the site belongs to the Richland Formation, a carbonate formation composed primarily of finely crystalline dolomite and oolitic limestone. Sandstone beds and pinnacles are present throughout the formation and sinkholes and closed depressions are prevalent. Hydrologic Soil Group (HSG) B and C soils are found on the site.

BMP Description
The porous pavement parking lot was installed on an existing lawn area and is underlain by a 24 -inch infiltration bed. The bed was excavated and unwoven geotextile fabric was placed on the undisturbed subsoil. Clean AASHTO #1 aggregate was placed in the bed in 12-inch lifts and lightly rolled to prevent settling. Finally, a 3-inch choker course comprised of AASHTO #57 was placed over the larger aggregate and was finish graded to prepare for the asphalt pavement.

The porous parking receives runoff from the center drive lane, which was constructed with conventional asphalt. The overflow design is comprised of four 4-inch pipes placed at the top of the infiltration bed and discharging to a well-vegetated area. Two 6-inch pipes, which discharge to an existing vegetated swale on the site, provide additional overflow. The project site has been observed during several high intensity storms and appears to be working successfully as there was little or no discharge apparent from the overflow pipes.



Figure 9-24. Completed porous asphalt parking lot at Lebanon County Conservation District.

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Case Study 7: Penn State University Berks County Campus, Berks County

- **Porous Asphalt Parking Lots underlain with Subsurface Infiltration Beds**
- **Subsurface Infiltration Trench underlying Standard Asphalt Walkway**
- **Minimum Disturbance**
- **Level Spreader Pipe in the Woods**

In addition to its Main Campus in State College, Pennsylvania State University maintains several satellite campus sites throughout the state. Each of these regional campus sites represents a major investment in educational resources and recently underwent a substantial expansion and development of additional facilities. In 1999, the PSU campus in Reading developed a dormitory complex to accommodate some 400 resident students. The dormitory complex, which consisted of seven attached buildings, was situated in a wooded knoll on the attractive campus. This facility required additional parking spaces for some 320 cars.

Prior to the new development, the area of the campus in question consisted of existing dormitories, a parking lot, a soccer field, a wooded hillside, and lower-lying meadow. The site drains to Tulpehocken Creek, a pristine tailwater fishery that provides habitat to numerous trout species. The soils on the site were mostly well-draining Hydrologic Soil Group 'B' classification. The campus had historically been hindered by the formation of sinkholes in the carbonate bedrock formation underlying it at shallow elevations. In fact, one of the two existing on-site detention basins (Figure 9-25) had suffered from severe sinkhole problems. This particular basin experienced at least two major sinkholes during its lifespan, which required massive (and expensive) remediation efforts involving concrete plugging and lining. The goal of the stormwater management for the new development was thus twofold: mitigation of newly generated site runoff and reduction of existing runoff to the existing basins.



Figure 9-25. Existing sinkhole-plagued detention basin.

The original development plan called for the construction of a new, standard asphalt parking lot in an area of existing woodlands, which would be drained by a new detention basin. The new dormitory complex was going to be located in a highly disruptive fashion in the wooded knoll. The original plan

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was eventually discarded in favor of a more sustainable approach involving minimum disturbance, volume reduction, water quality improvement, and groundwater recharge. The first major improvement to the plan was the repositioning of the new dormitories in a more organic fashion along the contours in the woods. This sensitive positioning preserved healthy trees and minimized earth disturbance, which was limited to within 15ft of the new structures. Another major improvement was relocating the new parking lot away from existing woods and into the meadow. Also, this parking lot was constructed with porous asphalt and underlain by an aggregate infiltration bed.

The stormwater management plan for the developed site was a great improvement over the existing condition. Stormwater management for new dormitories consisted of an aggregate infiltration trench beneath a standard asphalt walkway "interior" of the complex and "exterior" level spreader perforated pipes along contours in the woods. Roof leaders on the interior halves of the dormitories were connected to the aggregate trench/walkway. (These walkways were stabilized beyond the standard asphalt by a "grass pavement" for fire truck access.) Likewise, roof leaders on the exterior halves were directly connected to the level spreader perforated pipes in the woods. These laterally extending pipes were designed to maintain soil moisture for the woodlands.



Figure 9-26. Example of minimum disturbance and prevent erosion or disturbance on the hillside.



Figure 9-27. Level spreader pipe/infiltration trench in woods.



Figure 9-28. Standard asphalt walkway w/ subsurface infiltration trench.

The new porous asphalt parking lot was designed to mitigate incident rainfall and direct runoff from the nearby access road and existing dormitories. The porous parking lot has so far effectively discouraged the concentration of stormwater runoff downhill and allowed the incident rainfall to pass directly through the parking bays, slowly percolating into the soil and recharging the aquifer system. This system has also dramatically reduced discharges to the existing sinkhole-plagued basins. To date, neither the porous parking lot nor the existing basins have experienced additional sinkhole problems. Furthermore, polluted runoff from the site, usually described as nonpoint source pollution (NPS), was significantly removed by the overall plan. The new improvements at the PSU Berks County campus have had virtually zero impact on regional water resources.

The cost of the new porous asphalt parking lot with subsurface aggregate infiltration bed came to around $1100 per space, in 1999 dollars. When all related site work (lighting, landscaping, erosion and sedimentation control, etc.) was considered, the final cost per space was around $2200, also in 1999 dollars

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Figure 9-29. Porous asphalt parking lot with subsurface infiltration bed.

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Case Study 8: Warm Season Meadows at Williams Transco, East Whiteland Township, Chester County

- **Re-Vegetation as Natural Open Space Meadow, Using Native Plants and Replacing Maintained Lawn**

Project Background
This site is largely unpaved land consisting of fields interspersed with an office building, an employee parking area, and utility structures and right-of-way areas, all previously maintained as conventional lawn area. Utility line areas consist primarily of poles, towers, and guidelines that disturb minimum earth once in place.

At this utility company corporate office and utility right-of-way site in the Valley Creek Watershed (classified as Exceptional Value, EV), a re-landscaping plan was developed for the site, which included use of native warm season meadow grasses well suited to the local climate. Re-landscaping included switch grass and native blue stem, planted on about 25 acres of land that had previously been fields of relatively conventional turf grass that was subject to fertilizer and herbicide/pesticide applications as well as regular mowing. Prior to this planting of meadow grasses, herbicide was carefully applied to kill existing vegetation including undesirable invasive plants; this herbicide application was timed so that it wouldn't harm an existing stand of native blue stem. The native meadow grasses were planted using no-till planting practices to prevent excessive earth disturbance. The new grasses grow during the middle of the growing season and are dormant in the spring and fall. They are best harvested after the spring nesting season, but require no mowing.

Stormwater Management Functional Benefits
Establishing warm season meadow of native grasses is included in this manual as a BMP because the overall environmental performance of unmowed, unmaintained native grass meadows is superior to that of mowed and maintained turf grass fields, both in terms of stormwater quantity and stormwater quality. Meadows promote stormwater infiltration into the ground; through interception of any stormwater flow (sheet or channelized), rate of flow is slowed. Periodic application of fertilizers and herbicides is eliminated; therefore chemical pollution to surface runoff as well as to the groundwater is reduced. Native grasses also have a greater potential to uptake any pollutants present in stormwater runoff, in contrast to conventional turf grass, although no pollutant reduction analysis specifically has been performed for this BMP project. To a large extent, sediment and grit, oil and grease, as well as nutrients present in site stormwater runoff will be filtered by the natural biological and physical filtration processes provided by native meadow grasses prior to being discharged into receiving waters or being percolated deeper into the groundwater. Additionally, established warm season grassy meadows provide natural open space habitat and are especially attractive to wildlife, including birds.

Operation and Maintenance: The Chester County Conservation District considers planted meadows to be a "low maintenance" BMP. Warm season native meadow grasses should be burned every 3 to 4 years to invigorate stem growth, remove thatch, and eliminate growth of invasive plants. At this site, burning is not an acceptable management option due to the nature of current site activities and proximity to residential areas; however, as an alternative to burning, the site owner can harvest cut on a 3-4 year cycle. The new meadow grasses with their low nutrient requirements, do not require fertilization above and beyond available soil nutrients. Meadow grass does need to be periodically cut around guide wires, structures and buildings to permit inspection and maintenance of structures. To ensure that this BMP is maintained properly, procedures and specifications for meadow maintenance should be documented and maintained on the site.

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Cost Issues

The cost of establishing native meadows is low, relative to many other types of stormwater management practices, and is typically not significantly more expensive than installation of a conventional landscape. Operating and maintenance costs usually are less than conventional landscaping. For example, at this site, the warm season meadow offers the site owner cost savings conservatively estimated at $350 per acre per year through avoidance of mowing, without including the added costs of fertilization and herbicide applications. Additionally, the meadow grasses can be harvested annually and sold at current market value. Other factors that may affect cost of establishing a warm season grass meadow include site conditions, such as the cost of land, local topography, rocky or highly permeable soil, and bedrock.

For More Information

For more information about this BMP site, contact the site owner, Williams Transco, at 610-644-7373 (Robert Hill, Assistant District Manager). Although this site is part of the Chester County BMP Tour, site visits should be individually arranged. Also, Tim Smail at the Chester County office of the USDA-Natural Resource Conservation Service assisted in the BMP design.





Figures 9-30 & 9-31. Warm season native grassy meadows established at this site provide greater stormwater infiltration opportunities than maintained turf grass fields. Low maintenance meadows enhance wildlife habitat.

Case Study 9: Hills of Sullivan Residential Subdivision, London Grove Township, Chester County

- **Infiltration Trenches**
- **Berms**

Project Background

This sizable single-family development was constructed over 15 years ago and is located in the White Clay Creek watershed (classified CWF, TSF). London Grove Township at that time was one of the few municipalities in Chester County, as well as the state, to require in its stormwater regulations that runoff volumes for up to the 2-year storm not be increased, pre- to post-development. The site can be reached from Rose Hill Road south, left onto Avondale Road, right onto Clay Creek Road, left onto Angelica Drive and then best accessed via the trail located in HOA-owned open space (follow a narrow trail from Angelica Drive just above a bridge and above the creek).

Project Description

At the encouragement of the Township and its Municipal Engineer, an integrated system of berms and infiltration trenches was constructed. The typical berm/trench consisted of narrow, elongated, surface depressions created by built up earthen embankments, or berms, that promote stormwater infiltration. At this site, the infiltration trenches are elongated, shallow trenches on the surface that collect and temporarily store stormwater runoff from the upslope residential lots and streets and promote its infiltration (in contrast to sub-surface, excavated, fabric-wrapped, stone-filled trenches as described in Chapter 6). Stormwater that collects in these narrow depressions on the hillside gradually seeps through the soil into the ground and eventually into the creek and water table below. These berms/trenches follow the contours of the land in a parallel sequence. There are three 400 foot-long trenches terraced, or stepped, down the slope with one below another.

When the uphill trench is filled to capacity, stormwater overflows into the trench below. There is also a single 1,000 foot-long trench that functions independently of the three terraced trenches. This large trench receives stormwater through a subsurface pipe. Because stormwater entering this trench is conveyed through a pipe with a steep slope and has high velocity, a concrete chamber is used to dissipate its energy before discharging into the trench. When this trench overflows, stormwater spills over its downslope berm and flows down the bank into the stream below. For an infiltration trench to properly function, the bottom soil must be permeable and remain uncompacted for the life of the structure. Soil percolation tests performed prior to trench construction and at the conclusion of earth disturbance are used to ensure soil infiltration capacity. Vegetation has naturally established itself in the trenches. The berms, which double as a walking path, consist of a gravel and grassy base and are wide enough to permit access for future maintenance of these structures.

Stormwater Function

Infiltration trenches replenish the water table, recharge groundwater supplies, and stabilize base flow in streams. They provide efficient recharge because the infiltration occurs relatively close to where the runoff is generated, thus limiting evaporative loss and infiltrating more rainfall. Infiltration trenches provide an opportunity for physical filtration of pollutants in stormwater runoff removing suspended solids including dirt and sand particles (solids accumulate in vegetation and bottom soils). Oil and grease bound to suspended particles, and their heavy metal constituents, may also be filtered from runoff. These structures also provide naturally vegetated open space for wildlife. The trenches/berms function as a walking trail for the community and provide maintenance access.

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This BMP is not advisable for use in drainage areas that have extensive stormwater pollution sources (i.e., "hotspots"), because by itself such a system has limited pollutant removal capabilities. Functioning as designed, infiltration structures can approximate the following pollutant removal efficiencies for non-excessive nonpoint source pollutant loadings as would be expected from single-family residential land uses:

- Total Suspended Solids (TSS): 95 %
- Total Phosphorus: 70 %
- Total Nitrogen: 51 %
- Metals (copper and zinc): 99 %
- Bacteria: Not Applicable

Operation and Maintenance: The Chester County Conservation District considers infiltration trenches to have moderate maintenance requirements. Operation and maintenance requirements include the following (provided in this case by the Homeowners' Association):

- Regularly inspect to ensure adequate infiltration
- Regularly inspect structural components (i.e. energy dissipater, inlet structure) to ensure they are functioning properly
- Periodically trim plants to ensure their growth does not impede the flow of water through the structure
- Remove invasive plants as necessary (remove shoots and roots)
- Routinely remove accumulated trash and debris
- Avoid running heavy equipment in the trenches to prevent soil compaction
- At the completion of construction, scrape soils to remove accumulated sediment and conduct soil percolation test
- Do not apply chemical pesticides or fertilizers to turf in and around infiltration structures

Cost Factors

In general, the cost to construct and maintain infiltration trenches is usually comparable to the cost of constructing and maintaining large stormwater basins, which would have otherwise been necessary. Given the age of this project, specific cost data have not been available. Soil percolation tests performed before and after construction, as well as measures taken to protect the infiltration basin from sediment inundation during construction add moderately to project costs, but are essential in order to ensure proper function of the infiltration trenches/berms.

For More Information

Contact London Grove Township at 610-345-0100 or the Township Engineer, Larry Walker (URS) at 302-791-0700. London Grove Township has worked to apply this and other infiltration-oriented BMPs in other developments, such as Ashland Woods, located near the intersection of Sullivan Road and New Garden Station Road on Jack Reynolds Way, where infiltration basins are located on individual lots owned by individual homeowners.



Figure 9-32. View from Clay Creek Rd: trenches/berms at the base of the grassy hill in background; trenches/berms barely visible through trees as horizontal undulations.



Figure 9-33. This grassy path is an embankment, or berm, creating depressions for recharge trenches located to the left of the path.

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Figure 9-34. Narrow, vegetated infiltration trenches/berms follow land contours and take on a naturalized appearance.



Figure 9-35. This trench/berm has a subsurface energy dissipater to reduce the velocity of entering stormwater.

SARS_01074

Case Study 10: Applebrook Golf Course Community, Chester County

- **Constructed Treatment Wetland**
- **Two Wet Ponds**
- **Grass Swales**
- **Fertigation**
- **Cold Water Discharge**
- **Open Storage**

In the spring of 2002, stormwater management improvements were constructed at Applebrook Golf Course Community in East Goshen, Chester County. These improvements were intended to substantially improve the quality of site runoff, reduce the peak runoff rates, stabilize flow to adjacent natural wetlands and streams, and provide stable habitat for plants and wildlife, including sensitive and native endangered species. As the site is within the Ridley Creek watershed, which is deemed Exceptional Value by the state, these goals were especially important.



Figure 9-36. Constructed wetland in background.

The most significant BMPs constructed as part of the strategy were a constructed treatment wetland and two wet ponds. Other stormwater measures at the golf course included grass swales, fertigation (fertilization and irrigation), cold-water discharges, and open space donation. The constructed treatment wetland at the site was designed primarily with water quality objectives in mind. It was constructed in a low-lying area near natural wetlands in the Ridley Creek floodplain. This allowed it to take advantage of inflows of water between storm events and to maintain sufficient soil moisture. Through physical, biological, and chemical processes, constructed wetlands can efficiently remove a great many contaminants commonly found in runoff (suspended solids, nutrients (nitrogen and phosphorus), heavy metals, toxic organics, and petroleum compounds). Wetland vegetation, algae, and bacteria allow for the biological uptake of contaminants. Wetland vegetation also provides physical and chemical pollutant filtering mechanisms, which greatly enhance the quality of the runoff from the golf course, as well nearby residential development. Constructed wetlands also play a role in reducing peak rates from a site, stabilize flow, and provide valuable habitat opportunities.

A wet pond is a stormwater management feature that maintains a permanent pool of water (retention) and has additional capacity for stormwater detention. Two wet ponds were constructed at the golf course as part of the improvements. The smaller of these two wet ponds has the preferable elongated shape, while the larger is comprised of two cells. When the first cell has reached capacity, water spills over into the second cell. The larger pond receives treated wastewater from a nearby, township-owned wastewater treatment facility. Water is pumped from this pond and used in the site's fertigation system.

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Constructed wetlands are considered to be a low to moderate stormwater BMP. Typical operation and maintenance requirements include: manual adjustment of the water level (especially during plant establishment), manual removal of invasive plant species, and cleaning out of outlet structures when excessive amounts of sediment have accumulated.



Figure 9-37. Large pond, constructed wetland, managed and naturalized areas of golf course.

Other BMPs constructed at the golf course include grass swales, fertigation, cold-water discharges, and open space donation. The various grass swales at the golf course provide a sustainable alternative to concrete-lined channels or conventional storm sewers. Their many benefits include the filtering out of runoff pollutants, large storm conveyance, enhanced infiltration opportunities, and peak rate reduction.

The site's fertigation system provides a sustainable alternative to conventional fertilization. The system uses water from the larger of the two wet ponds, which receives wastewater effluent from the Township's nearby sewage treatment plant. Water from this wet pond is pumped for use in golf course irrigation and fertilization. This system allows fertilizers to be introduced to the irrigation water in solution form, a technique that allows 100% fertilizer use, as opposed to only 20% when dry fertilizer application is employed.

Water from the wet pond is pumped at or near the bottom so that the coldest water is returned to Ridley Creek. This is an important consideration for the trout in the exceptional value creek. The development includes an area of wetlands of approximately 70 acres that was donated by the developer to the Township as open space. There is a conservation easement on this land, which restricts the cutting/mowing of vegetation to permit wetland plants to mature. The eased land includes the constructed wetland, the natural wetland, the stream, and its adjacent floodplains.



Figure 9-38. Pond water is pumped up to a waterfall and returns to pond through grass swales enhancing aeration.

References

Chester County Stormwater BMP Tour Guide. Published by Chester County Conservation District.

Center for Watershed Protection. *A Review of Stormwater Treatment Practices* (published presentation).

SARB_015076

Pennsylvania Handbook of Best Management Practices for Developing Areas. Spring 1988.
CH2MHILL

Case Study 11: Swan Lake Drive Development, Delaware County

- **Vegetated Infiltration Beds**

Site Address
Swan Lake Drive
Concord, PA 19061
Delaware County

Project Background
This project consists of the development of eight single-family dwellings on approximately 12 acres near the intersection of Mattson and Concord Roads in Delaware County. Stormwater on the site is managed with on-lot vegetated infiltration beds which reduce runoff volume and help protect water quality within an existing spring fed pond and associated wetlands.

Site Description
The Swan Lake Drive Development is located within the Greens Creek Watershed, which drains to the West Branch of Chester Creek. Predevelopment conditions on the site consisted of rolling farmland with woodlands located on the northern third of the property. Three small streams traverse through the parcel from west to east. Adjacent to the streams are floodplains with some associated wetland areas.

Existing soils on the property consist of the Glenville, Glenelg, Brandywine and Worsham Series. All soils are classified as silt loams and range in permeability from moderate to low permeability. Infiltration testing was conducted on the site and the soils were found to be suitable for infiltration.

BMP Description
Vegetated infiltration beds were constructed to manage the rooftop runoff from each individual lot as well as runoff generated by driveway and road areas from a large portion of the development. The remaining runoff on site was conveyed to the existing pond. Shallow subsurface infiltration beds (no greater than 2.5 feet deep) were installed on all eight lots and rooftop runoff from each home is conveyed to the onsite infiltration bed. A larger infiltration bed was constructed to manage the runoff from driveways and Swan Lake Drive. Stormwater overflow and some overland flow are directed into the existing pond at the bottom of the site. The infiltration systems on the site provide capacity to store/infiltrate approximately 11,000 cubic feet of runoff over a 24-hour period.

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Appendix A – Water Quality

Pollutant Event Mean Concentrations by Land Cover & BMP Pollutant Removal Efficiencies



363-0300-002 / December 30, 2006

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Pollutant Event Mean Concentrations by Land Cover

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SARB_015082

TABLE A-1. EVENT MEAN CONCENTRATIONS (EMCs) FOR TOTAL SUSPENDED SOLIDS

	LAND COVER CLASSIFICATION	TSS EMC *(mg/l)*	SOURCES	COMMENTS
Pervious Surfaces	Forest	39	B, G, M	---
	Meadow	47	B, N	---
	Fertilized Planting Area	55	Q, R	R: "Residential" area had considerable mulched areas
	Native Planting Area	55	Q, R	R: "Residential" area had considerable mulched areas
	Lawn, Low-Input	180	C, O, Q, R	Median of four values
	Lawn, High-Input	180	C, O, Q, R	Median of four values
	Golf Course Fairway/Green	305	M, R	Average of two values
	Grassed Athletic Field	200	M, N	Average of two values
Impervious Surfaces	Rooftop	21	Q, S, V	Average of Residential, Commercial, and Industrial Roofs
	High Traffic Street / Highway	261	E, F, H, P, Q	Median of five values
	Medium Traffic Street	113	A, B, H, I, J, P, Q	Median of seven values
	Low Traffic / Residential Street	86	E, P, Q	Average of three values
	Res. Driveway, Play Courts, etc.	60	M	"Urban Recreation"
	High Traffic Parking Lot	120	J, N, Q	Median of three values
	Low Traffic Parking Lot	58	I, M, N, Q	Median of 4 values w/ "comm.", "indust.", "parking" & "comm/res."

TABLE A-2. EVENT MEAN CONCENTRATIONS (EMCs) FOR TOTAL PHOSPHORUS

	LAND COVER CLASSIFICATION	TP EMC *(mg/l)*	SOURCES	COMMENTS
Pervious Surfaces	Forest	0.15	B, I, J, M, R, X	---
	Meadow	0.19	F, W	Value from F, W reported no soluble phosphorus from meadow
	Fertilized Planting Area	1.34	F	Study indicated highly maintained landscapes in "High Density Resid."
	Native Planting Area	0.40	F, W	W had no soluble P from mulch, assumed equivalent to low-input lawn
	Lawn, Low-Input	0.40	F	Value for "Low Density Residential"
	Lawn, High-Input	2.22	K, L, S, V	Median of four values
	Golf Course Fairway/Green	1.07	R	---
	Grassed Athletic Field	1.07	R	No data found, assumed eqivalent to golf course
Impervious Surfaces	Rooftop	0.13	L, S, V	Median of three values
	High Traffic Street / Highway	0.40	L, P, S	Median of 3 values including "Arterial St." and "Urban St."
	Medium Traffic Street	0.33	I, L, M, X	Median of 4 values including "Transportation"
	Low Traffic / Residential Street	0.36	L, P, S, V	Median of 4 values including "Feeder St." and "Rural Rd."
	Res. Driveway, Play Courts, etc.	0.46	L, M, S, V	Median of 4 values including "Urban Recreation"
	High Traffic Parking Lot	0.39	S	---
	Low Traffic Parking Lot	0.15	N, S, V	Median of three values

TABLE A-3. EVENT MEAN CONCENTRATIONS (EMCs) FOR NITRATE

	LAND COVER CLASSIFICATION	Nitrate-Nitrite EMC *(mg/l as N)*	SOURCES	COMMENTS
Pervious Surfaces	Forest	0.17	J	---
	Meadow	0.3	B	EMC for TN adjusted
	Fertilized Planting Area	0.73	F, R	Studies indicated mulched areas & highly maintained landscapes
	Native Planting Area	0.33	T	Assumed equivalent to turfgrass w/o chemical treatment
	Lawn, Low-Input	0.44	T, U, W	Based on studies of lawn runoff and leachate
	Lawn, High-Input	1.46	C, T, U	Median of 3 studies in T and NURP data in C - consistent with U
	Golf Course Fairway/Green	1.84	M, R, U	Average of 3 values including one study of leachate
	Grassed Athletic Field	1.01	M	---
Impervious Surfaces	Rooftop	0.32	L, U	---
	High Traffic Street / Highway	0.83	D, F, I, L, P	Median of five values
	Medium Traffic Street	0.58	D, I, L, P	Median of four values
	Low Traffic / Residential Street	0.47	V	EMC for TN adjusted
	Res. Driveway, Play Courts, etc.	0.47	V	Assumed equivalent to residential street
	High Traffic Parking Lot	0.60	F	Value reported for "Retail"
	Low Traffic Parking Lot	0.39	C, F, L	Median of 3 values after EMC for TN adjusted

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BMP Pollutant Removal Efficiencies- Percent Efficiency

SARB_015089

Table A-4. Summary of pollutant removal efficiencies of stormwater BMPs.

COMPREHENSIVE BMP LIST				
		Pollutant Removal Efficiency %		
		TSS	TP	NO3
Non-Structural BMP				
5.4.1	Protect Sensitive / Special Value Features	SC	SC	SC
5.4.2	Protect / Conserve / Enhance Riparian Areas	SC	SC	SC
5.4.3	Protect / Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	30	20	0
5.5.1	Cluster Uses at Each Site; Build on the Smallest Area Possible	SC	SC	SC
5.5.2	Concentrate Uses Areawide through Smart Growth Practices	SC	SC	SC
5.6.1	Minimize Total Disturbed Area - Grading	40	0	0
5.6.2	Minimize Soil Compaction in Disturbed Areas	30	0	0
5.6.3	Re-vegetate and Re-forest Disturbed Areas using Native Species	85	85	50
5.7.1	Reduce Street Imperviousness	SC	SC	SC
5.7.2	Reduce Parking ImperviousnesS	SC	SC	SC
5.8.1	Rooftop Disconnection	30	0	0
5.8.2	Disconnection from Storm Sewers	30	0	0
5.9.1	Streetsweeping	85	85	50
Structural BMP				
6.4.1	Porous Pavement with Infiltration Bed	85	85	30
6.4.2	Infiltration Basin	85	85	30
6.4.3	Subsurface Infiltration Bed	85	85	30
6.4.4	Infiltration Trench	85	85	30
6.4.5	Rain Garden / Bioretention	85	85	30
6.4.6	Dry Well / Seepage Pit	85	85	30
6.4.7	Constructed Filter	85	85	30
6.4.8	Vegetated Swale	50	50	20
6.4.9	Vegetated Filter Strip	30	20	10
6.4.10	Infiltration Berm and Retentive Grading	60	50	40
6.5.1	Vegetated Roof	85	85	30
6.5.2	Rooftop Runoff - Capture and Reuse	100	100	100
6.6.1	Constructed Wetland	85	85	30
6.6.2	Wet Pond / Retention Basin	70	60	30
6.6.3	Dry Extended Detention Basin	60	40	20
6.6.4	Water Quality Filter	60	50	20
6.7.1	Riparian Buffer Restoration	65	50	50
6.7.2	Landscape Restoration	85	85	50
6.7.3	Soils Amendment and Restoration	85	85	50

SC, Self Crediting: The BMP reduces the pollutant load, thus is self-crediting. BMPs with this designation are labeled as " Preventive" in Section 5.

** All values shown represent professional interpretation, based upon best available data as provided in Appendix A.**

5.9.1 STREETSWEEPING

Type	Pollutant Removal % Efficiency								
	TSS	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Biweekly Sweeping	40-60					20-40	Kurahashi & Associates, Inc. 1997. Port of Seattle - Stormwater Treatment BMP Evaluation. Prepared for the Port of Seattle, Pier 66. Prepared by Kurahashi & Associates, in association with AGI Technologies.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring – Monitoring Case Study-Streetsweeping BMP Evaluation, Port of Seattle, Washington." U.S. Department of Transportation.	Land Use = cargo container yards
Weekly Sweeping	45-65					30-55	Kurahashi & Associates, Inc. 1997. Port of Seattle - Stormwater Treatment BMP Evaluation. Prepared for the Port of Seattle, Pier 66. Prepared by Kurahashi & Associates, in association with AGI Technologies.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring – Monitoring Case Study-Streetsweeping BMP Evaluation, Port of Seattle, Washington." U.S. Department of Transportation.	Land Use = cargo container yards
Twice Weekly Sweeping	45-70					35-60	Kurahashi & Associates, Inc. 1997. Port of Seattle - Stormwater Treatment BMP Evaluation. Prepared for the Port of Seattle, Pier 66. Prepared by Kurahashi & Associates, in association with AGI Technologies.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring – Monitoring Case Study-Streetsweeping BMP Evaluation, Port of Seattle, Washington." U.S. Department of Transportation.	Land Use = cargo container yards
Vacuum-assisted sweeper efficiency	42	77				74	NVPDC. 1992. Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia. Prepared by Northern Virginia Planning District Commission (NVPDC) and Engineers and Surveyors Institute.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet - Street Sweepers." U.S. Department of Transportation.	
Mechanical Sweeper	55	42				40	NVPDC. 1992. Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia. Prepared by Northern Virginia Planning District Commission (NVPDC) and Engineers and Surveyors Institute.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet - Street Sweepers." U.S. Department of Transportation.	
RANGE	**40 - 70**	**42 - 77**				**20 - 74**			

6.4.1 POROUS PAVEMENT

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Porous Pavement	80	80					Johnston Smith Consulting Limited. *Sustainable Urban Drainage Systems - SUDS.*		
Porous Pavement	95	88					Metropolitan Washington Council of Governments (MWCOG). 1983. Urban Runoff in the Washington Metropolitan Area: Final Report, Urban Runoff Project, EPA Nationwide Urban Runoff Program. Metropolitan Washington Council of Governments, Washington, DC.		
Porous Pavement	82	80				65	Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Department of Environmental Programs.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 13; STP Size = 0.553acres; Percent efficiency calculated using mass efficiency method.
Porous Pavement	95	85				65	Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Department of Environmental Programs.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Percent efficiency calculated using mass efficiency method.
Porous Pavement	97					94	St. John, M. 1997. Effect of Road Shoulder Treatments on Highway Runoff Quality and Quantity. University of Washington.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Asphalt void volume 22%"; # of storms = 9
Porous Pavement	95	82					Stormwater Manager's Resource Center (SMRC). *Stormwater Management Fact Sheet: Porous Pavement.*		
Porous Pavement	65-100	65-100				30-65	USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
RANGE	**65-100**	**65-100**				**30 - 94**			

6.4.2 INFILTRATION BASIN

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Infiltration Basin	95	65					Cahill Assoc. Technical BMP Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed. Nov 2002.		
Infiltration Basin	75	45 - 55				50 - 55	Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA, 1999. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* . Federal Highway Administration, U.S. Department of Transportation.	Capture of 12.7 mm (0.5 in) of runoff (first flush)
Infiltration Basin	99	60 - 70				65 - 75	Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA, 1999. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* . Federal Highway Administration, U.S. Department of Transportation.	Capture of 25.4 mm (1 in) of runoff
Infiltration Basin	90	55 - 60				60 - 70	Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA, 1999. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* . Federal Highway Administration, U.S. Department of Transportation.	Capture of 50.8 mm (2 in) of runoff
Infiltration Basin	50-80	50-80				50-80	USEPA. Preliminary Data Summary of Urban Storm Water Best Management Practices. Aug 1999.		
RANGE	**50 - 99**	**45 - 80**				**50 - 80**			

6.4.3 SUBSURFACE INFILTRATION BED

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Subsurface Infiltration Bed	90	60	27				Cahill Assoc. Technical BMP Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed. Nov 2002.		
Subsurface Infiltration Bed	95	51				70	Chester County Conservation District. *Chester County Stormwater BMP Tour Guide: Infiltration Beds* . 2002.		
RANGE	**90 - 95**	**51 - 60**	**27**			**70**			

6.4.4 INFILTRATION TRENCH

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Infiltration Trench		3.4	100		-12.3	4.5	Kuo, C.Y., G. D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"49.5 hours detention time", soil type = loam; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Infiltration Trench		42.3	-100		100	100	Kuo, C.Y., G. D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"47.75 hours detention time", soil type = sandy loam; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Infiltration Trench		50.5	82		70.1	100	Kuo, C.Y., G. D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"51.5 hours detention time", soil type = sandy; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Infiltration Trench	50-80	50-80				15-45	USEPA. *Preliminary Data Summary of Urban Storm Water Best Management Practices* . Aug 1999.		
Infiltration Trench	90	60					Schueler, T.R., 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments.	United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Infiltration Trench* (EPA 832-F-99-019). 1999.	
WQ Trench	75	45 - 55				50 - 55	Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA, 1999. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* . Federal Highway Administration, U.S. Department of Transportation.	Capture of 12.7 mm (0.5 in) of runoff (first flush)
WQ Trench	90	55 - 60				55 - 60	Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA, 1999. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* . Federal Highway Administration, U.S. Department of Transportation.	Capture of 50.8 mm (2 in) of runoff
RANGE	**50 - 90**	**3.4 - 80**	**(-100) - 100**		**(-12.3) - 100**	**4.5 - 100**			

6.4.5 RAIN GARDEN / BIORETENTION

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Rain Garden	53	49	16				Cahill Assoc. Technical BMP Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed. Nov 2002.		
Rain Garden	87						Davis, A.P. "Bioretention – Studies Completed by the University of Maryland" http://www.ence.umd.edu/~apdavis/Biodata.htm. Updated: August 27, 2002.	Low Impact Development Center. "Watershed Benefits of Bioretention Techniques". http://www.lid-stormwater.net/bioretention/bio_benefits.htm. Accessed: December 13, 2002.	
Rain Garden		57					Davis, A.P., M. Shokouhian, H. Sharma, and C. Minami. 2001. Laboratory Study of Biological Retention for Urban Stormwater Management. Water Environment Research. 73(1): 5-14.	Tetra Tech, Inc., 2003. Mecklenburg County Site Evaluation Tool Model Documentation.	
Rain Garden	91		-16			63	Hsieh, C. and A.P. Davis. Multiple-event Study of Bioretention for Treatment of Urban Storm Water Runoff. 2003. Percent efficiency calculated using mass efficiency method.		
Rain Garden	90						United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Bioretention* (EPA 832-F-99-012). 1999.		
RANGE	**53 - 91**	**49 - 57**	**(-16) - 16**			**63**			

6.4.6 DRY WELL / SEEPAGE PIT

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Dry Well	50-80	50-80				15-45	USEPA. Preliminary Data Summary of Urban Storm Water Best Management Practices. Aug 1999.		
RANGE	**50 - 80**	**50 - 80**				**15 - 45**			

6.4.7 CONSTRUCTED FILTER

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Filtering Practice	48					-78.5	Leif, W. 1999. Compost Stormwater Filter Evaluation. Snohomish County Public County Works. Everett, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 8; Drainage area = 0.69acres; "Filter is 12" deep"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	98			32		88	Corsi, S. and S. Greb. 1997. Demonstration project of Wisconsin Department of Natural Resources, United States Geological Survey and the City of Milwaukee. Personal communication with R. Pitt. 1997. In: Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = City Maintenance yard (pavement); %Impervious Cover = 100%; "treatment provided for the first 1/2in of runoff. (80% of the annual water load)"; # of storms = 5; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	88				61	47	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Large parking lot; % Impervious Cover = 82%; "Peat/sand filter media wit surface ED. Retrofit Site. Steep Slopes. Retention Capacity 1420ft3"; # of storms = 21; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	90				68	73	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Large parking lot; % Impervious Cover = 82%; "Peat/sand filter media wit surface ED. Retrofit Site. Steep Slopes. Retention Capacity 1420ft3"; # of storms = 21; Percent efficiency calculated using mass efficiency method.
Organic Filter	83		14			80	Pitt, R. 1996. The Control of Toxicants at Critical Source Areas. The Univerisity of Alabama at Birmingham. In: Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. 2(3): 445-449.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Parking Lot, vehicle service area; Treatment provided for 0.25-0.8in of rain; # of storms = 14; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	85					80	Pitt, R. 1997. Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. 2(3): 445-449.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Commercial Parking Lot; # of storms = 7; Drainage area = 2.5 acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	95		-34			41	Stewart, W. 1992. Compost Stormwater Treatment System. W&H Pacific Consultants. Draft Report. Portland, OR.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = 95%Residential, rest roadway; # of storms = 7, Drainage area = 73.9; "Compost media filter"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Media Filters	92		-145		57	49	Stormwater Management. 1994. Three Year Performance Summary of Stormwater Pollutant and Treatment – 185th Avenue, Hillsboro, Oregon. Technical Memorandum. Stormwater Management. Portland, Oregon.	US Department of Transportation, Federal Highway Administration. "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet - Organic Media Filters."	"3-year results for CSF® Type I system"
Other Media Filters	65-100	15-45				<30	USEPA. Preliminary Data Summary of Urban Storm Water Best Management Practices. Aug 1999.		

6.4.7 CONSTRUCTED FILTER (cont.)

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Packed Bed Filter	81	63	75				Egan, T., S. Burroughs and T. Attaway. 1995. Packed Bed Filter. Pp. 264-274 in Proceedings Fourth Biennial Stormwater Research Conference. October 19-20. Clearwater, FL. SW Florida Water Management District.	Center for Watershed Protection. *Design of Stormwater Filtering Systems* . Dec 1996. (pg 4-8)	Percent efficiency calculated using mass efficiency method.
Sand Filter	98		64		65	66	Barrett, M., M. Keblin; J. Malina; R. Charbeneau. 1998. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transportation Research. Texas Department of Transportation. University of Texas, Austin, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = 67% Highway/33%Commercial; Drainage area = 82.95acres; # of storms = 10; Treament Vol = first 0.5in of runoff; Percent efficiency calculated using mass efficiency method.
Sand Filter	79	47	-53.3		70.6	65.5	Bell, W., L. Stokes, L.J. Gavan and T.N. Nguyen. 1995. Assessment of the Pollutant Removal Efficiences of Delaware Sand Filter BMPs. Final Report. Department of Transportation and Environmental Services. Alexandria, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Parking Lot; STP Size = 477.6ft3; Drainage area = 0.7acres; # of storms = 20; "Perimeter sand filter"; Percent efficiency calculated using mass efficiency method.
Sand Filter	86	31	-5		48	19	City of Austin, TX. 1990. Removal Efficiences of Stormwater Control Structures. Final Report. Environmental Resource Management Division.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Multi-family housing; Impervious Cover = 50%; # of storms = 18; Drainage area = 3.1acres; Treatment Vol = 0.5in; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.
Sand Filter	87	32	-79		62	61	City of Austin, TX. 1990. Removal Efficiences of Stormwater Control Structures. Final Report. Environmental Resource Management Division.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Road; Impervious Cover = 81%; # of storms = 16; Drainage area = 9.5acres; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.
Sand Filter	75	44	-13		64	59	City of Austin, TX. 1990. Removal Efficiences of Stormwater Control Structures. Final Report. Environmental Resource Management Division.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Mall 86%; Commercial Cover = 86%; # of storms = 18; Drainage area = 79acres; Treatment Vol = 0.5in; STP Size = 3.5acre/ft; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.
Sand Filter	92	71	23		90	80	City of Austin, TX. 1990. Removal Efficiences of Stormwater Control Structures. Final Report. Environmental Resource Management Division.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 68%; # of storms = 17; Drainage area = 50acres; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.
Sand Filters	70	21					United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Sand Filters* (EPA 832-F-99-007) 1999.		
Sand Filter	78	27	-100		57	27	Welborn, C. and J. Veenhuis. 1987. Effects of Runoff Controls on the Quantity and Quality of Urban Runoff in Two Locations in Austin, TX. USGS Water Resources Investigations Report. 87-4004.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Commercial; Drainage area = 80acres; # of storms = 22; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.
Surface Sand Filters	50-80	<30				50-80	USEPA. Preliminary Data Summary of Urban Storm Water Best Management Practices. Aug 1999.		
RANGE	**48 - 100**	**21 - 71**	**(-145) - 75**	**32**	**48 - 90**	**(-78.5) - 88**			

6.4.8 VEGETATED SWALE

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
100 Foot Swale	60						Delaware DNREC and Brandywine Conservancy. *Conservation Design for Stormwater Management*. Sep. 1997.		
200 Foot Swale	83						Delaware DNREC and Brandywine Conservancy. *Conservation Design for Stormwater Management*. Sep. 1997.		
Drainage Channel	65		11				Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD-89/202.		
Drainage Channel	33						Oakland H. An evaluation of Stormwater Pollutant Removal Through Grassed Swale Treatment. Proceedings of the International Symposium of Urban Hydrology, Hydraulics and Sediment Control. 1983.		
Drainage Channel	31	37					Occoquan Watershed Monitoring Labortory (OWML). Final Report. Washington Area NURP Report. VPISU. Metropolitan Washington Council of Governments. Manassas, VA. 1983.		
Drainage Channel		13	11				Yousef, Y. et al. Best Management Practices – Removal of Highwy Contaminants by Roadside Swales. Final Report. Univerisity of Central Florida. Florida Department of Transportation. Orlando, FL. 1985.		
Dry Swale	87	84	80			83	Harper, H. 1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Interstate highway, 70% Impervious; # of storms = 16; "Infiltration Rate = 13.4in/hour. Time of Concentration = 45min" Drainage area = 0.83acres; Percent efficiency calculated using mass efficiency method.
Dry Swale	99	99	99			99	Kercher, W.C., J.C. Landon and R. Massarelli. 1983. Grassy Swales Prove Cost-Effective for Water Pollution Control. Public Works. Vol. 16: 53-55.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Residential; Soil Type = Sandy; # of storms = 13; drainage area = 14 acres; slope = 2%; Percent efficiency calculated using mass efficiency method.
Grass Channel	60			-25		45	Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Major roadway, residences, parks; impervious Cover = 47%; "grass channel design. 10 minute residence time for design storm; Drainage area = 15.5acres; slope = 4%; "Length 200ft. 5ft wide"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Grass Channel	67.8			31.4		4.5	Goldberg. 1993. Dayton Avenue Swale Biofiltration Study. Seattle Engineering Department. Seattle, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	%Impervious Cover = 20; "600ft long grass channel"; # of storms = 8; Drainage area = 90acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Grass Channel	83			-25		29	Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Major roadway, residences, parks; impervious Cover = 47%; "grass channel design. 10 minute residence time for design storm; Drainage area = 15.5acres; slope = 4%; "Length 200ft. 5ft wide"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.

6.4.8 VEGETATED SWALE (cont.)

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Grassed Swales	30-65	15-45				15-45	USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
Swales		24	-21				Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.		
Swales		27	-2				Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.		
Swales		39	48				Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.		
Swales		61	57				Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.		
Swales		73	67				Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.		
Swales		100	100				Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.		
Vegetated Filter Strip	87		50			44	Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX; Nov. 1997.		Site 1; Treatment Length = 7.5 to 8.8m; slope = .73%; vegetation = buffalo grass; higher traffic than site 2; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Vegetated Filter Strip	85		23			34	Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX; Nov. 1997.		Site 2; Treatment Length = 7.8 to 8.1m; slope = 1.7%; vegetation = mixed; lower traffic than site 1; Percent efficiency calculated using event mean concentration (EMC) efficiency method.

6.4.8 VEGETATED SWALE (cont.)

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Vegetated Swales	81		38				United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Vegetated Swales* (EPA 832-F-99-006). 1999		
Wet Swale	81	40	52			17	Harper, H. 1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Length= 210ft; Land Use = Interstate highway (100% Impervious); Treatment Vol= 2year critical velocity, 10 year capacity; Soil Type = saturated sandy; # of storms = 11; drainage area = 1.17 acres; slope = 1.8%; Percent efficiency calculated using mass efficiency method
WQ Swale	98		45		48	18	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD-89/202	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = highway, Impervious cover = 63%, soil type = sandy; length 185'; Age of facility = 5years
WQ Swale	80						Wang, T., D. Spyridakis, B. Mar and R. Horner. 1981. Transport, deposition, and control of heavy metals in highway runoff. FHWA-WA-RD-39-10. Dept. of Civil Engineering. University of Washington. Seattle, WA	Center for Watershed Protection. *Design of Stormwater Filtering Systems*. Dec 1996. (pg 4-19)	
RANGE	**30 - 99**	**13 - 100**	**(-21) - 100**	**(-25) - 31.4**	**48**	**4.5 - 99**			

6.4.9 VEGETATED FILTER STRIP

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
15 Foot Grass Filter Strip	70						Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000		
30 Foot Grass Filter Strip	84						Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000		
75 Foot Filter Strip	54		-27				Center for Watershed Protection. *Design of Stormwater Filtering Systems*. Dec 1996. (pg 4-26)		
150 Foot Filter Strip	84		20				Center for Watershed Protection. *Design of Stormwater Filtering Systems*. Dec 1996. (pg 4-26)		
Grass/Grass-Forest Filter Strip	60-90						Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000		
Vegetated Filter Strip	70	30	0				Center for Watershed Protection. *Design of Stormwater Filtering Systems*. Dec 1996. (pg 4-33)		
Vegetated Filter Strip	75	45	22				Cahill Assoc. Technical BMP Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed. Nov 2002		
RANGE	**54 - 90**	**30 - 45**	**(-27) - 22**						

6.6.1 CONSTRUCTED WETLAND

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Constructed Wetlands	50-80	<30				15-45	USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
Extended Detention Wetland	24			35		16	Athanas C. and C. Stevenson. 1986. Nutrient Removal from Stormwater Runoff by a Vegetated Collection Pond - The Mays Chapel Wetland Basin Project. Prepared for the City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Water Quality Management Office.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Treatment volume = 0.1in/acre; Drainage area = 97acres
Extended Detention Wetland	76				25	54	Barten, J.M. 1983. Treatment of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600 February	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Treatment volume = 0.15in/acre; Drainage area = 1070acres
Extended Detention Wetland	62		23		40	24	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commision on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 10; Treatment volume = 0.1in/acre; Drainage area = 413acres
Extended Detention Wetland	62	-2.1	1.2		15	8.3	Occoquan Watershed Monitoring Laboratory and George Mason Univeristy. 1990. Final Report: The Evaluation of a Created Wetland as an Urban Best Management Practice. Prepared for the Northern Virginia Soil and Water Conservation District.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; # of storms = 23; Treatment volume = 0.1in/acre; Drainage area = 40acres; "Data collected from Large storms >0.1watershed inch. Large storms overwhelm capacity of wetlands to remove nutrients."
Extended Detention Wetland	93	76	68		81	76	Occoquan Watershed Monitoring Laboratory and George Mason Univeristy. 1990. Final Report: The Evaluation of a Created Wetland as an Urban Best Management Practice. Prepared for the Northern Virginia Soil and Water Conservation District.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; # of storms = 23; Treatment volume = 0.1in/acre; Drainage area = 40acres; "Data collected from Small storms <0.1watershed inch."; Percent efficiency calculated using mass efficiency method.
Shallow Marsh	65	22.8	54.9	54.5		39.1	Athanas, C. and C. Stevenson. 1991. The Use of Artificial Wetlands in Treating Stormwater Runoff. Prepared for the Maryland Sediment and Stormwater Administration. Maryland Department of the Environment.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = High School roof, parking lot, athletic; Surface area of wetland = 0.6acres; Treatment volume = 0.5in/acre; Drainage area = 16acres; Percent efficiency calculated using mass efficiency method.
Shallow Marsh	37.5	13	25.5		11.5	47.5	Blackburn, R., P.L. Pimentel and G.E. French. 1986. Treament of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = Golf Course; Size of Wetland = 296acres; # of storms = 72; Treatment volume = 1in; Drainage area = 2340acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Shallow Marsh	86	46		94	34	70	Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Stormwater Research Program. Southwest Florida Water Management District. Brooksville	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 81; Drainage area = 15.3; STP size = 3acres; Percent efficiency calculated using mass efficiency method.

6.6.1 CONSTRUCTED WETLAND (cont.)

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Shallow Marsh	82.9	-1.6	80.2			7	Harper, H.H., M.P. Wanielista, B.M. Fries and D.M. Baker. 1986. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Runoff enters through a small shallow canal. This is a NATURAL WETLAND." Land Use = Large Residential Community; Treatment Volume = 1.08in/acre; Drainage area = 55.4acres; STP size = 2.47acres; Percent efficiency calculated using mass efficiency method.
Shallow Marsh	85.5		67			75	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands Ecological Engineering Vol. 3: 381-397.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Wetland 4. Land Use = 80%Agriculture, 20%Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to low flow conditions (2.8-6.3 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method
Shallow Marsh	87		82.5			77.5	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands Ecological Engineering Vol. 3: 381-397.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Wetland 1. Land Use = 80%Agriculture, 20%Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to high flow conditions (13.4 - 38.2 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method
Shallow Marsh	95.5		86			87	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands Ecological Engineering Vol. 3: 381-397.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Wetland 2. Land Use = 80%Agriculture, 20%Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to high flow conditions (13.4 - 38.2 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method
Shallow Marsh	99.5		99			99.5	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands Ecological Engineering Vol. 3: 381-397.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Wetland 3. Land Use = 80%Agriculture, 20%Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to low flow conditions (2.8-6.3 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method
Shallow Marsh	94					78	Hickok, E.A., M.C. Hannaman and N.C. Wenck. 1977. Urban Runoff Treatment Methods. Volume 1: Non-structural Wetland Treatment. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = 47%Residential. "This is a NATURAL WETLAND." STP size = 7.6acres. Treatment volume = 1.25 in/acre; Drainage area = 73.2acres;
Shallow Marsh	20			67		33	Koon, J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Two cell wetland; first cell 2ft deep pool with emergent wetlands; second cell is free." # of storms = 5; Design Basis = 2 & 25 year quantity control only; Drainage area = 7.7acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method
Shallow Marsh		54	78				Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss in Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"High Hydraulic Loading." Average Detention Time = 12days; Land Use = 80%Ag; STP size = 5.9acres, avg 24in deep; Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method
Shallow Marsh		59	84				Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss in Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"High Hydraulic Loading." Average Detention Time = 13days; Land Use = 80%Ag; STP size = 4.7acres, avg 28in deep; Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method

6.6.1 CONSTRUCTED WETLAND (cont.)

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Shallow Marsh		75	95				Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss in Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Low Hydraulic Loading." Average Detention Time = 95days; Land Use = 80%Ag; STP size = 5.9acres, avg 28in deep; Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.
Stormwater Wetland	67	28					Center for Watershed Protection, 1997. National Pollutant Removal Performance Database for Stormwater Best Management Practices. Prepared for the Chesapeake Research Consortium.	United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Storm Water Wetlands* (EPA 832-F-99-025) 1999.	
Stormwater Wetland	56		20			-2	Reinelt et al., 1990. In: The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit, EPA/600 February 1992.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 13; Treatment Volume = 0.03in/acre; Drainage Area = 214.8acres; "Channelization reduced effectiveness."
Stormwater Wetland	14		4			-2	Reinelt et al., 1992. In: The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit, EPA/600 February 1992.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 13; Treatment Volume = 0.01in/acre; Drainage Area = 461.7acres; "Channelization reduced effectiveness."
Stormwater Wetland	57			67		57	Rushton, B. and C. Dye. 1993. An In-Depth Analysis of a Wet Detention Stormwater System. Southwest Florida Water Management District. Brooksville, FL.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 25; Drainage Area = 6acres; Surface Area = 0.32acres, Max Depth = 18ft; Runoff conveyed by 200ft drainage channel; BMP apprx. 3-5 years old.; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Stormwater Wetland	-1.32					14.86	Yu, S; G. Fitch, and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot and highway; # of storms = 5; STP size = 0.7acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Stormwater Wetland	30.1					27.46	Yu, S; G. Fitch, and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot and highway; # of storms = 5; STP size = 0.7acres; Percent efficiency calculated using mass efficiency method.
Stormwater Wetland	52.02					68.09	Yu, S; G. Fitch, and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway; # of storms = 13; STP size = 5acres; Percent efficiency calculated using mass efficiency method.
Stormwater Wetland	56.96					68.61	Yu, S; G. Fitch, and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway; # of storms = 13; STP size = 5acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
RANGE	**(-1.32) - 99.5**	**(-2.1) - 76**	**1.2 - 99**	**35 - 94**	**11.5 - 81**	**(-2) - 95.5**			

6.6.2 WET POND / RETENTION BASIN

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Retention Basin	50-80	30-65				30-65	USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
Wet Extended Detention Pond	60.4	16	18.2			46.2	Borden, R.C., J.L. Dorn, J.B. Stillman and S.K. Liehr. 1996. Draft Report. Evaluation of Ponds and Wetlands For Protection of Public Water Supplies. Water Resources Research Institute of the Univeristy of North Carolina. Department of Civil Engineering. North Carolina State University. Raleigh, NC.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Dairy Farms, woodland; Impervious Cover = 16%; Percent efficiency calculated using mass efficiency method.
Wet Extended Detention Pond	54	39	45		26	46	City of Austin, TX. 1991. Design Guidelines for Water Quality Control Basins. Public Works Department. Austin, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious cover = 39%
Wet Extended Detention Pond	87			24	59	79	Fellows, D., W. Liang, S. Ristic, and M. Thompson. 1999. Performance Assessment of MTOs Rouge River, Highway 40, Stormwater Management Pond. SWAMP. Ontario Ministry of Environment and Energy.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Mostly residential; Impervious Cover = 34%; Percent efficiency calculated using mass efficiency method.
Wet Extended Detention Pond	83	55		85	52	52	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot/commercial
Wet Extended Detention Pond	98	54				79	Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Extended Detention Pond	61			63		56	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%
Wet Extended Detention Pond	67			61		57	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Residence time = 5 days
Wet Extended Detention Pond	69	28		67	25	75	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Residence time = 5 days
Wet Extended Detention Pond	71			64		62	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%
Wet Extended Detention Pond	94			88		90	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Land Use = rooftops, parking lots, vehicle storage; Residence Time = 14days

6.6.2 WET POND / RETENTION BASIN (cont.)

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Wet Extended Detention Pond	95			88		89	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Land Use = rooftops, parking lots, vehicle storage; Residence Time = 14days
Wet Extended Detention Pond	76		75		65	70	Yu, S.L. and D.E. Behelmoufrok. 1998. Field Testing of Selected Urban BMPs in Critical Water Issues and Computer Applications. In Proceedings of the 15th Annual Water Resources Conference. American Society of Civil Engineers, New York, NY.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet -Detention Ponds." U.S. Department of Transportation.	
Wet Pond	46		36		14	37	City of Austin. 1990. Removal Efficiencies of Stormwater Control Structures. Environmental Resources Management Division, Environmental and Conservation Services Department, City of Austin, Austin, TX.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet -Detention Ponds." U.S. Department of Transportation.	
Wet Pond	94		64		44	81	City of Austin. 1995 (Draft). Characterization of Stormwater Pollution for Austin, Texas Area. Environmental Resources Management Division, Environmental and Conservation Services Department, City of Austin, Austin, TX.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet -Detention Ponds." U.S. Department of Transportation.	
Wet Pond	68	12		93	-31	55	Cullum, M. 1984. Volume II Evaluation of the Water Management System at a Single Family Residential Site: Water Quality Analysis for Selected Storm Events at Timbercreek Subdivision in Boca Raton, FL. South Florida Water Management District.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = single family residential; Soil type = group A; Treatment Vol = 3.11in/acre; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Wet Pond	54			97	68	69	Dorman, M.E., J. Hartigan, R.F. Steg, and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD-89/202.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Pond	65			61	23	25	Dorman, M.E., J. Hartigan, R.F. Steg, and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD-89/202.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway; Percent efficiency calculated using mass efficiency method.
Wet Pond	32	6	-1		7	12	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Pond	32		7		14	18	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	

6.6.2 WET POND / RETENTION BASIN (cont.)

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Wet Pond	60					45	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Pond	81	37			27	54	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Pond	84					34	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Pond	91	62	66		60	79	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	
Wet Pond	54	16		24		30	Gain, S.W. The effects of Flow-Path Modifications on Urban Water-Quality Constituent Retention in Urban Stormwater Detention Pond and Wetland System, Orlando, Florida. Florida Departemtn of Transportation, Orlando, FL. 1996.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Pond was modified to increse detention time and was previously studied by Martin and Smoot (1988)." Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Wet Pond	85		92		26	54	Harper, H.H., and J.L. Herr. 1993. Treatment Efficiencies of Detention with Filtration Systems. Environmental Research and Design, Inc. Orlando, Fl.	Claytor, Richard, and T. Schueler, 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Silver Spring, MD.	
Wet Pond	7			23		40	Kantrowitz, I. And W. Woodham. 1995. Efficiency of a Stormwater Detention Pond in Reducing Loads of Chemical and Physical Constituents in Urban Streamflow, Pinellas County, Florida. U.S. Geological Survey. Water Resources Investigations Report: 94-4217. Tallahassee, Fl.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Very large online wet pond with detention" Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Wet Pond	45			36		45	Kantrowitz, I. And W. Woodham. 1995. Efficiency of a Stormwater Detention Pond in Reducing Loads of Chemical and Physical Constituents in Urban Streamflow, Pinellas County, Florida. U.S. Geological Survey. Water Resources Investigations Report: 94-4217. Tallahassee, Fl.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Very large online wet pond with detention"
Wet Pond	80			62	0	80	Liang, W. 1996. Performance Assessment of an Off-Line Stormwater Management Pond. Ontario Ministry of Environment and Energy.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Residential; Impervious Cover = 55%; Residential cover = 100%; Soil Type = clay till and clay loam

6.6.2 WET POND / RETENTION BASIN (cont.)

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Wet Pond	85						NC DENR, 1999. North Carolina Stormwater Best Management Practices Manual. Division of Water Quality.		
Wet Pond	85	30	24		31	48	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Age of Facility = 4years; Percent efficiency calculated using mass efficiency method.
Wet Pond	90	41	10		50	61	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Age of Facility = 6years
Wet Pond	-33.3	32				39	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Medium density residential; Impervious cover = 25%
Wet Pond	85	34				86	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Agriculture
Wet Pond	80-90						United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Wet Detention Ponds*. (EPA 832-F-99-048). 1999		
Wet Pond	62				21	36	Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = multi-unit housing, woodland; Impervious cover = 38%; Soil type = clay; Surface area = 3.3 acres, Mean pond depth = 3.8'; Volume=12.3acre feet; "No geese present." Percent efficiency calculated using mass
Wet Pond	93				32	45	Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = mixed residential, Impervious cover = 46%; Residential = 100%; Pond = 4.9 acres; Mean pond depth = 8'; Volume = 38.8 acre feet; "Geese population present increase N and P values." Percent efficiency calculated using mass efficiency method
RANGE	**(-33.3) - 98**	**6 - 65**	**(-1) - 92**	**23 - 97**	**(-31) - 68**	**12 - 90**			

6.6.3 DRY EXTENDED DETENTION BASIN

Type	Pollutant Removal % Efficiency						Primary Source	Secondary Source	Comments
	TSS	TN	NO_3	NO_x	TKN	TP			
Dry Detention Basins	30-65	15-45				15-45	USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
Dry Detention Pond	96		64		44	81	Yu, S.L., M. Barnes, R.J. Kaighn, and S.L. Laio. 1994. Field Test of Stormwater Best Management Practices in Watershed Wastewater Treatment. In Proceedings of the 1994 National Conference on Environmental Engineering. American Society of Civil	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet -Detention Ponds." U.S. Department of Transportation.	"Removal efficiencies based on mass loading."
Dry Extended Detention Pond	87		-10			26	Baltimore Department of Public Works. 1989. Detention Basin Retrofit Project and Monitoring Study Results. Water Quality Management Office. Baltimore, MD.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 9; Treatment Vol = 0.50in/acre; drainage area = 16.8acres
Dry Extended Detention Pond	89		-3		26	51	Barrett, M.E. et al., 1997. *Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions, CRWR Online Report 97-3*. Center for Research in Water Resources, Bureau of Engineering Research, The University of Texas at Austin, TX.		Land Use = Highway; Percent efficiency calculated using mass efficiency method.
Dry Extended Detention Pond	30	35	52			18	City of Austin, TX. 1991. Design Guidelines for Water Qualit Control Basins. Public Works Department. Austin, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 17; Treatment Vol = 0.50in/acre; drainage area= 28 acres
Dry Extended Detention Pond	47					21	Miller, T. 1987. Appraisal of Storm-Water Quality Near Salem, Oregon. US Geological Survey. Water Resources Report 87-4064.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious = 53%; Residential = 39%; Commercial = 38%; Industrial = 1%; # of storms = 11; soil = HSG-C; Drainage area = 512acres
Dry Extended Detention Pond	51.5	42.5				48	Occoquan Watershed Monitoring Laboratory. 1987. Final Report: London Commons Extended Detention Facility. Urban BMP Research and Demonstration Project. Virginia Tech University, Manassas, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 27; Treatment Vol = 0.22in/acre; detention provided up to 20hours; drainage area = 11.4 acres
Dry Extended Detention Pond	70	24			30	13	Schueler, T.R. and M. Helfrich. 1988. Design of Extended Detention Wet Pond Systems. In: Design of Urban Runoff Quality Controls. L.L. Roesner, B. Urbonas and M.B. Sonnen (Eds.). American Society of Civil Engineers. New York, NY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 25; Treatment Vol = 0.30in/acre; drainage area = 34acres
Dry Extended Detention Pond	71	26	-2			14	Stanley, D. 1994. An Evaluation of the Pollutant Removal of a Demonstration Urban Stormwater Detention Pond. Albermarle-Pamlico Estuary Study. APES Report 94-07.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 31%; Land Use = Residential/Commerical; # of storms = 8; Treatment Vol = 72hours detention for the first 0.5in; drainage area = 200acres; Percent efficiency calculated using mass efficiency method.
RANGE	**30 - 96**	**15 - 45**	**(-10) - 64**		**26 - 44**	**13 - 81**			

6.6.4 WATER QUALITY FILTER

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Catch Basins	60 - 97						Aronson, G. et al. Evaluation of Catch Basin Performance for Urban Stormwater Pollution Control. EPA-600/2-83-043	Stormwater Manager's Resource Center (SMRC). *Pollution Prevention Fact Sheet: Catch Basins.*	Only very small storms used
Catch Basins	10 - 25					5 - 10	Pitt, R. and G. Shawley.1982. *A Demonstration of Non-Point Pollution Management on Castro Valley Creek*, Alameda County Flood Control District (Hayward, California) and U.S. EPA, Washington, DC	Stormwater Manager's Resource Center (SMRC). *Pollution Prevention Fact Sheet: Catch Basins.*	
Catch Basins	32						Pitt, R. et al. 1997. Guidance Manual for Integrated Wet Weather Flow Collection and Treamtne Systems for Newly Urbanized Areas. US EPA. Office of Research and Development. Cincinnati, OH	Stormwater Manager's Resource Center (SMRC). *Pollution Prevention Fact Sheet: Catch Basins.*	
RANGE	**10 - 97**					**5 - 10**			

6.7.1 RIPARIAN BUFFER RESTORATION

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
25' buffer	57	27				34	Desbonnet, A., P, Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI	Schueler, T. 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.	
50' buffer	62	31				38	Desbonnet, A., P, Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI	Schueler, T. 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.	
75' buffer	65	33				41	Desbonnet, A., P, Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI	Schueler, T. 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.	
100' buffer	67	34				43	Desbonnet, A., P, Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI	Schueler, T. 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.	
200' buffer	72	38				47	Desbonnet, A., P, Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI	Schueler, T. 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.	
Deciduous Forest Buffers		68					Lowrance, R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984b. Riparian forests as nutrient filters in agricultural watersheds. Bioscience 34:374-377	Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000.	
Hardwood Riparian Area	84-90						Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian areas as filters for agricultural sediment. Soil Science Society of America Journal 51:416-420	Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000.	
Riparian Buffer			95				Jordan, T.E., D.L. Correll, and D.E. Weller. 1993. Nutrient interception by a riparian forest receiving inputs from adjacent croplands. Journal of Environmental Quality 22:467-473	Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000.	

6.7.1 RIPARIAN BUFFER RESTORATION (con't.)

	Pollutant Removal % Efficiency								
Type	**TSS**	**TN**	**NO_3**	**NO_x**	**TKN**	**TP**	**Primary Source**	**Secondary Source**	**Comments**
Riparian Buffer		89					Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65:1466-1475.	Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000.	
Riparian Buffer			48				Snyder, N.J., S. Mostaghimi, D.F. Berry, R.B. Reneau, E.P. Smith. 1995. Evaluation of a riparian wetland as a naturally occurring decontamination zone. Pages 259-262. In: Clean Water, Clean Environment - 21st Century. Volume III: Practices, Systems, and Adoption. Proceedings of a conference March 5-8, 1995 Kansas City, Mo. American Society of Agricultural	Klapproth, J.C. and J.E. Johnson. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Virgina Tech. Oct 2000.	
Switchgrass Buffer (7.1m)	95	80	62			78	Lee, K.H., T.M. Isenhart, and R.C. Schultz. "Sediment and nutrient removal in an established multi-species riparian buffer," Journal of Water Conservation, Vol. 58, No. 1	SWCS, 2003. Soil and Water Conservation Society.	
Switchgrass/ Woody Buffer (16.3m)	97	94	85			91	Lee, K.H., T.M. Isenhart, and R.C. Schultz. "Sediment and nutrient removal in an established multi-species riparian buffer," Journal of Water Conservation, Vol. 58, No. 1	SWCS, 2003. Soil and Water Conservation Society.	
RANGE	**57 - 97**	**27 - 94**	**48 - 95**			**34 - 91**			

BMP Pollutant Removal Efficiencies- Inflow vs. Outflow Pollutant concentrations

6.4.4 INFILTRATION TRENCH

****UNITS ARE IN MG/L UNLESS OTHERWISE NOTED****

Type	TSS		TN		NO_3		NO_x		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Infiltration Trench			6.59	3.8	0.95	3.8					0.24	0	Kuo, C.Y., G. D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"47.75 hours detention time", soil type = sandy loam
Infiltration Trench			5.38	5.2	0.75	0					0.66	0.63	Kuo, C.Y., G. D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"49.5 hours detention time", soil type = loam
Infiltration Trench			2.04	1.01	0.5	0.09					0.2	0	Kuo, C.Y., G. D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"51.5 hours detention time", soil type = sandy

6.4.5 RAIN GARDEN

****UNITS ARE IN MG/L UNLESS OTHERWISE NOTED****

Type	TSS		TN		NO_3		NO_x		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Rain Garden	87.4g	7.6g			1.60g	1.85g					1.62g	0.60g	Hsieh, C. and A.P. Davis. Multiple-event Study of Bioretention for Treatment of Urban Storm Water Runoff. 2003. Percent efficiency calculated using mass efficiency method		

6.4.7 CONSTRUCTED FILTER

****UNITS ARE IN MG/L UNLESS OTHERWISE NOTED****

Type	TSS		TN		NO_3		NO_x		TKN		TP				
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Primary Source	Secondary Source	Comments
Organic Filter	35.5	16											Leif, W. 1999. Compost Stormwater Filter Evaluation. Snohomish County Public County Works. Everett, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 8; Drainage area = 0.69acres; "Filter is 12" deep";
Organic Filter	49	6	1.76	0.858			0.481	0.552					Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Large parking lot; % Impervious Cover = 82%; "Peat/sand filter media wit surface ED. Retrofit Site. Steep Slopes. Retention Capacity 1420ft3"; # of storms = 21
Organic Filter	39.95	4.47					0.3	0.4					Stewart, W. 1992. Compost Stormwater Treatment System. W&H Pacific Consultants. Draft Report. Portland, OR.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = 95%Residential, rest roadway; # of storms = 7, Drainage area = 73.9; "Compost media filter"
Sand Filter	204	3.5	2.83	1.065			1.24	0.474					Barrett, M.; M. Keblin; J. Malina; R. Charbeneau. 1998. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transportation Research. Texas Department of Transportation. University of	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = 67% Highway/33%Commercial; Drainage area = 82.95acres; # of storms = 10; Treament Vol = first 0.5in of runoff
Sand Filter	76.2	16.84	7.93	3.8			1.27	1.99					Bell, W.; L. Stokes; L.J. Gavan and T.N. Nguyen. 1995. Assessment of the Pollutant Removal Efficiences of Delaware Sand Filter BMPs. Final Report. Department of Transportation and Environmental Services. Alexandria, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Parking Lot; STP Size = 477.6ft3; Drainage area = 0.7acres; # of storms = 20; "Perimeter sand filter"

6.4.8 VEGETATED SWALE

****UNITS ARE IN MG/L UNLESS OTHERWISE NOTED****

	TSS		TN		NO_3		NO_x		TKN		TP				
Type	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Primary Source**	**Secondary Source**	**Comments**
Dry Swale	50	4					0.549	0.347	0.83	0.74	0.218	0.304	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = highway, Impervious cover = 63%, soil type = sandy; length 185'; Age of facility = 5years
Grass Channel	47	15.13					1.24	0.85			0.228	0.22	Goldberg. 1993. Dayton Avenue Swale Biofiltration Study. Seattle Engineering Department. Seattle, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	%Impervious Cover = 20; "600ft long grass channel"; # of storms = 8; Drainage area = 90acres
Grass Channel	94.67	14					0.35	0.77			0.2	0.14	Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Major roadway, residences, parks; impervious Cover = 47%; "grass channel design. 10 minute residence time for design storm; Drainage area = 15.5acres; slope = 4%; "Length 200ft. 5ft wide" Soil Type = glacial till
Grass Channel	128	30					0.26	0.31			0.1	0.06	Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Major roadway, residences, parks; impervious Cover = 47%; "grass channel design. 10 minute residence time for design storm; Drainage area = 15.5acres; slope = 4%; "Length 100ft. 5ft wide" Soil Type = glacial till
Vegetated Swale	157	21			0.91	0.46			2.17	1.46	0.55	0.31	Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.		Site 1; Treatment Length = 7.5 to 8.8m; slope = .73%; vegetation = buffalo grass; higher traffic than site 2; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Vegetated Swale	190	29			1.27	0.97			2.61	1.45	0.24	0.16	Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.		Site 2; Treatment Length = 7.8 to 8.1m; slope = 1.7%; vegetation = mixed; lower traffic than site 1; Percent efficiency calculated using event mean concentration (EMC) efficiency method.

6.4.9 VEGETATED FILTER STRIP

****UNITS ARE IN MG/L UNLESS OTHERWISE NOTED****

	TSS		TN		NO_3		NO_x		TKN		TP				
Type	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Primary Source**	**Secondary Source**	**Comments**
Vegetated Filter Strip	157	21			0.91	0.46							Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.	Site 1; Treatment Length = 7.5 to 8.8m; slope = .73%; vegetation = buffalo grass; higher traffic than site 2; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Vegetated Filter Strip	190	29			1.27	0.97							Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.	Site 2; Treatment Length = 7.8 to 8.1m; slope = 1.7%; vegetation = mixed; lower traffic than site 1; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	

6.6.1 CONSTRUCTED WETLAND

****UNITS ARE MG/L UNLESS OTHERWISE NOTED****

	TSS		TN		NO_3		NO_x		TKN		TP				
Type	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Primary Source**	**Secondary Source**	**Comments**
Shallow Marsh	11.85 ppm	7.85 ppm	1.14 ppm	0.99 ppm			0.2 ppm	0.15 ppm			0.085ppm	0.045ppm	Blackburn, R., P.L. Pimentel and G.E. French. 1986. Treament of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W. J.M. Kersnar and E.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = Golf Course; Size of Wetland = 296acres; # of storms = 72; Treatment volume = 1in; Drainage area = 2340acres
Shallow Marsh	7.55	1.801	0.756	1.206			0.085	0.016			0.98	0.04	Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Stormwater Research Program. Southwest Florida Water Management District. Brooksville, FL	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 81; Drainage area = 15.3; STP size = 3acres
Shallow Marsh	14	12									0.097	0.071	Koon, J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Two cell wetland, first cell 2ft deep pool with emergent wetlands; second cell is free." # of storms = 5; Design Basis = 2 & 25 year quantity control only; Drainage area = 7.7acres; "Inflow and Outflow values are presented as mean concentrations."

6.6.2 WET POND / RETENTION BASIN

****UNITS ARE MG/L UNLESS OTHERWISE NOTED****

	TSS		TN		NO_3		NO_x		TKN		TP				
Type	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Primary Source**	**Secondary Source**	**Comments**
Wet Extended Detention Pond	177	39	3.352	1.459							0.761	0.214	Borden, R.C., J.L. Dorn, J.B. Stillman and S.K. Liehr. 1996. Draft Report. Evaluation of Ponds and Wetlands For Protection of Public Water Supplies. Water Resources Research Institute of the Univeristy of North Carolina. Department of Civil Engineering. North Carolina State University.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Dairy Farms, woodland; Impervious Cover = 16
Wet Extended Detention Pond	71	12	1.713	0.769			0.416	0.062			0.232	0.112	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot/commercial
Wet Extended Detention Pond	45	14	1.27	0.91			0.096	0.032			0.651	0.164	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Residence time = 5 days
Wet Extended Detention Pond	28	11	1.35	1.16			0.24	0.09			0.4	0.176	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Residence Time = 2 days
Wet Extended Detention Pond	131	7	1.61	0.722			0.396	0.062			0.497	0.053	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Land Use = rooftops, parking lots, vehicle storage; Residence Time = 14days
Wet Pond	20.6	6.5	0.93	0.65			0.18	0.02			0.136	0.035	Cullum, M. 1984. Volume II Evaluation of the Water Management System at a Single Family Residential Site: Water Quality Analysis for Selected Storm Events at Timbercreek Subdivision in Boca Raton, FL. South Florida Water Management	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = single family residential; Soil type = group A; Treatment Vol = 3.11in/acre

6.6.2 WET POND / RETENTION BASIN (cont.)

****UNITS ARE MG/L UNLESS OTHERWISE NOTED****

	TSS		TN		NO_3		NO_x		TKN		TP				
Type	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Primary Source**	**Secondary Source**	**Comments**
Wet Pond	7	15							1.2	1.27	0.272	0.155	Dorman, M.E., J. Hartigan, R.F. Steg, and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway
Wet Pond	52	23	2.62	1.92			0.729	0.224	1.89	1.7	0.3	0.4	Dorman, M.E., J. Hartigan, R.F. Steg, and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway
Wet Pond	45	19	1.64	1.39					0.31	0.31	0.17	0.12	Gain, S.W. The effects of Flow-Path Modifications on Urban Water-Quality Constitiuent Retention in Urban Stormwater Detention Pond and Wetland System, Orlando, Florida. Florida Departemtn of Transportation, Orlando, FL.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Inflow and Outflow are reported as a mean concentration. "Pond was modified to increse detention time and was previously studied by Martin and Smoot (1988)." Percent efficiency calculated using event mean concentration (EMC)
Wet Pond									0.79	0.63	0.12	0.08	Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = multi-unit housing, woodland; Impervious cover = 38%; Soil type = clay; Surface area = 3.3 acres, Mean pond depth = 3.8'; Volume=12.3acre feet; "No geese present." Percent efficiency calculated using
Wet Pond									0.86	0.59	0.14	0.08	Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = mixed residential; Impervious cover = 46%; Residential = 100%; Pond = 4.9 acres; Mean pond depth = 8'; Volume = 38.8 acre feet; "Geese population present increase N and P values." Percent efficiency calculated using

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Pennsylvania Stormwater Best Management Practices Manual

Appendix B – Pennsylvania Native Plant List



SARB_015121

Appendix B – Pennsylvania Native Plant List

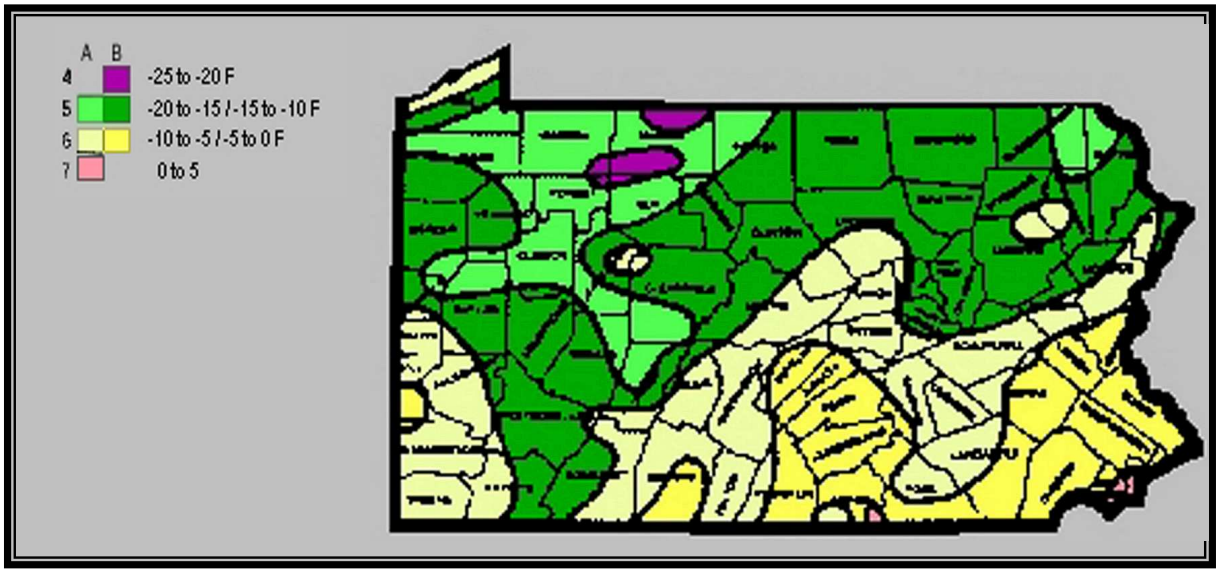
The BMP Plant List contains information about plant species native to Pennsylvania that are suitable for use in any number of BMPs. The list is sorted by plant type and then by scientific name. The table also contains information helpful for designing a planting plan for a successful BMP.

Plant Type

Herbaceous plants are broken down into the following categories; ferns, grasses, grass-like plants, and forbs. Woody plants are broken down into the following categories; shrubs, trees, and trees (small). Small trees are under story and ornamental trees. These trees are useful when a canopy tree is impractical or an aesthetic impact needs to be made.

Hardiness Zone

Ideal hardiness zone ranges are given for the plants. These zone numbers correspond to the "USDA Plant Hardiness Zone Map". Pennsylvania is mainly in zones five (5) and six (6). There is a small area of zone four (4) located in the northwestern part of the state and a small area of zone seven (7) located in the southeast. The map is available on line through the USDA.
http://www.usna.usda.gov/Hardzone/index.html



Commercial Availability

Care was taken to develop a list of plants that would be both successful and obtainable. It is still important to plan ahead and locate plant materials in advance of planting. Plant materials should be located at least six (6) months in advance of planting. This gives enough time to locate approved substitutions in the case that some species are unavailable

Wildlife Value

Attracting beneficial wildlife increases the function and value of a BMP. Wildlife pollinates plants, distributes seed, and enhances the ecological value of the wetland. Note that some wildlife, such as

Canada goose and muskrat can be problematic and will destroy new plantings unless exclusion fencing is provided.

Wetland Indicator Status

The wetland indicator status is from the National List of Plant Species that Occur in Wetlands: Northeast (Region 1) compiled by the U.S. Fish and Wildlife Service. This list indicates the likelihood that a plant will be found in a wetland. A "+" after the indicator symbol shows that the species is more often found in wetlands than other species with the same indicator symbol. Conversely, a "-" after the indicator symbol shows that the species is less often found in wetlands than other species with the same indicator symbol.

Since wetland indicator status is generalized and does not represent information about depth or frequency of inundation, the "Inundation Tolerance" "Hydrologic Zone" and fields are also included in this plant list to assist the designer in selecting the appropriate plant species.

Inundation Tolerance

Inundation Tolerance gives information about frequency and depth of inundation that plant species can tolerate during the growing season. A "no" indicates plants that do not survive saturated soils or standing water during the growing season. These are typically upland plants. "Saturated" indicates plants that survive inundation and saturated soils, typically during greater than 50% of the growing season. "Seasonal" indicates that the plant is able to withstand occasional inundation and saturated soils, typically during less than 50% of the growing season. Available information on water depths tolerated by aquatic plants are provided where available. It is difficult to give the exact hydrologic requirements of plants in a general list such as this. As such, we suggest that further research be performed to confirm the requirements of particular species.

Hydrologic Zone
Zone 1: Open Water: Permanent Pool (12 inches to 6 feet)

Open water and permanent pools range from 12 inches to 6 feet in depth and are best colonized by submergent plants, if at all. This deep-water zone is not routinely planted for several reasons. There are a limited number of plant species that typically survive and grow in this zone, and many are not commercially available; open water areas, free of vegetation, provide unique habitat; and, deep water aquatic plants can clog the stormwater facility outlet structure. In many cases, plants such as duckweed (*Lemna minor*), a floating plant, will naturally colonize open water via transport of plant fragments from upstream or on wildlife. If submerged plant material becomes more commercially available and clogging concerns are addressed, this area can be planted. If the designer chooses to vegetate a deep-water area, then the function of vegetated deep water areas is to absorb nutrients in the water column, enhance sediment deposition, improve oxidation and create additional aquatic habitat.

Select plants that can:
• Withstand constant inundation of water of 1 foot or greater in depth;
• Withstand being submerged partially or entirely;
• Enhance pollutant uptake; and
• Provide food and cover for waterfowl, fish, amphibians, desirable insects, and other aquatic life.

Suggested emergent or submergent species include, but are not limited to: water lily (Nymphaea odorata), wild celery (Vallisneria americana), sago pondweed (Potamogeton pectinatus), and redhead grass (Potamogeton perfoliatus).

Zone 2: Shallow Water Terrace / Aquatic Bench (6 inches to 12 inches)

Zone 2 includes all areas that are inundated by the normal pool to a depth of 1 foot. Zone 2 coincides with the aquatic bench or shelf found in many BMP's. This zone offers ideal conditions for the growth of wide variety of emergent wetland species. These areas will typically fringe the pond or can be developed on shallow water shelves constructed within the pond. When planted, Zone 2 provides important habitat for many aquatic animals, which will naturally regulate mosquito populations, eliminating the need for insecticide applications. In order to create a natural setting, emergent plants are typically planted in groups or clusters of like species. As this zone matures, some species will dominate portions of the site and some species may be eliminated. Local conditions will determine which species adapt most readily. Some species will migrate upslope into saturated soils and others will spread to colonize slightly deeper water.

Select plants that can:
- Withstand constant inundation of water to depths between six inches and 1 foot deep;
- Be partially submerged;
- Enhance pollutant uptake and transformation; and
- Provide food and cover for waterfowl, desirable insects, and other aquatic life.

Emergent herbaceous plants will stabilize the bottom and edge of the pond, slow water velocities, absorb wave energy, and reduce erosion when the water level fluctuates. Plants can also soften the engineered contours of the pond and conceal drawdowns during dry weather.

Appropriate herbaceous species include: water plantain (Alisma plantago-aquatica), common three square (Scirpus pungens), managrasses (Glyceria spp.), blue flag iris (Iris versicolor), soft rush (Juncus effusus), arrow arum (Peltandra virginica), smartweeds (Polygonum spp.), pickerelweed (Pontederia cordata), duck potato (Saggitaria latifolia), lizard tail (Saururus cernuus), soft stem bulrush (Scirpus tabernaemontanii), giant bur-reed (Sparganium eurycarpum) and American bur-reed (Sparganium americanum). There are few trees or shrubs, such as buttonbush (Cephalanthus occidentalis) and black willow (Salix nigra), that will become established or survive within Zone 2.

Zone 3: BMP Fringe: Low Marsh (0-6 inches regular inundation)

Zone 3 encompasses the waterward shoreline of a pond or wetland and its width will be determined by the design slope. This zone will be permanently inundated by the design elevation of any control structures. However, this zone is likely to become dryer during periods of drought. This zone provides the interface between the permanently inundated zone and the seasonally saturated. This zone can be planted with FACW- or FAC plants as identified in the attached BMP Plant List, as plants must be able to withstand periods of inundation as well as drought during the growing season. Zone 3 should be heavily planted to ensure vigorous cover to protect the shoreline. This zone provides opportunities for a number of herbaceous plants, shrubs and trees.

Select plants that can:
- Stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation;
- Withstand regular inundation of water, as plants will be partially submerged at times;

•Provide shade along the southern exposure to help reduce temperature of open waters;
• enhance pollutant uptake;
• Provide food and cover for waterfowl, songbirds, and wildlife (large plants can be selected and located to control overpopulation of waterfowl);
• Be located to reduce human access to potential hazards without blocking maintenance access;
• Have little or no maintenance requirements because they may be difficult or impossible to reach; and,

Herbaceous species that do well in Zone 3 include: blue flag iris (Iris versicolor), sweet flag (Acorus calamus), swamp milkweed (Asclepsis incarnata), redtop (Agrostis spp.), switchgrass (Panicum virgatum), Canada bluejoint (Calamagrostis canadensis), many bulrushes (Scirpus spp.), and spike rushes (Eleocharis spp.). If shading is needed along the shoreline, the following woody species are suggested: smooth or speckled alder (Alnus spp.), pussy willow (Salix discolor), swamp rose (Rosa palustris), buttonbush (Cephalanthus occidentalis), highbush blueberry (Vaccinium corymbosum), red osier/silky dogwood (Cornus stolonifera/amomum), gray dogwood (Cornus racemosa), arrowood (Viburnum dentatum), spicebush (Lindera Benzoin), sweet pepperbush (Clethra alnifolia), winterberry (Ilex verticillata), inkberry holly (Ilex glabra), serviceberry (Amelanchier spp.), river birch (Betula nigra), red maple (Acer rubrum), silver maple (Acer saccharinum), green ash (Fraxinus pennsylvanica), sweetgum (Liquidambar styraciflua), sweet bay magnolia (Magnolia virginiana), black gum (Nyssa sylvatica), American sycamore (Platanus occidentalis) willow oak (Quercus phellos), swamp white oak (Quercus bicolor), pin oak (Quercus palustris) and black willow (Salix nigra).

Zone 4: BMP Fringe: High Marsh (periodic inundation, saturated soils)

Zone 4 extends upslope from Zone 3 and encompasses the area that may be subject to periodic inundation after storms. The width of this zone will depend on the design slope. This zone will include the majority of the temporary extended detention area. The soil substrate will be periodically saturated.

Select plants that can:
• Withstand periodic inundation of water after storms, as well as significant drought during the warm summer months;
• Stabilize the ground from erosion caused by run-off;
• Provide shade along the southern exposure to help reduce temperature of open waters;
• Enhance pollutant uptake;
• Be very low maintenance, as they may be difficult or impossible to access;
• provide food and cover for waterfowl, songbirds, and wildlife (plants may also be selected and located to control overpopulation of waterfowl); and
• be located to create a natural barrier to the deeper pools.
• many species available for planting in this zone also include aesthetic qualities.

Native plants are preferred because they are low-maintenance and disease-resistant.

Frequently used plant species in Zone 4 include: asters (Aster spp.) and goldenrods (Solidago spp.), beebalm (Monarda didyma), bergamot (Monarda fistulosa), ironweed (Vernonia noveboracensis), blue vervain (Verbena hastata), spotted and purple Joe-pye weed (Eupatorium spp.), swamp milkweed (Asclepias incarnata), switchgrass (Panicum virgatum), shrub dogwoods (Cornus spp.), swamp rose (Rosa palustris), inkberry (Ilex glabra), arrowwood (Viburnum dentatum), sweet pepperbush (Clethra alnifolia), bayberry (Myrica pensylvanica), elderberry (Sambucus canadensis), serviceberry (Amelanchier arborea), sweetbay magnolia (Magnolia virginiana), green ash (Fraxinus pennsylvanica), river birch (Betula nigra), sweetgum (Liquidambar styraciflua), Ironwood (Carpinus caroliniana), eastern red cedar (Juniperus virginiana), and red maple (Acer rubrum).

Zone 5: Floodplain Terrace (infrequent inundation, temporarily saturated soils)

Zone 5 is infrequently inundated by floodwaters that quickly recede in a day or less. Key landscaping objectives for Zone 5 are to stabilize the slopes characteristic of this zone and establish low maintenance natural vegetation.

Select plants that can:
• Withstand infrequent but brief inundation during storms and, between storms, typical moisture conditions that may be moist, slightly wet, or even swinging entirely to drought conditions during the dry weather period;
• Stabilize the basin slopes from erosion;
• Be very low maintenance as ground cover since they may be difficult to access on steep slopes or mowing frequency may be limited (a dense tree cover may help reduce maintenance and discourage resident geese); and
• Provide food and cover for waterfowl, songbirds, and wildlife.

Some commonly planted species in Zone 5 include:
black eyed Susan (Rudbeckia hirta), purple coneflower (Echinacea purpurea), warm season grasses such as switchgrass (Panicum virgatum), Indian grass (Sorghastrum nutans), and little bluestem (Schizacyrium scoparium), many viburnums (Viburnum spp.), Virginia rose (Rosa virginiana), Ironwood (Carpinus caroliniana), cherries (Prunus spp.), red oak (Quercus rubra), scarlet oak (Quercus coccinea), willow oak (Quercus phellos), hickories (Carya spp.), eastern red cedar (Juniperus virginiana), hackberry (Celtis occidentalis) and witch-hazel (Hamamelis virginiana).

Zone 6: Upland (never inundated)

This zone extends above the maximum design water surface elevation and often includes the outermost buffer of a pond or wetland. Plant selections should be made based on soil condition, light, and function within the landscape because little or no water inundation will occur. Ground covers should require infrequent mowing to reduce the cost of maintaining this landscape. Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, serve as a buffer, or provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

Some frequently used plant species in Zone 6 include:
Large growing trees such as basswood (Tilia americana), white oak (Quercus alba), scarlet oak (Quercus coccinea), Black oak (Quercus velutina), American beech (Fagus grandifolia), white ash (Fraxinus americana), Tulip poplar (Liriodendron tulipifera) and white pine (Pinus strobus); and small ornamental trees such as Flowering dogwood (Cornus florida) and redbud (Cercis canadensis). The herbaceous layer should be seeded or planted with a mix of warm season grasses and upland wildflowers.

Notes

This column contains helpful details about the plant species.

BMP PLANT LIST

Common Name	Scientific Name	Plant Type	Wetland Indicator	Hydrologic Zone	Inundation Tolerance	Hardiness Zone	Commercial Availability	Wildlife Value	Notes
Fern, hay-scented	*Dennstaedtia punctilobula*	Fern	NI	4,5,6	No	4-8	Plants	Tolerate Deer Browsing.	Shade to partial sun.
Fern, marginal shield	*Dryopteris marginalis*	Fern	FACU-	4,5,6	No	5-8	Plants		Partial sun. Shade tolerant. Evergreen.
Fern, sensitive	*Onoclea sensibilis*	Fern	FACW	[3,4],5	Saturated	4-9	Plants	Moderate. Songbirds and small mammals	Full to partial sun. Shade tolerant
Fern, cinnamon	*Osmunda cinnamomea*	Fern	FACW	2,[3,4]	Saturated	4-8	Plants	Moderate. Songbirds and small mammals	Full to partial sun. Shade tolerant. Young "fiddle heads"
Fern, royal	*Osmunda regalis*	Fern	OBL	2,[3,4]	Saturated	4-9	Plants	Moderate. Small mammals.	Full to partial sun, Shade
Fern, New York	*Thelypteris noveboracensis*	Fern	FAC	[3,4],5	Saturated	2-8	Plants	Moderate. Songbirds and small mammals.	Partial sun. Shade tolerant. Drought tolerant.
Sweetflag	*Acorus americanus*	Forb	OBL	3,4	Seasonal	Plants, Rhizomes		Low food. Good cover.	Tolerant of dry periods. Not a rapid colonizer. Tolerates acidic conditions.
Plantain, water	*Alisma plantago-aquatica (subcordatum)*	Forb	OBL			3-7			
Columbine, wild	*Aquilegia canadensis*	Forb	FAC	[4,5],6	No	3-8	Plants, Seed	Moderate. Butterflies, hummingbirds, and beneficial insects.	Full sun to full shade. Spreads by seed. Early spring flowers.
Milkweed, swamp	*Asclepias incarnata*	Forb	OBL	2,[3,4]	Saturated, 0-6"	3-8	Plants, Seed	Moderate. Butterflies, small mammals, and beneficial insects.	Full to partial sun. Drought tolerant. Not eaten by wildlife. Attractive flowers.
Milkweed, common	*Asclepias syriaca*	Forb	NI	5,6	No	4-9	Plants, Seed	High. Food for butterflies (esp. Monarch) and beneficial insects.	Full sun. Drought tolerant.
Butterflyweed	*Asclepias tuberosa*	Forb	NI	5,6	No	4-10	Plants, Seed	Moderate. Butterflies and beneficial insects.	Full to partial sun. Attractive orange flower.
Aster, white wood	*Aster divercatus*	Forb	NI	4,[5,6]	No	4-8	Plants	Low. Butterflies and beneficial insects.	Very shade tolerant. Long lasting white flowers.
Aster, New England	*Aster novae-angliae*	Forb	FACW	[3,4],5	Seasonal	3-9	Plants, Seed	Cover for birds and mammals.	Attractive purple flowers. Tolerates dry soils.
Aster, New York	*Aster novibelgil*	Forb	FACW+	[3,4],5	Seasonal		Plants, Seed	Low. Butterflies and beneficial insects.	Pale purple flowers. Tolerates dry soils.
Trumpetweed	*Eupatorium fistulosum*	Forb	FACW	[3,4],5	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partials sun. Tall plant with pink-purple flowers.
Joe-pye-weed, spotted	*Eupatorium maculatum*	Forb	FACW	[3,4],5	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partial sun. Tall plant with pale purple flowers.
Boneset	*Eupatorium perfoliatum*	Forb	FACW+	[2,3],4	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partial sun. Shade tolerant. Long lasting white
Joe-pye-weed, purple	*Eupatorium purpureum*	Forb	FAC	3,[4,5]	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partial sun. Tall with showy flower.
Hibiscus, marsh	*Hibiscus moscheutos*	Forb	OBL	2,3	0-12"	5-11	Plants	Low. Hummingbirds.	Full to partial sun. Persistent during winter. Drought tolerant. Very showy pink to white flowers.
Iris, blue flag	*Iris versicolor*	Forb	OBL	2,[3,4]	0-6"	2-7	Plants, Seed	Moderate. Food muskrat and wildfowl. Cover, marshbirds. Persists under heavy grazing.	Slow growth. Full sun to partial shade. Tolerates clay. Fresh to moderately brackish water. Attractive blue flower.
Cardinal flower	*Lobelia cardinalis*	Forb	FACW+	3,4	Saturated	2-8	Plants, Seed	High. Nectar for hummingbird, oriole, butterflies.	Tolerates Partial shade. Does not persist well. Blood red flower.
Blue lobelia	*Lobelia siphilitica*	Forb	FACW+	3,4	Saturated		Plants, Seed	Moderate. Butterflies, hummingbirds, songbirds, and beneficial insects.	Full to partial sun. Shade tolerant. Attractive blue flower.
Monkey-flower	*Mimulus ringens*	Forb	OBL	3,4	Saturated	4-10	Plants, Seed	Low.	Full to partial sun. Interesting flower.

Common Name	Scientific Name	Plant Type	Wetland Indicator	Hydrologic Zone	Inundation Tolerance	Hardiness Zone	Commercial Availability	Wildlife Value	Notes
Fern, hay-scented	*Dennstaedtia punctilobula*	Fern	NI	4,5,6	No	4-8	Plants	Tolerate Deer Browsing.	Shade to partial sun.
Fern, marginal shield	*Dryopteris marginalis*	Fern	FACU-	4,5,6	No	5-8	Plants		Partial sun. Shade tolerant. Evergreen.
Fern, sensitive	*Onoclea sensibilis*	Fern	FACW	[3,4],5	Saturated	4-9	Plants	Moderate. Songbirds and small mammals	Full to partial sun. Shade tolerant
Fern, cinnamon	*Osmunda cinnamomea*	Fern	FACW	2,[3,4]	Saturated	4-8	Plants	Moderate. Songbirds and small mammals	Full to partial sun. Shade tolerant. Young "fiddle heads" edible.
Fern, royal	*Osmunda regalis*	Fern	OBL	2,[3,4]	Saturated	4-9	Plants	Moderate. Small mammals.	Full to partial sun, Shade tolerant.
Fern, New York	*Thelypteris noveboracensis*	Fern	FAC	[3,4],5	Saturated	2-8	Plants	Moderate. Songbirds and small mammals.	Partial sun. Shade tolerant. Drought tolerant.
Sweetflag	*Acorus americanus*	Forb	OBL	3,4	Seasonal	Plants, Rhizomes		Low food. Good cover.	Tolerant of dry periods. Not a rapid colonizer. Tolerates acidic conditions.
Plantain, water	*Alisma plantago-aquatica (subcordatum)*	Forb	OBL			3-7			
Columbine, wild	*Aquilegia canadensis*	Forb	FAC	[4,5],6	No	3-8	Plants, Seed	Moderate. Butterflies, hummingbirds, and beneficial insects.	Full sun to full shade. Spreads by seed. Early spring flowers.
Milkweed, swamp	*Asclepias incarnata*	Forb	OBL	2,[3,4]	Saturated, 0-6"	3-8	Plants, Seed	Moderate. Butterflies, small mammals, and beneficial insects.	Full to partial sun. Drought tolerant. Not eaten by wildlife. Attractive flowers.
Milkweed, common	*Asclepias syriaca*	Forb	NI	5,6	No	4-9	Plants, Seed	High. Food for butterflies (esp. Monarch) and beneficial insects.	Full sun. Drought tolerant.
Butterflyweed	*Asclepias tuberosa*	Forb	NI	5,6	No	4-10	Plants, Seed	Moderate. Butterflies and beneficial insects.	Full to partial sun. Attractive orange flower.
Aster, white wood	*Aster divercatus*	Forb	NI	4,[5,6]	No	4-8	Plants	Low. Butterflies and beneficial insects.	Very shade tolerant. Long lasting white flowers.
Aster, New England	*Aster novae-angliae*	Forb	FACW	[3,4],5	Seasonal	3-9	Plants, Seed	Cover for birds and mammals.	Attractive purple flowers. Tolerates dry soils.
Aster, New York	*Aster novibelgil*	Forb	FACW+	[3,4],5	Seasonal		Plants, Seed	Low. Butterflies and beneficial insects.	Pale purple flowers. Tolerates dry soils.
Trumpetweed	*Eupatorium fistulosum*	Forb	FACW	[3,4],5	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partials sun. Tall plant with pink-purple flowers.
Joe-pye-weed, spotted	*Eupatorium maculatum*	Forb	FACW	[3,4],5	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partial sun. Tall plant with pale purple flowers.
Boneset	*Eupatorium perfoliatum*	Forb	FACW+	[2,3],4	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partial sun. Shade tolerant. Long lasting white flower.
Joe-pye-weed, purple	*Eupatorium purpureum*	Forb	FAC	3,[4,5]	Seasonal		Plants, Seed	Moderate. Butterflies, songbirds, and beneficial insects.	Full to partial sun. Tall with showy flower.
Hibiscus, marsh	*Hibiscus moscheutos*	Forb	OBL	2,3	0-12"	5-11	Plants	Low. Hummingbirds.	Full to partial sun. Persistent during winter. Drought tolerant. Very showy pink to white flowers.
Iris, blue flag	*Iris versicolor*	Forb	OBL	2,[3,4]	0-6"	2-7	Plants, Seed	Moderate. Food muskrat and wildfowl. Cover, marshbirds. Persists under heavy grazing.	Slow growth. Full sun to partial shade. Tolerates clay. Fresh to moderately brackish water. Attractive blue flower.
Cardinal flower	*Lobelia cardinalis*	Forb	FACW+	3,4	Saturated	2-8	Plants, Seed	High. Nectar for hummingbird, oriole, butterflies.	Tolerates Partial shade. Does not persist well. Blood red flower.

Common Name	Scientific Name	Plant Type	Wetland Indicator	Hydrologic Zone	Inundation Tolerance	Hardiness Zone	Commercial Availability	Wildlife Value	Notes
Reedgrass, bluejoint	*Calamagrostis canadensis*	Grass	FACW+	2,[3,4]	0-6", saturated		Seed, Plants		
Managrass, fowl	*Glyceria striata*	Grass	OBL	[2,3],4	Seasonal		Plants, Seed		
Fowl mannagrass	*Glyceria striata*	Grass	OBL	[2,3],4	Seasonal		Plants, Seed	High. Food for waterfowl, muskrat, and deer.	Partial to full shade.
Cutgrass, rice	*Leersia oryzoides*	Grass	OBL	[2,3],4	0-6"		Plants, Seed	High. Food and cover.	Full sun although tolerant of shade. Shoreline stabilization.
Switchgrass	*Panicum virgatum*	Grass	FAC	[4,5],6	Seasonal	4-9	Seed and Plants	High. Seeds, cover for waterfowl, songbirds.	Tolerates wet/dry conditions.
Indiangrass	*Sorghastrum nutans*	Grass	UPL	5,6	No	3-9	Seed, Plants	High. Good food and cover.	Full sun. Grows 4-6 feet tall.
Bluestem, little	*Schizachyrium scoparium*	Grass	FACU-	6	No	3-9	Seed, Plants		Full sun. Tolerates poor soils and drought.
Sedge, fringed	*Carex crinita*	Grass-like	OBL	2,[3,4]	Saturated		Plants, Seed	Moderate. Songbirds and waterfowl. Good food and cover.	Full to partial sun.
Sedge, Pennsylvania	*Carex pennsylvanica*	Grass-like	NI	5,6	Yes	4-8	Plants, Seed	Moderate. Songbirds and waterfowl.	Partial sun. Shade tolerant.
Sedge, broom	*Carex scoparia*	Grass-like	FACW	3,[4],5	Sat, 0-6"		Plants, Seed	Moderate. Good food and wildlife cover.	Tolerates moist to dry conditions.
Sedge, tussock	*Carex stricta*	Grass-like	OBL	1,[2,3],4	Sat. 0-6"	5-9	Plants, Seed	Moderate. Songbirds.	Full sun. Persists during winter.
Sedge, fox	*Carex volpinoidea*	Grass-like	OBL	1,2,[3],4	Sat. 0-6"		Plants, Seed	High. Songbirds and waterfowl.	Full to partial sun. Prefers fluctuating water levels.
Rush, Canada	*Juncus canadensis*	Grass-like	OBL	2,[3,4]	Sat. 0-6"		Plants, Seed	Moderate. Songbirds, waterfowl, and small mammals	Full to partial sun. Shown to have good nutrient uptake
Rush, soft	*Juncus effusus*	Grass-like	FACW+	[2,3],4	0-1'	3-8	Plants, Seed	Moderate	Tolerates occasional dry conditions. Full to partial sun. Shown to have good nutrient uptake properties.
Bulrush, hard-stem	*Scirpus acutus*	Grass-like	OBL	[1,2],3	0-3'		Plants, Seed	High. Cover, food (achenes, rhizomes) ducks, geese, muskrat, fish. Nesting for bluegill and bass.	Quick to establish, fresh to brackish. Good for sediment stabilization and erosion control. Shown to have good nutrient uptake.
Woolgrass	*Scirpus cyperinus*	Grass-like	FACW	2,[3,4]	Saturated	4-8	Plants, Seed	Moderate. Cover, food.	Requires full sun. Can tolerate acidic soils, drought. Colonizes disturbed areas, moderate growth. Shown to have good nutrient uptake.
Bulrush, three-square	*Scirpus pungens*	Grass-like	FACW+	[2,3],4	Saturated, 0-6"		Plants, Seed	High. Seeds, cover. Waterfowl and fish.	Shown to have good nutrient uptake. High metal removal. Drought tolerant.
Bulrush, softstem	*Scirpus tabermontanii*	Grass-like	OBL	1,[2,3]	0-1'		Plants, Seed	High. Good cover and food.	Full sun. Aggressive colonizer. High pollutant removal.
Bur-reed, American	*Sparganium americanum*	Grass-like	OBL	[2,3],4	Saturated, 0-6"		Plants, Seed	Good food and cover.	Spreads rapidly. Tolerates partial shade.
Bur-reed, giant	*Sparganium eurycarpum*	Grass-like	OBL	1,[2,3]	0-12"		Plants, Seed	High. Food (seeds, plant) waterfowl, beaver and other mammals. Cover for marshbirds, waterfowl.	Rapid spreading. Tolerates partial sun. Good for shoreline stabilization. Salinity <0.5 ppt.
Cattail, narrowleaf	*Typha angustifolia*	Grass-like	OBL	1,[2,3]	0-1'	3-11	Plants	Low food. Good nesting and cover.	Spreads rapidly, can be invasive. Shown to have good nutrient uptake properties.
Cattail, broadleaf	*Typha latifolia*	Grass-like	OBL	1,[2,3]	0-1'	3-9	Plants	Low food. Good nesting and cover.	Spreads rapidly, can be invasive. Shown to have good nutrient uptake properties.
Alder, speckled	*Alnus Rugosa*	Shrub	FACW+	2,3	Saturated		Yes	High. Cover, browse for deer, seeds for birds.	Rapid growth. Stabilizes streambanks. Roots fix N2.
Alder, smooth	*Alnus serrulata*	Shrub	OBL	[1,2],3	Saturated, 0-3"		Yes	High. Food, cover.	Rapid growth. Stabilizes streambanks. Roots fix N2.

Common Name	Scientific Name	Plant Type	Wetland Indicator	Hydrologic Zone	Inundation Tolerance	Hardiness Zone	Commercial Availability	Wildlife Value	Notes
Choke Berry, Red	*Aronia arbutifolia*	Shrub	FACW	3,[4,5]	Seasonal	4-9	Yes	Moderate. Songbirds.	Bank stabilizer. Partial sun. White flowers with red fruit.
Choke Berry, Black	*Aronia melanocarpa*	Shrub	FAC	3,[4,5]	Seasonal		Yes	Moderate. Songbirds.	Partial sun. White flowers with black fruit.
Bottonbush, common	*Cephalanthus occidentalis*	Shrub	OBL	[1,2],3	0-3'	5-10	Yes	High. Ducks and shorebirds. Seeds, nectar and nesting.	Full sun to partial shade. Will grow in dry areas. Interesting flowers and seed.
Pepper-bush, sweet	*Clethra alnifolia*	Shrub	FAC+	[3,4],5	Seasonal	3-9	Yes	Moderate. Butterflies, songbirds, waterfowl, small mammals, and beneficial insects.	Partial sun. Shade tolerant. Attractive white flower spikes.
Dogwood, silky	*Cornus amomum*	Shrub	FACW	[3,4],5	Seasonal	5-8	Yes	High. Songbirds and mammals.	Shade and drought tolerant. Good bank stabilizer. White flowers with blue fruit. Stems have good winter color.
Dogwood, gray	*Cornus racemosa*	Shrub	FAC	3,[4,5]	Seasonal		Yes	High. Songbirds, waterfowl, and small mammals.	Full to partial sun. Shade tolerant. Drought tolerant. White flowers and fruit.
Dogwood, redtwig	*Cornus sericia*	Shrub	FACW+	[3,4],5	Seasonal		Yes	High. Songbirds, waterfowl, and small mammals.	Full to partial sun. Shade tolerant. Drought tolerant. Good streambank stabilizer. White flowers and fruit.
Hazel-nut, American	*Corylus americana*	Shrub	FACU-	4,[5,6]	No	4-9	Yes	Moderate. Songbirds and small mammals	Partial sun to shade. Inhabits dry woodlands. Edible nuts. Wood used for divining rods.
Witch-hazel, American	*Hamamelis virginiana*	Shrub	FAC-	4,[5,6]	No	4-9	Yes	Low. Food for squirrels, deer, and ruffed grouse.	Prefers shade. Ornamental. Unusual flowers in Nov. - Dec.
Inkberry	*Ilex glabra*	Shrub	FACW-	3,[4,5]	Seasonal		Yes	High. Songbirds, waterfowl, and small mammals.	Full to partial sun. Shade tolerant. Evergreen. Avoided by
Winterberry, common	*Ilex verticillata*	Shrub	FACW+	[3,4],5	Seasonal	3-9	Yes	High. Cover and fruit for birds. Holds berries into winter.	Full sun to partial shade. Seasonally flooded areas. Red fruits persist through winter.
Spice Bush	*Lindera benzoin*	Shrub	FACW-	3,4,5	seasonal	5-9	Yes	Very high. Songbirds.	Shade and rich soils. Tolerates acidic soils. Good understory species. Red berries.
Bayberry, northern	*Myrica pennsylvanica*	Shrub	FAC	[3,4],5	Seasonal		Yes	High. Nesting, food, cover. Berries last into winter.	Coastal Plain species. Roots fix N2. Drought tolerant.
Azalea, swamp	*Rhododendron viscosum*	Shrub	OBL	[3,4],5	Saturated	3-9	Yes	Low. Waterfowl and small mammals.	Full to partial sun. Susceptible to damage form disease and insects. Showy pink and white flowers.
Sumac, smooth	*Rhus glabra*	Shrub	NI	4,[5,6]	No	3-8	Yes	High. Songbirds, small mammals, and beneficial insects.	Full sun. Drought resistant.
Rose, pasture	*Rosa carolina*	Shrub	NI	5,6	No	5-9	Yes	High. Songbirds, and small mammals.	Full to partial sun.
Rose, swamp	*Rosa palustris*	Shrub	OBL	2,[3,4]	Saturated	5-8	Yes	High. Food (hips) for birds including turkey, ruffed grouse and mammals. Fox cover.	Prefers full sun. Easy to establish. Low salt tolerance. Avoided by deer.
Rose, Virginia	*Rosa virginiana*	Shrub	FAC	3,[4,5]	Seasonal	3-8	Yes	High. Songbirds, and small mammals.	Full to partial sun.
Blackberry, common	*Rubus allegheniensis*	Shrub	FACU-	4,5,6	No		Yes	High Butterflies, songbirds, small mammals, and beneficial insects.	Full to partial sun. Edible fruit.
Willow, pussy	*Salix discolor*	Shrub	FACW	[3,4],5	Yes	4-8	Yes	Low. Buds eaten by grouse.	Furry catkins are a harbinger of spring. Good streambank stabilizer. Roots easily from cuttings.
Elderberry	*Sambucus canadensis*	Shrub	FACW-	3,4,5,6	Yes	3-9	Yes	Extremely high. Food and cover, birds and mammals.	Full sun to partial shade. Drought tolerant. Bears fruit when four years old.

Common Name	Scientific Name	Plant Type	Wetland Indicator	Hydrologic Zone	Inundation Tolerance	Hardiness Zone	Commercial Availability	Wildlife Value	Notes
Blueberry, highbush	*Vaccinium corymbosum*	Shrub	FACW-	[3,4],5,6	Seasonal	3-8	Yes	High. Butterflies, songbirds, waterfowl, and small mammals.	Full to partial sun. Shade tolerant. Prefers acid soils. Attractive plant year round.
Arrow-wood, southern	*Viburnum dentatum*	Shrub	FAC	3,[4,5],6	Seasonal	4-8	Yes	High. Songbirds and mammals.	Grows best in sun to partial shade. Drought tolerant.
Black-haw	*Viburnum prunifolia*	Shrub	FACU	4,5,6	No	3-9	Yes	High. Songbirds and small mammals.	Full to partial sun. Shade
Box-elder	*Acer negundo*	Tree	FAC+	3,[4,5]	Seasonal	2-9	Yes	Moderate. Songbirds and small mammals.	Full to partial sun. Forms thickets. Wood can be brittle.
Maple, red	*Acer rubrum*	Tree	FAC	3,[4,5]	Seasonal	3-9	Yes	High. Seeds and browse.	Rapid growth. Tolerates acidic soil.
Maple, silver	*Acer saccharinum*	Tree	FACW	3,[4,5]	Seasonal	3-9	Yes	Moderate. Songbirds and small mammals. Excellent for cavity nesting wildlife.	Full to partial sun.
Birch, river	*Betula nigra*	Tree	FACW	[3,4],5	Seasonal	4-9	Yes	High. Songbirds.	Bank erosion control. Full sun. Nice ornamental.
Birch, gray	*Betula populifolia*	Tree	FAC	[4,5],6	Seasonal		Yes	Moderate. Songbirds.	Short lived tree (30-50 years). Early successional species.
Ironwood	*Carpinus caroliniana*	Tree	FAC	3,[4,5],6	Seasonal	3-9	Yes	Moderate. Songbirds, waterfowl, and small mammals.	Partial sun. Shade tolerant. Small understory tree. Smooth gray bark.
Hickory, sweet pignut	*Carya glabra*	Tree	FACU-	4,[5,6]	No	4-9	No	Moderate. Songbirds, waterfowl, and small mammals.	Full to partial sun. Hardy and slow growing.
Hickory, shag-bark	*Carya ovata*	Tree	FACU-	4,[5,6]	No	4-8	Yes	Moderate. Songbirds, waterfowl, and small mammals.	Full sun. Distinctive peeling bark.
Cedar, Atlantic white	*Chamaecyparis thyoides*	Tree	OBL	[1,2],3,4	Saturated	4-8	Yes		Partial sun. Shade tolerant. Edible nuts, prolific seed production. Usually found in areas with fluctuating water tables. Evergreen.
Beech, American	*Fagus grandifolia*	Tree	FACU	4,[5,6]	No	4-9	Yes	High. Songbirds, waterfowl, and small mammals.	Full to partial sun. Good nut crop every 2-3 years. Smooth gray bark.
Ash, white	*Fraxinus americana*	Tree	FACU	4,[5,6]	No	4-9	Yes	High. Food.	All sunlight conditions. Well drained soils. Grows to 100' tall.
Ash, black	*Fraxinus nigra*	Tree	FACW	3,4,5	Saturated		Yes	Moderate.	Rapid growth.
Ash, green	*Fraxinus pennsylvanica*	Tree	FACW	3,4,5	Seasonal	2-9	Yes	Moderate. Songbirds. Prolific seeder.	Rapid growing streambank stabilizer. Full sun to partial shade. Small tree 30-50' tall.
Holly, American	*Ilex opaca*	Tree	FACU	4,5,6	No	5-9	Yes	Moderate. Songbirds.	Full to partial sun. Shade tolerant. Evergreen. Attractive red fruits persist through winter.
Cedar, eastern red	*Juniperus virginiana*	tree	FACU	4,5,6	No	2-9	Yes	High. Songbirds and small mammals.	Full sun. Good wind break or screening plant. Early successional species. Evergreen
Tuliptree	*Liriodendron tulipifera*	Tree	FACU	4,5,6	No	4-9	Yes	Moderate. Seeds and nest sites.	Full sun to partial shade. Well drained soils. Rapid growth. Grows to 120' tall.
Blackgum	*Nyssa sylvatica*	Tree	FACW+	2,[3,4],5	Seasonal	3-9	Yes	High. Songbirds, egrets, herons, raccoons, owls.	Can be difficult to transplant. Prefers sun to partial shade. Nice ornamental with deep red fall color.
Pine, pitch	*Pinus rigida*	Tree	FACU	4,5,6	No	4-7	Yes	High. Songbirds and small mammals.	Full sun. Old trees are fire resistant due to their thick bark. Grows well on poor sites. Evergreen.

Common Name	Scientific Name	Plant Type	Wetland Indicator	Hydrologic Zone	Inundation Tolerance	Hardiness Zone	Commercial Availability	Wildlife Value	Notes
Pine, eastern white	*Pinus strobus*	Tree	FACU	4,5,6	No	3-8	Yes	High. Songbirds and small mammals.	Full sun. Rapid growth. Large and long lived tree. Evergreen.
Sycamore, American	*Platanus occidentalis*	Tree	FACW-	[3,4],5	Seasonal	4-9	Yes	Low. Food, cavities for nesting.	Rapid growth. Common in floodplains and alluvial woodlands. Drought tolerant.
Cotton-wood, eastern	*Populus deltoides*	Tree	FAC	[3,4],5	Seasonal	2-9	Yes	Moderate. Cover, food.	Shallow rooted, subject to windthrow. Invasive roots. Will grow on dry sites. Weak wooded. Rapid growth.
Aspen, big-tooth	*Populus grandidentata*	Tree	FACU	[4,5,6]	No		Yes	Moderate. Ruffed Grouse eats buds and catkins.	Rapid growing and short lived (40-50 years).
Aspen, quaking	*Populus tremuloides*	Tree	FACU	[4,5],6	Seasonal	1-7	Yes	Moderate. Buds and some nesting.	Nice fall color. Short lived tree.
Cherry, black	*Prunus serotina*	Tree	FACU	[4,5],6	No	2-8	Yes	High. Food.	Moist soils or wet bottomland areas. Excellent fruit production. Early successional species.
Oak, white	*Quercus alba*	Tree	FACU	4,5,6	No	3-9	Yes	High. Songbirds and small mammals.	Full to partial sun. Slow growing. Longest lived tree in the northeast.
Oak, swamp white	*Quercus bicolor*	Tree	FACW+	2,[3,4],5	Seasonal	4-8	Yes	High. Songbirds, waterfowl and small mammals.	Full sun to partial shade. Good bottomland tree. Drought tolerant. Nice ornamental.
Oak, scarlet	*Quercus coccinea*	Tree	NI	5,6	No	4-9	Yes	High. Songbirds and small mammals.	Full to partial sun. Rapid growing and long lived. Nice fall color.
Oak, pin	*Quercus palustris*	Tree	FACW	[3],4,5,6	Seasonal	4-8	Yes	High. Songbirds and small mammals.	Gypsy moth target.
Oak, willow	*Quercus phellos*	Tree	FAC+	[3,4],5	Seasonal	5-9	Yes	High. Songbirds, waterfowl, and small mammals.	Full to partial sun.
Oak, red	*Quercus rubra*	Tree	FACU-	5,6	No	3-8	Yes	High. Small mammals.	Full to partial sun. Rapid growing and long lived. Valuable timber tree.
Willow, black	*Salix nigra*	Tree	FACW+	[2,3],4	Seasonal		Yes	High. Browsing and cavity nesters.	Rapid growth, stabilizes streambanks. Full sun. Roots easily from cuttings.
Bald Cypress	*Taxodium distichum*	Tree	OBL	1,[2,3],4	Saturated, 0-2"	4-9	Yes	Little food value, but good perching site for waterfowl.	Tolerates drought.
Basswood, American	*Tilia americana*	Tree	FACU	[4,5],6	No	2-8	Yes	Moderate. Butterflies, songbirds, small mammals, and beneficial insects.	Partial sun. Shade tolerant. Important pollen source for honey bees.
Serviceberry, downy	*Amelanchier arborea*	Tree (small)	FAC-	3,[4,5],6	Seasonal	4-9	Yes	Moderate. songbirds and small mammals.	Partial sun. Shade tolerant. Very early spring flowers. Handsome tree.
Serviceberry, shadbush	*Amelanchier canadensis*	Tree (small)	FAC	4,5,6	Seasonal	4-7	Yes	High. Nesting, cover, food. Birds and mammals.	Prefers partial shade. Common in forested wetlands and upland woods. Very early spring flowers.
Hackberry, common	*Celtis occidentalis*	Tree (small)	FACU	4,5,6	No	3-9	Yes	High. Food and cover.	Full sun to partial shade. Small tree 30-50' tall. Fruit persists into winter.
Redbud, eastern	*Cercis canadensis*	Tree (small)	FACU-	4,5,6	No	4-9	Yes	Moderate. Butterflies, songbirds, and small mammals.	Partial sun. Shade tolerant. Nitrogen fixer. Nice ornamental.
Hackberry, common	*Celtis occidentalis*	Tree (small)	FACU	4,5,6	No	3-9	Yes	High. Food and cover.	Full sun to partial shade. Small tree 30-50' tall. Fruit persists into winter.
Redbud, eastern	*Cercis canadensis*	Tree (small)	FACU-	4,5,6	No	4-9	Yes	Moderate. Butterflies, songbirds, and small mammals.	Partial sun. Shade tolerant. Nitrogen fixer. Nice ornamental.
Dogwood, flowering	*Cornus florida*	Tree (small)	FACU-	4,5,6	No	5-9	Yes	High. Songbirds, waterfowl, and small mammals. Fruits eaten by >100 species of bird.	Partial sun to shade. Understory plant in hardwood forests. Nice ornamental.
Magnolia, sweetbay	*Magnolia virginiana*	Tree (small)	FACW+	[3,4],5	Seasonal		Yes	Moderate. Seeds.	Southeast part of state. Shade and drought tolerant. Attractive and fragrant flowers.

Pennsylvania Stormwater Best Management Practices Manual

Appendix C – Site Evaluation and Soil Testing



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Protocol 1
Site Evaluation and Soil Infiltration Testing

A. Purpose of this Protocol

The purpose of the *Site Evaluation and Soil Infiltration Testing Protocol* is to describe evaluation and field testing procedures to:

a. Determine if Infiltration BMPs are suitable at a site, and at what locations.
b. Obtain the required data for infiltration BMP design.

B. When to Conduct Testing

Designers are encouraged to conduct the Soil Evaluation and Investigation early in the site planning and design process. The Site Development process outlined in Chapters 4 and 5 of this Manual describe a process for site development and BMPs. Soil Evaluation and Investigation should be conducted early in the preliminary design of the project so that information developed in the testing process can be incorporated into the design. Adjustments to the design can be made as necessary. It is recommended that Soil Evaluation and Investigation be conducted following the development of an early Preliminary Plan. The Designer should possess a preliminary understanding of potential BMP locations prior to testing. Prescreening test may be carried out in advance to site potential BMP locations.

C. Who Should Conduct Testing

Qualified professionals who can substantiate by qualifications/experience their ability carry out the evaluation should conduct test pit soil evaluations. A professional, experienced in observing and evaluating soils conditions is necessary to ascertain conditions that might affect BMP performance, which can not be thoroughly assessed with the testing procedures. Such professionals must conduct these evaluations in risk areas, or areas indicated in the guidance as non-preferred locations for testing or BMP implementation.

D. Importance of Stormwater BMP Areas

Sites are often defined as unsuitable for Infiltration BMPs and soil based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas should be identified early in the design process and should not be subject to a building program that precludes infiltration BMPs. An exemption should not be provided for “full build-outs” where suitable soils otherwise exist for infiltration.

E. Safety

As with all field work and testing, attention should be given to all applicable OSHA regulations and local guidelines related to earthwork and excavation. Digging and excavation should never be conducted without adequate notification through the Pennsylvania One Call system (**PA OneCall** 1-800-242-1776 or www.paonecall.org). Excavations should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work.

INFILTRATION TESTING: A MULTI-STEP PROCESS

Infiltration Testing is a four-step process to obtain the necessary data for the design of the stormwater management plan. The four steps include:

1. Background Evaluation
    - Based on available published and site specific data
    - Includes consideration of proposed development plan
    - Used to identify potential BMP locations and testing locations
    - Prior to field work (desktop)
    - On-site screening test
2. Test Pit (Deep Hole) Observation
    - Includes Multiple Testing Locations
    - Provides an understanding of sub-surface conditions
    - Identifies limiting conditions
3. Infiltration Testing
    - Must be conducted on-site
    - Different testing methods available
    - Alternate methods for - additional-Screening and Verification testing
4. Design Considerations
    - Determination of a suitable infiltration rate for design calculations
    - Consideration of BMP drawdown
    - Consideration of peak rate attenuation

Step 1. Background Evaluation

Prior to performing testing and developing a detailed site plan, existing conditions at the site should be inventoried and mapped including, but not limited to:

- Existing mapped individual soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including the location of any dikes, faults, fracture traces, solution cavities, landslide prone strata, or other features of note.
- Existing streams (perennial and intermittent, including intermittent swales), water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters and 1st order streams.
- Existing topography, slope, and drainage patterns.
- Existing and previous land uses.
- Other natural or man-made features or conditions that may impact design, such as past uses of site, existing nearby structures (buildings, walls), etc.

A sketch plan or preliminary layout plan for development should be evaluated, including:

- The preliminary grading plan and areas of cut and fill.
- The location and water surface elevation of all existing and location of proposed water supply sources and wells.
- The location of all existing and proposed on-site wastewater systems.
- The location of other features of note such as utility right-of-ways, water and sewer lines, etc.
- Existing data such as structural borings, drillings, and geophysical testing.

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- The proposed location of development features (buildings, roads, utilities, walls, etc.). In Step 1, the Designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be located on the proposed development plan and should serve as the basis for the location and number of tests to be performed on-site.

Important: If the proposed development program is located on areas that may otherwise be suitable for BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the Designer is *strongly* encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary. Full build-out of areas suitable for infiltration BMPs should *not* preclude the use of BMPs for volume reduction and groundwater recharge.

Step 2. Test Pits (Deep Holes)

A Test Pit (Deep Hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. An extensive number of Test Pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for Test Pits strongly is discouraged, as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings. Borings and other procedures, however, might be suitable for initial screening to develop a preliminary plan for testing, or verification testing.

A Test Pit consists of a backhoe-excavated trench, 2-1/2 to 3 feet wide, to a depth of between 72 inches and 90 inches, or until bedrock or fully saturated conditions are encountered. The trench should be benched at a depth of 2-3 feet for access and/or infiltration testing.

At each Test Pit, the following conditions shall be noted and described. Depth measurements should be described as depth below the ground surface:

___ Soil Horizons (upper and lower boundary)

___ Soil Texture and Color for each horizon

___ Color Patterns (mottling) and observed depth

___ Depth to Water Table

___ Depth to Bedrock

___ Observance of Pores or Roots (size, depth)

___ Estimated Type and Percent Coarse Fragments

___ Hardpan or Limiting Layers

___ Strike and dip of horizons (especially lateral direction of flow at limiting layers)

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___ Additional comments or observations

The Sample Soil Log Form at the end of this protocol may be used for documentation of each Test Pit.

At the Designer's discretion, soil samples may be collected at various horizons for additional analysis. Following testing, the test pits should be refilled with the original soil and the surface replaced with the original topsoil. A Test Pit should *never* be accessed if soil conditions are unsuitable for safe entry, or if site constraints preclude entry. OSHA regulations should always be observed.

It is important that the Test Pit provide information related to conditions at the bottom of the proposed Infiltration BMP. If the BMP depth will be greater than 90 inches below existing grade, deeper excavation will be required. However, *such depths are discouraged, especially in Karst topography.* Except for surface discharge BMPs (filter strips, etc.) the designer is cautioned regarding the proposal of systems that are significantly lower than the existing topography. The suitability for infiltration may decrease, and risk factors are likely to increase. *Locations that are not preferred* for testing *and* subsurface infiltration BMPs include swales, the toe of slopes for most sites, and soil mantels of less than three feet in Karst topography.

The designer and contractors should reducing grading and earthwork as needed to reduce site disturbance and compaction so that a greater opportunity exists for testing and stormwater management.

The number of Test Pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot BMPs, one test pit per lot is recommended, preferably within 25 feet of the proposed BMP area. Verification testing should take place when BMPs are sited at greater distances.
- For multi-family and high density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four (4) to six (6) tests per acre of BMP area.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction is not recommended.

Step 3. Infiltration Tests/Permeability Tests

A variety of field tests exist for determining the infiltration capacity of a soil. Laboratory tests are strongly discouraged, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Tests should not be conducted in the rain or within 24 hours of significant rainfall events (>0.5 inches), or when the temperature is below

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freezing. However, the preferred testing *is* between January and June, the wet season. This is the period when infiltration is likely to be diminished by saturated conditions. Percolation tests carried out between June 1 and December 31 should use a 24 hour presoaking before the testing. This procedure is not required for Infiltrometer testing, or permeometer testing

At least one test should be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per Test Pit is recommended. More tests may be warranted if the results for first two tests are substantially different. The highest rate (inches/hour) for test results should be discarded when more than two are employed for design purposes. The geometric mean should be used to determine the average rate following multiple tests.

Based on observed field conditions, the Designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting Infiltration Tests should be prepared to adjust test locations and depths depending upon observed conditions.

Methodologies discussed in this protocol include:

- Double-ring Infiltrometer tests.
- Percolation tests (such as for on-site wastewater systems and described in Pa Code Chapter 73).

There are differences between the two methods. A Double-ring Infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test must be adjusted to represent the discharge that is occurring on both the bottom and sides of the percolation test hole.

For *infiltration basins*, it is *strongly* advised that an Infiltration Test be carried out with an infiltrometer (not percolation test) to determine the saturated hydraulic conductivity rate. This precaution is taken to account for the fact that only the surface of the basin functions to infiltrate, as measured by the test. Alternatively, permeability test procedures that yield a saturated hydraulic conductivity rate can be used (see formulas developed by Elrick and Reynolds (1992), or others for computation of hydraulic conductivity and saturated hydraulic conductivity).

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer
- Testing as described in the Maryland Stormwater Manual Appendix D.1 using 5-inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093-90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph Permeameter
- Constant Head Permeameter (Amoozemeter)

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a. Methodology for Double-Ring Infiltrometer Field Test

A Double-ring Infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils. The diameter of the inner ring should be approximately 50% to 70% of the diameter of the outer ring, with a minimum inner ring size of 4-inches, preferably much larger. (Bouwer, 1986). Double-ring infiltrometer testing equipment that is designed specifically for that purpose may be purchased. However, field testing for stormwater BMP design may also be conducted with readily available materials.

Equipment for Double-Ring Infiltrometer Test:

___ Two concentric cylinder rings 6-inches or greater in height. Inner ring diameter equal to 50% - 70% of outer ring diameter (i.e., an 8-inch ring and a 12-inch ring). Material typically available at a hardware store may be acceptable.

___ Water supply

___ Stopwatch or timer

___ Ruler or metal measuring tape

___ Flat wooden board for driving cylinders uniformly into soil

___ Rubber mallet

___ Log sheets for recording data

Procedure for Double-Ring Infiltrometer Test

___ Prepare level testing area.

___ Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two inches.

___ Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of two inches. The bottom rim of both rings should be at the same level.

___ The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30 minute intervals for 1 hour. The minimum water depth should be 4-inches. The drop in the water level during the

last 30 minutes of the presoaking period should be applied to the following standard to determine the time interval between readings:

- If water level drop is 2-inches or more, use 10-minute measurement intervals.
- If water level drop is less than 2-inches, use 30-minute measurement intervals.

___ Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring shall be made from a fixed reference point and shall continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 1/4 inch or less of drop between the highest and lowest readings of four consecutive readings.

___ The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, shall represent the infiltration rate for that test location.

b. Methodology for Percolation Test

Equipment for Percolation Test:

___ Post hole digger or auger

___ Water supply

___ Stopwatch or timer

___ Ruler or metal measuring tape

___ Log sheets for recording data

___ Knife blade or sharp-pointed instrument (for soil scarification)

___ Course sand or fine gravel

___ Object for fixed-reference point during measurement (nail, toothpick, etc.)

Procedure for Percolation Test

This percolation test methodology is based largely on the Pennsylvania Department of Environmental Protection (PADEP) criteria for on-site sewage investigation of soils (as described in Chapter 73 of the Pennsylvania Code). This should include the 24 hour presoak procedure between June 1 and December 31. The presoak is done primarily to simulate saturated conditions in the environment (generally Spring) and to minimize the influence of

unsaturated flow. If a presoak procedure is not employed between June1 and December 31, than the rate reduction formula described by Elrick and Reynolds (1992), or Fritton, et.,al. (1986) is recommended to account for the influence of unsaturated conditions in the test.

Prepare level testing area.

___ Prepare hole having a uniform diameter of 6 to 10 inches and a depth of 8 to 12-inches. The bottom and sides of the hole should be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.

___ (Optional) two inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.

___ Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of 6 inches over the bottom and readjusted every 30 minutes for 1 hour.

___ The drop in the water level during the last 30 minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:

- If water remains in the hole, the interval for readings during the percolation test should be 30 minutes.
- If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.

___ After the final presoaking period, water in the hole should again be adjusted to a minimum depth of 6-inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.

___ Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 1/4 inch or less of drop between the highest and lowest readings of four consecutive readings.

___ The drop that occurs in the percolation hole during the final period, expressed as inches per hour, shall represent the percolation rate for that test location.

___ The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average/final percolation rate should be adjusted for each percolation test according to the following formula:

Infiltration Rate = (Percolation Rate) / (Reduction Factor)

Where the Reduction Factor is given by**:

$$R_f = \frac{2d_1 - \Delta d}{DIA} + 1$$

With:

d_1 = Initial Water Depth (in.)
Δd = Average/Final Water Level Drop (in.)
DIA = Diameter of the Percolation Hole (in.)

The Percolation Rate is simply divided by the Reduction Factor as calculated above or shown in the table below to yield the representative Infiltration Rate. In most cases, the Reduction Factor varies from about 2 to 4 depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower Reduction Factors because proportionately less water exfiltrates through the sides. For design purposes additional safety factors are employed (see Protocol 2, Infiltration Systems Design and Construction Guidelines)

*** The area Reduction Factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.*

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Perc. Hole Diameter, DIA (in.)	Initial Water Depth, d_1 (in.)	Ave./Final Water Level Drop, Δd (in.)	Reduction Factor, $\mathbf{R_f}$
6	**6**	0.1	3.0
		0.5	2.9
		2.5	2.6
	8	0.1	3.7
		0.5	3.6
		2.5	3.3
	10	0.1	4.3
		0.5	4.3
		2.5	3.9
8	**6**	0.1	2.5
		0.5	2.4
		2.5	2.2
	8	0.1	3.0
		0.5	2.9
		2.5	2.7
	10	0.1	3.5
		0.5	3.4
		2.5	3.2
10	**6**	0.1	2.2
		0.5	2.2
		2.5	2.0
	8	0.1	2.6
		0.5	2.6
		2.5	2.4
	10	0.1	3.0
		0.5	3.0
		2.5	2.8

Table 1. Sample Percolation Rate Adjustments

Step 4. Design Considerations beginning with *Protocol 2 – Infiltration System Design and Construction Guidelines*

ADDITIONAL POSSIBLE TESTING - BULK DENSITY, OTHERS

Other testing methods are acceptable to assess a soil's suitability for infiltration for early screening and occasionally for verification. They can be especially helpful where consultants wish to cull out the better soils. Percolation testing can also be performed without presoaking as a *pre*-screening procedure.

Alternate tests or investigations can be used for verification. For instance, if the BMPs are not located precisely over the test locations, alternate testing or investigations can be used to verify that the soils are the same as the soils that yielded the earlier test results. However, consultants should document these verification test results or investigations. Professionals with substantiated qualifications should carry out verification procedures.

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Bulk Density Tests measure the level of compaction of a soil, which is an indicator of a soils' ability to absorb rainfall. Developed and urbanized sites often have very high bulk densities and therefore possess limited ability to absorb rainfall (and have high rates of stormwater runoff). Vegetative and soil improvement programs can improve, (i.e. lower), the soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Macropores occur primarily in the upper soil horizons and are formed by plant roots (both living and decaying), soil fauna such as insects, the weathering processes caused by the movement of water, the freeze-thaw cycle, soil shrinkage due to desiccation of clays, chemical processes, and other mechanisms. These macropores provide an important mechanism for infiltration prior to development, extending vertically and horizontally for considerable distances. It is the intent of good engineering and design practice to maintain these macropores in the installation of Infiltration BMPs as much as possible. Bulk Density Tests can help determine the relative compaction of soils before and after site disturbance and/or restoration and should be used at the discretion of the designer/reviewer.

Various procedures are available to conduct bulk density tests. The density measurements should be carried out in conjunction with a soil texture analysis. Sandy soils infiltrate well, but tend to have a somewhat higher bulk density than finer soils. Experienced personnel can do the texture analysis manually on site.

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Sample Soil Log

Tested by: _____ Date: _____ Elevation: _____ Equipment Used: _____

Test Pit: _____ Soil Type: _____ Land Use: _____ Weather: _____

Geology: _____

Additional comments: _____

Horizon	Upper Boundary	Lower Boundary	Soil Textural Class	Type, Size, Coarse Fragments, etc.	Soil Color	Color Patterns	Pores, Roots, Rock Structure	Depth to Bedrock	Depth to Water	Comments

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Protocol 2
Infiltration Systems Design and Construction Guidelines

Role of Infiltration BMPs

The phrase "infiltration BMPs" describes a wide range of stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon and eventually into deeper groundwater. In this manual the major infiltration strategies are grouped into four categories or types, based on construction and performance similarities:

- Surface Infiltration Basins
- Subsurface Infiltration Beds
- Bioretention Areas/Rain Gardens
- Other BMPs that support infiltration (vegetated filter/buffer strips, level spreaders, and vegetated swales)

Infiltration BMPs are one of the most beneficial approaches to stormwater management for a variety of reasons including:

- Reduction of the peak rate of runoff
- Reduction of the volume of runoff
- Removal of a significant portion of the particulate-associated pollutants and some portion of the solute pollutants.
- Recharge of groundwater and maintenance of stream baseflow.

Infiltration BMPs attempt to replicate the natural hydrologic regime. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events. During periods of reduced rainfall, this recharged water serves to provide baseflow to streams and maintain in-stream water quality. Qualitatively, infiltration BMPs are known to remove nonpoint source pollutants from runoff through a complex mix of physical, chemical, and biological removal processes. Infiltration promotes maintenance of the natural temperature regimes of stream systems (cooler in summer, warmer in winter), which can be critical to the aquatic ecology. Because of the ability of infiltration BMPs to reduce the volume of runoff, there is also a corresponding reduction in erosive "bankfull" conditions and downstream erosion and channel morphology changes.

Infiltration BMPs are designed to infiltrate some portion of runoff during every runoff event. During small storm events, a large percentage of the runoff may infiltrate, whereas during large storm events, the volume that infiltrates may only be a small portion of the total runoff. However, because most of the rainfall in Pennsylvania occurs in small (less than 1-inch) rainfalls, the annual benefits of an infiltration system may be significant.

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Purpose of Protocol 2: Infiltration Systems Guidelines
The purpose of this protocol is to provide the designer with specific guidelines for the successful construction and long-term performance of Infiltration BMPs. These guidelines fall into three categories:

1. Site conditions and constraints
2. Design considerations
3. Construction requirements

All of these guidelines are important, and successful infiltration is dependent on careful consideration of site conditions, careful design, and careful construction.

1. SITE CONDITIONS and CONSTRAINTS

a) It is desirable to **maintain a 2-foot clearance above regularly occurring seasonally high water table**. This reduces the likelihood that temporary groundwater mounding will affect the system, and allows sufficient distance of water movement through the soil to allow adequate pollutant removal. Some minor exceptions for very shallow systems and on grade systems, filter strips, buffers, etc.

b) **Maintain a minimum depth to bedrock of 2-feet to assure adequate pollutant removal**. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist.

c) It is desired that **soils underlying infiltration devices should have infiltration rates between 0.1 and 10 inches per hour**, which in most development programs should result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible but the surface area required could be large, and other volume reduction methods may be warranted. Undisturbed Hydrologic Soil Groups B and C often fall within this range and cover most of the state. Soils with rates in excess of 6.0 inches per hour may require an additional soil buffer (such as an organic layer over the bed bottom) if the Cation Exchange Capacity (CEC) is less than 5 and pollutant loading is expected to be significant. In carbonate soils, excessively rapid drainage may increase the risk of sinkhole formation, and some compaction or additional soil may be appropriate.

d) **Infiltration BMPs should be sited so that any risk to groundwater quality is minimized**, at least 50 feet from individual water supply wells, and 100 feet from community or municipal water supply wells. Horizontal separation distances or buffers may also be appropriate from Special Geologic Features, such as fractures traces and faults, depending on water supply sources.

e) **Infiltration BMPs should be sited so that they present no threat to sub-surface structures**, at least 10 feet down gradient or 100 feet up gradient from building basement foundations, and 50 feet from septic system drain fields unless specific circumstances allow for reduced separation distances.

In general, soils of Hydrologic Soil Group D will not be suitable for infiltration. Similarly, areas of floodplains and areas of close proximity to wetlands and streams will generally not be suitable

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for infiltration (due to high water table and/or low permeability). In developing areas that were previously used for agricultural purposes, the designer should consider the past patterns of land use. Areas that were suitable for cultivation will likely be suitable for some level of infiltration. Areas that were left out of cultivation often indicate locations that are too wet or too rocky, and will likely not be suitable for infiltration.

2. DESIGN CONSIDERATIONS

a) **Do Not Infiltrate in Compacted Fill.** Infiltration in native soil without prior fill or disturbance is preferred but not always possible**.** Areas that have experienced historic disturbance or fill are suitable for infiltration provided sufficient time has elapsed and the Soil Testing indicates the infiltration is feasible. In disturbed areas it may be necessary to infiltrate at a depth that is beneath soils that have previously been compacted by construction methods or long periods of mowing, often 18-inches.

b) **A Level Infiltration Area (1% or less slope) is preferred.** Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. Infiltration areas should be flat, nearly so, or on contour.

c) **The soil mantle should be preserved to the maximum extent possible**, and excavation should be minimized. Those soils that do not need to be disturbed for the building program should be left undisturbed. Macropores can provide a significant mechanism for water movement in infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle also increases the pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

d) **Isolate "hot spot areas"**. Site plans that include 'hot spots' need to be considered. 'Hot spots' are most often associated with some industrial uses and high traffic – gasoline stations, vehicle maintenance areas, and high intensity commercial uses (fast food restaurants, convenience stores, etc.). These "hot spots" are defined in Section 3.3, Stormwater Standards for Special Areas. Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns. Pretreatment requirements need to be analyzed, especially for 'hot spots' and areas that produce high sediment loading. Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. The pollutants of greatest concern, site by site, should guide selection of pretreatment depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether the pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.

e) **The Loading Ratio of impervious area to bed bottom area must be considered**. One of the more common reasons for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration

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systems work best when the water is "spread out". The Loading Ratio describes the ratio of imperious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following Loading Ratio guidelines are recommended:

- Maximum Impervious Loading Ratio of 5:1 relating impervious drainage area to infiltration area.
- A Maximum Total Loading Ratio of 8:1 relating total drainage area to infiltration area.
- Maximum Impervious Loading Ratio of 3:1 relating impervious drainage area to infiltration area for Karst areas.

f) **The Hydraulic Head or Depth of Water should be limited**. The total effective depth of water should generally not be greater than two feet to avoid excessive pressure and potential sealing of the bed bottom. Typically the water depth is limited by the Loading Ratio and Drawdown Time and is not an issue.

g) **Drawdown Time must be considered**. In general, infiltration BMPs should be designed so that they completely empty within the time period specified in Chapter 3.

h) **All infiltration BMPs should be designed with a positive overflow** that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration in all situations.

i) **Geotextiles should be incorporated into the design as necessary in certain infiltration BMPs**. Infiltration BMPs that are subject to soil movement and deposition must be constructed with suitably well-draining non-woven geotextiles to prevent to movement of fines and sediment into the infiltration system. The designer is encouraged to err on the side of caution and use geotextiles as necessary at the soil/BMP interface.

j) Avoid severe slopes (>20%), and toes of slopes, where possible. Specific on-site investigations by experienced personnel need to be made to determined acceptability of each case.

3. CONSTRUCTION REQUIREMENTS

a) **Do not compact soil infiltration beds during construction**. Prohibit all heavy equipment from the infiltration area and minimize all other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as tracked vehicles.

b) **Protect the infiltration area from sediment until the surrounding site is completely stabilized.** Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Where geo-textile is used as a bed bottom liner, this should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed. Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be utilized as a temporary

sediment basin, excavation should be limited to within 1 foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting the soil horizon, and final grade removed when the contributing site is fully stabilized. All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover.

c) **Provide thorough construction oversight.** Long-term performance of infiltration BMPs is dependent on the care taken during construction. Plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.

d) **Provide Quality Control of Materials.** As with all BMPs, the final product is only as good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

BMP Effectiveness

Infiltration BMPs produce excellent pollutant removal effectiveness because of the combination of a variety of natural functions occurring within the soil mantle, complemented by existing vegetation (where this vegetation is preserved). Soil functions include physical filtering, chemical interactions (e.g., ion exchange, adsorption), as well as a variety of forms of biological processing, conversion, and uptake. The inclusion of native vegetation for filter strips, rain gardens, and some vegetated infiltration basins, reinforces the work of the soil by reducing velocity and erosive forces, soil anchoring, and further uptake of nonpoint source pollutants. In some cases the more difficult-to-remove soluble nitrates can be reduced as well. It should be noted that infiltration BMPs tend to be excellent for removal of many pollutants, especially those that are in particulate form; however, there are limitations to the removal of highly solubilized pollutants, such as nitrate, which can be transmitted through the soil.

In addition to the removal of chemical pollutants, infiltration can address thermal pollution. Maintaining natural temperatures in stream systems is recognized as an issue of increasing importance for protection of overall stream ecology. Detention facilities tend to discharge heated runoff flows. The return of runoff to the groundwater through use of infiltration BMPs guarantees that these waters will be returned at natural groundwater temperatures, considerably cooler than ambient air in summer and warmer in winter, so that seasonal extreme fluctuations in stream water temperature are minimized. Fish, macroinvertebrates, and a variety of other biota will benefit as the result.

Although precise data on pollutant removal efficiencies is somewhat limited, infiltration BMPs have been shown to have excellent efficiencies for a wide range of pollutants. In fact, recent EPA guidance has suggested that infiltration BMPs can be considered 100 percent effective at removing pollutants from surface water for the fraction of water that infiltrates (EPA, 1999a). Other more conservative removals are reported in a variety of other sources. Estimated removals for all BMPs are contained in Section 9.

Fate of Infiltrated Contaminants

The protection of groundwater quality is of utmost importance in any PA watershed. The potential to contaminate groundwater by infiltrating stormwater in properly designed and constructed BMPs with proper pretreatment is low, if come common sense rules are followed, as discussed above. Numerous studies have shown that stormwater infiltration BMPs have a minor risk of contaminating either groundwater or soil. Perhaps the most comprehensive research was conducted by the U.S. Environmental Protection Agency, summarized in "Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration" (Pitt et al., 1994). The publication presents a summary table that identifies the potential of pollutants to contaminate groundwater as either low, low/moderate, moderate, or high. Of the 25 physical pollutants listed, only one has a "high" potential (chloride), and only two have even "moderate" potential (fluoranthene and pyrene) for polluting groundwater through the use of shallow infiltration systems with some sediment pretreatment. While chloride can be found in significant quantities due to winter salting, relatively high concentrations are generally safe for both humans and aquatic biota (in fact, chloride is not even included in U.S. EPA's primary drinking water standards and the secondary standard concentration is given as 250 mg/L at http://www.epa.gov/safewater/mcl.html#mcls). Pentachlorophenol, cadmium, zinc, chromium, lead, and all the pesticides listed are classified as having a "low" contamination potential. Even nitrate which is soluble and mobile (discussed further below) is only given a "low/moderate" potential.

Legret et al. (1999) simulated the long term effects of heavy metals in infiltrating stormwater and concluded that the "long-term pollution risks for both soil and groundwater are low," and "metals are generally well retained in the upper layers of the soil (0-20 cm) [0-8 inches]…" Barraud et al. (1999) studied a thirty year-old infiltration BMP and found that both metal and hydrocarbon concentrations in the soil under the infiltration device decreased rapidly with depth "to a low level after a few decimeters down [3 decimeters = 1 foot]…" A study concerning the infiltration of highway runoff (Dierkes and Geiger, 1999) found that polycyclic aromatic hydrocarbons (PAH) were effectively removed in the upper 4 inches of the soil and that runoff that had passed through 14 inches of soil met drinking water standards for cadmium, zinc, and copper. This extremely high pollutant removal and retention capacity of soils is the result of a multitude of natural processes including physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake.

Several studies have also found that porous pavement and stone-filled subsurface infiltration beds can significantly reduce the pollutant concentrations (especially hydrocarbons and heavy metals) of stormwater runoff before it even reaches the underlying soil due to adsorption, filtering, sedimentation, and bio-degradation by a diverse microbial community in the pavement and infiltration beds (Legret and Colandini, 1999; Balades et al., 1995; Swisher, 2002; Newman et al., 2002; and Pratt et al., 1999).

Common Causes of Infiltration BMP "Failures"

The concept of failure is simple – a design no longer provides the benefit or performance anticipated. With respect to stormwater infiltration BMPs, the term requires some qualification, since the net result of "failure" may be a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of some pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration

systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability to support surface vegetation, caused by too much or too little water.

The primary causes of reduced performance appear to be:

a) Poor construction techniques, especially soil compaction/smearing, which results in significantly reduced infiltration rates.
b) A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces.
c) Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates.
d) Lack of proper maintenance (erosion repair, re-vegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs.
e) Inadequate design

Infiltration systems should always be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.

Consideration of Infiltration Rate in Design and Modeling Application

For the purposes of site suitability, areas with tested soil infiltration rates as low as 0.1 inches per hour may be used for infiltration BMPs. However, in the design of these BMPs and the sizing of the BMP, the designer should incorporate a safety factor. Safety factors between 1 (no adjustment) and 10 have commonly been used in the design of stormwater infiltration systems, with a factor of two being recommended for most cases.

The minimum safety for design purposes that may used for any type of tests is two (2). For percolation tests this safety factor is only applicable for soils more coarse than a loam. It should be applied ***after*** (in addition to) using the reduction formula outlined in Protocol 1, Site Evaluation and Soil Infiltration Testing.

For Percolation tests in loams and finer soils (silty loam, clay loams, silty clay loams, sandy clay loams, clays) a minimum design safety factor of three (3) is recommended ***after*** using the reduction formula in Protocol 1, Site Evaluation and Soil Infiltration Testing. This higher factor is to account for the unwanted capillary suction force that can occur from *un*saturated conditions during percolation testing.

Therefore, a percolation rate of 0.5 inches per hour (***after*** reduction formula) should generally be considered as a rate of 0.25 inches per hour when designing an infiltration BMP for a sandy loam. The same rate for a loam would yield a *design* rate of 0.17 inches/hour.

For other test procedures a safety factor of 3 should also be considered for problem or less preferred locations, basins, swales, toe of slopes, loadings greater than 5:1 (drainage area to infiltration area) where saturated hydraulic conductivity rate (Ksat) was **not** determined (A raw infiltration rate was used. The Ksat rate will normally be less than the infiltration rate.)

As discussed in Section 9 of this Manual, infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is convenient to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the Stage-Storage-Discharge table.

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Pennsylvania Stormwater Best Management Practices Manual

Appendix D – Stormwater Calculations and Methodology: Case Study



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EXAMPLE 1: Control Guideline 1 for Residential 10-Lot Subdivision

This example describes a 10-lot residential subdivision in Blair County, Pennsylvania with the following conditions:

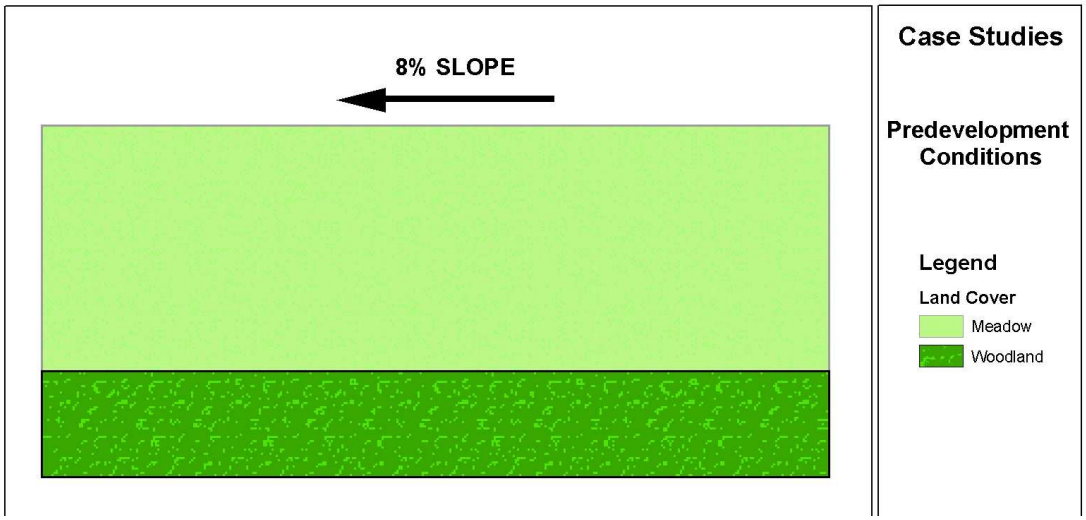
1. In this 10-lot subdivision, on-lot structural BMPs provide volume reduction and infiltration for the net increase in volume for the 2-year, 24-hour storm event. Peak rate calculations are developed by two different techniques. Because of the relatively slow-draining soils and a small total infiltration area, increased storage in the BMPs or downstream detention is required to mitigate the peak rate of runoff for the larger storm events.

2. The same design is then revised to incorporate Non-structural BMPs to reduce the requirements of the structural BMPs. Adjusted volume calculations are provided.

3. In addition, the 10-lot subdivision is modeled with a dry detention basin for conventional peak rate control for comparison. Finally, the site is routed with an extended detention (ED) basin for ED of the 1-year storm and peak rate control for the larger storms.

Follow Flow Chart A

- **Step 1**: Provide General Site Information (Worksheet 1)



In this example, the pre-development condition is a 10-acre site with 7 acres of meadow and 3 acres of woods. The underlying soils are classified as hydrologic group “C”, and the overall site slope is approximately 8%.

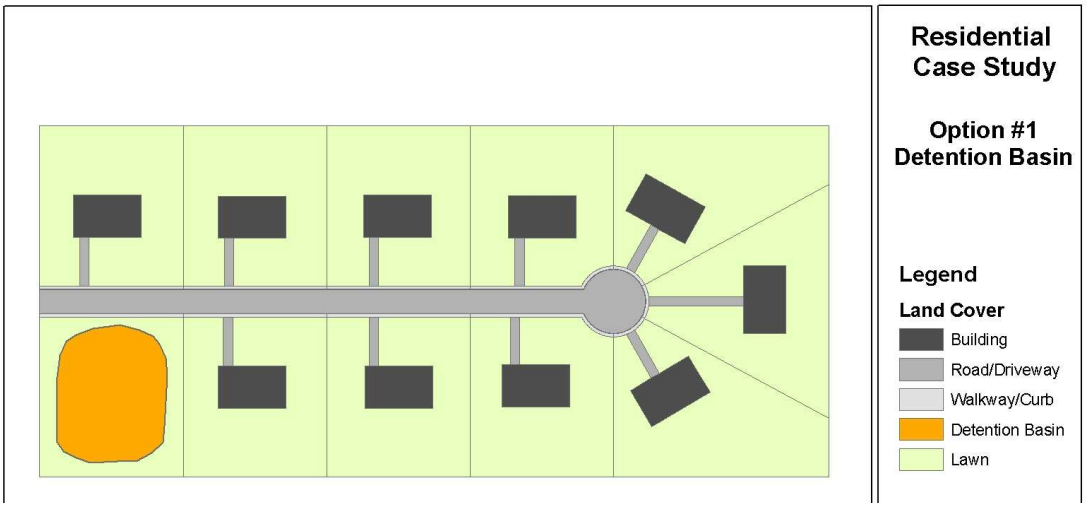
- **Step 2**: Identify sensitive natural resources (if applicable) and what areas will be protected or maintained. (Worksheet 2).

Note: In this example, there are 3 acres of woodlands that are not protected.

- **Step 3**: Estimate the benefits of Non-structural BMPs in the stormwater design (Worksheet 3).

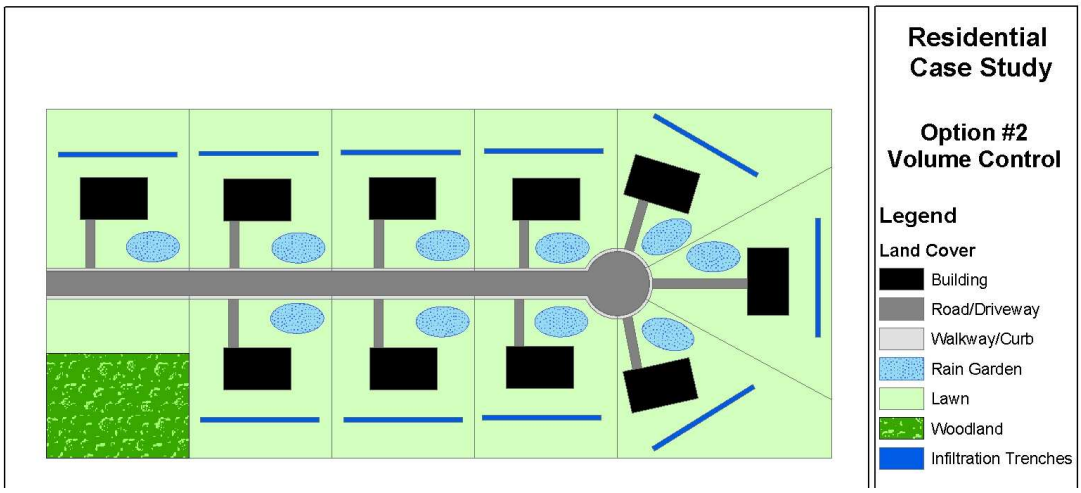
Note: In this example, Non-structural BMPs are not initially applied.

- **Step 4**: Based on the proposed design, estimate the increased volume of runoff for the 2-year storm event, using the Cover Complex Curve Number method. **Using a weighted curve number is NOT acceptable**. Runoff volume should be calculated based on major land use types and soil types (Worksheet 4).



The proposed development includes 10 residential lots, each covering 0.91 acres.

- **Step 5**: Design and incorporate Structural and Non-Structural BMPs that provide volume control for the 2-Year volume increase (Worksheet 5).



Note: In this example, Rain Gardens and Infiltration Trenches are placed on each lot.

Calculations are provided to demonstrate that the required volume is provided. The storage volume is calculated for each rain garden and infiltration trench. The total

volume is indicated on Worksheet 5 and compared to the volume requirement for CG1 of the net increase in runoff volume for the 2-year storm (Worksheet 4).

For this example, the net increase in runoff volume for the 2-year storm is approximately 25,913 ft^3, and the combined storage provided by the rain garden and infiltration trench BMPs is approximately 26,020 ft^3, so the volume requirement of CG1 has been met.

- **Step 6**: Demonstrate Peak Rate Control for the 2-year through 100-year events.

    - If Conditions for Peak Rate mitigation can be met, detailed Peak Rate Analysis and Flood Routing can be waived (Worksheet 6). This example does not meet those conditions because it has 2 acres of impervious cover. The maximum impervious area for a waiver is 1 acre.

    - If Conditions for Peak Rate mitigation cannot be met, detailed Peak Rate Analysis and Flood routing is required.

One of the challenges designers often face in using many BMPs throughout the site is that traditional engineering models and methods of peak rate calculation do not lend themselves to this type of design. As a result, designers often include BMPs for volume control, infiltration, or water quality, and then add detention measures. These detention measures may be greatly oversized because the volume-reduction and detention benefits of the BMPs and the effects of slowing the movement of runoff from the site are not accounted for. Chapter 8 provides a discussion titled "Guidelines: Volume Credits for Detention Routing" that proposes several options for considering the volume and rate mitigation benefits of multiple volume-reducing BMPs.

In this example, some of those techniques are applied, including: Composite BMP and Travel Time Adjustment with Volume Diversion.

For the Composite BMP example, the volume and discharge of the multiple BMPs (ten rain gardens and ten infiltration trenches) are combined to create a "synthetic" storage reservoir with a composite stage-storage-discharge curve. The post-development runoff hydrograph for the entire site is routed into the composite storage reservoir represented by the combined stage-storage-discharge characteristics of the many BMPs. The routed discharge from this "synthetic reservoir" is then used to size the required detention facility for the site to meet the peak rate attenuation requirements of the 1- to 100- year storm events. This method allows the designer to "take credit" for the storage/detention volume and infiltration occurring in the many BMPs, and to reduce the size of the downstream detention facility that will be built. The method is limited because it does <u>not</u> provide adequate consideration of the effect that many BMPs have on how <u>fast</u> water travels from and across the site. Since the peak of the runoff hydrograph is strongly influenced by how fast water travels across the site (or the Time of Concentration, T_c), this method is somewhat conservative.

For the Travel Time Adjustment example, the post-development Time of Concentration (T_c) is increased to take into consideration the amount of time it takes for runoff to move <u>through</u> the various BMPs. Both structural and non-structural

BMPs can significantly slow the movement of water and reduce the peak flow rate. In this approach, the total storage of the volume-reduction BMPs (in cubic feet) is divided by the peak flow rate (calculated without the BMPs in place, in cubic feet per second) for the 100-year storm event to estimate how long it will take for water to move "through" the BMPs. This estimated time where runoff is essentially slowed by the BMP is added to the original post-development T_c in determining the post-development runoff hydrograph. Because the T_c increases, the calculated peak rate of flow for the site will be lower and the required downstream detention facility will be smaller. To account for the actual storage and infiltration of the volume-reducing BMPs (trenches and rain gardens), a diversion is incorporated into the modeling framework.

Residential 10 Lot Subdivision – Part 2

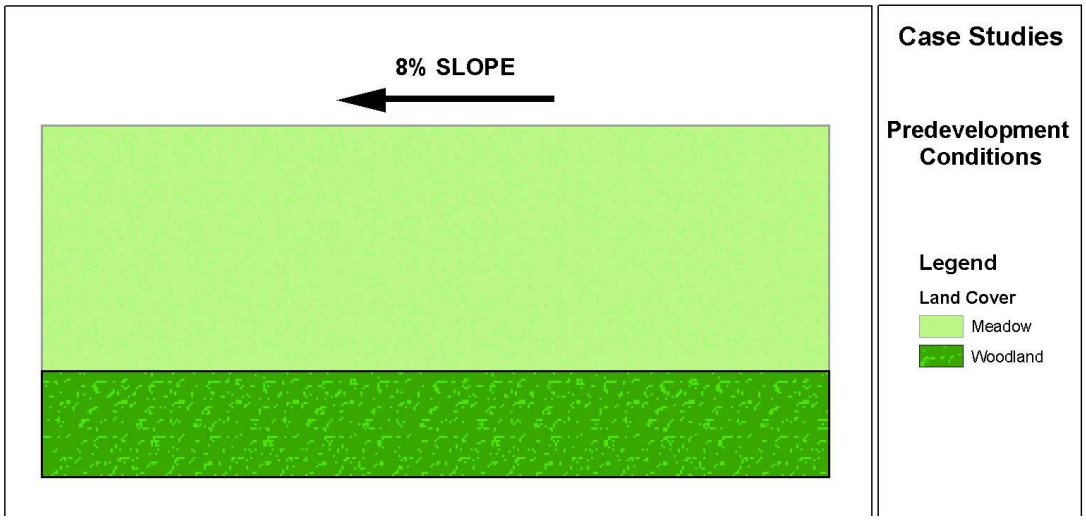
In this example, the same 10-lot residential subdivision is evaluated, but the design has been revised to incorporate Non-structural BMPs. These non-Structural BMPs include:

- Maintaining the existing 3 acres of woods (BMP 5.4.1, Protect Sensitive/Special Value Features and BMP 5.6.1, Minimize Total Disturbed Area). This has the effect of reducing the volume and rate of runoff that must be managed. ***Because this area remains undisturbed, there is no requirement to manage the volume of runoff. The total area considered in Worksheet 4 is reduced from 10 acres to 7 acres.***
- Reducing the amount of cleared and disturbed area in the construction of the homes (BMP 5.6.2, Minimize Soil compaction). Rather than clearing and grading the entire site, approximately one-half of the proposed lawn area on the lots will not be graded and stripped of topsoil. This area will be protected from heavy equipment movement during construction, but much of this area will be converted into lawn as part of the development. A portion of the site (approximately ½ an acre) will be planted in meadow mix (BMP 5.6.3, Re-vegetate Using Native Species). Protecting these areas from grading and compaction during construction maintains their ability to both absorb rainfall and slow the rate of flow across the site. ***To encourage this practice, a "volume credit" is given under BMP 5.6.2. This reduces the volume of runoff to be managed in structural BMPs.***
- Shortening the house setbacks and driveway lengths reduces the amount of impervious cover (BMP 5.5.1, Cluster) as does reducing the street width (BMP 5.7.1 Reduce Street Imperviousness). ***The benefit of BMPs 5.5.1 and 5.7.2 is significant – the amount of impervious area is reduced from 2 acres to 1.6 acres, and the total site imperviousness is reduced from 20% to 16%.***

Rooftop leaders will also be disconnected, but because the disconnected roof leaders will discharge into the Rain Gardens and Infiltration Trenches, the 75-foot overland flow requirement will not be met, and so no additional volume reduction credit is given. Existing trees will also be protected, but because this area is addressed under BMP 5.6.1 (Minimize Total Disturbed Area) additional credit for protecting trees is not given. In other words, credit for a measure (structural or non-structural) can only be taken once.

Following the same Design and Calculation Process for the design with Non-Structural BMPs is as follows:

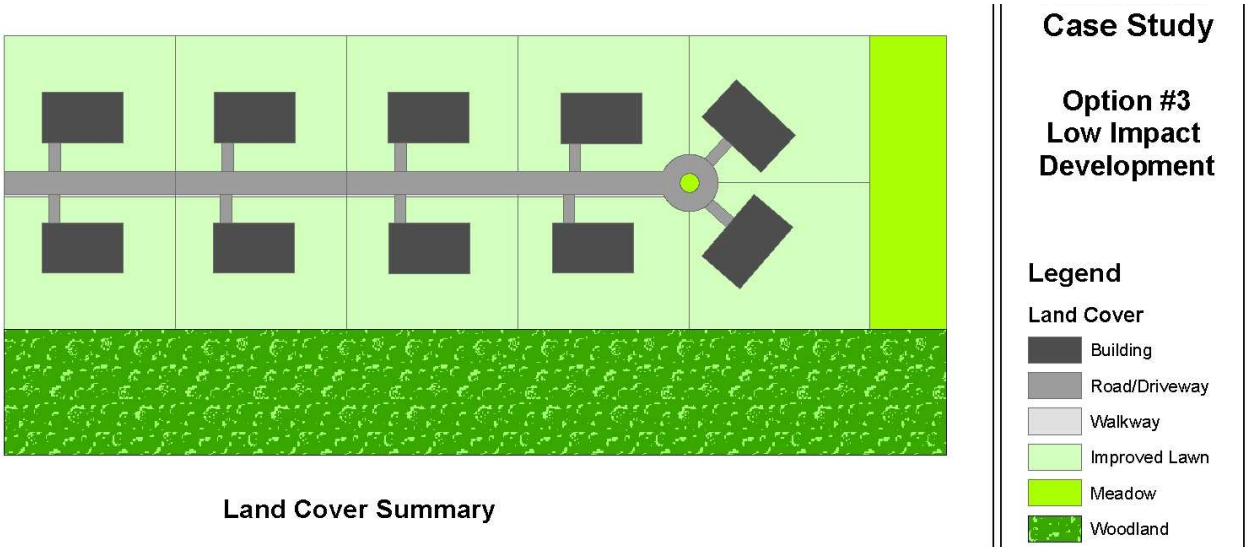
- **Step 1**: Provide General Site Information (Worksheet 1). The Existing Site conditions are the same.



- **Step 2**: Identify sensitive natural resources (if applicable) and what areas will be protected or maintained. (Worksheet 2).

Note: In this example, there are 3 acres of woodlands that ARE protected. Therefore, the overall site area contributing to runoff volume requirements is reduced from 10 acres to 7 acres.

- **Step 3**: Estimate the benefits of Non-structural BMPs in the stormwater design (Worksheet 3).



Land Cover Summary

In this example, Woods are maintained, lot setbacks and driveway lengths are reduced, the street width is reduced, and areas of lawn are protected from topsoil

removal and compaction. Portions of lawn are replaced with meadow. Rain Gardens and Infiltration Trenches are placed on each lot, however, these BMPs are reduced in size. The proposed development still includes 10 residential lots.

Note: Direct volume credit can be calculated for certain Non-Structural BMPs. In this example, a volume credit of approximately 2,900 ft^3 is provided by creating lawns and meadows in areas that have NOT been cleared of topsoil and have been protected from compaction during construction.

- **Step 4**: Based on the proposed design, estimate the increased volume of runoff for the 2-Year storm event, using the Cover Complex Curve Number method. **Using a weighted curve number is NOT acceptable**. Runoff volume should be calculated based on major land use types and soil types (Worksheet 4).

Note: Because a number of Non-structural BMPs are applied (as discussed above), the stormwater management volume requirement is reduced from 25,913 ft^3 to 18,088 ft^3. This is a 30% reduction in the volume requirement.

- **Step 5**: Design and incorporate Structural and Non-Structural BMPs that provide volume control for the 2-Year volume increase (Worksheet 5).

Calculations are provided to demonstrate that the required volume is provided. The storage volume is calculated for each rain garden and infiltration trench. The total volume is indicated on Worksheet 5 and compared to the volume requirement for CG1 of the net increase in runoff volume for the 2-year storm (Worksheet 4).

For this example that includes Non-Structural BMPs, the volume requirement has been reduced and so the Structural BMPs are reduced in size. The volume requirement for the original design (without Non-structural BMPs) was 25,913 ft^3. By incorporating the Non-structural BMPs, this volume requirement has been reduced to 15,199 ft^3 (including the non-structural volume credits). Correspondingly, the structural BMPs have been reduced in size: the rain gardens are reduced from 1,820 ft^2 to 1,070 ft^2 each, and the infiltration trenches are reduced from 1,500 ft^2 to 875 ft^2.

Part 1 – Structural BMP Design

Worksheet 1. General Site Information

INSTRUCTIONS: Fill out Worksheet 1 for each watershed

Date: _____

Project Name: 10 Lot Residential Subdivision

Municipality: Smith Township

County: Blair County

Total Area (acres): 10

Major River Basin: _____

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm#newtopics

Watershed: Purdy Creek

Sub-Basin: _____

Nearest Surface Water(s) to Receive Runoff: Tributary to Purdy Creek

Chapter 93 - Designated Water Use: HQ

http://www.pacode.com/secure/data/025/chapter93/chap93toc.html

Impaired according to Chapter 303(d) List?

http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/303d-Report.htm

Yes	
No	X

List Causes of Impairment:

Is project subject to, or part of:

Municipal Separate Storm Sewer System (MS4) Requirements?

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralPermits/default.htm

Yes	
No	X

Existing or planned drinking water supply?

Yes	
No	X

If yes, distance from proposed discharge (miles): _____

Approved Act 167 Plan?

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/Approved_1.html

Yes	
No	X

Existing River Conservation Plan?

http://www.dcnr.state.pa.us/brc/rivers/riversconservation/planningprojects/

Yes	
No	X

Worksheet 2. Sensitive Natural Resources

INSTRUCTIONS:

1. Provide Sensitive Resources Map according to non-structural BMP 1.1 in Section 5.0 Non-Structural BMPs. This map should identify waterbodies, floodplains, riparian areas, wetlands, woodlands, natural drainage ways, steep slopes, and other sensitive natural features.

2. Summarize the existing extent of each sensitive resource in the Existing Sensitive Resources Table (below, using Acres).

3. Summarize Total Protected Area as defined under BMPs in Section 5.0.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once.

EXISTING NATURAL SENSITIVE RESOURCE	MAPPED? yes/no/n/a	TOTAL AREA (Ac.)	PROTECTED AREA (Ac.)
Waterbodies			
Floodplains			
Riparian Areas			
Wetlands			
Woodlands	YES	3	0
Natural Drainage Ways			
Steep Slopes, 15% - 25%			
Steep Slopes, over 25%			
Other:			
Other:			
TOTAL EXISTING:		3	0

Worksheet 3. Nonstructural BMP Credits

PROTECTED AREA

5.1 Area of Protected Sensitive/Special Value Features (see WS 2) 0 Ac.

5.2 Area of Riparian Forest Buffer Protection 0 Ac.

5.6 Area of Minimum Disturbance/Reduced Grading 0 Ac.

TOTAL 0 Ac.

Site Area	*minus*	Protected Area	=	Stormwater Management Area
10	-	0	=	10

This is the area that requires stormwater management

VOLUME CREDITS

5.3 Protect/Utilize Natural Flow Paths

Flow Path/Depression _____ ft^2 x 1/4" x 1/12 = _____ ft^3

5.7 Minimum Soil Compaction

Lawn _____ ft^2 x 1/4" x 1/12 = _____ ft^3

Meadow _____ ft^2 x 1/3" x 1/12 = _____ ft^3

3.3 Protect Existing Trees

For Trees within 100 feet of impervious area:

Tree Canopy _____ ft^2 x 1/2" x 1/12 = _____ ft^3

For Trees within 20 feet of impervious area:

Tree Canopy _____ ft^2 x 1" x 1/12 = _____ ft^3

5.1 Disconnect Roof Leaders to Vegetated Areas

For Runoff directed to areas protected under 3.1 and 3.2

Roof Area _____ ft^2 x 1/3" x 1/12 = _____ ft^3

For all other disconnected roof areas

Roof Area _____ ft^2 x 1/4" x 1/12 = _____ ft^3

5.2 Disconnect Non-Roof impervious to Vegetated Areas

For Runoff directed to areas protected under 3.1 and 3.2

Impervious Area _____ ft^2 x 1/3" x 1/12 = _____ ft^3

For all other disconnected roof areas

Impervious Area _____ ft^2 x 1/4" x 1/12 = _____ ft^3

TOTAL NON-STRUCTURAL VOLUME CREDIT* 0 ft^3

** For use on Worksheet 5*

WORKSHEET 4 . CHANGE IN RUNOFF VOLUME FOR 2-YR STORM EVENT

PROJECT: 10 Lot Subdivision
Drainage Area: 1 (acres)
2-Year Rainfall: 2.8 in

Total Site Area: 10 **acres**
Protected Site Area: 0 **acres**
Stormwater Management Area: 10 **acres** (From Worksheet 3)

Existing Conditions:

Cover Type	Soil Type	Area (sf)	Area (ac)	CN	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Woodland	C	130,680	3.0	70	4.29	0.61	6,600
Meadow	C	304,920	7.0	71	4.08	0.65	16,469
Impervious	C	-	0.0				
TOTAL:			**10**				**23,069**

Developed Conditions:

Cover Type	Soil Type	Area (sf)	Area (ac)	CN	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Buildings	C	45050	1.0	98	0.20	2.57	9,645
Roads, Driveways, walks	C	42070	1.0	98	0.20	2.57	9,007
Lawn	C	333480	7.7	79	2.66	1.04	29,024
Detention Basin	C	15,000	0.3	79	2.66	1.04	1,306
TOTAL:			**10**				**48,982**

2-Year Volume Increase (ft3): 25,913

2-Year Volume Increase = Developed Conditions Runoff Volume - Existing Conditions Runoff Volume
= 48,982 - 23,069 = 25, 913 ft3

1. Runoff (in) = $Q = (P - 0.2S)^2 / (P + 0.8S)$ where

P = 2-Year Rainfall (in)

$S = (1000/CN) - 10$

2. Runoff Volume (CF) = Q x Area x 1/12 x 43,560 ft^2/acre

Q = Runoff (in)

Area = Stormwater Management Area (ac) *from Worksheet 3*

Note: Runoff Volume must be calculated for EACH land use type and soil.
The use of a weighted CN value for volume calculations is not acceptable.

WORKSHEET 5 . STRUCTURAL BMP VOLUME CREDITS

PROJECT: 10 Lot Subdivision
SUB-BASIN: 1

Required Control Volume (ft^3) - *from Worksheet 4* :		25,913
Non-structural Volume Credit (ft^3) - *from Worksheet 3* :	-	0
Structural Volume Reqmt (ft^3)		25,913

(Required Control Volume minus Non-structural Credit)

	Proposed BMP*	Area (ft^2)	Storage Volume (ft^3)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench	10	6,000
6.4.5	Rain Garden/Bioretention	10	20,020
6.4.6	Dry Well / Seepage Pit		
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			26,020

Total Structural Volume (ft^3):	26,020
Structural Volume Requirement (ft^3):	25,913
DIFFERENCE	107

* Complete BMP Design Checklist for each measure proposed
Note: rovide supporting Volume Calculations for each Structural BMP

Supporting Calculations for Worksheet 5: Part 1 Structural BMPs

Design Volume Calculations for Structural, Volume-Reduction BMPs

1. Infiltration Trenches:

Storage Volume = Area x Depth to overflow x Void Space in Stone
= 1,500 ft^2 x 1.0 ft x 40%
= 600 ft^3

Infiltration Volume for "Volume Abstraction" in Routing Process:
= Infiltration Rate x Infiltration Area x Infiltration Period (assume 6 hours)
= 1/2 in/hour x 1,500 ft^2 x 6 hr x (1/12) ft/in
= 375 ft^3

Total "Volume Abstraction" = Storage Volume + Infiltration Volume
= 600 ft^3 + 375 ft^3 = **975 ft^3**

2. Rain Gardens

Storage Volume = Surface Storage + Soil Storage*
= (Area x Depth) + (Area x Soil Depth x 10%)
= (1,820 ft^2 x 1.0 ft) + (1,820 ft^2 x 1 ft x 10%)
= 2,002 ft^3

Infiltration Volume for "Volume Abstraction" in Routing Process:
= Infiltration Rate x Infiltration Area x Infiltration Period (assume 6 hours)
= 1/2 in/hour x 1,820 ft^2 x 6 hr x (1/12) ft/in
= 455 ft^3

Total "Volume Abstraction" = Storage Volume + Infiltration Volume
= 2,002 ft^3 + 455 ft^3 = **2,457 ft^3**

Structural Volume Storage per Lot = Infiltration Trench + Rain Garden = 2,602 ft^3

* *Assume 1 ft depth modified soil with 10% void space for water retention.*

WORKSHEET 6 . SMALL SITE / SMALL IMPERVIOUS AREA EXCEPTION FOR PEAK RATE MITIGATION CALCULATIONS

The following conditions must be met for exemption from peak rate analysis for small sites under CG-1:

Yes The 2-Year Runoff Volume increase must be met in BMPs designed in accordance with Manual Standards

No Total Site Impervious Area may not exceed **1 acre.**

Yes Maximum Development Area is **10 acres**.

Yes Maximum site impervious cover cannot be greater than 50%.

Yes No more than 25% Volume Control can be in Non-structural BMPs

Yes Infiltration BMPs must have an infiltration rate of 0.5 in/hr.

Site Area	Percent Impervious	Total Impervious
10 acre	10%	1 acre
5 acre	20%	1 acre
2 acre	50%	1 acre
1 acre	50%	0.5 acre
0.5 acre	50%	0.25 acre

Peak Rate Calculations for Structural BMP Case

As discussed previously, the residential subdivision was modeled for peak rate mitigation using two techniques: Composite BMP and Travel Time Adjustment with Volume Diversion. As a comparison, dry detention basins were also simulated for conventional peak rate control as well as for extended detention. The properties of the infiltration trenches and rain gardens as shown in tables D-1 and D-2.

Table D-1. Properties of Infiltration Trenches

Stage (ft)	Area (SF)	Individual Storage (AF)	Total Storage (AF)	Individual Discharge (cfs)	Total Discharge (cfs)	Individual Infiltration (cfs)	Total Infiltration (cfs)
0.00	1,500	0.000	0.000	0.00	0.00	0.00	0.00
0.01	1,500	0.000	0.001	0.02	0.17	0.02	0.17
0.1	1,500	0.001	0.014	0.02	0.17	0.02	0.17
0.2	1,500	0.003	0.028	0.02	0.17	0.02	0.17
0.3	1,500	0.004	0.041	0.02	0.17	0.02	0.17
0.4	1,500	0.006	0.055	0.02	0.17	0.02	0.17
0.5	1,500	0.007	0.069	0.02	0.17	0.02	0.17
0.6	1,500	0.008	0.083	0.02	0.17	0.02	0.17
0.7	1,500	0.010	0.096	0.02	0.17	0.02	0.17
0.8	1,500	0.011	0.110	0.25	2.54	0.02	0.17
0.9	1,500	0.012	0.124	0.69	6.88	0.02	0.17
1	1,500	0.014	0.138	1.25	12.49	0.02	0.17

Table D-2. Properties of Rain Gardens

Stage (ft)	Area (SF)	Individual Storage (AF)	Total Storage (AF)	Individual Discharge (cfs)	Total Discharge (cfs)	Individual Infiltration (cfs)	Total Infiltration (cfs)
0.00	1,820	0.000	0.000	0.00	0.00	0.00	0.00
0.01	1,820	0.005	0.046	0.02	0.21	0.02	0.21
0.1	1,820	0.008	0.084	0.02	0.21	0.02	0.21
0.2	1,820	0.013	0.125	0.02	0.21	0.02	0.21
0.3	1,820	0.017	0.167	0.02	0.21	0.02	0.21
0.4	1,820	0.021	0.209	0.02	0.21	0.02	0.21
0.5	1,820	0.025	0.251	0.02	0.21	0.02	0.21
0.6	1,820	0.029	0.292	0.38	3.81	0.02	0.21
0.7	1,820	0.033	0.334	1.02	10.21	0.02	0.21
0.8	1,820	0.038	0.376	1.78	17.81	0.02	0.21
0.9	1,820	0.042	0.418	2.74	27.41	0.02	0.21
1	1,820	0.046	0.460	3.06	30.61	0.02	0.21

For the Composite BMP method, the infiltration trenches and rain gardens are summed into a single combined storage reservoir for modeling purposes. The properties of the "Composite BMP" are given in Table D-3.

Table D-3. Properties of Composite Infiltration Trench/Rain Garden

Stage (ft)	Total Storage (AF)	Total Discharge (cfs)	Total Infiltration (cfs)
0.00	0.000	0.00	0.00
0.01	0.047	0.38	0.38
0.1	0.097	0.38	0.38
0.2	0.153	0.38	0.38
0.3	0.208	0.38	0.38
0.4	0.264	0.38	0.38
0.5	0.320	0.38	0.38
0.6	0.375	3.98	0.38
0.7	0.431	10.38	0.38
0.8	0.486	20.35	0.38
0.9	0.542	34.29	0.38
1	0.597	43.10	0.38

All scenarios were modeled using the U.S. Army Corp of Engineers' Hydrologic Modeling System (HEC-HMS) Version 2.2.2 (May 28, 2003). The model schematic for the Composite BMP method is shown in Figure D-1. Notice that the impervious and pervious areas are routed separately to the Composite Storage Reservoir ("Comp. RG&Trench") and then the runoff being infiltrated is removed through a Composite Infiltration Rate ("Compos. Infilt") based on the design infiltration rate of the BMPs.

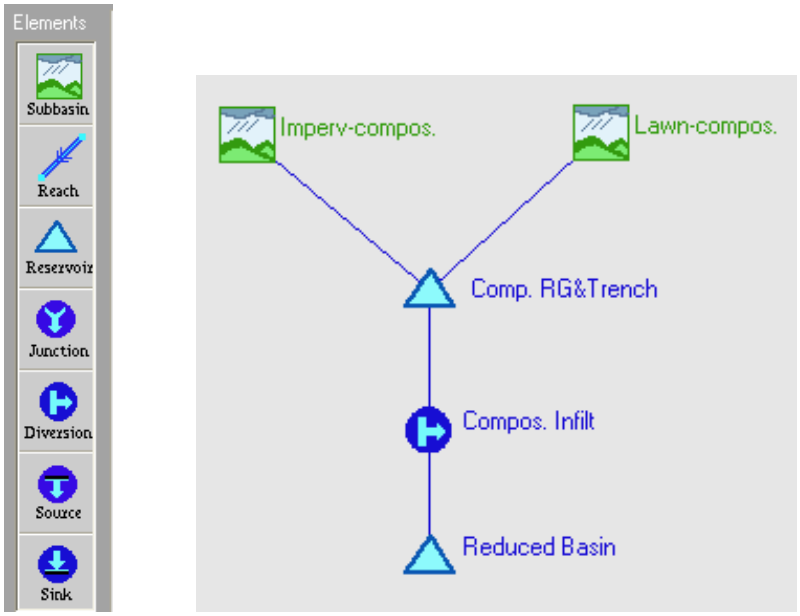


Figure D-1. Model Schematic for Composite BMP

The model schematic for 'Travel Time Adjustment with Volume Diversion' method is shown in Figure D-2. Figures D-3 and D-4 shown the model setups for conventional peak rate control and extended detention respectively.

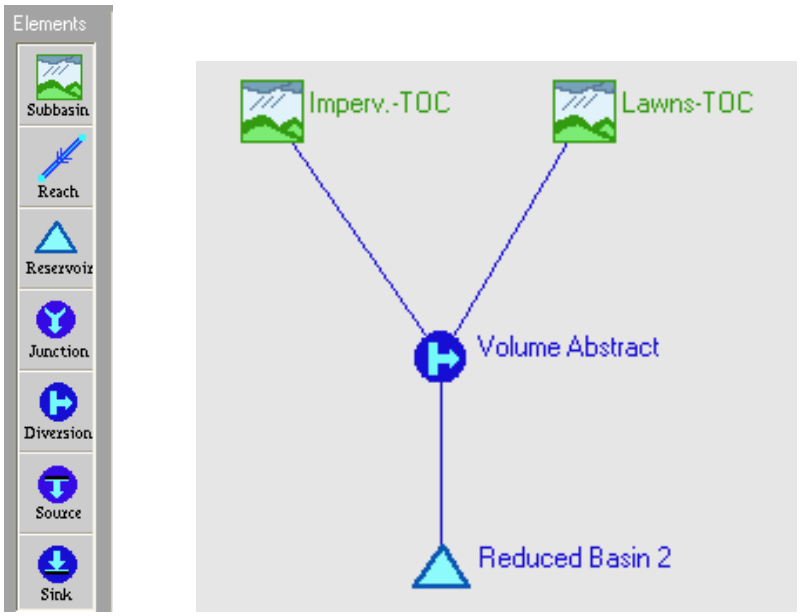


Figure D-2. Model Schematic for 'Travel Time Adjustment with Volume Diversion' method

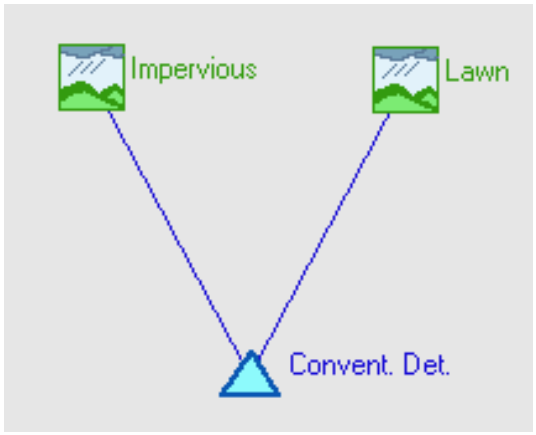


Figure D-3. Model Schematic for conventional peak rate control

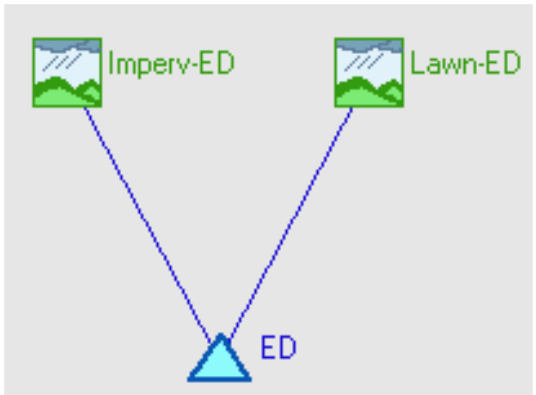


Figure D-4. Model Schematic for extended detention

In the 'Travel Time Adjustment with Volume Diversion' method the Time of Concentration was increased by the average residence time of the volume-reducing BMPs that were not be routed. The residence time for the 100-year storm was used to be conservative. The residence time is simply calculated by dividing the storage volume of the BMPs by the unmitigated post-development 100-year peak flow. As shown in Table D-4, this results in an average residence time of 9.1 minutes. The post-development time of concentration was increased by this amount in the model to account for the slowing effect of the volume-reduction BMPs.

Table D-4. Time of Concentration Adjustment

Storm Event	Peak Flow without BMPs (cfs)	Volume Control BMP Storage (CF)	Ave. Residence Time/ Time of Conc. Increase (min.)
100	47.5	26,020	9.1

In addition to increasing the time of concentration, the volume-reduction BMPs will also significantly reduce the amount of runoff being discharged by the site. In order to account for this in the 'Travel Time Adjustment with Volume Diversion' method and "volume abstraction" is incorporated into the model. The runoff simulated in the model is abstracted or "diverted" until the storage and infiltration volume of the BMPs is full. After that point, the diversion has no effect on the runoff rate or volume. The total volume abstracted in the model is calculated in Table D-5.

Table D-5. Total Volume Abstraction from Infiltration Trenches and Rain Gardens

BMP Type	Total Bottom Area (SF)	Design Infiltration Rate (in./hr)	Applied Infiltration Period Prior to Peak Runoff (hr)	Infiltration Volume (CF)	Storage Volume (CF)	Total Volume Abstraction (CF)
Infilt. Trench	15,000	0.5	6	3,750	6,000	9,750
Rain Garden	18,200	0.5	6	4,550	20,020	24,570
TOTAL	33,200	---	---	8,300	26,020	**34,320**

The results for the various scenarios are shown in Table D-6. Important results to note include:

- **The drastic increase in runoff for both cases without volume-reduction BMPs**
- **The volume control provided by infiltration BMPs, even for the 10- and 100-year storms**
- **The reduced downstream extended detention requirements when using infiltration BMPs:**
  - **Reduced from 45,000 to 25,000 for the "Composite BMP" method**
  - **Reduced from 45,000 to 16,000 for the "Travel Time Adjustment with Volume Diversion" method**
- **The improved peak rate control with volume-reduction BMPs**

Table D-6. Modeling Results for all scenarios

Runoff Volume Results

		Conv. Basin (40,000 CF)		Infilt. BMPs (26,000 CF)	
Storm Event	Pre-Dev. Runoff (in.)	Post-Dev. Runoff (in.)	Change (%)	Post-Dev. Runoff (in.)	Change (%)
1	0.43	1.09	153%	0.23	-47%
2	0.64	1.39	117%	0.47	-27%
10	1.57	2.62	67%	1.58	1%
100	2.71	3.96	46%	2.86	6%

Peak Rate for Detention - 40,000 CF Convential Basin & 45,000 CF E.D. Basin*

			Conventional Basin		Extended Det. Basin	
Storm Event	Pre-Dev. Peak (cfs)	Post-Dev. Peak (cfs)	Post-Dev. Peak w/ Basin (cfs)	Change (%)	Post-Dev. Peak w/ ED (cfs)	Change (%)
1	3.9	12.2	3.0	-23.1%	1.14	-62.0%
2	6.3	16.0	5.0	-20.6%	2.6	-48.0%
10	17.6	31.2	15.4	-12.6%	14.2	-7.8%
100	30.9	47.5	29.9	-3.2%	29.2	-2.3%

** Extended detention flow target for 1-year storm is 1.15 cfs from WS 9*

Peak Rate for Volume Control Approaches (Trenches/RGs & Reduced Detention)

			Composite Volume BMPs & 25,000 Det.		TOC Adj./ Vol. Abstract. & 16,000 CF Det.	
Storm Event	Pre-Dev. Peak (cfs)	Post-Dev. Peak (cfs)	Post-Dev. Peak w/ Volume Control (cfs)	Change (%)	Post-Dev. Peak w/ Volume Control (cfs)	Change (%)
1	3.9	12.2	1.2	-69.2%	0.22	-81.7%
2	6.3	16.0	3.0	-52.4%	0.7	-78.3%
10	17.6	31.2	14.9	-15.5%	11.8	-20.8%
100	30.9	47.5	30.8	-0.3%	30.4	-1.3%

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Part 2 – Structural and Non-structural BMP Design

Worksheet 1. General Site Information

INSTRUCTIONS: Fill out Worksheet 1 for each watershed

Date: _____

Project Name: 10 Lot Residential Subdivision

Municipality: Smith Township

County: Blair County

Total Area (acres): 10

Major River Basin: _____

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm#newtopics

Watershed: Purdy Creek

Sub-Basin: _____

Nearest Surface Water(s) to Receive Runoff: Tributary to Purdy Creek

Chapter 93 - Designated Water Use: HQ

http://www.pacode.com/secure/data/025/chapter93/chap93toc.html

Impaired according to Chapter 303(d) List?

http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/303d-Report.htm

Yes [ ]
No [X]

List Causes of Impairment:

Is project subject to, or part of:

Municipal Separate Storm Sewer System (MS4) Requirements?

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralPermits/default.htm

Yes [ ]
No [X]

Existing or planned drinking water supply?

Yes [ ]
No [X]

If yes, distance from proposed discharge (miles): _____

Approved Act 167 Plan?

http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/Approved_1.html

Yes [ ]
No [X]

Existing River Conservation Plan?

http://www.dcnr.state.pa.us/brc/rivers/riversconservation/planningprojects/

Yes [ ]
No [X]

Worksheet 2. Sensitive Natural Resources

INSTRUCTIONS:

1. Provide Sensitive Resources Map according to non-structural BMP 1.1 in Section 5.0 Non-Structural BMPs. This map should identify waterbodies, floodplains, riparian areas, wetlands, woodlands, natural drainage ways, steep slopes, and other sensitive natural features.

2. Summarize the existing extent of each sensitive resource in the Existing Sensitive Resources Table (below, using Acres).

3. Summarize Total Protected Area as defined under BMPs in Section 5.0.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once.

EXISTING NATURAL SENSITIVE RESOURCE	MAPPED? yes/no/n/a	TOTAL AREA (Ac.)	PROTECTED AREA (Ac.)
Waterbodies			
Floodplains			
Riparian Areas			
Wetlands			
Woodlands	YES	3	3
Natural Drainage Ways			
Steep Slopes, 15% - 25%			
Steep Slopes, over 25%			
Other:			
Other:			
TOTAL EXISTING:		3	3

Worksheet 3. Nonstructural BMP Credits

PROTECTED AREA

5.1 Area of Protected Sensitive/Special Value Features (see WS 2) **0** **Ac.**

5.2 Area of Riparian Forest Buffer Protection **0** **Ac.**

5.6 Area of Minimum Disturbance/Reduced Grading **3** **Ac.**

TOTAL **3** **Ac.**

Site Area	*minus*	Protected Area	=	Stormwater Management Area
10	-	3	=	7

This is the area that requires stormwater management

VOLUME CREDITS

5.3 Protect/Utilize Natural Flow Paths

Flow Path/Depression NA ft^2 x 1/4" x 1/12 = **0** ft^3

5.7 Minimum Soil Compaction

Lawn 105,006 ft^2 x 1/4" x 1/12 = **2,188** ft^3

Meadow 25,240 ft^2 x 1/3" x 1/12 = **701** ft^3

3.3 Protect Existing Trees

For Trees within 100 feet of impervious area:

Tree Canopy NA ft^2 x 1/2" x 1/12 = **0** ft^3

For Trees within 20 feet of impervious area:

Tree Canopy NA ft^2 x 1" x 1/12 = **0** ft^3

5.1 Disconnect Roof Leaders to Vegetated Areas

For Runoff directed to areas protected under 3.1 and 3.2

Roof Area NA ft^2 x 1/3" x 1/12 = **0** ft^3

For all other disconnected roof areas

Roof Area NA ft^2 x 1/4" x 1/12 = **0** ft^3

5.2 Disconnect Non-Roof impervious to Vegetated Areas

For Runoff directed to areas protected under 3.1 and 3.2

Impervious Area NA ft^2 x 1/3" x 1/12 = **0** ft^3

For all other disconnected roof areas

Impervious Area NA ft^2 x 1/4" x 1/12 = **0** ft^3

TOTAL NON-STRUCTURAL VOLUME CREDIT* 2,889 ft^3

** For use on Worksheet 5*

WORKSHEET 4 . CHANGE IN RUNOFF VOLUME FOR 2-YR STORM EVENT

PROJECT: 10 Lot Subdivision
Drainage Area: 1 (acres)
2-Year Rainfall: 2.8 in

Total Site Area: 10 **acres**
Protected Site Area: 3 **acres**
Stormwater Management Area: 7 **acres** (From Worksheet 3)

Existing Conditions:

Cover Type	Soil Type	Area (sf)	Area (ac)	CN	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Woodland Not Included							
Meadow	C	304,920	7.0	71	4.08	0.65	16,469
Impervious	C	-	0.0				
TOTAL:			**7**				**16,469**

Developed Conditions:

Cover Type	Soil Type	Area (sf)	Area (ac)	CN	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Buildings	C	45050	1.0	98	0.20	2.57	9,645
Roads, Driveways, walks	C	24619	0.6	98	0.20	2.57	5,271
Lawn	C	90006	2.1	79	2.66	1.04	7,834
Detention Basin	C	15,000	0.3	79	2.66	1.04	1,306
Lawn with Minimal Comp	C	105,005	2.4	79	2.66	1.04	9,139
Meadow	C	25,240	0.6	71	4.08	0.65	1,363
Woods Not Included	C						
TOTAL:			**7**				**34,557**

2-Year Volume Increase (ft3): 18,088

2-Year Volume Increase = Developed Conditions Runoff Volume - Existing Conditions Runoff Volume
= 34,5577 - 16,469 = 18,088 ft3

1. Runoff (in) = $Q = (P - 0.2S)^2 / (P + 0.8S)$ where

P = 2-Year Rainfall (in)

S = (1000/CN)-10

2. Runoff Volume (CF) = Q x Area x 1/12 x 43,560 ft^2/acre

Q = Runoff (in)

Area = Stormwater Management Area (ac) *from Worksheet 3*

Note: Runoff Volume must be calculated for EACH land use type and soil.
The use of a weighted CN value for volume calculations is not acceptable.

WORKSHEET 5 . STRUCTURAL BMP VOLUME CREDITS

PROJECT: 10 Lot Subdivision
SUB-BASIN: 1

Required Control Volume (ft^3) - *from Worksheet 4* :		18,088
Non-structural Volume Credit (ft^3) - *from Worksheet 3* :	-	2,889
Structural Volume Reqmt (ft^3)		15,199

(Required Control Volume minus Non-structural Credit)

Proposed BMP*		Area (ft^2)	Storage Volume (ft^3)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench	10	3,500
6.4.5	Rain Garden/Bioretention	10	11,770
6.4.6	Dry Well / Seepage Pit		
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			15,270

Total Structural Volume (ft^3):	15,270
Structural Volume Requirement (ft^3):	15,199
DIFFERENCE	71

* Complete BMP Design Checklist for each measure proposed BMP
NOTE: Provide supporting Volume Calculations for each Structural BMP

Supporting Calculations for Worksheet 5: Part 2 – Structural and Non-Structural BMP Design

Volume Credits for Structural BMPs

1. Infiltration Trench:

Storage Volume = Area x Depth to overflow x Void Space in Stone
= 875 ft^2 x 1.0 ft x 40%
= 350 ft^3

Infiltration Volume for "Volume Abstraction" in Routing Process:
= Infiltration Rate x Infiltration Area x Infiltration Period (assume 6 hours)
= 1/2 in/hour x 875 ft^2 x 6 hr x (1/12) ft/in
= 219 ft^3

Total "Volume Abstraction" = Storage Volume + Infiltration Volume
= 350 ft^3 + 219 ft^3 = **569 ft^3**

2. Rain Garden:

Storage Volume = Surface Storage + Soil Storage*
= (Area x Depth to Overflow) + (Area x Soil Depth x 10%)
= (1,070 ft^2 x 1.0 ft) + (1,070 x 1 ft x 10%)
= 1,177 ft^3

Infiltration Volume for "Volume Abstraction" in Routing Process:
= Infiltration Rate x Infiltration Area x Infiltration Period (assume 6 hours)
= 1/2 in/hour x 1,070 ft^2 x 6 hr x (1/12) ft/in
= 268 ft^3

Total "Volume Abstraction = Storage Volume + Infiltration Volume
= 1,177 ft^3 + 268 ft^3 = **1,445 ft^3**

Structural Volume Storage per Lot = Infiltration Trench + Rain Garden = 1,527 ft^3

** Assume 1 ft depth modified soil with 10% void space for water retention.*

GLOSSARY

alkalinity - A measure of the capacity of water to neutralize acids because of the presence of one or more of the following bases in the water: carbonates, bicarbonates, hydroxides, borates, silicates, or phosphates.

ammonia nitrogen (NH_4-N) - A reduced form of nitrogen produced as a by-product of organic matter decomposition and synthesized from oxidized nitrogen by biological and physical processes.

aspect ratio - Ratio of wetland cell length to width.

attenuation - Reduction in magnitude, as in the lowering of peak runoff discharge rates, in the case of dry ponds; or the reduction of contaminant concentrations, as in the action of biodegradation in wetlands or bioretention facilities.

base flow - Normally refers to the stream levels associated primarily with groundwater or subsurface contributions, as opposed to storm flow which corresponds to stream levels associated with recent precipitation and surface runoff.

bedrock - Layer of consolidated rock over which lies an overburden of soil (regolith), including unconsolidated rock.

benthic - Pertaining to occurrence on or in the bottom sediment of wetland and aquatic ecosystems, including wetlands.

Best Management Practices (BMP) - Activities, facilities, measures, or procedures used to manage the volume, rate and water quality of stormwater runoff.

biodiversity - The number of species of plants and animals in a defined area. Biodiversity is measured by a variety of indices that consider the number of species and, in some cases, the distribution of individuals among species.

biomass - The total mass of living tissues (plant and animal).

biochemical oxygen demand (BOD) - A measure of the concentration of aerobically degradable compounds in water. Measured as the oxygen consumed during degradation of organic and inorganic materials in water.

BMP fingerprinting - A series of techniques for locating BMPs (particularly ponds) within a development site so as to minimize their impacts to wetlands, forest, and sensitive stream reaches.

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BOD_5 - Five-day biochemical oxygen demand.

buffer - A vegetated strip immediately adjacent to a water body. The primary function of buffers is to protect the receiving water from sediment and pollutants derived from upstream areas. Ancillary benefits may include infiltration of rainfall and habitat enhancement. A buffer is a special case of a filter strip. Forested riparian buffers are one example of a best management practice related to the use of buffers.

channelization - The creation of a channel or channels resulting in faster water flow, a reduction in hydraulic residence time, and less contact between water and solid surfaces in the water body.

chemical oxygen demand (COD) - A measure of the concentration of substances which can be oxidized in water. Expressed as the oxygen equivalent consumed when an aqueous sample is reacted of the organic matter in water, based on reaction with a strong chemical oxidant.

choker course - A filter layer of finer material, usually crushed stone, that is installed over a coarse road base material. The purpose of the choker course is to provide a stable foundation for the construction of a pavement.

critical depth - The depth of flow at which the specific energy is a minimum for a given discharge rate. Flow is critical when the Froude number is equal to one:

$$F = \frac{V}{\sqrt{gD}}$$

where V, is the velocity of the flow, g, is the gravitational constant, and D, is the hydraulic depth of the flow.

denitrification – The removal of nitrate ions from soil or water, anaerobic microbial reduction of oxidized nitrate nitrogen to nitrogen gas.

dense graded material - Granular mixture characterized by a large range in particle sizes. Dense graded materials have superior structural properties to open graded materials. However, they are less permeable.

detritus - Dead plant material that is in the process of microbial decomposition.

diurnal - Occurring daily or during the daylight.

ecosystem - All organisms and the non-living environmental factors with which they interact.

ecotone - The boundary between adjacent ecosystem types. An ecotone can include environmental conditions that are common to both neighboring ecosystems and can have higher species diversity.

Eh - A measure of the reduction-oxidation (redox) potential of soil according to a hydrogen scale.

emergent plant - A rooted, vascular plant that grows in periodically or permanently flooded areas and has parts of the plant (stems and leaves) extending through and above the water plane.

eutrophic - Water containing an excess of plant-growth nutrients that typically result in algae blooms and extreme (high and low) dissolved-oxygen concentrations.

evapotranspiration - The combined processes of evaporation from the water or soil surface and transpiration of water by plants.

excessively rapid drainage - For purposes of this manual, corresponds to infiltration rates of soils in excess of 6 inches per hour. (Normally 6 inches is considered rapid drainage but the manual indicates that special precautions need to be taken with an infiltration rate of 6 inches per hour or more)

exfiltrate - The leaking of water to surrounding ground through openings in structures.

exotic species - A plant or animal species that has been intentionally or accidentally introduced and that does not naturally occur in a region.

extended detention - A function provided by BMPs which incorporate a water quality storage. BMPs with extended detention, intercept runoff and then release it over an extended period of time.

extended detention (ED) pond - Temporarily detains part of stormwater runoff for up to 24 hours after a storm by using a fixed orifice. ED ponds normally are "dry" between storm events and do not have permanent standing water. An enhanced ED pond is designed to prevent clogging and re-suspension. It provides flexibility in achieving target detention times. It may be equipped with plunge pools near the inlet, a micropool at the outlet, and may have an adjustable reverse-sloped pipe at the ED control device.

extended detention control device - A pipe or series of pipes that extend from the riser of the stormwater pond that are used to gradually release stormwater from the pond over a 12- to 48-hour interval.

fascine - Bundled willow cuttings used to stabilize stream banks. Bundling allows otherwise weak green twigs to reinforce each other and resist the forces of stream currents.

field capacity - The quantity of water which will not freely drain from the root zone of shallow soil layers. Usually measured as the moisture content (by volume) in soil at a capillary tension of .33 bars.

filter strip - A vegetated boundary characterized by uniform mild slopes. Filter strips may be provided down-gradient of developed tracts to trap sediment and sediment-borne pollutants and to reduce imperviousness. Filter strips may be forested or vegetated turf. Filter strips located adjacent to waterbodies are called buffers.

flash boards - Removable boards used in a weir to control water levels.

floating aquatic plant - A rooted or non-rooted vascular plant that is adapted to have some plant organs (generally the chlorophyll-bearing leaves) floating on the surface of the water in wetlands, lakes, and rivers.

flood fringe - The flood fringe occupies the distal parts of the floodplain, outside of the floodway. Complete obstruction of the flood fringe will not significantly increase flood levels. The flood fringe boundary is typically based on an increase in flood level of one foot during the 100-year return frequency flooding event.

floodplain – Lands adjoining a river or stream that have been or may be expected to be inundated by flood waters in a 100-year frequency flood.

floodway – The channel of the watercourse and portions of the adjoining floodplains which are reasonably required to carry and discharge the 100-year frequency flood. Unless otherwise specified, the boundary of the floodway is as indicated on maps and flood insurance studies provided by FEMA. In an area where no FEMA maps or studies have defined the boundary of the 100-year frequency floodway, it is assumed, absent evidence to the contrary, that the floodway extends from the stream to 50 feet from the top of the bank of the stream.

forebay - Stormwater design feature that uses a small basin to settle out incoming sediment before it is delivered to a stormwater BMP.

freeboard - The vertical distance between water surface elevation experienced during the design flood and the crest elevation of a dam, levee, floodwall or other embankment.

fresh water - Water with a total dissolved solids content less than 500 mg/L (0.5 parts per thousand salts).

gabion - Wire cage used to contain rip rap and stone. Gabions are used to increase the resistance of rip rap to movement caused by flowing water.

geotextile - A fabric manufactured from synthetic fiber that is designed to achieve specific engineering objectives, including seepage control, media separation (e.g., between sand and soil), filtration, or the protection of other construction elements such as geomembranes.

greenway - A strip or belt of vegetated land that typically includes both *upland* and *riparian* areas. Greenways are often used for recreation, as a land use buffer, or to provide a corridor and habitat for wildlife.

habitat - The environment occupied by individuals of a particular species, population, or community.

headwall - A wall of stone, metal, concrete, or wood at the end of a culvert or drain to protect fill from scour or undermining, increase hydraulic efficiency of conduit, divert flow, retard disjointing of short sectional pipe, or serve as a retaining wall.

heavy metals - Metallic elements having atomic weights above 21 on the periodic table.

herbaceous - Plant parts that contain chlorophyll and are non-woody.

hydraulic conductivity (K) - An expression of the readiness with which a liquid such as water flows through a soil in response to a given potential gradient. Hydraulic conductivity is a constant physical property of soil or rock, one of several components responsible for the dynamic phenomenon of flow.

hydraulic loading rate (HLR) - Ratio of the surface area of a hydraulic device and the average rate at which water is delivered to the A measure of the application of a volume of water to a land area with units of volume per area per time or simply reduced to applied device water depth per time (for example, $m^3/(m^2/d)$ or cm/d).

hydraulic residence time (HRT) - A measure of the average time that water occupies a given volume with units of time. The theoretical HRT is calculated as the volume divided by the flow (for example, $m^3/(m^2/d)$). The actual HRT is estimated on the basis of tracer studies that used conservative tracers such as lithium or dyes.

hydric soil - A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions. Hydric soil that is in areas having indicators of hydrophytic vegetation and wetland hydrology is wetland soil.

hydrograph - A record of the change in flow rate with time.

hydrologic soil group - A designation developed by the NRCS which describes the infiltration capacity of soil. Soil associations are categorized in decreasing infiltration capacity from A to D.

hydroperiod - The period of wetland soil saturation or flooding. Hydroperiod is often expressed as a number of days or a percentage of time flooded during an annual period (for example, 25 days or 7 percent).

infiltration - The entrance of surface water into the soil, usually at the soil/air interface.

infiltration testing - Specific tests designed to measure the saturated movement of water into the soil in a single direction downward through a two dimensional soil surface.

lacustrine - The deep-water zone of a lake or reservoir.

limnetic - Relating to or inhabiting the open water part of a freshwater body with a depth that light penetrates. The area of a wetland without emergent vegetation.

littoral zone - The shoreward zone of a lake or *wetland*. The area where water is shallow enough for emergent vegetation to dominate.

macrophyte - Macroscopic (visible to the unassisted eye) vascular plants.

manning's equation - A formula for calculating the anticipated uniform flow in an open-channel flow, published by Manning in 1890.

marsh - A wetland dominated by herbaceous emergent plants.

micronutrient - A chemical substance that is required for biological growth in relatively low quantities and in small proportion to the major growth nutrients. Some typical micronutrients include molybdenum, copper, boron, cobalt, iron, and iodine.

mitigation - The replacement of functional values lost when an ecosystem is altered. Mitigation can include replacement, restoration, and enhancement of functional values.

nitrification - Biological transformation (oxidation) of ammonia nitrogen to nitrite and nitrate forms.

nitrogen fixation - A microbial process in which atmospheric nitrogen gas is incorporated into the synthesis of organic nitrogen.

open graded material - Uniform granular mixture with a narrow distribution of grain sizes. Open graded material has higher permability than dense graded material.

organic nitrogen (Org-N) - Nitrogen that is bound in organic compounds.

palustrine wetland - All nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens; and all such tidal wetlands in areas where salinity from ocean-derived salts is below 0.5 parts per thousand.

peak attenuation storage - The volume set aside within a BMP for the purpose of attenuating the inflow runoff peak rate.

percolation - The downward movement under the influence of gravity of water under hydrostatic pressure through the interstices of the rock or soil.

perennial - Persisting for more than one year. Perennial plant species persist as woody vegetation from year to year or resprout from their rootstock annually.

periphyton - The community of microscopic plants and animals that grows on the surface of emergent and submergent plants in water bodies.

permeability – The ability of rock, soil or other material to transmit a gas or liquid.

permittivity (cross-plane flow capacity) - Rate that water will flow freely through a thin layer, such as a geotextile. Equal to the hydraulic conductivity divided by the thickness of the layer. Permittivity is measured in units of inverse time (e.g., sec^{-1}).

photic zone - The area of a water body receiving sunlight.

piezometric surface - The surface defined by elevation to which groundwater will rise in a well.

plant community - All of the plant species and individuals occurring in a shared habitat or environment.

plug flow - Linear flow along the length of a wetland cell. Ideal plug flow does not involve the dispersion or diffusion of constituents. The flow can be perceived as a series of independent "packets" of water that do not interact with each other.

plunge pool - A small permanent pool at either the inlet to a BMP or at the outfall from a BMP. The primary purpose of the pool is to dissipate the velocity of stormwater runoff.

pollutant removal - Removing pollutants by decomposing them or eliminating them from an area or system (eg. volitize), or rendering non-harmful or unavailable in a soil or medium by means of adsorption, chelation, and similar binding mechanisms.

pore space - Open space in rock or granular material; also known as interstices.

precipitation - A deposit on the earth of hail, mist, sleet, rain or snow.

protozoa - Small, one-celled animals including amoebae, ciliates, and flagellates.

receiving water - A water body into which wastewater or treated effluent is discharged.

recharge - Replenishment of groundwater reservoirs by infiltration through permeable soils.

return period (storm event) - The average period of time between the occurrence of storms of equal or greater magnitude. The probability that such a storm will occur in any given year is equal to the reciprocal of the return period (e.g. there is a 50% chance that a 2-year storm event will occur in any given year, but only a 10% chance that a 10-year storm event will occur).

rhizosphere - The chemical sphere of influence of plant roots growing in flooded soils. Depending on the overall oxygen balance (availability and consumption), the rhizosphere can be oxidized, resulting in the presence of aerobic soil properties in an otherwise anaerobic soil environment.

riparian - Pertaining to a stream or river. Also, plant communities occurring in association with any spring, lake, river, stream, or creek through which waters flow at least periodically.

riparian corridor - Narrow strip of land, centered on a stream, that includes the floodplain as well as related riparian habitats adjacent to the floodplain.

riverine wetlands - Wetlands associated with rivers.

runoff capture design storm - Benchmark rainfall event, used to develop criteria for designing the groundwater recharge function of BMPs. The runoff capture design storm is the largest rainfall event from which no appreciable runoff is expected to occur. Complete specification of the storm includes the rainfall depth in inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a Type II rainfall distribution. See Section 5.3 of the Handbook.

runoff capture storage - The combined storage volume provided by BMPs on a site for the retention and eventual infiltration of rainfall.

runoff capture volume - The minimum volume of rainfall that should be retained and completely infiltrated onsite during every storm. It is also equal to the rainfall quantity associated with the runoff capture design storm. The runoff capture volume is conveniently stated as a rainfall volume, in inches, over the area of the site.

runoff curve number (CN) - A parameter developed by the NRCS which is an indicator of runoff potential. Curve number is related to hydrologic soil group and land use type. The larger the runoff curve number, the greater the percentage of rainfall that will appear as runoff.

runoff peak attenuation design storm - Benchmark rainfall event, used to develop criteria for the design of runoff peak attenuation BMPs. The design criteria generally requires that the predicted post development peak runoff rate for the selected runoff peak attenuation design storm will not exceed the peak associated with redeveloped condition. Complete specification of the storm includes rainfall depth in inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a Type II rainfall distribution. See Section 5.3 of the Handbook.

saturated soil - Soil in which the pore space is completely filled with water.

seasonally high water table - Shallow water tables associated with periods of recent high levels of precipitation and/or low levels of evapo-transpiration. Frequently determined in the spring.

seed bank - The accumulation of viable plant seeds occurring in soil and available for germination under favorable environmental conditions.

setback - A distance from the edge of a water body within which intensive development is restricted. Setbacks are established by local regulation for the purpose of maintaining open

space next to streams, lakes, and other water bodies. The area within setbacks is frequently used for flood control, recreation, preservation of drinking water supply, and wildlife habitat enhancement.

sheet flow - Water flow with a relatively thin and uniform depth.

short-circuit - A faster, channelized water flow route that results in a lower actual hydraulic residence time than the theoretical hydraulic residence time. This may reduce the effectiveness of a BMP.

spillway design flood (SDF) - Benchmark rainfall event, used to develop criteria for the design of BMPs that incorporate emergency spillways or overflows. Complete specification of the storm includes rainfall depth in inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a Type II rainfall distribution. See Section 5.3 of the Handbook.

stage-area curve – A line graph showing the relationship between the depth of water and the surface area of a pond, wetland, or lake.

stage-discharge curve – a line graph showing the relationship between water depth and outflow from a body of water.

subcritical flow - The state of flow when the depth is greater than the critical depth.

substrate - Substances used by organisms for growth in a liquid medium. Surface area of solids or soils used by organisms to attach.

succession - The temporal changes of plant and animal populations and species in an area that has been disturbed.

super critical flow - The state of flow when the depth is less than the critical depth. Transitions between supercritical and sub-critical flow may result in turbulence associated with a hydraulic jump.

surface infiltration rate - The rate at which water enters the soil or other porous surface. The measurement of surface infiltration rates requires that the underlying soil be completely saturated and that infiltration occurs by gravity under a unit hydraulic gradient.

tailwater condition—minimum and maximum - The depth of water in the receiving water body at a structure outfall.

terrestrial - Living or growing on land that is not normally flooded or saturated.

total nitrogen (TN) - A measure of all organic and inorganic nitrogen forms in a water sample. Functionally, TN is equal to the sum of TKN and NO_3 + NO_2-N.

total organic carbon (TOC) - A measure of the total reduced carbon in a water sample.

total phosphorus (TP) - A measure of the total phosphorus in a water sample, including organic and inorganic phosphorus in particulate and soluble forms.

total suspended solids (TSS) - A measure of the filterable matter in a water sample.

tractive force - The total cross-sectional force experienced by a rigid channel or conduit as a result of channel flow (expressed in units of force per length). This force tends to displace soil particles, rocks and channel liners in the downstream direction and must be resisted by friction or by structural anchors. The tractive force is equal to the unit tractive force multiplied by the wetted perimeter of the conduit.

transition zone - The area between habitats or ecosystems (see ecotones). Frequently, transition zone is used to refer to the area between uplands and wetlands. In other cases, wetlands are referred to as transitional areas between uplands and aquatic ecosystems.

transmissivity (in-plane flow capacity) - Rate that water can be made to flow through the cross section of a thin layer or conduit under the influence of a unit hydraulic gradient. Measured as a volumetric rate per unit width (e.g., square feet meters per minute, or gallons per minute per foot). Equal to the hydraulic conductivity times the thickness of the layer or conduit.

transpiration - The transport of water vapor from the soil to the atmosphere through growing plants.

type II rainfall distribution - Standard NRCS 24-hour rainfall distribution which applies to the state of Pennsylvania. The distribution allocates rainfall as a percentage of total rainfall over discrete time intervals.

uniformity coefficient - A measure of the range in particle sizes associated with a granular mixture. Materials with the lowest uniformity coefficients are most uniform. Uniform materials are also called open graded materials. If the uniformity coefficient is less than 4 or 5, the material is considered uniform in particle size. The uniformity coefficient is computed as follows:

$$C_u = (D_{60} / D_{10})$$

D_{60} is the sieve opening size through which 60 percent of the layer material will pass. D_{10} is the sieve opening size through which 10 percent of the layer material will pass.

unit tractive force (or tractive stress) - The stress (expressed in units of force per area) induced by open channel flow on the bottom and sides of its conduit or channel. This stress is responsible for sediment erosion and the downstream transport of streambed materials. The average unit force acting on a channel cross-section is equal to the product of the unit weight of water, the slope of the channel, and the hydraulic radius of the flow.

upland - An area that is not an aquatic, wetland, or riparian habitat. An area that does not have the hydrologic regime necessary to support hydrophytic vegetation.

water quality design storm - Benchmark rainfall event, used to develop criteria for the design of water quality BMPs. Water quality design storms are used to size BMPs that are intended to achieve specific quality treatment objectives. Criteria based on water quality storms generally require that the design treatment efficiency be achieved during the water quality design storm and all smaller events. Complete specification of the storm includes rainfall depth in inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a type II rainfall distribution. See Section 5.3 of the Handbook.

water quality storage - The volume set aside within a BMP to detain storm runoff. The detained water is released over an extended period of time. The water quality storage is frequently expressed as a multiple of the water quality volume.

water quality velocity - The maximum flow velocity encountered in a water quality BMP during the course of the water quality design storm.

water quality volume - The total volume of runoff which is delivered to the inlet of a water quality BMP during the course of the water quality design storm.

wattles - Fence or barrier constructed of interwoven twigs and branches used to stabilize soil from erosive forces.

weir - A device used to control and measure water flow.

weir gate - Water-control device used to adjust water levels and measure flows simultaneously.

wetland - An area that is inundated or saturated by surface water or groundwater at a frequency, duration, and depth sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs and similar areas.

wilting point - Quantity of water which will not be removed from soil under normal conditions of evaporation and plant transpiration. Usually measured as the moisture content (by volume) in soil with a capillary tension of 15 bars.

zonation - The development of a visible progression of plant or animal communities in response to a gradient of water depth or some other environmental factor.

Stormwater Management Guidance Manual

Version 2.0

City of Philadelphia

Prepared by:
Philadelphia Water Department
Office of Watersheds

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Philadelphia Stormwater Management Guidance Manual Version 2.0

The following list summarizes the significant changes introduced with Version 2.0 of the Philadelphia Stormwater Management Guidance Manual. Please note, this is not a complete list of all changes.

Earth Disturbance: Section 2.1: Earth Disturbance has been added to provide more information on how to calculate the limits of earth disturbance.

Applicability: Section 2.2: Determining Applicability has been expanded to discuss the applicability of Conceptual Reviews, Erosion and Sediment Control, Watershed Specific Requirements, the Philadelphia Water Department (PWD) Stormwater Management Regulations, and Public Health and Safety Rates.

Conceptual Review: All projects that generate an earth disturbance of 5,000 square feet or more must submit an ERSA worksheet to PWD for conceptual review. Refer to **Section 3**: Site Planning for more information.

Green Project Review: Projects that are able to disconnect 95% or more of the post construction Directly Connected Impervious Area (DCIA) may be eligible for a 5-day project review time. Refer to **Section 4.2.1**: Green Project Review for more information.

Tree Credits: New trees must now be planted within 10 feet of ground level DCIA to be eligible for the 100 square foot tree credit. Refer to **Section 4.2.4**: Maximize Tree Canopy over Impervious Cover.

Water Quality: When infiltration is not feasible all or a portion of the water quality volume must be routed through PWD-approved stormwater management practices that provide volume reduction, flow attenuation and water quality treatment. Refer to **Section 4.3.1**: Estimate Level of Control Needed for more information.

Erosion and Sediment Pollution (E & S) Control: Section 5.1: Erosion and Sediment Pollution Control Plan has been added to provide more information on the requirements for E &S Control.

Rational Method: The use of the Rational Method will no longer be accepted for runoff estimation. Refer to **Section 5.3.2**: Runoff Estimation for more information.

Predevelopment Condition: The predevelopment condition for runoff calculation is defined as the dominant land use for the previous ten (10) years. Refer to **Section 5.3.2**: Runoff Estimation for more information.

Flood Control: For the purposes of Flood Control calculations, all nonforested, pervious area and 20% of existing impervious area must be considered meadow. Refer to **Section 5.3.2**: Runoff Estimation for more information.

Sections 6, 7, and 8: Previous Section 6.1, 6.2. and 6.3 have been converted into **Section 6**: Utilizing Existing Site Features, **Section 7**: Stormwater Management Practice Design Guidelines, and **Section 8**: Landscape Guidance.

Waiver Request Forms: Standard waiver request forms for release from the infiltration requirement and the 3-inch minimum orifice size are available in **Appendix F.4**: Special Circumstances and Waiver Requests.

Worksheets: Worksheets 2 and 3 have been updated and are now Worksheet 2: Directly Connected Impervious Area, Worksheet 3A: Water Quality, Channel Protection, and Worksheet 3B: Flood Control. Refer to **Appendix E**: Worksheets and Checklists for more information.

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1 Introduction

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1.1 Background

1.1.1 Stormwater Ordinance and Regulations

Existing Policy

Chapter 14-1600 of Philadelphia's Code, houses the stormwater legislation for the City. See the following Code sections:

§14-1603.1. Stormwater Management Controls

§14-1603.2. Environmental Controls for the Wissahickon Watershed

§14-1606. Flood Plain Controls

The Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations) have been developed as per the Philadelphia Code, Chapter 14-1603.1.6.c.1

Overview of the Stormwater Regulations

There are three major elements to the Stormwater Regulations: Water Quality, Channel Protection, and Flood Control requirements.

Water Quality Requirement

The Water Quality requirement stipulates management of the first one inch of runoff from all Directly Connected Impervious Areas (DCIA) within the limits of earth disturbance. The Water Quality requirement is established to: (1) recharge the groundwater table and increase stream base flows; (2) restore more natural site hydrology; (3) reduce pollution in runoff; and (4) reduce combined sewer overflows (CSO) from the City's combined sewer systems. The requirement is similar to water quality requirements in surrounding states and in other major cities.

1) The requirement must be met by infiltrating the water quality volume unless infiltration is determined to be infeasible (due to contamination, high groundwater table, shallow bed rock, poor infiltration rates, etc.) or where it can be demonstrated that infiltration would cause property or environmental damage.

2) A waiver from the infiltration requirement must be submitted and approved if infiltration is not feasible. Waivers are available in **Appendix F.4**: Special Circumstances and Waiver Requests. When infiltration is not feasible for all or a portion of the water quality volume, the remaining portion must be treated by a PWD-approved stormwater management practice (SMP). Treatment and release requirements differ for separate and combined sewer areas, but all areas must route a minimum of 20% of the water quality volume through a PWD-approved SMP that provides volume reduction.

- **Separate sewer areas:** The water quality volume must be routed through a SMP that provides volume reduction, flow attenuation, and water quality treatment.

- **Combined sewer areas:** Runoff from a minimum of 20% of the DCIA must be routed through a PWD-approved volume reducing SMP. The release rate for the water quality volume must not exceed 0.24 cfs per acre of DCIA, and the volume must be detained in the SMP for no less than 24 hours and no more than 72 hours.

Channel Protection Requirement

The Channel Protection requirement is a slow release of the 1-year, 24-hour storm event detained from DCIA. The Channel Protection requirement is established to: (1) protect quality of stream channels and banks, fish habitat, and man-made infrastructure from the influences of high stream velocity erosive forces and (2) reduce the quantity, frequency and duration of CSOs.

The requirement applies equally to rivers and streams, and also to sites discharging to drainage ditches, natural or man-made ponds, and sewers if those systems ultimately discharge to receiving waters. However, the Channel Protection requirement does not apply to redevelopment which is under one acre or discharges to the Delaware River and the Schuylkill River main channels.

Philadelphia's Channel Protection requirement is modeled after those adopted in many other cities and states, including Atlanta, Baltimore, Boston, Detroit, Minneapolis, Portland, Seattle, Washington D.C., Maryland, New Jersey, and New York.

- Channel Protection requirement: Detain and release runoff from DCIA at a maximum rate of 0.24 cfs per acre in no less than 24 hours and no more than 72 hours.

- *Reducing DCIA within the limints of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Channel Protection requirement.*

The Water Quality and Channel Protection requirements are not additive. Management of the Water Quality requirement may reduce the storage volume required to meet the Channel Protection requirement. It might also be possible to meet both requirements in the same SMP or in a train of linked SMPs.

Flood Control Requirement

The Flood Control requirement is established to: (1) reduce or prevent the occurrence of flooding in areas downstream of the development site, as may be caused by inadequate sewer capacity or stream bank overflow and (2) to reduce the frequency, duration and quantity of overflows in combined sewer sheds.

The Flood Control requirement is based upon ongoing watershed wide Pennsylvania Stormwater Management Act (Act 167) planning studies determining flood management districts for controlling peak rates of runoff. In general, a development project is required to meet peak rates of runoff post-development equal to pre-development conditions. As Act 167 planning programs are completed for Philadelphia's watersheds, new Flood Control Districts will be listed in the Manual which will more accurately reflect the level of flood protection needed in localized settings.

In Flood Management District C, development sites which can discharge directly to the Delaware River or Schuylkill River main channels without the use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the pre-development conditions peak rate as required in District A provisions for the specified design storm.

- *Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Flood Control requirement.*

1.1.2 The Changing Regulatory Environment

Stormwater runoff from almost all the developed areas of the City, whether served by separate stormwater sewers or combined sewers, is causing impairment to the aquatic and riparian habitats of streams and rivers in Philadelphia. These water bodies are suffering from streambank and channel erosion resulting in the exposure of sewer infrastructure and decreased stream baseflow due to reduced groundwater recharge. The streams do not support healthy aquatic communities, do not meet uses designated by the State, do not serve as amenities to the community, and occasionally causes property damage due to flooding. In addition, stormwater is an important source of pollution to the drinking water intakes on the Schuylkill and Delaware Rivers.

These problems are not unique to Philadelphia. Stormwater Regulations are changing around the country to address these and similar problems. In general, these newer approaches to stormwater management require controls to improve the quality of stormwater prior to discharge, to reduce the effects of stormwater caused erosion and siltation, and measures to increase groundwater recharge. The Stormwater Regulations in Philadelphia ensures that Philadelphia has an up-to-date and effective stormwater program that meets the state and federal requirements and can be coordinated with the changing Regulations occurring in upstream municipalities.

The Stormwater Regulations were developed to meet a number of environmental, economic, social and regulatory goals for the City:

Quality of Life – Along the Riverfront and in the Neighborhoods

The quality of life for people living and working in Philadelphia depends on both a healthy economy and a healthy environment. Philadelphia sits at the confluence of the Schuylkill and Delaware Rivers and has an extensive park system that conserves most land along its smaller creeks in a natural condition. This creates an opportunity for improved recreational and economic activities along the waterfronts and stream corridors. Philadelphia is making a substantial public investment in parks, greenways (links between neighborhoods and water corridors), and access to water-based activities over the coming decades to identify itself as a New River City. Effective stormwater management is necessary to make these riverfront and stream corridor areas safe and inviting.

Flooding

Historically, Philadelphia's stormwater management requirements have focused on avoidance of flooding caused by increases in impervious coverage. These measures have been generally effective and will be continued. However, some problem areas have been identified in existing developed areas through the Act 167 program. As Act 167 planning studies continue for Philadelphia's watersheds new Flood Control Districts will be determined that more accurately reflect the level of flood protection needed in localized settings. The Stormwater Regulations will ensure that, over time, flooding frequency and severity will decrease as areas are redeveloped according to the stormwater requirements.

Impaired Water Bodies and TMDLs

The Commonwealth of Pennsylvania designates uses that streams and rivers are required to support. These uses generally include water supply, recreation and fish consumption, and support of healthy aquatic communities. Currently, every river and stream in the City is listed as impaired, or not attaining its designated uses. Urban runoff, storm sewers, and CSOs are listed as sources of impairment for most Philadelphia streams. Some water bodies are listed as impaired by specific pollutants. For these, the State ultimately requires TMDL (Total Maximum Daily Load) to be set and attained. A TMDL is the maximum load of a specific pollutant that can be discharged by all sources and still allow the stream to meet water quality standards. The Stormwater Regulations are designed to significantly reduce the pollution associated with stormwater and CSOs, and will be a significant part of the measures used to attain TMDLs.

NPDES Stormwater Permits and Regulations

Storm sewers discharging to surface waters in Philadelphia are regulated under NPDES (National Pollution Discharge Elimination System). Measures required under NPDES stormwater permits include stormwater management during construction and stormwater management on the developed site after construction. The Stormwater Regulations keep Philadelphia in compliance with requirements in its stormwater permit.

Pennsylvania Stormwater Management Act

The Pennsylvania Stormwater Management Act (Act 167) is administered by Pennsylvania Department of Environmental Protection (PADEP) and is designed to address the management of stormwater runoff resulting from development. Act 167 addresses both water quantity and quality, but it is most focused on quantity and flooding issues. Philadelphia collaborated with Delaware, Montgomery, and Chester Counties to produce an Act 167 Plan for the Darby-Cobbs Creek in 2004. Ultimately, plans will be produced for Tookany/Tacony-Frankford Creek, Pennypack Creek, Poquessing Creek, and Wissahickon Creek. Due to overlapping requirements of the NPDES and Act 167 programs, PADEP encourages municipalities to develop stormwater management programs that meet the requirements of both concurrently. The Stormwater Regulations bring Philadelphia into compliance and ensure that the entire region has similar stormwater management controls in place.

NPDES Combined Sewer Permits and Regulations

Approximately 40% of Philadelphia's land area is served by sewers that carry sanitary sewage and stormwater in a single pipe. During dry weather, all this flow is treated at water pollution control plants before discharge to receiving waters. During wet weather, total flow exceeds the capacity of the sewer system and a portion of the flow is discharged untreated to receiving waters (combined sewer overflow).

Stormwater management is an integral part of Philadelphia's approach to CSO management. United States Environmental Protection Agency's (USEPA) CSO Control Policy, published in 1994, promotes effective stormwater management on a watershed basis. The most effective SMPs increase infiltration and evaporation at the site level and reduce the amount of wet weather flow in the sewer system. Other SMPs detain stormwater and release it to the sewer system at a slower rate, taking advantage of sewer system capacity over a longer period of time. These techniques are most effective during small storms. Techniques designed to limit streambank erosion and flood damage during large storms work equally well in areas of combined sewers and separate storm sewers. The Stormwater Regulations will, over time, significantly decrease the number of CSOs and are necessary if Philadelphia is to comply with federal and state CSO policy.

Drinking Water Source Protection

The Delaware River and Schuylkill River are sources of drinking water for Philadelphia residents. The intakes on these rivers are also influenced by the water quality found in the Wissahickon, Pennypack, and Poquessing Creeks. Protection of source water is critical to citizen health and future economic development in Philadelphia. One of the many critical links between the Stormwater Regulations and the protection of Philadelphia's drinking water sources is USEPA's Surface Water Treatment Rule (SWTR) to address microbial and virus contamination. The SWTR requires that a surface water system have sufficient treatment to reduce source water concentrations of *Giardia lamblia* cysts and viruses by at least 99.9 percent (3 log) and 99.99 percent (4 log), respectively. A watershed control program that includes reduction in stormwater related pollutant loads will be an important aspect of meeting these microbial and virus reduction requirements.

Improving the Development Process in Philadelphia

Clarification of stormwater management requirements and simplification of the development process can benefit both the environment and the economy. Efforts to redevelop vacant and abandoned lands provide opportunities to integrate better stormwater management with economic development. The Stormwater Regulations are designed to create standards consistent with industry practice, to provide checklists and manuals so that developers know exactly what is required, and to apply known, objective standards to all new development or redevelopment applications.

1.2 Organization

This Manual is intended to guide the developer in meeting the requirements of the Stormwater Regulations. Currently some practices and design methods in this manual are considered standards while others are simply recommendations. It is likely that with future revisions some elements will become more prescriptive while others become less prescriptive. Please be aware that these changes might occur and that the most up-to-date version can always be found at the Philadelphia Stormwater website www.PhillyRiverInfo.org.

The Manual is laid out to guide the developer through the entire site design process, beginning with initial site design considerations, through the Post-Construction Stormwater Management Plan (PCSMP) submittal elements, and ultimately PWD prerequisite approval on Building Permit approval. Tools are provided to assist in completion and submittal of a PCSMP consistent with the intent of PWD. They include flowcharts to guide the developer through each section, worksheets to assist with calculations, and checklists to ensure the PCSMP is complete. These tools work together to address stormwater management on the development site from concept to completion.

Each section of the Manual has been arranged with a specific purpose in mind:

- **Section 1** provides an overview of how and why stormwater management is a critical part of holistic site planning in Philadelphia.
- **Section 2** discusses the applicability of the Stormwater Regulations.
- **Section 3** covers preliminary site planning considerations and conceptual review.
- **Section 4** steps through an integrated site design process once the initial site layout is determined. This section describes approaches for using Nonstructural and Structural Controls to manage stormwater.
- **Section 5** explains all of the elements necessary for completing and submitting the PCSMP for the development project.
- **Section 6** presents methods for integrating stormwater management into site design for both non-structural and structural SMPs applicable to urban development in Philadelphia.
- **Section 7** presents technical design guidance for managing stormwater and specifications for structural SMPs.
- **Section 8** provides landscape guidance for non-structural and structural SMPs and lists recommended native plant species as well as prohibited invasive species.

1.3 How to Use this Manual

The following flow chart depicts how the manual can be used to work through the development review process.

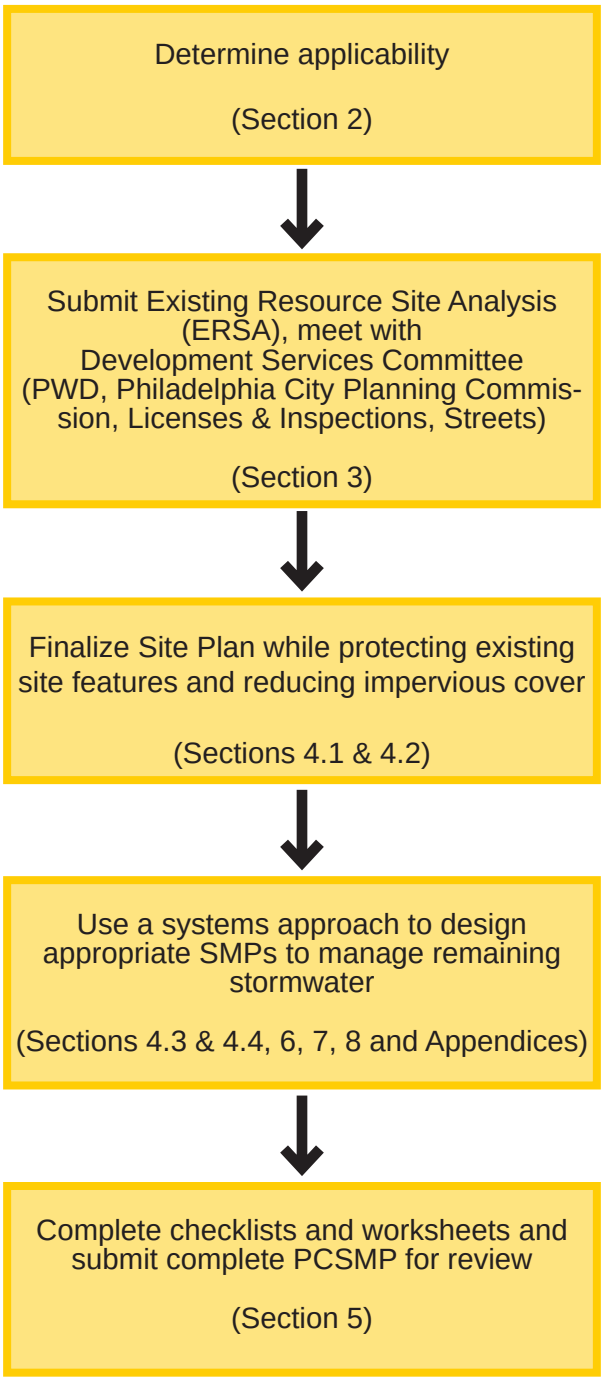

Figure 1.1: Using the Manual

Checklists and Worksheets are provided electronically on www.PhillyRiverInfo.org/PWDDevelopmentReview to assist the developer in meeting the requirements of the Stormwater Regulations.

2 Applicability and Approval

2.0 Introduction

2.1 Earth Disturbance

2.2 Determining Applicability

2.2.1 Conceptual Review
2.2.2 Erosion and Sediment Control
2.2.3 Watershed Specific Requirements
2.2.4 Stormwater Management Requirements
2.2.5 Public Health and Safety Rates

2.3 The Development Review Process

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2.0 Introduction

All projects that generate earth disturbance of 5,000 square feet or more must have their Building Permit application signed by the Philadelphia Water Department (PWD) before it will be issued. The requirements that must be met to obtain PWD's signature depend on the project size and location. The requirements include six main components. In general terms these are the Water Quality, Channel Protection, Flood Control, Non-structural Project Control, Erosion and Sediment Pollution Control, and the Post-Construction Stormwater Management Plan requirements.

Table 2.1: Primary Components of Requirements

Stormwater Requirements	Technical Details
Water Quality: Management of the first one inch of runoff from Directly Connected Impervious Areas (DCIA) within the limits of earth disturbance.	**Section 4.3.1**: Estimate Level of Control Needed
Channel Protection: Management of the 1-year, 24-hour, NRCS Type II storm event such that the peak rate of discharge does not exceed 0.24 cfs/acre.	
Flood Control: Attenuation of runoff from larger storm events required depending upon project location within the City.	
Non-structural Project Control: Use of practical alternatives to surface discharges of stormwater, creation of impervious surfaces and protection of Waters of the Commonwealth.	**Section 4.1**: Protect and Utilize Existing Site Features **Section 4.2**: Reduce Impervious Cover to be Managed
Erosion and Sediment Pollution Control (E & S): Plan must be prepared in accordance with Pennsylvania Department of Environmental Protection (PADEP) guidelines.	**Section 5.1**: Erosion and Sediment Pollution Control Plan
Post-Construction Stormwater Management Plan (PCSMP): Submittal to PWD demonstrating compliance with the PWD Stormwater Management Regulations (Stormwater Regulations).	**Section 5.2**: Components of the Post-Construction Stormwater Management Plan
Note: Some redevelopment projects may be exempt from the Channel Protection and Flood Control requirements.	

2.1 Earth Disturbance

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine applicable requirements and the level of review and approval required. A project may have multiple boundaries, each of which has significance when determining applicability during the development process. For example, the parcel boundary, earth disturbance, and area that must be managed for stormwater may all be different. The trigger for determining the Stormwater Regulations apply to a project is the area of earth that is disturbed as part of the project. However, some areas with the limits of earth disturbance do not require stormwater management. In the discussion that follows descriptions of earth disturbance boundaries provide guidance on determining the area that is subject to the Stormwater Regulations.

What is earth disturbance:

Earth disturbance is defined as any human activity which moves or changes the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, moving, depositing, stockpiling or storing of soil, rock or earth materials. All earth disturbance activities must be included on all E & S Plans.

- Land Development
- Utility Connections (Including work in public rights-of-way: sidewalks and roads)
- Private Roads
- Rock Construction Entrances
- Stockpiles
- Temporary Stockpiles
- Construction Vehicle Paths
- Grading
- Excavation
- Clearing and Grubbing
- Embankments

What is not earth disturbance:

- Interior renovations
- Restriping or milling and repaving of paved areas, parking lots, basketball courts, tennis courts etc., as long as the subbase remains undisturbed.

What earth disturbance area does not have to manage stormwater?

- Replacement of public sidewalks
- Replacement of existing roads when stormwater runoff characteristic are not significantly affected
- Temporary Stockpiles on existing impervious surfaces as long as all necessary E & S pollution control measures are implemented.

What earth disturbance area in the public right-of-way does have to manage stormwater?

- New public streets that are determined by City Streets Department, Philadelphia City Planning Commission (PCPC) and PWD to not conform to the grid
- New private streets and private sidewalks

When in doubt be conservative:

- Projects that are close to 15,000 square feet of earth disturbance are required to provide a Pennsylvania P.E. stamped and sealed E & S Plan clearly delineating the limits of disturbance before PWD will confirm that Stormwater Management requirements are not applicable to the project. Should a site inspection reveal that more than 15,000 square feet have been disturbed the site will be issued an immediate Stop Work Order and will be subject to the Stormwater Regulations.

- Should a site inspection reveal that more than 1 acre of earth disturbance the site will be issued an immediate Stop Work Order and be required to apply for a PADEP NPDES (National Pollutant Discharge Elimination System) permit. The Stop Work Order will not be lifted until the applicant receives an approved NPDES Permit.

2.2 Determining Applicability

The review components for both Stormwater Management and Erosion and Sediment Control depend on the limits of earth disturbance associated with the project as well as the watershed in which the project is located. Table 2.1 summarizes the requirements that each site must meet. Additional information on each the requirements is provided below.

Table 2.2: Applicability of Requirements

Site Information		**Project Requirements**					
Earth Disturbance Area (square feet)	Project Location	Submit an ERSA	Comply with Stormwater Management Regulations	Implement E & S BMPs as needed	Submit an E & S Plan to PWD	Have an E & S Plan Approved by PWD	Obtain a NPDES Permit
Less than 5,000 square feet	Project is **not** located in the Wissahickon Watershed			X			
	Project is located in the Wissahickon Watershed	Contact PWD and PCPC for instructions.	Contact PWD and PCPC for instructions.	X	Contact PWD and PCPC for instructions.	Contact PWD and PCPC for instructions.	
More than 5,000 square feet and less than 15,000 square feet	Project is **not** located in the Darby-Cobbs or Wissahickon Watershed	X		X	X		
	Project is located in the Wissahickon Watershed	X	Contact PWD and PCPC for instructions.	X	Contact PWD and PCPC for instructions.	Contact PWD and PCPC for instructions.	
	Project is located in the Darby-Cobbs Watershed	X	X	X	X	X	
More than 15,000 square feet and less than 1 acre (43,560 square feet)	All project locations	X	X	X	X	X	
More than 1 acre (43,560 square feet)	All project locations	X	X	X	X	X	X

Note: Some projects can physically be located in one watershed while connecting project infrastructure to another watershed. Projects that are in close proximity to watershed and sewershed boundaries will have the receiving watershed reviewed as part of the conceptual plan review process.

If during the course of construction additional area is disturbed which changes the applicable requirements, construction will have to cease until new plans are prepared and approved by all relevant regulatory agencies.

2.2.1 Conceptual Review

All projects with that generate an earth disturbance of 5,000 square feet or more must submit an Existing Resources and Site Analysis (ERSA) worksheet to PWD for conceptual review. See **Section 3**: Site Planning for more information.

2.2.2 Erosion and Sediment Control

The Owner is responsible for ensuring that their active construction site is not creating violations of 25 Pa. Code Chapters 92 and/or 102 and the Clean Streams Law, the act of June 22, 1937, P.L. 1987, 35 P.S. §691.1 et seq. Depending on the limit of earth disturbance associated with a project there are specific preparation, review, and approval requirements. All E & S Plans must be prepared in accordance with PADEP guidelines as laid out in the following Manual:

> PADEP, Bureau of Watershed Management. April 15, 2000. *Erosion and Sediment Pollution Control Program Manual.* Document 363-2134-008.

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine the level of review and approval required. Once the limits of earth disturbance have been accurately determined the applicant will follow one of the four E & S review paths listed below:

A. Less than 5,000 square feet (not located in the Wissahickon Watershed*)

- E & S Plan is not mandatory.
- Owner **must** implement E & S Best Management Practices in accordance with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000).

B. More than 5,000 square feet, less than 15,000 square feet**

- E & S Plan must be **prepared**, implemented, and kept on site at all times during construction.
- The E & S Plan, which complies with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000), must be maintained and submitted to PWD, but does not need to be approved.
- If the site is not subject to the Stormwater Regulations, then submit E & S Plans as an attachment to the ERSA online application at www.PhillyRiverInfo.org/PWDDevelopmentReview.

C. More than 15,000 square feet, less than 1 acre (43,560 square feet)**

- E & S Plan must be prepared, **approved**, implemented and kept on site at all times during construction.
- The E & S Plan **must** be reviewed and approved by PWD before earth disturbance can begin.
- Project is subject to Stormwater Regulations and requires a full PCSMP submittal.
- A copy of the approved E & S Plan must be forwarded to the PWD E & S Unit.
- Notify the PWD E & S Unit of any pre-construction meetings, and notify the PWD E & S Unit three days prior to commencement of construction activities.

D. More than 1 acre (43,560 square feet)

- E & S Plan must be prepared, **approved**, implemented and kept on site at all times during construction.
- A **NPDES permit application** must be submitted to PADEP. Proof of issuance of the NPDES permit must be provided to PWD before PWD will sign the applicant's Building Permit application. A Building Permit must be issued prior to commencement of any earth disturbance.

- Project is subject to Stormwater Regulations and requires a full PCSMP submittal.
- A copy of the approved E & S Plan must be forwarded to the PWD E & S Unit.
- Notify the PWD E & S Unit of any pre-construction meetings, and notify the PWD E & S Unit three days prior to commencement of construction activities.



*Projects located in the Wissahickon Watershed may be subject to additional requirements which will be assessed as part of the project review performed by PCPC staff.

**If during the course of construction additional area is disturbed which changes the applicable requirements, construction will have to cease until new plans are prepared and approved by all relevant regulatory agencies.

2.2.3 Watershed Specific Requirements

The Stormwater Regulations apply to all projects that generate an earth disturbance of 15,000 square feet or more. However, watershed based Regulations can supersede the Stormwater Regulations. Projects will be required to meet the more stringent of the two requirements. There are currently two watersheds in Philadelphia that have specific Regulations which affect the applicability of the Stormwater Regulations. Additional watershed Regulations may be created. For updated information on watershed specific Regulations go to www.PhillyRiverInfo.org/PWDDevelopmentReview.

Darby-Cobbs Creek Watershed

Projects located in the Darby-Cobbs Creek Watershed are subject to the *Darby and Cobbs Creeks Watershed Act 167 Stormwater Management Plan*. Because of this, all projects of over 5,000 square feet of earth disturbance located in the Darby-Cobbs Creek Watershed are subject to the Stormwater Regulations as described below in **Section 2.2.4**: Stormwater Management Requirements.

Wissahickon Watershed

Projects located in Wissahickon Watershed are subject to §14-1603.2 *Environmental Controls for the Wissahickon Watershed* of the Philadelphia Code. The requirements that must be met depend on the location of the project within the watershed, the impervious cover proposed by the project, and the amount of earth disturbance associated with the project. Contact PCPC for more information on the requirements of a specific site.

2.2.4 Stormwater Management Requirements

The following steps and flow charts assist in determining applicability and exemption possibilities for a development project.

Step 1: Does my proposed project result in earth disturbance of 15,000 sq ft or more (5,000 sq ft or more in the Darby-Cobbs Creek Watershed)?

Yes. Continue to Step 2 and comply with PADEP (E & S) Controls.

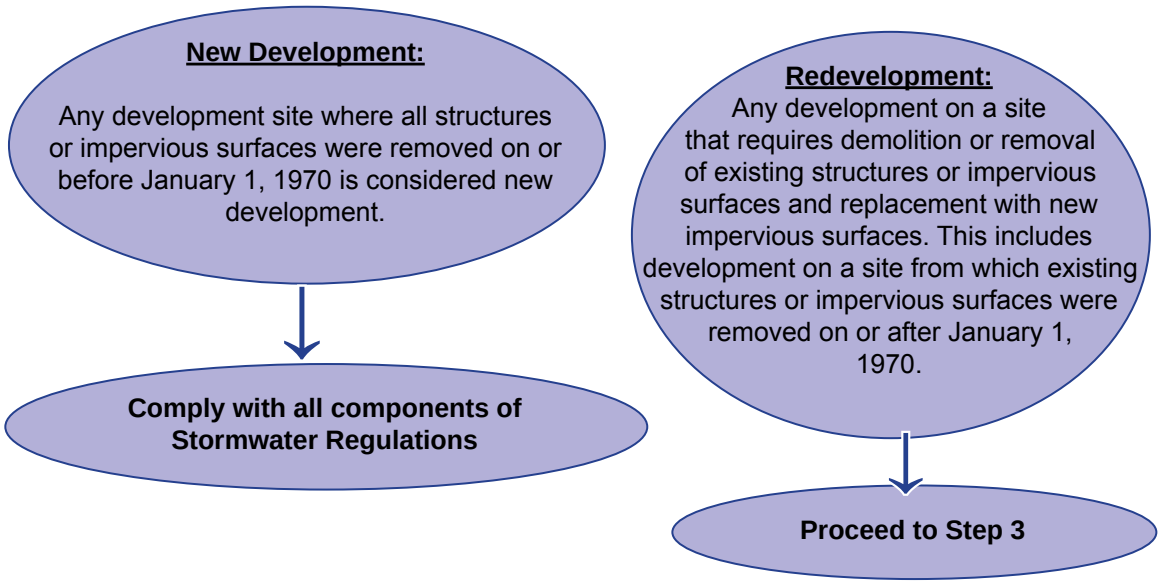
No. Is my proposed project located in the Wissahickon Watershed?

Yes. Contact PCPC for instructions.

No. See **Appendix K**: Voluntary Small Sites Checklist and comply with PADEP E & S Controls for earth disturbances.

Step 2: Is my development project new development or redevelopment?

Development encompasses both new development and redevelopment and includes the entire development, even when the development is performed in stages. The project will fit into one of the following two categories:



Step 3: Which components of the Stormwater Regulations are required for my development project?

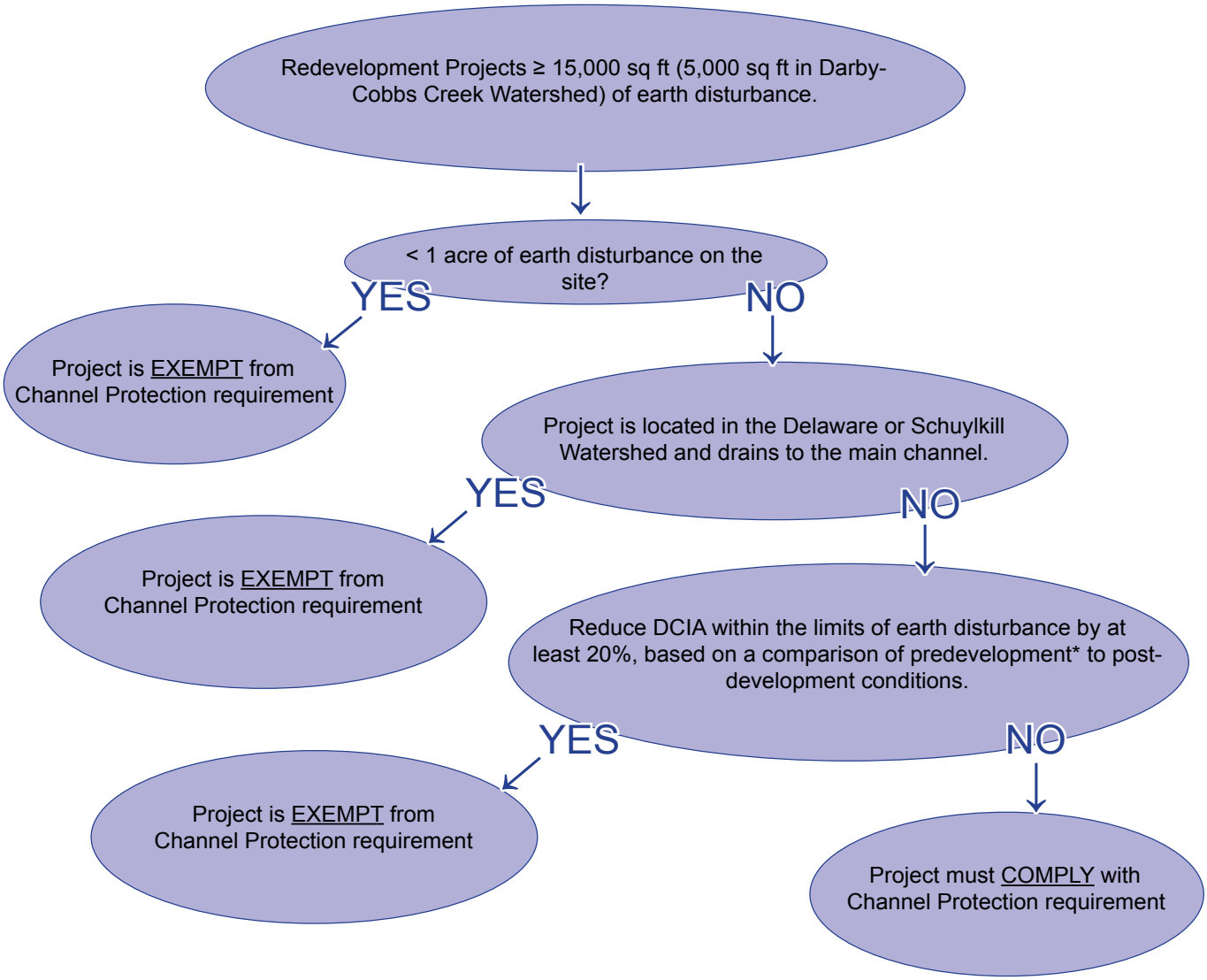
Table 2.3: Required Components of the Stormwater Regulations

Requirement	New Development	Redevelopment
Water Quality	Comply	Comply
Channel Protection	Comply	May be Exempt (see step 4)
Flood Control	Comply	May be Exempt (see step 5)
Nonstructural Site Design	Comply	Comply

New Development projects must comply with all components of the Stormwater Regulations.

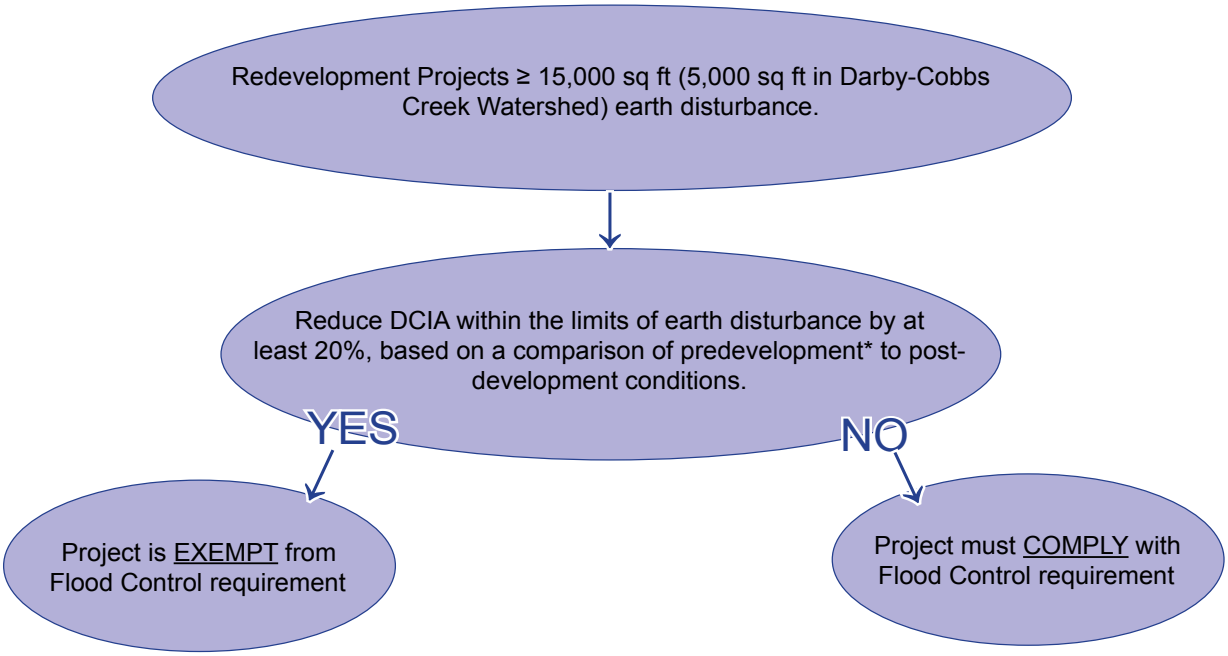
Redevelopment projects must comply with Nonstructural Project Design, and Water Quality requirements. Exemptions and alternative criteria for Channel Protection and Flood Control requirements may be applicable to your project as detailed in the following flow chart.

Step 4: Do I have to comply with the Channel Protection requirement?



* For the purposes of calculating reduction in DCIA from the predevelopment to post-development condition, the predevelopment condition DCIA is determined by the dominant land use for the ten (10) years preceding the planned project.

Step 5: Do I have to comply with the Flood Control requirement?



*For the purposes of calculating reduction in DCIA from the predevelopment to post-development condition, the predevelopment condition DCIA is determined by the dominant land use for the ten (10) years preceding the planned project.

Step 6: What happens next?

After determining which Stormwater Regulations apply to your project site, refer to **Section 3**: Site Planning, **Section 4**: Integrated Site Design, and **Section 5**: Post Construction Stormwater Management Plans for guidance, directions, and requirements before submitting a PCSMP to PWD for approval.

2.2.5 Public Health and Safety Rates

Sites located in areas where known flooding has occurred are required to comply with a maximum release rate (cfs/acre) for the 1-10 year storms. This rate is determined by PWD based on analysis of available capacity for the project within the sewershed. If a public health and safety (PHS) release rate is required for your site, it will be noted during the Conceptual Review process. Applicants should contact PWD when they start technical design for their project, to obtain a calculated PHS rate. Note, this PHS release rate applies to the entire site, not just DCIA.

2.3 The Development Review Process

Stormwater management is one part of the PWD approval process and is only one step in the overall development review process. When a developer has a conceptual idea for a project in Philadelphia, the first step is to conduct an Initial Plan Review with the PCPC. After guidance from PCPC, the developer prepares the ERSA Worksheet, ERSA Map, site photographs, and a Conceptual Site Plan and submit to PWD (See **Section 3**: Site Planning). These must be submitted prior to scheduling a PWD Development Review Meeting. Staff from PWD will provide a Conceptual Review of these materials and, if needed, meet with the developer and their engineers to discuss the Conceptual Site Plan in terms of water and sewer connections, and stormwater management. This meeting is designed to give PWD and developers an opportunity early in the design process to address any potential problem areas and maximize the site's potential.

Upon completion of the PWD Conceptual Review, PWD Staff will send an electronic version followed by a paper copy of the signed and stamped Checklist A: PWD Conceptual Review to the developer. The developer will then complete their Site Plan based on comments received during the Development Review Meeting. A signed and stamped copy of Checklist A: PWD Conceptual Review is one of the required components of a complete Zoning Application.

PWD approval is a required prerequisite on the City's Building Permit application. **Before a Building Permit can be issued by the City of Philadelphia, full PWD approval for Water, Sewer, Erosion and Sediment Control, and Stormwater Management must be obtained.** In order to obtain Stormwater Management approval, the developer must submit a complete PCSMP as described in this Manual (See **Section 5**: Post Construction Stormwater Management Plans). In addition, if more than one (1) acre of earth disturbance will take place on the site, a PADEP issued NPDES Permit must also be obtained before PWD will sign a Building Permit Application.

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3 Site Planning

3.0 Introduction

3.1 Site Inventory - Existing Resources and Site Analysis

3.2 Philadelphia Water Department Conceptual Review

3.3 Site Plan Preparation

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3.0 Introduction

Philadelphia Water Department (PWD) requires a conceptual review for all projects which are subject to the PWD Stormwater Management Regulations, the *Darby and Cobbs Creek Watershed Act 167 Stormwater Management Plan*, or Philadelphia Code §14.1603.2 *Environmental Controls for the Wissahickon Watershed*. In addition, projects which involve a site larger than 5,000 sq ft may be required by Licenses and Inspections (L & I) to obtain PWD approval for zoning purposes. The Conceptual Site Plan review is designed to assist developers and their engineers in developing a Site Plan that minimizes impacts and stormwater management costs and identifies water and sewer infrastructure constraints and opportunities. This is done early in the development process before significant resources have been spent on final design of the project. This section describes the required submittal items and the review process that must take place during the initial phase of development.

3.1 Site Inventory - Existing Resources and Site Analysis

The developer's first task is to assess features and conditions at the site before design begins. It is during this initial step that the developer is required to complete the **Existing Resources and Site Analysis (ERSA) Worksheet.** Not only does the worksheet assist in site planning, but it is a required submittal for PWD Development Review and included as part of the Post-Construction Stormwater Management Plan (PCSMP) submittal.

The ERSA map or Existing Conditions Plan is intended to help the developer to identify existing features, soil, vegetation, structures (if any), and existing drainage pathways. PWD will discuss opportunities to protect these features and their potential use for more effective post-construction stormwater management. Opportunities identified during the site analysis may help to minimize impacts and stormwater management costs.

For the most recent checklists and worksheets as well as an example Conceptual Site Plan, please refer to www.PhillyRiverInfo.org/PWDDevelopmentReview. Once the existing conditions are analyzed, a Conceptual Site Plan is prepared and the applicant should submit an ERSA submittal. The ERSA Submittal must include the following:

√ ERSA Worksheet (Worksheet 1),

√ ERSA Map,

√ Conceptual Site Plan showing proposed conditions, and

√ Site Photographs (one from each face of the parcel).

All of the above items should be submitted online at www.PhillyRiverInfo.org/PWDDevelopmentReview. PWD will review the ERSA submittal for content and format requirements (see ERSA checklist).

3.2 Philadelphia Water Department Conceptual Review

Upon receipt of the ERSA Submittal (described above), PWD representatives review the submittal and if needed, schedule a meeting with the developer and their engineers to discuss the Conceptual Site Plan in terms of water and sewer connections and availability and stormwater management. Sometimes a meeting with PWD Staff is the most efficient manner in which to address complex site constraints. PWD will schedule a meeting if requested by the applicant or deemed necessary by PWD Staff. The following may take place at the meeting:

- Based on the ERSA, the developer will discuss existing features, soil, vegetation, structures (if any), and existing drainage pathways. PWD will discuss opportunities to protect these features and their potential use for more effective post-construction stormwater management.

- PWD and the applicant will discuss potential issues related to water, sewer, and stormwater design as well as any other PWD concerns associated with the project.

- The developer along with PWD will review the Conceptual Site Plan and discuss ways to minimize impacts and stormwater management cost.

- PWD will provide guidance to developers and assist them with questions regarding the PCSMP Process. This early consultation will contribute to a more effective and economic PCSMP for both the developer and PWD.

Upon completion of the PWD review of the ERSA submittal, PWD Staff will send an electronic copy and hard copy of the following to the applicant:

- Completed Checklist A: PWD Conceptual Review with detailed recommendations for the Site Plan and

- Stamped and signed copy of the Conceptual Site Plan approved for Zoning purposes.

PWD routinely copies the Philadelphia City Planning Commission (PCPC) Staff on the electronic copy of Checklist A and the Conceptual Site Plan to help better coordinate plan reviews. A copy of this checklist is provided at www.PhillyRiverInfo.org/PWDDevelopmentReview for reference.

3.3 Site Plan Preparation

Based on the recommendations from PWD, PCPC, and Streets Department, the developer will prepare and submit their complete Zoning Permit Application. As the developer moves forward with Site Plans and Building Plans, they should refer to **Section 4.1**: Protect and Utilize Existing Site Features and **Section 4.2**: Reduce Impervious Cover to be Managed to maximize the efficiency of their Site Plan.

4 Integrated Site Design

4.0 Introduction

4.1 Protect and Utilize Existing Site Features

4.1.1 Protect Sensitive/Special Value Features
4.1.2 Cluster and Concentrate
4.1.3 Minimize Impacts of Disturbance

4.2 Reduce Impervious Cover to be Managed

4.2.1 Green Project Review
4.2.2 Minimize Area of Impervious Cover
4.2.3 Disconnect Impervious Cover
4.2.4 Maximize Tree Canopy over Impervious Cover
4.2.5 Install Green Rooftops to Reduce Directly Connected Impervious Area
4.2.6 Install Porous Pavement to Reduce Directly Connected Impervious Area

4.3 Manage Remaining Stormwater

4.3.1 Estimate Level of Control Needed
4.3.2 Design Stormwater Management Practices Using a Systems Approach

4.4 Consider Operations and Maintenance in Design

4.4.1 Designing to Minimize Maintenance
4.4.2 Provide Access
4.4.3 Post-Construction Ownership
4.4.4 Maintenance Tasks and Schedule

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4.0 Introduction

A recommended site design procedure for comprehensive stormwater management is set forth in this section. The site design procedure is based on the Pennsylvania Department of Environmental Protection (PADEP) recommendations, with minor modifications adapted to conditions in Philadelphia. This procedure includes nonstructural controls that reduce the quantity of stormwater to be managed and structural controls that meet the Water Quality, Channel Protection, and Flood Control requirements of the Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations). The integrated site design procedure can be summarized in three steps:

Nonstructural Project Design

1. Protect and Utilize Existing Site Features
2. Reduce Impervious Cover to be Managed

Structural Project Design

3. Manage Remaining Stormwater using a Systems Approach to Stormwater Management Practice (SMP) Design

These steps are implemented initially in sequence and then in an iterative approach leading to formulation of a comprehensive Post Construction Stormwater Management Plan (PCSMP). The intent of the planning process is to promote development of stormwater management solutions that protect receiving waters in a cost effective manner. By introducing stormwater management in the initial stages of site planning, it can be integrated effectively into the site design process.

4.1 Protect and Utilize Existing Site Features

4.1.1 Protect Sensitive/Special Value Features

In order to minimize stormwater impacts, land development should avoid encroachment on areas with important natural stormwater functional values (such as floodplains, wetlands, and riparian areas) and on areas that are especially sensitive to stormwater impacts (such as steep slopes). These features may not be widespread in the urban environment, but where they do exist they should be identified and steps should be taken to minimize impacts. On larger sites, existing drainage pathways should be identified and utilized whenever possible in the post-development condition.

The Existing Resources and Site Analysis (ERSA) worksheet guides the designer through this stage of the design process. Detailed design guidance is available in the following sections, taken directly from the Pennsylvania Stormwater Best Management Practices (BMP) Manual (PA SBMPM):

- PA SBMPM BMP 5.4.1: Protect Sensitive and Special Value Features
- PA SBMPM BMP 5.4.2: Protect/Conserve/Enhance Riparian Areas
- PA SBMPM BMP 5.4.3: Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

4.1.2 Cluster and Concentrate

Clustering development in a smaller area can reduce disturbance, reduce maintenance, increase open space, and retain the urban character of the City. These principles apply on urban sites where large areas are being redeveloped. Detailed design guidance is available in the following section, taken directly from the PA SBMPM:

- PA SBMPM BMP 5.5.1: Cluster Uses at Each Site; Build on the Smallest Area Possible

4.1.3 Minimize Impacts of Disturbance

Site design can minimize re-grading, vegetation removal, and soil compaction. Areas left as open space following disturbance can be re-vegetated with native species where practical. Detailed design guidance is available in the following sections, taken directly from the Pennsylvania Stormwater Management Manual:

- PA SBMPM BMP 5.6.1: Minimize Total Disturbed Area – Grading
- PA SBMPM BMP 5.6.2: Minimize Soil Compaction in Disturbed Areas
- PA SBMPM BMP 5.6.3: Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species

4.2 Reduce Impervious Cover to be Managed

Reduction of impervious cover will reduce runoff from the site and will thereby reduce the structural stormwater management requirements for the development project. Impervious cover can be effectively removed by limiting the amount of actual impervious surfaces or by reducing the impervious area that is directly connected to the stormwater conveyance system. The directly connected impervious area (DCIA) Worksheet (Worksheet 2), guides the designer through this stage of the design process.

4.2.1 Green Project Review

PWD offers a Green Project Review for redevelopment projects that are able to disconnect 95% or more of the impervious area in the post construction condition. When performing a Green Project Review, PWD is committed to providing review of the stormwater management component within 5 business days of receipt of a complete project submittal. A Green Project Review may not necessarily include review of additional elements outside stormwater management such as Private Cost or Act 537 review. To be eligible for a Green Project Review a project must meet the following criteria**:**

- Project is redevelopment;
- 95% or more of the post construction impervious area is disconnected;
- Project may not adversely impact or further exacerbate rates and quality of runoff contributing to public infrastructure; and
- Public Health and Safety issues may preclude a project from a Green Project Review.

The submittee **MUST** identify their project as eligible for a Green Project Review in the letter of transmittal sent with the technical submittal. PWD may not be able to provide review comments within 5 business days without this notification. For more information or to determine if a project is eligible for a Green Project Review please contact PWD**.**

4.2.2 Minimize Area of Impervious Cover

In many cases, alternative configurations for streets and parking lots can provide the same function as traditional designs with reduced impervious area. Minimizing the area of pavement and rooftops will reduce the size and cost of SMPs that must be constructed. Detailed guidelines, examples, and additional references are discussed in **Section 6**: Integrated Site Design.

- **Section 6.1**: Street Design
- **Section 6.2**: Parking Lot Design

4.2.3 Disconnect Impervious Cover

Impervious area is considered either connected or disconnected depending on where stormwater runoff is discharged. When stormwater runoff from an impervious area flows directly to a stormwater management facility it is considered DCIA. However, some impervious cover can be disconnected by directing the flow over a pervious area which allows for infiltration, filtration, and increased time of concentration. When this is done correctly, the area may be considered Disconnected Impervious Cover (DIC). Depending on the configuration, all or a portion of the DIC may be deducted from total impervious cover. Minimizing DCIA will reduce the size and cost of SMPs that must be constructed. When performing calculations for applicability and runoff estimation, DIC should be considered as follows:

- DIC may be treated as pervious when determining stormwater control requirements and whether a redevelopment site has met the 20% reduction in impervious surface.
- DIC need not be managed for Water Quality or Channel Protection.
- If the site is required to provide flood control appropriate Curve Number (CN) values must be utilized.

The following sections describe situations in which impervious area can be considered partially or fully disconnected.

Rooftop Disconnection

An adjustment to DCIA is permitted when the downspout is disconnected and then directed to a pervious area which allows for infiltration, filtration, and increased time of concentration. PWD will support the applicant in their request to obtain relevant necessary plumbing Code variances for approved rooftop disconnections DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

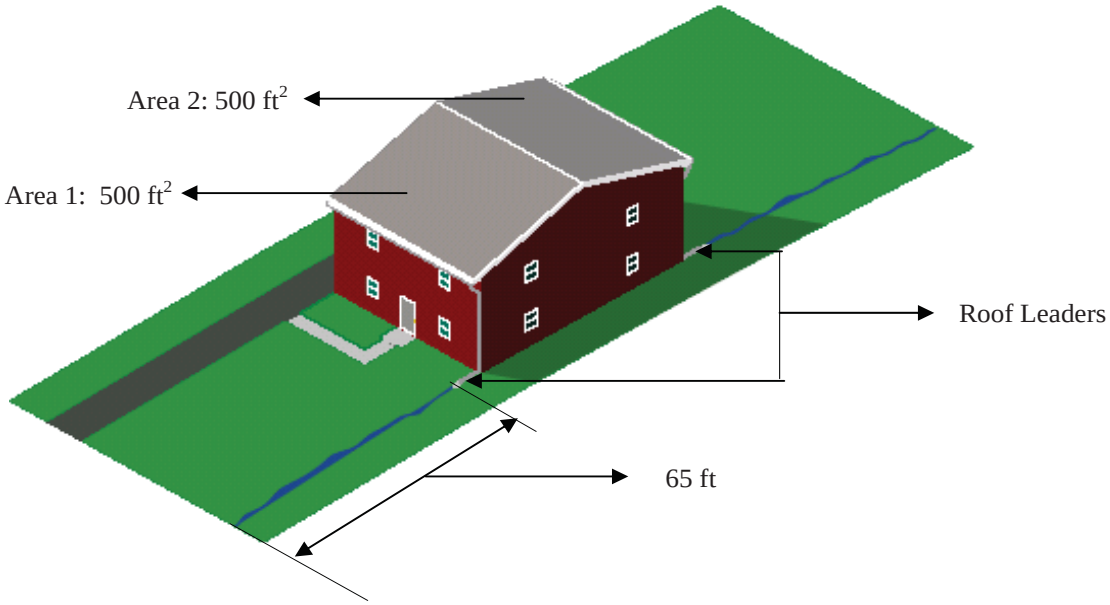
A rooftop is considered to be completely or partially disconnected if it meets the requirements below:

- The contributing area of rooftop to each disconnected discharge is 500 square feet or less, and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The overland flow path has a positive slope of 5% or less.

For designs that meet these requirements, the portion of the roof that may be considered disconnected depends on the length of the overland path as designated in Table 4.1.

Table 4.1: Partial Rooftop Disconnection	
Length of Pervious Flow Path*	Roof Area Treated as Disconnected
(ft)	(% of contributing roof area)
0 - 14	0
15 - 29	20
30 - 44	40
45 - 59	60
60 - 74	80
75 or more	100
* Flow path cannot include impervious surfaces and must be at least 15 feet from any ground level impervious surfaces.	

For example, consider a 1,000 square foot roof with two roof leaders each draining an area of 500 square feet. Both roof leaders discharge to a lawn. The lawn has type B soils and a slope of 3%. The distance from the downspout discharge point to the street is 65 feet. Therefore, based on Table 4.1, 80% of the roof area may be considered disconnected and treated as pervious cover when calculating stormwater management requirements. Disconnecting the roof leaders will significantly reduce the size and cost of stormwater management facilities at this site.



Total Roof Area: (Area 1 + Area 2): 1000 ft²
Disconnected Roof Area: (0.8) x (Total Roof Area): 800 ft²
Remaining DCIA: (Total Roof Area - Disconnected Roof Area): 200 ft²

Figure 4.1: Rooftop disconnection

Pavement Disconnection

An adjustment to DCIA is permitted when pavement runoff is directed to a pervious area which allows for infiltration, filtration, and increases the time of concentration. This method is generally applicable to small or narrow pavement structures such as driveways and narrow pathways through otherwise pervious areas (e.g., a bike path through a park). For structures that meet the requirements, all of the DIC may be deducted from the total impervious cover. DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations. The following sections describe situations in which impervious area can be considered partially or fully disconnected.

Pavement is disconnected if it meets the requirements below:

- The contributing flow path over impervious cover is no more than 75 feet, and
- The length of overland flow over pervious areas is greater than or equal to the contributing length, and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The slope of the contributing impervious area is 5% or less, and
- The slope of the overland flow path is 5% or less.
- If discharge is concentrated at one or more discrete points, no more than 1,000 square feet may discharge to any one point. In addition, a gravel strip or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

4.2.4 Maximize Tree Canopy over Impervious Cover

A reduction in DCIA is permitted when new or existing tree canopy from approved species list extends over or is in close proximity to the impervious cover. Under these circumstances, a portion of impervious cover may be treated as disconnected. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

The DCIA reduction is calculated for **new trees** as follows:

- The tree species must be chosen from the approved list (see **Section 8**: Landscape Guidance).
- New trees planted must be planted within 10 feet of ground level DCIA within the limits of earth disturbance.
- New deciduous trees must be at least 2-inch caliper and new evergreen trees must be at least 6 feet tall to be eligible for the reduction.

- A 100 square foot DCIA reduction is permitted for each new tree. This credit may only be applied to the impervious area adjacent to the tree.

- The maximum reduction permitted, for both new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of the impervious area is less than 10 feet. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

■ The DCIA reduction is calculated for **existing trees** as follows:

- The tree species must be on the approved list (see **Section 8**: Landscape Guidance).

- Existing trees whose canopies are within 20 feet of ground level DCIA within the limits of earth disturbance.

- Existing trees must be at least 4-inch caliper to be eligible for the reduction.

- A DCIA reduction equal to one-half the canopy area is permitted. This credit may only be applied to the DCIA adjacent to the tree.

- The maximum reduction permitted, for both new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of the impervious area is less than 10 feet. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets, specifically Worksheet 2: Directly Connected Impervious Area for guidance on using the tree adjustment calculations.

4.2.5 Install Green Roofs to Reduce Directly Connected Impervious Area

A reduction in DCIA is permitted when a green roof is installed on a proposed building. The design, construction, and maintenance Plan must meet the minimum requirements specified in **Section 7**: SMP Design Guidelines. To encourage this emerging technology, the entire area of the green roof area may be considered DIC. However, since a green roof is not a zero discharge system, the remaining site design must safely convey roof runoff to the approved point of discharge. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

4.2.6 Install Porous Pavement to Reduce Directly Connected Impervious Area

A reduction in DCIA is permitted when a porous pavement system is installed on the site such that it does not create any areas of concentrated infiltration. Porous pavement systems, including porous asphalt; porous concrete; porous/permeable pavers; and other PWD-approved porous structural surfaces can be considered to be DIC if they receive direct rainfall only and are underlain by a crushed stone infiltration bed that is at least 8 inches deep. Porous/permeable pavers must also meet minimum standards for flow-through rate or void percentage. If an underdrain is proposed, the porous pavement will only be considered DIC if the first inch of runoff can be stored below the

lowest overflow from the underdrain system. Porous asphalt systems must meet the minimum requirements detailed in **Section 7.13**: Porous Pavement. Infiltration testing is not required for disconnected porous pavement areas; however, it is recommended to ensure timely drainage of the stone base. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

In most cases, if the porous surface receives runoff (overland or piped directly into the subsurface storage bed) from adjacent conventional pavement surfaces, roof, or other impervious surfaces, the porous pavement/infiltration bed system will be considered a structural SMP and the porous surface will be considered DCIA. Those areas considered structural SMPs will require infiltration testing. In some cases, where a small amount of run-on cannot be avoided, it may still be possible to consider the porous pavement disconnected. Such allowances will be considered on a case-by-case basis by PWD.

4.3 Manage Remaining Stormwater

Worksheets 3A and 3B: Stormwater Control Sizing guide the designer through the stage of the design process that manages remaining stormwater after utilizing existing site features and reducing impervious cover. Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets.

4.3.1 Estimate Level of Control Needed

After determining which stormwater management requirements are applicable to the site, the Design Professional then determines the magnitude of those requirements. All requirements must be met concurrently. The Design Professional may choose to meet multiple requirements using a single facility or multiple facilities.

Water Quality Requirement

The required water quality volume is calculated from the following formula:

$$WQ_v = \left(\frac{P}{12}\right) * \left(I\right) \qquad \text{Eqn: 405.1}$$

Where:
WQ_v = Water Quality Volume (cubic feet)
P = 1.0 inch
I = DCIA within the limits of earth disturbance (square feet)

To meet the Water Quality requirement, SMPs must be designed to collect and treat the first inch of runoff from all DCIA. It is not acceptable to treat an equivalent volume collected from only a portion of the DCIA.

The water quality volume must be infiltrated except in cases where the Design Professional determines that infiltration is infeasible on the site. Infiltration systems must provide adequate static storage for the entire water quality volume; see design guidelines in **Section 7:** SMP Design Guidelines for information on calculation of static storage. Please note, all infiltration

practices must be located a minimum of 10 feet from all building foundations. Infiltration systems must also be a minimum of 10 feet from property lines not adjacent to open public streets unless a deed restriction is put in place extending at least 10 feet from the perimeter of the infiltrating system.

To determine whether or not infiltration is feasible, the Design Professional must perform the following three procedures:

Appendix A: Hotspot Investigation Procedure

Appendix B: Soil Infiltration Testing Procedure

Appendix C: Geotechnical Investigation (Subsurface Stability) Procedure

The intent of the Water Quality requirement is to protect Philadelphia's rivers and streams from polluted runoff associated with rain events. Runoff from the first inch of rainfall accounts for the majority of the annual rainfall volume, and typically carries the majority of the pollutants. Runoff from impervious surfaces is generally more polluted than runoff from pervious surfaces because of the associated uses. Because the Water Quality requirement is designed to make sure that this first inch of water is infiltrated or treated before it leaves the site, the water quality volume must be collected as the first inch of runoff from all DCIA.

Infiltration provides groundwater recharge needed to restore more natural (historical) dry weather flows in creeks while reducing high stream flows and velocities during small storms. However, some sites may not be able to infiltrate all of the water quality volume safely and may request a waiver from infiltration. Waivers are available in **Appendix F.4**: Special Circumstances and Waiver Requests and online at www.PhillyRiverInfo.org/PWDDevelopmentReview. In cases where a waiver is requested for all or a portion of the infiltration component of the Water Quality requirement, the Design Professional is required to supply the following documentation:

- summary of testing as outlined in **Appendices A**, **B**, and **C,**
- a complete infiltration waiver request cover letter and worksheet detailing the reasons that infiltration is not feasible, and
- supporting evidence why a site should be released from the infiltration requirement.

If it is determined that infiltration of all or part of the water quality volume is not feasible, remaining water quality volume must be treated and released. Treatment and release requirements differ for separate and combined sewer areas, but all areas must route a minimum of 20% of the water quality volume through a PWD-approved SMP that provides volume reduction (See Table 4.3)

Separate Sewer Areas: The water quality volume must be routed through a SMP that provides volume reduction, flow attenuation, and water quality treatment. PWD-approved practices include: underdrained filters, underdrained bioretention, swales with check dams, ponds and wet basins, and constructed wetlands (see Table 4.3 for a complete list).

Combined Sewer Areas: Runoff from a minimum of 20% of the DCIA must be routed through a PWD-approved volume reducing SMP (see Table 4.3 for a complete list). The release rate for the water quality volume must not exceed 0.24 cfs per acre DCIA*, and the volume must be detained in the SMP for no less than 24 hours and no more than 72 hours.

*If a SMP will be emptied by a pumping system the average rate must not exceed 0.12 cfs per acre DCIA.

Channel Protection Requirement

SMPs must be designed to detain the runoff from all DCIA within the limits of earth disturbance from a one-year, 24-hour NRCS (Natural Resources Conservation Service) Type II design storm in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours to drain from the facility. Discharge of water may begin at the beginning of the storm.

Channel Protection requirement: Detain and release runoff from DCIA at a maximum rate of 0.24 cfs per acre of DCIA in no less than 24 hours and no more than 72 hours.

However, the Channel Protection requirement does not apply to redevelopment which is under one acre or discharging to the Delaware River and the Schuylkill River main channels.

- *Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Channel Protection requirement.*

The effects of infiltration may be accounted for when performing Channel Protection calculations. Infiltrating more than the water quality volume is allowed; the Design Professional must determine the best management option based on site-specific conditions.

Flood Control Requirement and Management Districts

Table 4.2 lists the required level of flood control based on location (Management District) within the City. Refer to **Appendix D.2**: Management Districts to determine which Management District requirements apply to a given site. Peak runoff in the proposed condition (left column) must be no greater than peak runoff in the pre-development condition (right column) using the stated design storms. For a given district, the five criteria must be met concurrently. Peak rate reduction provided by facilities that meet the Water Quality and Channel Protection requirements may be considered in sizing calculations for peak rate controls.

If a project is located near or across a Management District border it is strongly recommended that the Developer contact PWD to confirm the Management District requirements that apply to the project. In most cases, a project that is located in multiple management districts will be required to meet the requirements of the management district that covers the majority of the disturbed area.

In Flood Management District C, development sites which can discharge directly to the Delaware River main channel or Schuylkill River major tributary without the use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the pre-development conditions peak rate as required in District A provisions for the specified design storm. Refer to **Appendix F.5**: PWD Review Policies.

- *Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Flood Control requirement.*

Table 4.2: Peak Runoff Rates for Management Districts		
District	**NRCS Type II 24-hour Design Storm applied to Proposed Condition**	**NRCS Type II 24 –hour Design Storm applied to Pre-Development Condition**
A	2 - year	1 - year
A	5 - year	5 - year
A	10 - year	10 - year
A	25 - year	25 - year
A	100 - year	100 - year
B-1	2 - year	1 - year
B-1	10 - year	5 - year
B-1	25 - year	10 - year
B-1	50 - year	25 - year
B-1	100 - year	100 - year
B-2	2 - year	1 - year
B-2	5 - year	2 - year
B-2	25 - year	5 - year
B-2	50 - year	10 - year
B-2	100 - year	100 - year
C*	Conditional Direct Discharge District	

4.3.2 Design Stormwater Management Practices Using a Systems Approach

The intent of this section is to propose a systems approach as an organizing principle in SMP design. The designer first defines the level of control needed and then designs a system to provide that level of control.

SMP Selection and Design Process

The following is a general procedure for choosing and designing SMPs on a site.

- Determine whether infiltration is feasible according to **Appendix B:** Soil Infiltration Testing Procedures.
- Identify space constraints, and adjust site design as much as possible to provide open space for stormwater management.
- Where infiltration is feasible, vegetated techniques are preferred. When infiltration is not feasible other volume reducing techniques should be used (see Table 4.3).
- Determine pretreatment requirements for the selected SMP.
- Determine release rate requirements. Design of orifices and underdrains to meet the release rate requirements for small structures on small sites will be the most challenging.

On sites where infiltration is not feasible some or all (20% in combined sewer areas, 100% in separate sewer areas) of the DCIA must be routed to an approved volume reducing stormwater management practice. Table 4.3 below presents the SMPs that PWD currently accepts as reducing stormwater volume. Each SMP has design guidelines detailed in **Section 7**. Alternate volume reducing practices may be proposed and will be reviewed on a case-by-case basis. A waiver from the accepted volume reducing practices must be submitted and approved. See **Section F.4**: Special Circumstances and Waiver Requests or www.PhillyRiverInfo.org/PWDDevelopmentReview for the required forms.

Table 4.3: Acceptable Volume Reducing Stormwater Management Practices

	Infiltration and Groundwater Recharge	Volume Reduction without Infiltration
Landscaped-Intermittently Wet		
Section 6.3 Planter Boxes	Yes	Yes
Section 7.4 Filters	Yes	No
Section 7.5 Bioinfiltration/Bioretention	Yes	Yes (U)
Section 7.7 Berms and Retentive Grading	Yes	No
Section 7.8 Swales	Yes	Yes (U)
Landscaped-Usually Wet		
Section 7.9 Constructed Wetlands	No	Yes
Section 7.10 Ponds & Wet Basins	No	Yes
Subsurface		
Section 7.12 Subsurface Infiltration	Yes	No
Section 7.13 Porous Pavement	Yes	No
Rooftops		
Section 7.1 Green Roofs	No	Yes
Capture & Reuse		
Section 7.2 Rain Barrels and Cisterns	No	Yes
U = Underdrained Systems		

SMP Functions and Configurations

SMPs are systems that use physical, chemical, and biological processes to provide the level of stormwater control required. This level of control typically includes a required storage volume, a volume to be infiltrated, and an acceptable release rate. These requirements are met through the five principle hydraulic functions of SMPs: storage, infiltration, evapotranspiration, controlled release, and overflow or bypass flow. Figure 4.2 illustrates a variety of design elements available to provide these functions. Depending on the configuration, physical, chemical, and biological processes lead to removal of pollutants during these processes.

By combining design components in a variety of ways, the designer can identify alternative systems that achieve a given function. Figure 4.3 illustrates several different designs that are capable of meeting the Water Quality and Channel Protection requirements.

Figure 4.2:
Systems approach to SMP design

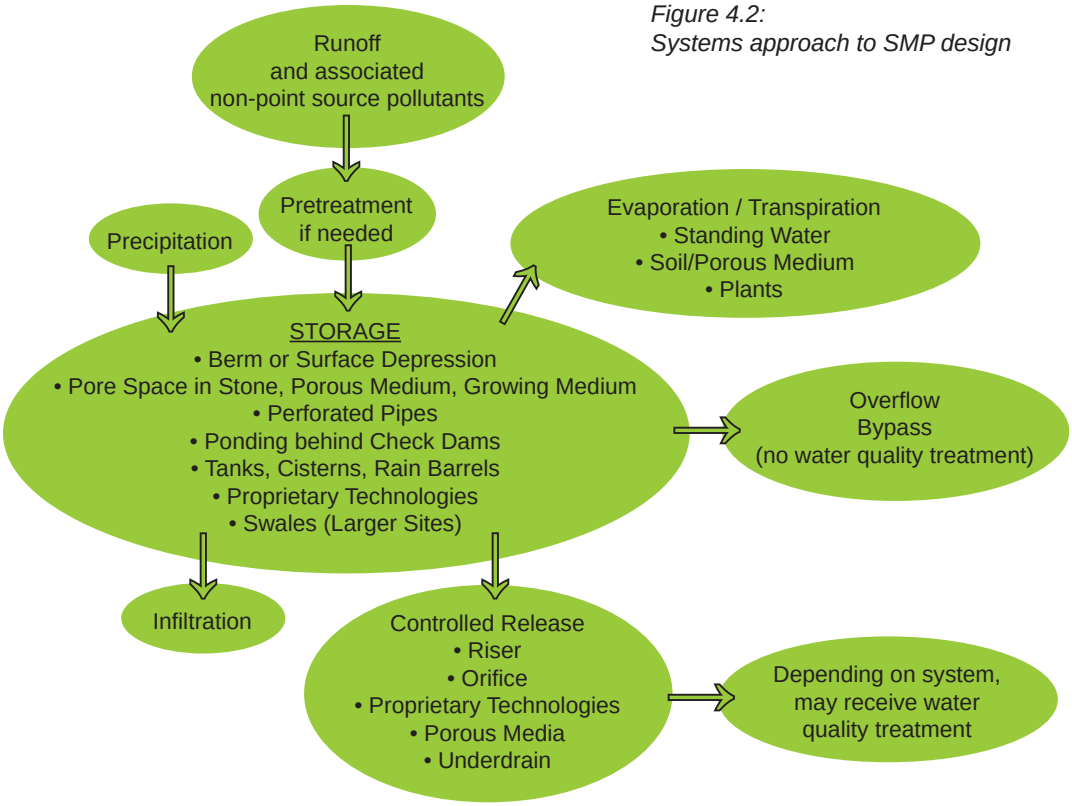
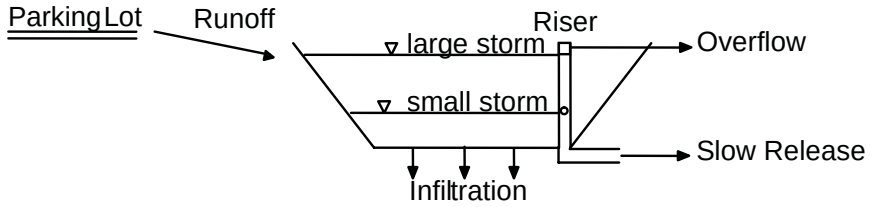


Figure 4.3: Alternative designs for storing runoff

Site: 1 acre parking lot
Objective: Meet Water Quality and Channel Protection requirements
Note: These diagrams are intended to depict general design concepts. Please refer to **Section 7** for detailed design requirements.

Alternative 1: Traditional detention / infiltration basin



Alternative 2: Porous pavement with deep sub-base

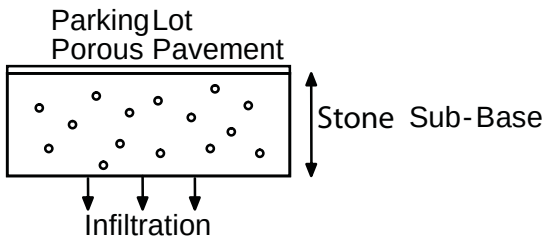
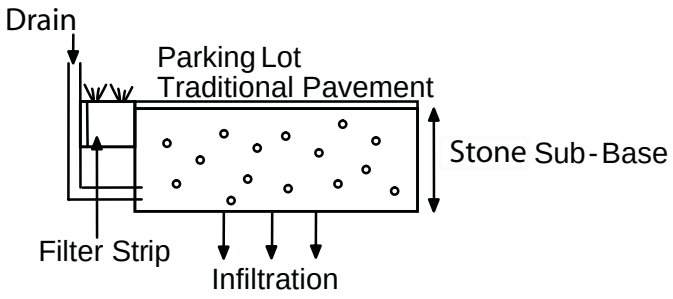
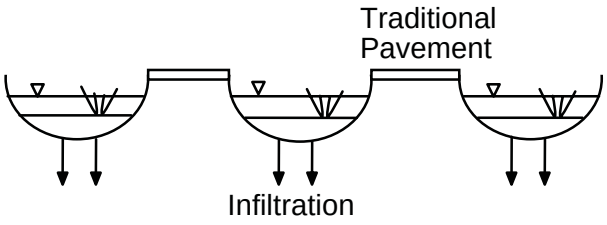


Figure 4.3: Alternative designs for storing runoff (continued)

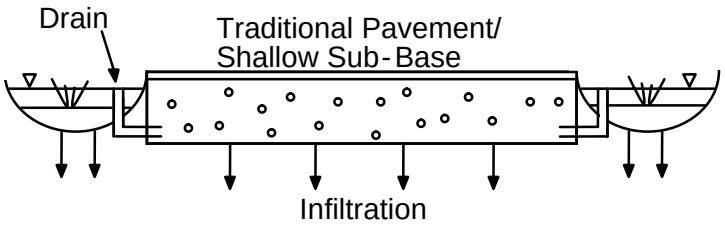
Alternative 3: Traditional pavement with perimeter drains and subsurface infiltration



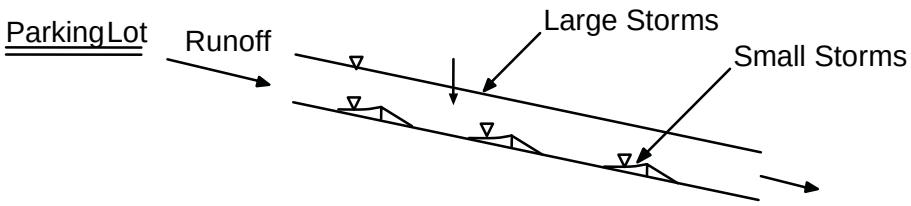
Alternative 4: Bioretention only



Alternative 5: Bioretention and subsurface storage



Alternative 6: Swale (large site option)



Storage A traditional detention/infiltration basin (alternative 1, Figure 4.3) provides storage entirely through surface ponding. Subsurface stone storage beds (alternatives 2 and 3) provide storage in stone pore spaces. A bioretention system (alternative 4) provides a combination of surface ponding and storage in soil pores. Bioretention combined with a subsurface stone bed (alternative 5) provides storage in a combination of surface ponding, storage in soil pores, and storage in stone pores. A swale (alternative 6) can provide storage through surface ponding behind check dams, while also functioning as a conveyance system during larger events.

Infiltration All six alternatives allow stored water to infiltrate into the underlying soil. Surface vegetation (alternatives 1, 4, 5, and 6) helps prolong design life because growth of plant roots helps to keep the soil pore structure open over time. This effect is greatest with vegetation that has a deeper root structure (e.g., trees, shrubs, and native herbaceous species rather than turf grass). Traditional structures such as detention basins and swales can be designed with either type of vegetation. Using such attractive landscaping practices improves quality of life in the urban landscape.

Slow Release Stored water is either infiltrated or released at a slow rate to a sewer or receiving stream. The subsurface storage and bioretention designs (alternatives 2-5) are designed to infiltrate the entire design storm. These designs have a relatively large ratio of infiltration area to drainage area; they provide diffuse infiltration and do not require design or maintenance of a slow release structure. The traditional infiltration basin (alternative 1) provides more concentrated infiltration; depending on site conditions, the designer may choose to infiltrate a portion of runoff and release the remainder slowly through a riser structure. This structure may require design and maintenance measures to avoid clogging. Finally, the swale (alternative 6) infiltrates the portion of runoff that pools behind check dams. The designer in this case ensures that detention behind check dams and peak attenuation in the flowing swale combine to meet any release rate requirement by the time flow reaches the end of the swale. The swale does not store the entire design storm through ponding at any one time, but it is functionally equivalent to the other designs when resulting flows leave the property.

Evaporation and Transpiration Evaporation and transpiration are minor SMP functions when measured over the course of one storm, but they are significant when measured over time. Surface systems will provide the greatest evaporation and transpiration benefit, particularly if they are vegetated. Some water that infiltrates the surface will evaporate. For this reason, vegetated systems provide both water quality and volume reduction.

Controlled Overflow or Bypass Flow Although not shown for all the examples, all designs must have a mechanism for water to overflow or bypass the system unimpeded during events larger than the design event. For alternatives 1 through 5, a riser or other overflow structure can be incorporated in the design. For alternative 6, the flow capacity of the swale itself acts as a bypass mechanism.

Water Quality Treatment All six design alternatives provide some water quality benefit by slowing water down and allowing settling of suspended solids. A portion of pollutants in stormwater (e.g., nutrients, metals, and/or organics) is associated with this solid fraction. Systems combining soil, water, and plants (alternatives 4 and 5) provide the most treatment. The level of treatment provided by the traditional detention basin (alternative 1) and swale (alternative 6) depends on configuration and vegetation type.

Infiltration reduces the pollutant load reaching surface water and should not endanger groundwater if the soil layer is sufficiently thick. Vegetated filter strips in alternative 3 remove solids through settling and filtration. In alternative 5, a small bioretention basin provides pretreatment for a subsurface stone system. Both pretreatment methods will prolong the life of the subsurface stone bed. The choice between alternatives 3 and 5 is one of designer preference and cost, not one of function.

In areas with combined sewers, two factors contribute to receiving water quality. First, any water that is infiltrated does not reach a combined sewer, does not contribute to combined sewer overflows (CSO), and will not contribute to receiving water pollution. Second, detention and slow release reduces peak flow in the combined sewer during wet weather events, reducing the frequency and magnitude of overflows. Water quality improvement in combined sewered areas is more a matter of managing the quantity and timing of runoff, rather than reducing pollutant concentrations in that runoff.

Space Constraints Traditional basins (alternative 1) and swales (alternative 6) can be implemented on larger sites. On smaller sites, bioretention is an attractive solution due to the benefits of vegetation, including appearance, design life, and water quality. However, surface vegetation does require space to install. A designer might choose to combine bioretention with a subsurface stone bed (alternative 5) to save space, or to use a subsurface stone bed (alternative 2 or 3) alone if all available space is needed for parking.

4.4 Consider Operations and Maintenance in Design

An Operations and Maintenance (O & M) Plan is required to be submitted with the PCSMP. Decisions made in the design phase can affect operations and maintenance and can extend the design life of stormwater facilities. Key factors to consider are ownership, access, maintenance tasks and frequency. The Operations and Maintenance Plan worksheet found at www.PhillyRiverInfo.org/PWDDevelopmentReview provides a simple format.

4.4.1 Designing to Minimize Maintenance

Consider the following design features to minimize maintenance and maximize design life:

- Maximize use of pretreatment systems, particularly for infiltration systems. Reducing velocities and pollutant loads entering SMPs will extend their design lives. (See **Section 7** for appropriate pretreatment design.)

- For infiltration, choose surface vegetated SMPs with deeper-rooted vegetation (trees, shrubs, and native herbaceous species) whenever possible. Root growth helps to keep the soil's pore structure open and maximizes the life of infiltration SMPs. Routine landscaping tasks are the primary maintenance required.

- On smaller sites, choose SMPs that do not require slow-release control structures. These structures can clog and require periodic inspection and maintenance.

4.4.2 Provide Access

Vehicle access from a public right-of-way can help to minimize the difficulty of maintenance. A 15-foot wide vehicle access path leading from a public right-of-way to all stormwater controls is strongly recommended.

4.4.3 Post-Construction Ownership

The owner of the land where the SMP is located is responsible for performing long term maintenance. In the case of a single property owner, that owner is responsible for maintenance. In cases of common ownership, a homeowners' or condominium association may assume responsibility for maintenance. Considering the type of ownership and owner preference can help the designer choose between smaller, distributed SMPs and a single centralized SMP.

4.4.4 Maintenance Tasks and Schedule

Maintenance tasks and frequencies are specific to each type of SMP. Maintenance guidance is provided in **Section 7**: SMP Design Guidelines for each SMP. A Maintenance Plan must be completed, signed and filed with the Recorder of Deeds to comply with the requirements of the Stormwater Regulations.

5 Post Construction Stormwater Management Plans

5.0 Introduction

5.1 Erosion and Sediment Pollution Control Plan

5.2 Components of the Post Construction Stormwater Management Plan

5.2.1 The Standard Submittal Format
5.2.2 Proof of Application for Applicable Permits
5.2.3 Documentation of Special Circumstances

5.3 Acceptable Methods for Calculations

5.3.1 Design Storms
5.3.2 Runoff Estimation
5.3.3 Storage Volume Estimation
5.3.4 Flow Routing
5.3.5 Storm Sewer Design

5.4 Post Construction Stormwater Management Plan Submittal Process

5.4.1 Project Screening
5.4.2 Technical Review Process
5.4.3 Inspections

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5.0 Introduction

This section is provided to guide developers through the necessary submittals required for stormwater management in Philadelphia. **Section 5.1** describes requirements for the Erosion and Sediment Pollution Control (E & S) Plan. **Section 5.2** describes the required components of the Post Construction Stormwater Management Plan (PCSMP). Acceptable calculation methods for determining sizing and appropriate stormwater management practices (SMPs) are contained in **Section 5.3**. **Section 5.4** describes the PCSMP submittal process.

5.1 Erosion and Sediment Pollution Control Plan

The Owner is responsible for ensuring that their active construction site is not creating violations of 25 Pa. Code Chapters 92 and/or 102 and the Clean Streams Law, the act of June 22, 1937, P.L. 1987, 35 P.S. §691.1 et seq. Depending on the limit of earth disturbance associated with a project there are specific preparation, review, and approval requirements. All E & S Plans must be prepared in accordance with Pennsylvania Department of Environmental Protection (PADEP) guidelines as laid out in the following Manual:

> PADEP, Bureau of Watershed Management, April 15 2000. *Erosion and Sediment Pollutant Control Program Manual*. Document 363-2134-008.

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine the level of review and approval required. Submittal requirements for E & S Plans are located in **Section 2.2**: Determining Applicability. Once the limits of earth disturbance have been accurately determined the applicant will follow one of the four E & S review paths listed below:

Earth Disturbance Categories:

A. Less than 5,000 square feet (not located in the Wissahickon Watershed*)
- E & S Plan is not mandatory.
- Owner must implement E & S best management practices (BMPs) in accordance with the most recent version of PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000).

B. More than 5,000 square feet, less than 15,000 square feet**
- E & S Plan must be prepared, implemented, and kept on site available for inspection at all times.
- The E & S Plan which complies with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000) must be maintained on submitted to the Philadelphia Water Department (PWD), but does not need to be approved.
- If the site is not subject to the PWD Stormwater Management Regulations (Stormwater Regulations), then submit E & S Plans as an attachment to the Existing Resources and Site Analysis (ERSA) online application at www.PhillyRiverInfo.org/PWDDevelopmentReview.

C. More than 15,000 square feet, less than 1 acre (43,560 square feet)**
- E & S Plan must be prepared, approved, implemented and kept on site available for inspection at all times.
- The E & S Plan must be reviewed and approved by PWD before PWD will sign the applicant's Building Permit Application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to the Stormwater Regulations and requires a full PCSMP submittal. E & S Plans are a component of the full PCSMP. These must be submitted together to:

  Projects Control
  Philadelphia Water Department
  1101 Market St, 2nd Floor
  Philadelphia, PA 19107

The submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

- A copy of the approved plans must be forwarded to the PWD E & S Unit.
- Notify the PWD E & S Unit of any pre-construction meetings, and notify the PWD E & S Unit three days prior to commencement of earth disturbance.

D. More than 1 acre (43,560 square feet)

- E & S Plan must be prepared, approved, implemented and kept on site at all times.
- A NPDES Permit application must be submitted to PADEP. Proof of issuance of the NPDES Permit must be provided to PWD before PWD will sign the applicant's Building Permit Application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to Stormwater Regulations and requires a full PCSMP submittal. E & S Plans are a component of the full PCSMP. These must be submitted together to:

  Projects Control
  Philadelphia Water Department
  1101 Market St, 2nd Floor
  Philadelphia, PA 19107

The submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

- A copy of the approved E & S Plan must be forwarded to the PWD E & S Unit.
- Notify the PWD E & S Unit of any pre-construction meetings, and notify the PWD E & S Unit three days prior to commencement of earth disturbance.

*Projects located in the Wissahickon Watershed may be subject to additional requirements which will be assessed as part of the project review performed by Philadelphia City Planning staff.

**If during the course of construction additional area is disturbed which changes the applicable requirements, construction will have to cease until new plans are prepared and approved by all relevant regulatory agencies.

Inspections

E & S inspections occur on both a scheduled and complaint driven basis. The E & S inspectors expect that the E & S controls contained within the prepared or approved E & S Plan (depending on the limits of disturbance) are implemented and maintained on site at all times. The E & S Inspectors are authorized to access a site and inspect the effectiveness of E & S BMPs. E & S Inspectors will advise the Owner or responsible party(s) of E & S control problems found during the inspection and what must be done to correct the violations. This may include implementing additional E & S BMPs not shown on the approved plans. Should a project site be disturbing earth without the appropriate approvals or ineffective E & S control BMPs,a Stop Work Order will be issued.

For a more detailed discussion of E & S issues please refer to Fact Sheet #7: Understanding Erosion and Sedimentation Control requirements in Philadelphia located on www.PhillyRiverInfo.org/PWDDevelopmentReview

5.2 Components of the Post Construction Stormwater Management Plan

The PCSMP must contain the elements found in the Checklist B: The Standard Submittal Format. If any of these are missing from a submitted plans, the plan will be returned to the developer for completion prior to review. All items should be submitted together to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

5.2.1 The Standard Submittal Format

Checklist B: The Standard Submittal Format contains an easy to use checklist to determine completion of the PCSMP. It is provided to assist the developer in ensuring that all necessary elements of the PCSMP are complete. Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets. This process has been designed to make submittal of the PCSMP easier for both developers and reviewers.

5.2.2 Proof of Application for Applicable Permits

Other state and federal permits may be required for development on a given site. PWD approval of a PCSMP is contingent upon approval by other regulatory agencies. Other permits that may be required include but are not limited to:

- NPDES (National Pollutant Discharge Elimination System) Phase II Permit for Construction Activities
- Pennsylvania Code and Charter Chapter 105: Water Obstruction and Encroachment General and Joint Permits

This list is not exhaustive nor does it imply that all of these permits are required. It is the **responsibility of the developer** to determine which permits are required by other regulatory agencies. **Appendix F.3**: Local Permitting requirements and **Appendix F.4**: Federal and State Permitting requirements provide resources to assist in determining which permits may apply.

Proof of the issuance of all applicable permits **MUST** be provided to obtain PWD sign off on any Building Permit. However, at the time of submittal of a PCSMP, the applicant must demonstrate that they have applied for all relevant permits. A photocopy of permit applications will serve as proof of application. If for some reason approval is denied or revoked by another regulatory agency, it is the developer's responsibility to notify PWD and other City agencies and rectify the situation before the project can proceed any further.

5.2.3 Documentation of Special Circumstances

The City recognizes that on-site stormwater management may not be feasible in part or in full for some development projects. Under these circumstances PWD requires that technical documentation demonstrating the site constraints be submitted to and reviewed by PWD. Alternatives to on-site stormwater management are accepted at the sole discretion of PWD. Complete details of documentation, stormwater management alternatives and contact information are provided in **Appendix F.4**: Special Circumstances and Waiver Requests.

5.3 Acceptable Methods for Calculations

The worksheets are intended to standardize and summarize the results of design calculations. The designer must also attach relevant data, field testing results, assumptions, hand calculations, and computer program results. This section summarizes calculation methods that are considered acceptable by PWD. Other methods will be considered on a case-by-case basis.

5.3.1 Design Storms

Sizing requirements for the Stormwater Regulations have been developed using long-term computer simulations. These requirements have been translated to single event design conditions that yield roughly equivalent results.

Design Rainfall Totals

The rainfall depths of design storms shown in Table 5.1 are taken from the Pennsylvania Department of Transportation Field Manual (1986). These totals indicate the largest depth one can expect over the specified interval in the specified return period. These design precipitation depths are similar to those found in other standard references such as National Oceanic and Atmospheric Administration (NOAA) Technical Publication 40 or the NOAA Atlas 14; however, Design Professionals must use the values provided in Table 5.1 for their design calculations.

Table 5.1: Design Precipitation Depths (in)

	Return Period						
Duration	1 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min	0.33	0.38	0.45	0.50	0.56	0.63	0.68
15 min	0.64	0.75	0.90	1.00	1.15	1.35	1.50
1 hr	1.10	1.35	1.61	1.85	2.15	2.60	2.98
2 hrs	1.34	1.66	2.00	2.34	2.70	3.26	3.76
3 hrs	1.50	1.86	2.28	2.67	3.09	3.69	4.29
6 hrs	1.86	2.28	2.82	3.36	3.90	4.62	5.40
12 hrs	2.28	2.76	3.48	4.20	4.92	5.76	6.72
24 hrs	2.64	3.36	4.32	5.28	6.24	7.20	8.40

Design Rainfall Distribution

For the Channel Protection and Flood Control calculations, the design rainfall depth must be distributed in a NRCS (National Resources Conservation Service) Type II dimensionless rainfall distribution. The Type II distribution was selected not because it represents a typical event but because it includes periods of low-intensity and high-intensity rainfall; design using this distribution results in a facility that can manage a variety of event types, particularly high intensity storms.

Table 5.2: Tabulated NRCS 24-Hour Type II Distribution		
Time	Dimensionless Rainfall	
(hr)	Cumulative	Incremental
0.00	0.000	0.000
2.00	0.022	0.022
4.00	0.048	0.026
6.00	0.080	0.032
7.00	0.098	0.018
8.00	0.120	0.022
8.50	0.133	0.013
9.00	0.147	0.014
9.50	0.163	0.016
9.75	0.172	0.009
10.00	0.181	0.009
10.50	0.204	0.023
11.00	0.235	0.031
11.50	0.283	0.048
11.75	0.357	0.074
12.00	0.663	0.306
12.50	0.735	0.072
13.00	0.772	0.037
13.50	0.799	0.027
14.00	0.820	0.021
16.00	0.880	0.060
20.00	0.952	0.072
24.00	1.000	0.048

Storm Return Periods for Large Events and Flow Bypass

At a minimum, safe conveyance of the 10-year, 24-hour design storm must be provided to and from SMPs to comply with the requirements of §14.1603.1.6.C.4. Additionally, the flow that is leaving the system must meet the requirements of the Stormwater Regulations. Many SMPs will be designed to manage smaller storms. A designer might choose to allow runoff from larger storms to bypass or quickly pass through a storage element.

5.3.2 Runoff Estimation

A number of mathematical models are available to estimate stormwater runoff from a given storm. For sites that are dominated by impervious cover, most methods will yield similar results. For sites with significant pervious cover contributing flows to SMPs, infiltration loss models provide more realistic results than the empirical, statistically based methods. However, a thorough understanding of soil behavior is necessary to generate realistic runoff estimates.

The empirical methods can be implemented by computer programs. Examples of computer programs available in the public domain are listed in Table 5.3. In addition, a wide range of proprietary programs are available. Designers are strongly urged to consider the assumptions and mathematical models underlying these programs when choosing an appropriate tool to aid in design.

Table 5.3: Acceptable Calculation Methods for Runoff Estimation					
Type	Mathematical Model	Impervious Cover	Experience Modeling Soil Properties	Hand/Spreadsheet Calculations	Example Computer Programs
Empirical Methods	NRCS Curve Number method	Any	Moderate-High	Yes (smaller sites)	NRCS, TR-55, TR-20, HEC-HMS
Infiltration Loss Models	Constant Loss	Any	Moderate-High	Yes (smaller sites)	HEC-HMS
	Green-Ampt	Any	High	No	EPA SWMM, HEC-HMS
	Horton	Any	High	No	EPA SWMM

Rational Method

The rational method may **not** be used for SMP design, outlet control design, or detention routing. It may be used for storm sewer capacity design as described in **Section 5.3.5**: Storm Sewer Design.

NRCS Curve Number (Soil Complex) Method

The NRCS Curve Number Method is widely used to produce estimates of runoff for both pervious and impervious cover. It empirically accounts for the fact that soils become saturated and gradually yield more runoff during the course of a storm. For a detailed description of the Curve Number Method, see Urban Hydrology for Small Watersheds (NRCS Technical Release 55).

Care should be taken to select appropriate curve number (CN) values since this calculation method is very sensitive to changes in these values. In order to obtain conservative results, use separate calculations for pervious and impervious area. The resulting flows can be routed if necessary and then added. See Table 5.4 for PWD approved CN values for each Hydrologic Soil Group.

Infiltration Loss Models

Infiltration loss models estimate runoff quantity by subtracting depression storage and infiltration losses from rainfall. These models are based on the physics of soil behavior and provide more precise results than empirical models. Used by an experienced modeler with ample soil data, these models produce more realistic estimates than empirical models on sites where a significant portion of runoff is generated by pervious cover. Results depend most strongly on soil properties.

Table 5.4: PWD Accepted Curve Number Values

Cover Description		Curve Number for Hydrologic Soil Group				
Cover Type	Hydrologic Condition	A	B	C	D	Ub
Lawns, parks, golf courses, etc...						
	Poor (grass cover < 50%)	68	79	86	89	79
	Fair (grass cover 50% to 75%)	49	69	79	84	69
	Good (grass cover > 75%)	39	61	74	80	61
Meadow		30	58	71	78	58
Athletic Fields		68	79	86	89	79
Porous Turf		70	70	79	84	69
Brush (brush-weed-grass mixture with brush the major element)						
	Poor	57	73	82	86	73
	Fair	43	65	76	82	65
	Good	32	58	72	79	58
Woods-grass combination (orchard or tree farm)						
	Poor	57	73	82	86	73
	Fair	43	65	76	82	65
	Good	32	58	72	79	58
Woods						
	Poor	45	66	77	83	66
	Fair	36	60	73	79	60
	Good	30	55	70	77	55
Paved parking lots, roofs, driveways. streets, etc.		98	98	98	98	98
Gravel		76	85	89	91	89
Dirt		72	82	87	89	87
Porous Pavement		70	70	74	80	70
Permeable Pavers		70	70	79	84	70
Pour-in-Place Rubber		70	70	74	80	70
Green Roof*		86	86	86	86	86

* Existing rainfall runoff models are limited in their ability to predict runoff from green roofs since this process is dominated by percolations through a thin veneer of soil and is not surface runoff. Green roof research studies have back-calculated a range of CN values for various storms and roof media types/ thicknesses. CN values different from that listed in the table may be permitted if appropriate citations are provided with the stormwater report.

Determining the Predevelopment Conditions for Runoff Calculations

The predevelopment condition for any project is determined by the dominant land use for the previous ten (10) years preceding the planned project. If a redevelopment project is able to reduce the DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development conditions, is it exempt from the Channel Protection and Flood Control requirements.

When performing Flood Control calculations, PWD requires the following land use designations for all development and redevelopment in City of Philadelphia:

1) Redevelopment sites in the predevelopment condition:

- All nonforested, pervious areas **must** be considered meadow (good condition) for the predevelopment runoff calculations.
- In addition to any other pervious area, twenty percent (20%) of the existing impervious cover on site, when present, **must** be considered meadow (good condition) for the predevelopment runoff calculations.

2) New Development sites in the predevelopment condition:

- All nonforested, pervious areas **must** be considered meadow (good condition) for the predevelopment runoff calculations.

5.3.3 Storage Volume Estimation

Surface storage: A rough estimate of surface storage can be obtained by averaging the surface area and bottom area of a basin and multiplying by the average depth. For irregular shapes, volume can be estimated by finding the area inside each contour, multiplying each area by the contour interval, and adding the results.

Stone Storage: Storage in stone pores is equal to the volume of the crushed stone bed times the porosity. A design porosity of 40% can be assumed for the stone if specifications for the crushed stone meet those provided in **Section 7**: SMP Design Guidelines.

Porous Media Storage: Storage available in porous media is equal to the initial moisture deficit, the portion of total porosity that is not already occupied by moisture. This portion varies at the beginning of every storm; acceptable design values are 30% for sand and 20% for growing soil.

Active Storage: Not all physical space in a given SMP is active. The maximum elevation that should be considered as active storage is the overflow elevation. In tanks draining by gravity whose bottoms do not infiltrate, any volume below the invert of the orifice or control structure is not considered active storage.

5.3.4 Flow Routing

Sheet Flow and Shallow Concentrated Flow

Sheet flow consists of shallow flow spread out over a plane. Eventually, this flow will generally concentrate into a deeper, narrower stream. There is debate over how prevalent sheet flow is in the natural environment. However, it provides a reasonable mathematical basis for predicting travel time and infiltration losses over short distances. *Urban Hydrology for Small Watersheds* (TR-55) provides a sheet flow equation based on Manning's kinematic solution. Tables of roughness values for sheet flow are available in *Urban Hydrology for Small Watersheds* and in Table 5.5 shown below. There is debate over the appropriate length of sheet flow; however, PWD will only accept sheet flow for the first 150 feet. After sheet flow,

overland flow is considered shallow concentrated flow. Shallow concentrated flow will be considered as flowing over paved or unpaved surface for the purpose of estimating velocity. Another method for routing overland flow is the kinematic wave solution, obtained by coupling the momentum and continuity equations with simplifying assumptions, may be solved in a computer program using numerical methods. A computer program also allows practical calculations at a much smaller time step than hand or spreadsheet calculations.

Channel Flow

Channel flow equations may be used to estimate flows in free-flowing gutters and swales. Manning's equation is sufficient for these estimates on many sites. Tables of roughness values are available in *Civil Engineering Reference Manual* (CERM*)* Appendix 19.A. For channels with significant backwater, culverts which may flow under pressure, or other complex features, the St. Venant equations may be needed. These equations represent the complete solution of the momentum and continuity equations in one dimension. They require a computer program to solve.

For reference, the post development time of concentration will be less than or equal to the predevelopment time of concentration values unless the site is specifically altered to increase this path.

Table 5.5: Roughness Coefficients (Manning's n) for sheet flow

Surface Description	n [1]
Roof tops	0.011
Concrete	0.013
Asphalt	0.015
Bare Soil	0.018
Sparse Vegetation [2]	0.1
Grass:	
Short grass prairie	0.15
Dense grasses [3]	0.24
Range (natural)	0.13
Woods: [4]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information compiled by Engman (1986) and Akan (1985).

[2] Areas where vegetation is spotty and consists of less than 50% vegetative cover.

[3] Species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[4] Consider cover to a height of 0.1 ft. This is the part of the plant cover that will obstruct sheet flow.

Storage Routing

For small storage elements where travel time within the element is insignificant, simple mass balance routing may be performed in a spreadsheet. At each time step, the change in storage volume is the difference between inflows and outflows. Inflows and outflows are a function of design and soil properties.

For larger or more complex structures, where the shape and size of the element have a significant effect on outflows, the Modified Puls (also called storage-indication) method provides more accurate routing.

Table 5.6: Summary of Recommended Methods for Flow Routing				
Type	Mathematical Model	Appropriate For…	Hand/ Spreadsheet Calculations	Example Computer Programs
Overland Flow	simplified Manning kinematic solution	sheet flow path up to 150 feet	Yes	TR-55, TR-20
	shallow concentrated / NRCS empirical curve	overland flow longer than 150 feet	Yes	TR-55, TR-20
	kinematic wave	larger or more complex sites	No	EPA SWMM, HEC-HMS
Channel Flow	Manning equation	uniform flow without backwater	Yes	TR-55, TR-20, EPA SWMM, HEC-HMS
	St. Venant equations	channels with storage, backwater	No	EPA SWMM, HEC-RAS
Storage Routing	simple mass balance	small storage elements	Yes	USACE STORM
	Modified Puls / storage-indication	large or irregularly-shaped elements	Yes	TR-55, TR-20, HEC-HMS

5.3.5 Storm Sewer Design

The storm sewer must be designed to safely convey the 10-year storm without surcharging inlets. If Flood Control is required, runoff from larger storms must be safely conveyed off the site, either through overland flow or a storm sewer. Please note, runoff may not be conveyed to a neighboring property.

Rational method may be utilized when designing storm sewers. Recommended assumptions to obtain conservative results using the rational method include:

- Choose appropriate runoff coefficients based on the Engineer's best judgment of land use type (e.g., see CERM Appendix 20.A).

- For pervious areas with rational coefficients less than 0.2, use a coefficient of 0.2.

For a table of rational method coefficients, see CERM Appendix 20.A.

5.4 Post Construction Stormwater Management Plan Submittal Process

Because the **PWD Approval Signature and Stamp on Building Permits will only be issued upon approval of Water, Sewer and Stormwater, it is strongly recommended that developers submit Water, Sewer and PCSMP materials at the same time.** All items should be submitted together to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

The PCSMP submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

5.4.1 Project Screening

Only a complete PCSMP will be accepted for review. When a new project is received it undergoes a screening process to make sure it includes all the components necessary to complete a review. If any portion is found to be missing or incomplete the developer will be notified by email. Any additional information that is required should be mailed to PWD Projects Control. If necessary, incomplete PCSMP submittals will be returned to the developer for completion. When a project is screened incomplete no additional review of the project will be done until the required materials have been received. Once a project submittal is found to be complete the developer will be notified and the project will be moved into technical review.

Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets. Checklist B: The Standard Submittal Format is provided to guide the developer and help them ensure that their application is complete prior to submittal.

5.4.2 Technical Review Process

Once a project submittal has been screened and determined to be complete, it will be put in line for technical review. Projects are generally reviewed in the order in which they were received. Because of this, review times depend heavily on the number of projects under review at the time of the submittal.

During the technical review, PWD will examine the submittal to determine if all applicable requirements are being met. Should any deficiencies be identified, PWD will email a letter of review comments to the developer. Additional information or revised materials required based on the comments should be submitted to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

Technical review of the submittal will not continue until a new submittal addressing the comments is received. This submittal should include all required revisions and new material as well as an explanation of how each review comment was addressed. PWD will review the comment responses and new and revised material for compliance with all applicable requirements. Should any deficiencies are identified PWD will update the review letter and email the developer. Please note that additional comments may be added to the review comments based on changes to the plans and calculations. This process continues until all review comments are addressed.

The developer can influence the amount of time their review will take in several ways. If the developer chooses to use development practices that allow disconnection of 95% or more of the post construction directly connected impervious area (DCIA) most projects will be eligible for a Green Project Review. PWD is committed to performing Green Project Reviews within 5 business days. For more information see **Section 4.2**: Reduce Impervious Cover to be Managed. The developer may also influence the length of the review time by being responsive when review comments are issued. Reviews often take less time when a project is resubmitted in a short amount of time because reviewer is less likely to be involved in other projects and will be more familiar with the original comments.

Once all of the review comments have been addressed PWD will email the developer an approval letter. The developer **must** bring this approval letter and proof of issuance of any additional required permits to PWD when acquiring signature on Building Permit applications.

5.4.3 Inspections

During any stage of work, if the City or its designee determines that the permanent SMPs and/or stormwater management facilities are not being installed in accordance with the permitted PCSMP, the City shall revoke any existing permits or other approvals and issue a “Stop Work Order.” Work will be suspended until the installation is corrected according to the original PCSMP or a revised PCSMP is submitted, a permit granted, and the deficiencies are corrected.

Prior to the final inspection, all SMPs and/or stormwater management facilities as-built drawings must be submitted to PWD. The final inspection shall be conducted by the City or its designee to confirm compliance with the permitted PCSMP prior to the issuance of any Certificate of Occupancy. The City or its designee may inspect any phase of the installation of the permanent SMPs and/or stormwater management facilities as deemed appropriate by PWD.

6 Utilizing Existing Site Features

6.0 Introduction

6.1 Street Design

6.2 Parking Lot Design

6.3 Planter Boxes

6.4 Special Detention Areas (see Pennsylvania Stormwater BMP Manual)

6.5 Disconnecting Impervious Cover

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6.0 Introduction

This manual emphasizes an integrated site design approach to stormwater management. By considering stormwater management in conjunction with site uses and functions from the assessment phase through final design, it is possible to develop a site plan that meets the Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations) and other site objectives concurrently.

The following sections present examples from Pennsylvania and across the nation that integrate stormwater management approaches into both original and retrofit site designs. In this way, comprehensive stormwater management can be integrated effectively and economically into the site design process.

The following set of sections illustrates concepts and benefits provided through the application of holistic stormwater management approaches.

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6.1 Street design


City of Portland, Bureau of Environmental Services

Sidewalk planter managing street runoff

provides an opportunity to distribute stormwater management practices (SMPs) and integrate them with neighborhood aesthetics. Street location, width, and design can reduce the volume of stormwater runoff leaving the streets. Utilizing vegetated areas along a street for water quality treatment and detention can also reduce the costs of development by creating less need for underground stormwater infrastructure. Other benefits of low-impact street design include slowed traffic in residential areas, enhanced visual appearance, and improved water quality.

Low-impact street design can be difficult to accomplish within the City of Philadelphia. Design of public streets is highly regulated and structural SMPs are typically not permitted within the public right-of-way. The current residential street width requirements from the Philadelphia City Code are shown below. However, the City is working to develop a green street design that can be implemented throughout Philadelphia. There are also opportunities for low-impact design elements to be applied on private streets and drives such as those within a condominium. This section includes several examples of street design that can serve as a model for development in Philadelphia.

Note:
SMP Design and combinations are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Table 6.1: Philadelphia's City Codes for Street Widths

(§14-2104.) - **Minimum street right-of-way and cartway widths shall conform to the Physical Development Plan of the City and where not shown thereon shall conform to the following:**	
primary residential street	64 feet in width, right-of-way 88 feet in width
secondary residential street	34 feet in width, right-of-way 54 feet in width
tertiary residential street	26 feet in width, right-of-way 50 feet in width
marginal access street	26 feet in width, right-of-way might vary with conditions but in no case shall be less than 36 feet
(§11-407.) **- Minimum street width shall conform to the provisions of** *(§ 14-2104.)* **A street which does not conform to** *(§ 14-2104(5))* **may be accepted and placed upon the City Plan if it was physically or legally opened or built upon:** Civil Engineering Reference Manual	
prior to April 2, 1906	must be at least 40 feet in width;
prior to April 8, 1890	must be at least 30 feet in width;

example:

The City of Portland "Green Streets Project" on NE Siskiyou Street incorporates landscaped curb extensions or bumpouts designed to capture stormwater.

Green Streets Project: Portland, Oregon



NE Siskiyou before



NE Siskiyou during construction



NE Siskiyou after



City of Portland, Bureau of Environmental Services

Diverse plants make the curb extension pleasing while absorbing runoff.

project overview

The neighborhood is served by combined sewers that carry both sewage from homes and stormwater runoff from streets. When it rains, combined sewer pipes fill to capacity and overflow to the Willamette River.

Portland's Bureau of Environmental Services built two landscaped curb extensions in the parking zone on each side of Siskiyou Street just above the storm drain inlets. Stormwater slows when it enters the landscaped areas, water infiltrates into the ground, and vegetation help filter pollutants. The Northeast Siskiyou Green Street Project is Portland's first residential, on-street stormwater management project. It is a sustainable approach that mimics natural conditions while improving water quality and neighborhood aesthetics.

Private developments within the City of Philadelphia may not currently use area within the public right-of-way to meet their stormwater management requirements. However, this design may be modified for on-site treatment or applied to private roads such as those within a condominium.

design elements

- Dense, low growing plant material in a bioinfiltration bed for stormwater capture, filtration, and recharge to local soils.
- Curb openings to allow stormwater runoff into the planted area.
- Check dams to increase retention times to promote infiltration and uptake by native plantings.



Figure 6.1: Traffic calming device on secondary street that also provides stormwater management

example:

The City of Seattle's Pilot Street Edge Alternative Project (SEA Streets) provides drainage that mimics the natural landscape prior to development more closely than traditional systems.

Street Edge Alternatives (SEA) Seattle, Washington







Curbless roads allows stormwater to runoff to the streets



Bioretention swale between sidewalk and paved road

project overview

As the Street Edge Alternatives Project gathered more data and information concerning the damage runoff causes, they began exploring new approaches to manage stormwater. These natural drainage systems meet multiple goals and help manage flooding in neighborhoods. At the same time, they improve the appearance and function of the street right-of-way. Two years of monitoring shows that SEA Streets reduce the volume of stormwater runoff by 99% for a two-year storm event, and help the city meet Local, State, and Federal Environmental Regulations.

design elements

- Curbless roads provide traffic calming and soft-edged, aesthetic environments.
- Bioretention swales mimic the natural landscape and provide drainage and absorption of pollutants.
- Infiltration in bioretention swales can be used to meet Water Quality requirements for contributing Directly Connected Impervious Area (DCIA).



Figure 6.2: Secondary street with bioretention basins

cul-de-sac design

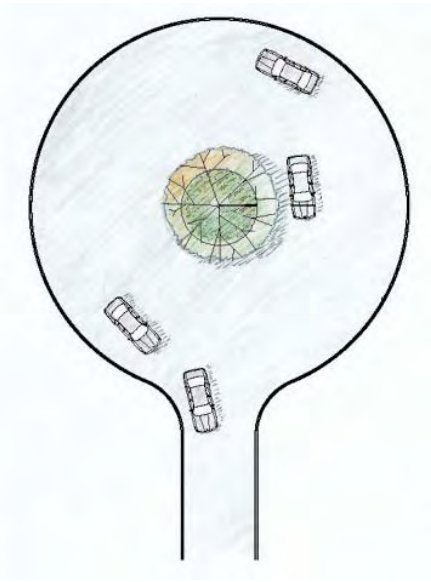

Figure 6.3: Cul-de-sac with bioretention

Though cul-de-sacs and 'dead ends' are not encouraged in urban street design, they do exist within urban areas. In Philadelphia, dead end streets are prohibited, except as short stubs to permit future street extension into adjoining tracts, or when designed as a cul-de-sac. (§14-2104. Subdivision Design Standards.) Where cul-de-sacs are unavoidable, they can be designed with central islands that reduce impervious area and to allow for infiltration of stormwater runoff.

design overview

Careful cul-de-sac design can greatly reduce total impervious area and can create a stormwater management facility. Philadelphia Code stipulates, "Cul-de-sacs, permanently designed as such shall have at the closed end a turn-around containing a right-of-way having an outside radius of not less than 50 feet, which shall be paved to a radius of 40 feet." (§14-2104)

A cul-de-sac can be designed to meet these standards and still provide stormwater management. An island can be designed in the center of a cul-de-sac that provides a sufficient travel lane, but reduces impervious area and manages stormwater from the street and adjacent properties. The entire street should be graded to the central island to the extent that surrounding topography allows. The island would be designed like a bioretention facility and runoff can enter the island through curb openings or a curbless design.

design elements

- Bioretention islands capture stormwater runoff.
- Flow controls direct stormwater from street and adjacent properties into the island.

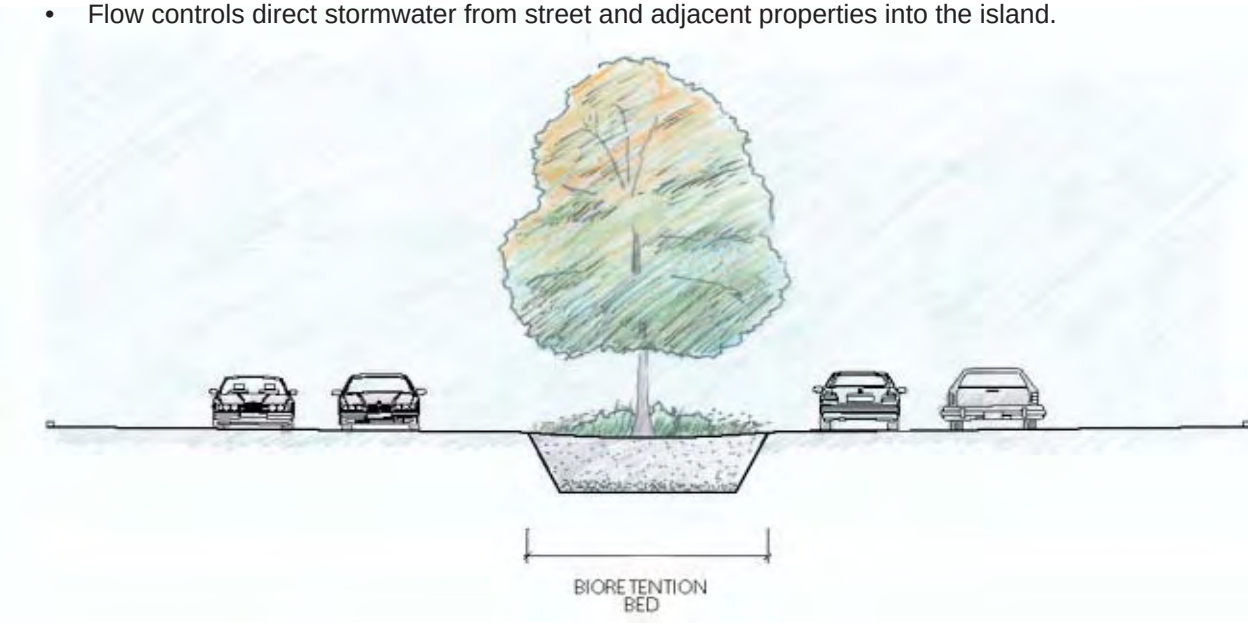

Figure 6.4: Cross-section view of a bioretention cul-de-sac. The island of the cul-de-sacs accepts stormwater from surrounding pavement

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vegetated medians



Dan Burden

Bioretention incorporated in highway median



Pennsylvania Stormwater BMP Manual

Vegetated swale in street median

Medians that are retrofitted to provide stormwater control are effective elements of traffic calming and stormwater management while enhancing the visual quality of the streetscape. There are different ways to help prevent stormwater runoff pollution from reaching Philadelphia's rivers. Bioinfiltration swales and concave designs are just a few examples of effective stormwater control. These provide for an attractive and healthier appearance of the city, but still deliver the necessary benefits to our natural resources.

design overview

Median strips can be graded concave and incorporate vegetated SMPs (see **Section 7.5:** Bioretention and **Section 7.8:** Swales). Water draining into these SMPs can be treated for water quality through infiltration or an underdrained system may be installed to allow water to be treated and slowly released depending on soil conditions.

design elements

- Bioinfiltration swales for runoff control on both sides of traffic.
- Planted native vegetation to enhance appearance and provide capture and filtration
- Curb openings or curbless design to allow controlled stormwater inflow

Note:
Designs and combinations are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.



Figure 6.5: Cross-section view of secondary street with bioretention basins

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6.2 Parking lot design

The requirements of the Stormwater Regulations, including non-structural project design, can be met in many cases by rethinking parking lot design. Effective use of the minimum parking space and aisle dimensions as permitted in the City's Zoning Code allows the number of parking spaces to remain the same, while reducing impervious surface, providing stormwater management, and adding valuable green space to a parking lot.



City of Portland, Bureau of Environmental Services

OMSI, 2001 (1945 SE Water Ave.)



City of Portland, Bureau of Environmental Services

Glencoe Elementary School Parking Lot (825 SE 51st)

bioretention garden

design overview

Sheet flow from the parking lot is directed toward shallow bioretention gardens. The runoff is then temporarily detained and infiltrated into the subsurface. Bioretention gardens can replace the need for other conventional stormwater management techniques. Distributed bioretention gardens offer the greatest benefit. Sites can benefit from bioretention gardens placed along the edges of the site as well as in islands and medians.

Traditional stormwater infrastructure can be reduced, and parking lot aesthetics are also greatly improved. The use of large trees help improve the air quality and provide shading for the cars in the parking lot.

design elements

- Bioretention garden with acceptable vegetation (refer to **Section 7.5:** Bioinfiltration/Bioretention and **Section 8:** Landscape Guidance)
- Curb openings with flow controls, such as flow spreaders and energy dissipaters (refer to **Section 7.15**: Inlet and Outlet Controls).

porous/permeable pavement

design overview

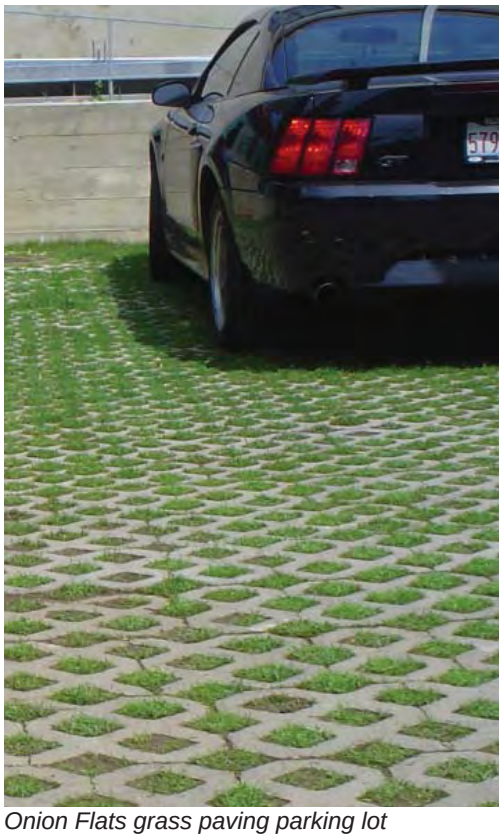
The use of porous or permeable pavement creates a parking lot that distributes stormwater evenly into a subsurface infiltration bed. These systems can be designed to infiltrate even the large storms. Seasonal maintenance is required for most porous pavement systems to ensure continued function.


City of Portland, Bureau of Environmental Services

Multnomah Arts Center Eco-Stone parking lot

design elements

- Porous pavement combined with subsurface infiltration (refer to **Section 7.13**: Porous Pavement).
- Documentation of flow through rate or void percentage must be provided when using permeable pavers



Onion Flats grass paving parking lot

grass paving

design overview

Void spaces found in grass paving techniques offer area infiltration while maintaining parking support. Replacement of conventional pavement with grass paving systems can reduce urban heat effects.

design elements

- Reinforced grid system (refer to **Section 7.13**: Porous Pavement)

6.3 Planter boxes

reduce impervious cover by retaining stormwater runoff rather than allowing it to directly drain into nearby sewers. There are two main types of planter boxes: Flow-through and Contained. Planter boxes can play an important role in the city by minimizing stormwater runoff, reducing water pollution, and creating a greener and healthier look. Planter boxes can be used on sidewalks, plazas, rooftops and other otherwise impervious areas. They can also be constructed alongside buildings, provided proper waterproofing measures are used to protect foundations.



Broad Street planter box

flow-through

The flow-through planter box is designed with an impervious bottom or is placed on an impervious surface. Water quality treatment, attenuation of flow, and some volume reduction is achieved as the water filters through the soil. Flow control is obtained by storing the water in a reservoir above the soil. This type of planter can be used adjacent to a building if lined properly.



City of Portland, Bureau of Environmental Services

Flow-through planter box

The planters should be designed to retain and slowly release water. Vegetation includes rushes, reeds, sedges, irises, dogwoods, and other acceptable shrubs, trees, and forbs/grasses. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff.

planter boxes

Suggested structural elements of planters include stone, concrete, brick, or pressure-treated wood. Certain treated wood should be avoided if it leaches toxic chemicals that can contaminate any filtered stormwater. The flow-through planter is completely contained and is not designed to drain directly into the ground. Irrigation is optional and used to maintain plant viability and reservoir height. Pipes can also be designed to transport water to an approved disposal point.

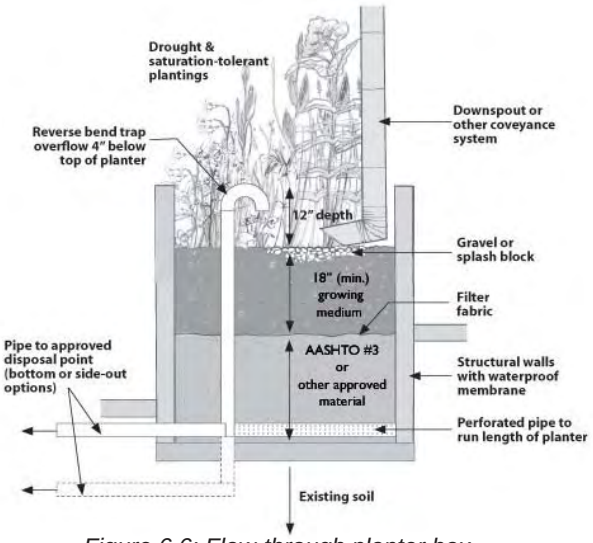


Figure 6.6: Flow-through planter box



City of Portland, Bureau of Environmental Services



Broad Street planter box

contained

Contained planter boxes reduce impervious area by retaining rainwater which slows stormwater runoff from draining into sewers. Contained planters are used for planting trees, shrubs, and ground cover. The planter is either prefabricated or permanently constructed and has a variety of shapes and sizes. Planters are placed on impervious surfaces like sidewalks, plazas, and rooftops. Contained planters may drain onto impervious surfaces through their base or by an overflow structure.

Plants should be hardy and self-sustaining with little need for fertilizers or pesticides. Irrigation is optional though plant viability should be maintained. Trees are highly encouraged because of the natural canopy they will provide and the reduction of urban heat. The structural elements of the planters should be stone, concrete, brick, wood, or any other suitable material. Treated wood should be avoided if it leaches any toxic chemicals.

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Information on Special Detention Areas
can be found in the
Pennsylvania Stormwater BMP Manual

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6.5 Disconnecting impervious cover

will reduce runoff from the site and therefore can reduce the structural stormwater management requirements for the development project. Impervious cover can be disconnected by directing the flow over a pervious area which allows for infiltration, filtration, and increased time of concentration. When this is done correctly, the area may be considered Disconnected Impervious Cover (DIC). Depending on the site configuration, all or a portion of impervious cover can be effectively removed by limiting the amount of actual impervious surfaces or by reducing the impervious area that is directly connected to the stormwater conveyance system. The DCIA Worksheet guides the designer through this stage of the design process.

minimize area of impervious cover

In many cases, alternative configurations for streets and parking lots can provide the same function as traditional designs with reduced area. Minimizing the area of pavement and rooftops will reduce the size and cost of SMPs that must be constructed. See the Parking Lot Design, **Section 6.2** for more information and ideas on how to minimize the impervious area.

disconnect impervious cover

Rooftop Disconnection

An adjustment to DCIA is permitted when the downspout is disconnected and then directed to a pervious area which allow for infiltration, filtration, and increased time of concentration. PWD will support the applicant in their request to obtain relevant necessary Plumbing Code variances for approved rooftop disconnections.

- DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface.

- DIC need not be managed for Water Quality. However, for Flood Control and Channel Protection, appropriate Curve Number (CN) values must be utilized when calculating management for these requirements.

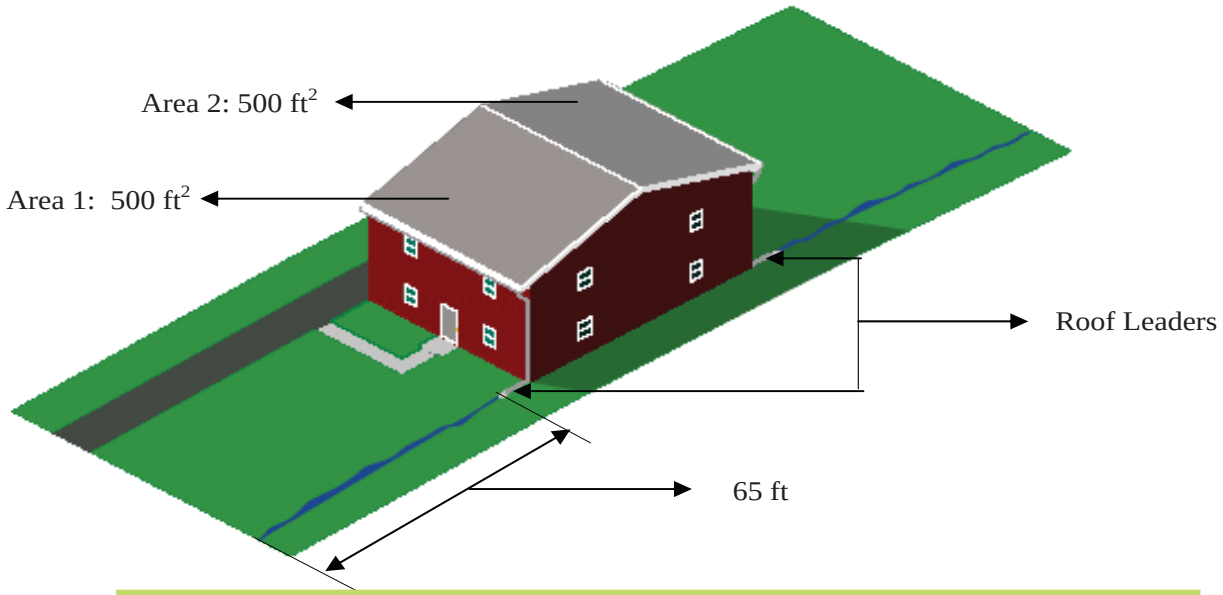
A rooftop is considered to be completely or partially disconnected if it meets the requirements below:

- The contributing area of rooftop to each disconnected discharge is 500 square feet or less,
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The overland flow path has a positive slope of 5% or less.

For designs that meet these requirements, the portion of the roof that may be considered DIC depends on the length of the overland path as designated in the following table.

Table 6.2: Partial Rooftop Disconnection	
Length of Pervious Flow Path*	Roof Area Treated as Disconnected
(ft)	(% of contributing roof area)
0 - 14	0
15 - 29	20
30 - 44	40
45 - 59	60
60 - 74	80
75 or more	100
* Flow path cannot include impervious surfaces and must be at least 15 feet from any impervious surfaces.	

For example, consider a 1,000 square foot roof with two roof leaders each draining an area of 500 square feet. Both roof leaders discharge to a lawn. The lawn has type B soils and a slope of 3%. The distance from the downspout discharge point to the street is 65 feet. Therefore, based on Table 4.1, 80% of the roof area may be considered DIC and treated as pervious cover when calculating stormwater management requirements. Disconnecting the roof leaders will significantly reduce the size and cost of stormwater management facilities at this site.



Total Roof Area: (Area 1 + Area 2): 1000 ft²
Disconnected Roof Area: (0.8) x (Total Roof Area): 800 ft²
Remaining DCIA: (Total Roof Area - Disconnected Roof Area): 200 ft²

Figure 6.7: Rooftop disconnection

Pavement Disconnection

An adjustment to DCIA is permitted when pavement runoff is directed to a pervious area which allows for infiltration, filtration, and increase the time of concentration. This method is generally applicable to small or narrow pavement structures such as driveways and narrow pathways through otherwise pervious areas (e.g., a bike path through a park). For structures that meet the requirements, all of the DIC may be deducted from the total impervious cover. DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality. If the site does not successfully reduce impervious cover by 20%, then appropriate CN values must be utilized when calculating Flood Control and Channel Protection. Pavement is disconnected if it meets the requirements below:

- The contributing flow path over impervious cover is no more than 75 feet,
- The length of overland flow is greater than or equal to the contributing length,
- The soil is not designated as a hydrologic soil group “D” or equivalent,
- The slope of the contributing impervious area is 5% or less, and
- The slope of the overland flow path is 5% or less.

If discharge is concentrated at one or more discrete points, no more than 1,000 square feet may discharge to any one point. In addition, a gravel strip or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

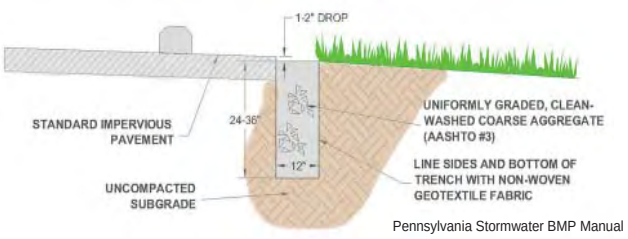


Figure 6.8: Gravel filter strip

Note:
Filter strips are recommended only as a viable stormwater management pretreatment option. Filter strips are recommend for use as pretreatment for many intensive structural SMPs.

maximize tree canopy over impervious cover

A reduction in DCIA is permitted when new or existing tree canopy from the approved species list extends over or is in close proximity to the impervious cover. Under these circumstances, a portion of impervious cover under tree canopy may be treated as DIC and deducted from total impervious cover. DIC is considered pervious when calculating stormwater control requirements.

For a new tree to be eligible for the reduction:

- The tree species must be chosen from the approved list provided by the PWD Office of Watersheds.
- Trees must be planted within 10 feet of ground level DCIA within the limits of earth disturbance.
- New deciduous trees must be at least 2-inch caliper and new evergreen trees must be at least 6 feet tall to be eligible for the reduction.
- A 100 sq. ft DCIA reduction is permitted for each new tree. This credit may only be applied to the impervious area directly adjacent to the tree.
- The maximum reduction permitted, including existing trees is 25% of ground level impervious area within the limits of earth disturbance.

Install Green Roofs to Minimize DCIA

A reduction in DCIA is permitted when a green roof is installed on a proposed building. The design, construction, and maintenance Plan must meet the minimum requirements specified in **Section 7**: SMP Design Guidelines. To encourage this emerging technology, the entire area of the green roof area may be considered DIC. However, since a green roof is not a zero discharge system, the remaining site design must safely convey roof runoff to the approved point of discharge. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

Install Porous Pavement to Reduce DCIA

A reduction in DCIA is permitted when a porous pavement system is installed on the site such that it does not create any areas of concentrated infiltration. Porous pavement systems, including porous asphalt; porous concrete; porous/permeable pavers; and other PWD-approved porous structural surfaces can be considered to be DIC if they receive direct rainfall only and are underlain by a crushed stone infiltration bed that is at least 8 inches deep. Porous/permeable pavers must also meet minimum standards for flow-through rate or void percentage. If an underdrain is proposed, the porous pavement will only be considered DIC if the first inch of runoff can be stored below the lowest overflow from the underdrain system. Porous asphalt systems must meet the minimum requirements detailed in **Section 7.13**: Porous Pavement. Infiltration testing is not required for disconnected porous pavement areas; however, it is recommended to ensure timely drainage of the stone base. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

In most cases, if the porous surface receives runoff (overland or piped directly into the subsurface storage bed) from adjacent conventional pavement surfaces, roof, or other impervious surfaces, the porous pavement/infiltration bed system will be considered a structural SMP and the porous surface will be considered DCIA. Those areas considered structural SMPs will require infiltration testing. In some cases, where a small amount of run-on cannot be avoided, it may still be possible to consider the porous pavement disconnected. Such allowances will be considered on a case-by-case basis by PWD.

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7 Stormwater Management Practice Design Guidelines

7.1 Green Roofs

7.2 Rain Barrels and Cisterns

7.3 Filter Strips

7.4 Filters

7.5 Bioinfiltration / Bioretention

7.6 Detention Basins

7.7 Berms and Retentive Grading

7.8 Swales

7.9 Constructed Wetlands (see PA Stormwater BMP Manual)

7.10 Ponds & Wet Basins (see PA Stormwater BMP Manual)

7.11 Subsurface Vaults

7.12 Subsurface Infiltration

7.13 Porous Pavement

7.14 Pre-fabricated and Proprietary Designs (see PA Stormwater BMP Manual)

7.15 Inlet and Outlet Controls

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7.1 Green roofs


City of Portland, OR

(vegetated roof/eco roof/roof garden) consist of a layer of vegetation that completely covers an otherwise conventional flat or pitched roof. The hydrologic response of a green roof bears closer resemblance to a lawn or meadow than impervious surface. The green roof system is composed of multiple layers including waterproofing, a drainage layer, engineered planting media, and specially selected plants. Vegetated roof covers can be optimized to achieve water quantity and quality benefits. Through the appropriate selection of materials, vegetated covers can provide rainfall retention and detention functions.

key elements :

- Extensive green roofs with engineered media at least 3 inches in depth can be considered pervious in stormwater design calculations.
- Vegetated roof covers intended to achieve water quality benefits should maintain a soluble nitrogen level of 4ppm.
- Internal drainage, including provisions to cover and protect deck drains or scuppers, must anticipate the need to manage large rainfall events without inundating the cover.
- Provide urban green space and aesthetically pleasing views.
- Act as heat sink to reduce heating and cooling costs.
- Can extend roof life by two to three times.
- Improve air quality by filtering dust particles.

potential applications

Residential Subdivision:	Case by case
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	No

acceptable forms of pre-treatment

N/A

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction:	Yes
(no infiltration)	
Channel Protection:	Not included in DCIA
Flood Control:	Low

Green Roofs in the Urban Landscape

Unlike conventional roofing, green roofs promote retention, slow release, and evapotranspiration of precipitation. This stormwater management technique is very effective in reducing the volume and velocity of stormwater runoff from roofs.

Green roofs can be installed on many types of roofs, from small slanting roofs to large commercial flat roofs. Green roofs are an ideal option for new buildings that are taking long term cost savings and energy conservation into consideration. Many existing buildings can also be retrofitted with green roofs.



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Example of a green roof at the Heinz 57 Center Pittsburgh, PA

Although green roofs are more expensive than conventional roofs up front, they provide long term benefits and cost savings. The vegetated cover assembly should be compatible with and designed to protect the underlying waterproofing materials. By protecting the waterproofing from mechanical damage, shielding it from UV radiation, and buffering temperature extremes, the service life of the roof can be extended by two to three times. Green roofs also may also reduce energy costs by acting as a heat sink. The roof slowly absorbs energy from the sun during the day and releases it as the air cools, thereby reducing heating and cooling costs. The benefits will be greatest during the summer months, especially for low buildings. Green roofs also reduce the urban heat island effect by providing evaporative cooling and can improve air quality by filtering dust particles.

Components of a Green Roof

There are two basic types of green roofs. An extensive green roof system is a thin (usually less than 6 inches), lighter weight system planted predominantly with drought-tolerant succulent plants and grasses. An intensive green roof is a deeper, heavier system designed to sustain more complex landscapes. A green roof system, extensive or intensive, is often comprised of the same components:

- Plant material
- Growing medium
- Filter fabric
- Drainage layer
- Waterproof membrane/root barrier
- Roof structure

Plant Material

The plant material chosen for green roofs is designed to take up much of the water that falls on the roof during a storm event. Plant selection is very important to the sustainability of the roof. About 50% of the vegetation on an extensive green roof should be Sedums. Plant material also collects dust, creates oxygen, releases moisture, and provides evaporative cooling.

Growing Medium
The growing medium is a critical element of stormwater storage and detention on a green roof, and provides a buffer between the roof structure and vegetation for root development. Storage is provided by a green roof primarily through water held in tension in the growing medium pores. The growing medium in an extensive green roof should be a lightweight mineral material with a minimum of organic material and should stand up to freeze/thaw cycles.

Filter Fabric
An engineered filter fabric prevents fine soil particles from passing into the drainage layer of the green roof system.

Drainage Layer
The drainage layer may be either a lightweight granular medium or a synthetic layer that underlays and promotes free drainage of the planting medium. In some assemblages, synthetic drainage layers may also incorporate depressions that can intercept and retain small quantities of runoff.

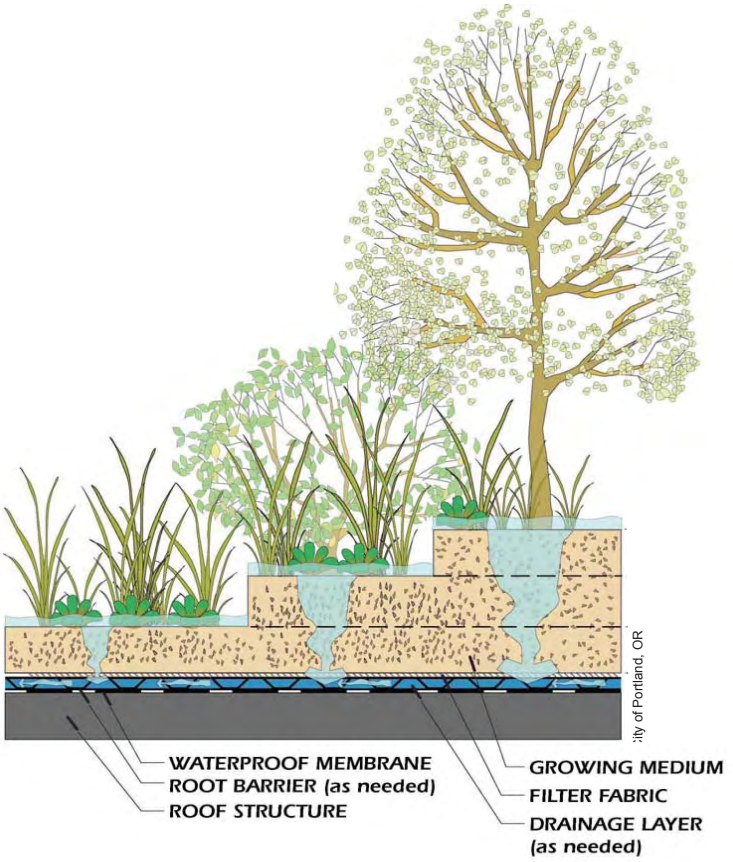

Figure 7.1: Cross-section view of roof garden

Waterproof Membrane/Root Barrier
To maintain structural integrity of the roof, a waterproof material is laid above the roof structure. Some waterproofing materials are inherently root resistant, whereas others require an additional root barrier.

Roof Structure
The load capacity of a roof structure must be taken into account when considering the installation of a green roof. Extensive green roofs typically weigh between 15 and 30 lbs per square foot and are compatible with wood or steel decks. Intensive green roofs weigh more than 36 lbs per square foot and typically require concrete supporting decks.



Ponding of water on standard rooftop



Rooftop after greenroof installation

Recommended Design Procedure

- Investigate the feasibility of the installation of a green roof. A Structural Engineer should verify that the roof will support the weight of the green roof system. It is important to consider the wet weight of the roof in the design calculations.
- Determine the portion of roof that will have a green roof.
- Extensive green roofs that have an engineered media at least 3 inches thick are permitted a DCIA reduction equal to the entire area of the green roof.
- The green roof is considered pervious area when determining whether a redevelopment project has reduced DCIA by 20%.
- The area of the green roof is not included in the calculation of the Water Quality Volume, because it is not considered DCIA.
- The area of the green roof is not included in the calculation of the Channel Protection Volume, because it is not considered DCIA.
- The green roof area can be considered pervious open space in good condition with moderate soils when determining post-development flow rates for the Flood Control requirement.
- Although green roofs are not considered as impervious surfaces when determining applicability of stormwater management requirements, they are not zero discharge systems. The roof drainage system and the remainder of the site drainage system must safely convey roof runoff to the storm sewer, combined sewer, or receiving water.
- Green roofs with a media thickness less than 3 inches can only be considered pervious if the designer can demonstrate that the initial abstraction of the green roof will be 0.5 inches or greater.
- Develop Planting Plan based on the thickness of the planting media.
- Complete construction plans and specifications.

Materials

Presently, the most complete established standards for green roof construction are those developed in Germany by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). The FLL standards and guidelines include industry standard tests for the weight, moisture, nutrient content, and grain-size distribution of growing media. These guidelines are available in English translation directly from FLL. Laboratories in the United States are now offering a full range of FLL tests for green roof materials. Among them is the Agricultural Analytical Services Laboratory (AASL) at Pennsylvania State University. AASL can also conduct tests of waterproofing membranes for root penetration resistance using FLL protocol. Currently there is an American Standard Testing Methods (ASTM) task group that is developing comprehensive American standards for green roof installation. As of June 2007, the following ASTM standards have been developed;

- E2396 Standard Testing Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems
- E2397 Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems
- E2398 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems

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- E2399 Standard Test Method for Maximum Media Density for Dead Load Analysis*
- E2400 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

*Method E2399 includes tests to measure moisture retention potential and saturated water permeability of media, total porosity, and air content of media.

Materials for green roofs will vary somewhat depending on the media thickness, intended uses, and desired appearance. The specifications provided below focus on those for a 3 inch extensive green roof system;

Plant Material

- Green roof plantings should be able to withstand heat, cold, and high winds. After establishment, the plants should be self-sustaining and tolerant of drought conditions.

- For extensive green roofs, about half of the plants should be varieties of Sedums. To ensure diversity and viability, at least four different species of sedum should be used. For an extensive green roof, the remainder of the plants should be herbs, meadow grasses, or meadow flowers, depending on the desired appearance.

- The only Sedum known to be invasive and which should be avoided is Sedum sarmentosum, also known as star sedum, gold moss, stringy stonecrop, or graveyard moss.

- Green roofs should include a significant percentage of evergreen plants to minimize erosion in winter months.

- When fully established, the selected plantings should thoroughly cover the growing medium.

Growing Medium

- Green roof growing medium should be a lightweight mineral material with a minimum of organic material and should meet the following standards:

  - Moisture content at maximum water holding capacity (ASTM E2399 or FLL): ≥ 35%
  - porosity at maximum water holding capacity (ASTM E2399 or FLL): ≥ 6%
  - Total organic matter (MSA) 3-8%
  - pH (MSA) 6.5-8.0
  - Soluble salts (DPTA saturated media extraction) ≤ 6 mmhos/cm
  - Water permeability (ASTM E2399 or FLL) ≥ 0.5 in/min
  - Grain-size distribution, as recommended by FLL

- The nutrients shall be initially incorporated in the formulation of a suitable mix for the support of the specified plant materials.

Filter Fabric

- Filter or separation fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer. The fabric should be a non-woven polypropylene geotextile.

Drainage Layer

- A drainage layer is required to promote aerated conditions in the planting medium and to convey excess runoff during large rainfall events. The drainage layer must prevent ponding of runoff into the planting medium during the 10-minute maximum rainfall rate associated with the one-year storm.

- For vegetated roof cover assemblies with thicknesses of less than 5 inches synthetic drainage layers may be used in lieu of granular drainage layers.


Northwest Ecobuilding Guild, © 2001

Membrane installation


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Chicago City Hall

- For vegetated cover assemblies with an overall thickness of 5 inches, or greater, the drainage lay shall meet the following specifications:
  - Abrasion resistance (ASTM-C131-96): ≤ 25% loss
  - Soundness (ASTM-C88): ≤ 5% loss
  - Porosity (ASTM-C29): ≥ 25%
  - Percent of particles passing 1/2-inch sieve (ASTM-C136) ≥ 75%
  - The minimum thickness of the granular layer shall be 2 inches. The granular layer may be installed in conjunction with a synthetic reservoir sheet.

Waterproof Membrane/Root Barrier

- PVC, EPDM, and thermal polyolefin (TPO) are inherently root resistant; other common waterproofing materials might require a root barrier between waterproofing and vegetative cover.

- Avoid using herbicides to prevent root penetration of waterproofing.

Irrigation System

- Extensive systems can be designed so that they do not require irrigation.

- When using an irrigation system for an intensive system, opt for a subsurface drip irrigation system rather than a surface drip or spray irrigation system.

Roof Structure

- Both new and retrofit roof systems should have structural stability inspected by Structural Engineer.

Construction Guidelines

- Apply waterproof membrane and inspect for any irregularities that would interfere with its elemental function within the green roof system. Testing of the layer can display product flaws.

- Install irrigation system, if included in design.

- Install drainage layer, taking care to protect the waterproof membrane from damage.

- Test the drainage and irrigation systems (if used).

- Install the filter fabric or separation layer over entire drainage layer.

- Install growing medium component as specified.

- Establish vegetation
  - Green roofs can be effectively established by broadcasting fresh Sedum cuttings during April-May and September-October. Depending on seasonal conditions, temporary irrigation may be required in the first couple of months after planting.

  - Plugs of Sedum and many perennial plants can be installed anytime between April and November. Depending on the time of installation, temporary irrigation may be required.

- Perennials can be seeded, except during summer months.

- A biodegradable or photodegradable wind barrier or hydromulch is required to prevent erosion during the establishment period. It generally takes about two growing seasons for full establishment.

- All drains and scupper should be covered and protected by an enclosure, typically a square or round chamber with a locking lid. These chambers are designed to prevent clogging of the drains by debris.

Note:
Design of Green roofing is not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.



Pennsylvania Stormwater Management Manual

Fencing academy roof in Philadelphia, PA

Maintenance Guidelines

All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof.

Table 7.1: Green Roof Maintenance Guidelines

Activity	Schedule
• Roof drains should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. Sources of sediment and debris may be identified and corrected. • Plant material should be maintained to provide 90% plant cover. Weeding should be manual with no herbicides or pesticides used. Weeds should be removed regularly. • Irrigation can be accomplished either through hand watering or automatic sprinkler systems if necessary during the establishment period.	As needed
• Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium similar to the original material.	Quarterly
• Inspect drain inlet pipe and containment system. • Test growing medium for soluble nitrogen content. Fertilize as needed.	Annually
• Maintain a record of all inspections and maintenance activity.	Ongoing

- Fertilization should be minimized. Fertilization should be applied according to soil test in order to maintain soluble nitrogen (nitrate and ammonium ion) levels between 1 and 4 ppm. The best source of nutrients for fertilization is mature compost.

- During the plant establishment period, maintenance staff should conduct 3-4 visits per year to conduct basic weeding, fertilization, and in-fill planting. Thereafter, only two annual visits for inspection and light weeding should be required (irrigated assemblies will require more intensive maintenance).

- Spill prevention measures from mechanical systems located on roofs should be exercised when handling substances that can contaminate stormwater.

SARB_015294

7.2 Rain barrels



cisterns, and tanks are structures designed to intercept and store runoff from rooftops. Rain barrels are used on a small scale while cisterns and tanks may be larger. These systems may be above or below ground, and they may drain by gravity or be pumped. Stored water may be slowly released to a pervious area or used for irrigation. These techniques only serve an effective stormwater control function if the stored water is emptied between most storms, freeing up storage volume for the next storm.

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key elements:

- Storage devices designed to capture a portion of small, frequent storm events.
- Storage techniques may include rain barrels, underground concrete or prefabricated tanks, above ground vertical storage tanks, or other systems.
- Systems must provide for overflow or bypass of large storm events.
- Placement of storage elements higher than areas where water will be reused may reduce or eliminate pumping needs.
- For effective stormwater control, water must be used or discharged before the next storm event.
- Most effective when designed to meet a specific water need for reuse.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	No

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	Yes
Channel Protection:	Low
Flood Control:	Low

acceptable forms of pre-treatment

- Screens

Rain Barrels, Cisterns, and Tanks in the Urban Landscape


Aaron's Rain Barrels

Irrigation system connected to rain barrel

Rain barrels, cisterns, and other tanks are storage devices meant to promote detention of small volumes of stormwater runoff. Collectively, these systems can be effective at preventing large volumes of stormwater from entering the sewer system. Rain barrels, cisterns, and vertical storage are suitable where there is a use and need for the stored water or where there is a pervious area to which water can be slowly released between storms. Single-family residences and high-density commercial areas can incorporate these systems into the stormwater management plan. The design of these systems is flexible, because there are many ways to capture and reuse stormwater. The application and use of rain barrels, cisterns, or other tank storage systems are not limited to the examples provided below.

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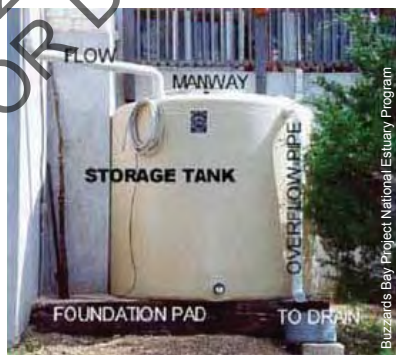
Pittsburgh Three Rivers Wet Weather Demonstration Project

Residential cistern

Rain Barrels on Individual Homes

The most common use of rain barrels is connection of one roof leader (downspout) to a single barrel on a residential property. Stored water can provide irrigation for a garden or can be released slowly to a lawn. Barrels can either be purchased or can be built by the homeowner. They are ideal for gardeners and concerned citizens who want to manage stormwater without a large initial investment. They are also an easy retrofit.

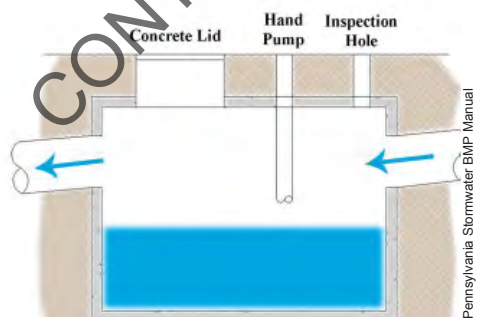


Buzzards Bay Project National Estuary Program

An example of a large surface tank

Large Surface Tanks

Surface tanks may be larger than rain barrels but serve the same function. They can be integrated into commercial sites or homes where a significant water need exists. They may drain by gravity or be pumped.



Pennsylvania Stormwater BMP Manual

Figure 7.2: Subsurface Storage and reuse is possible using a cistern

Subsurface Storage and Water Reuse

Subsurface systems can be larger and more elaborate than rain barrels. These systems are typically pumped and may be used to supply water to sprinkler systems. Because the cisterns are below the surface, they do not interfere with the landscape. These systems have higher initial costs than rain barrels and are appropriate for commercial and institutional sites.

SARB_015296



Oregon Convention Center rainfall water features

Water Features in Public and Institutional Landscapes

Architectural designs have incorporated water storage into site design. Features such as water fountains and ponds capture stormwater from design storms to provide water sources for these landscape features. The photographs below show the water features created at the Oregon Convention Center, which capture roof runoff and integrate it into the landscape design.



Oregon Convention Center rainfall water features

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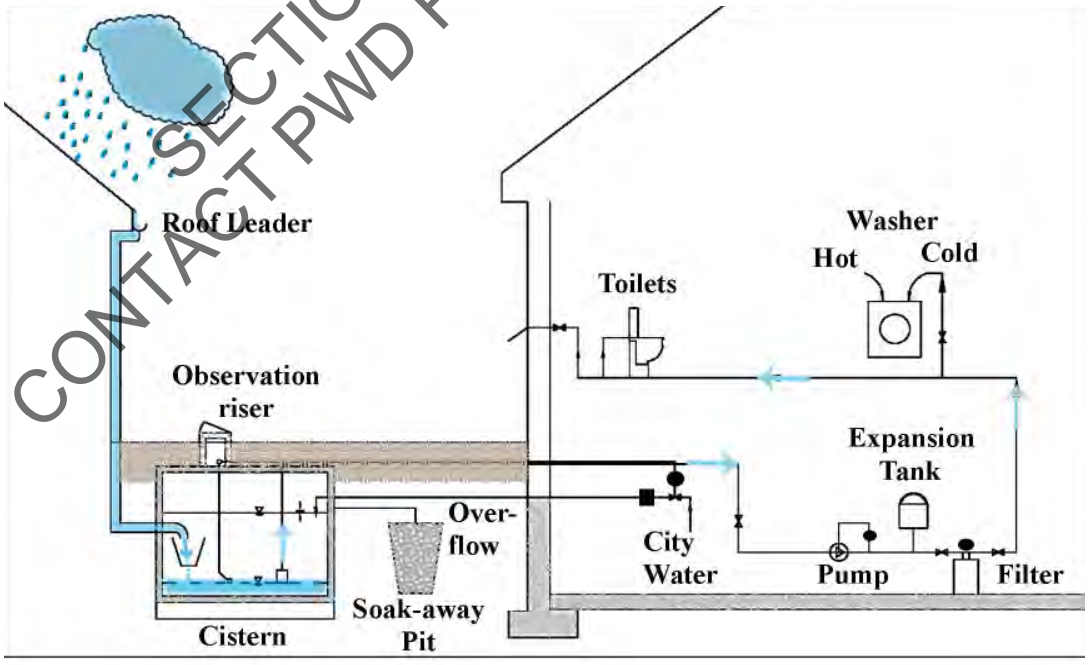
Reusing Stormwater for Indoor Use

Roof runoff can be captured and stored for reuse in washing machines, and for showering purposes if properly filtered, treated, and tested. Roof runoff used in toilets does not need to meet portable water standards. A rain barrel or cistern can be directly connected to the plumbing of a residential or commercial site; however, plumbing for non-potable rainwater reuse should be separate from potable plumbing. With more extensive treatment, rainwater may be used for drinking purposes. For more information on reusing rainwater for potable purposes refer to the *Texas Guide to Rainwater Harvesting.*



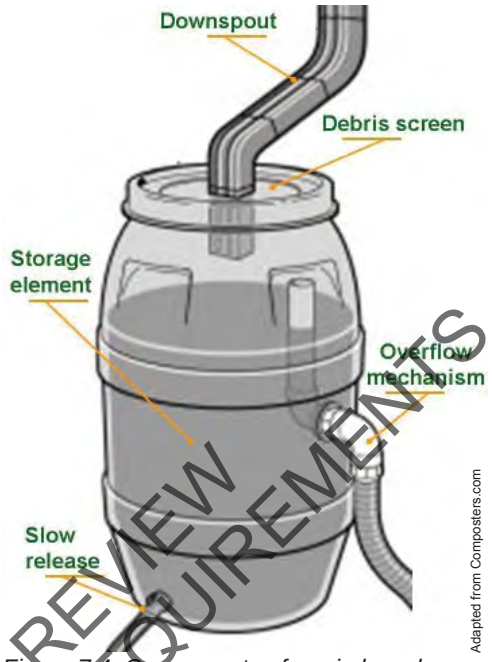
Texas Guide to Rainwater Harvesting

Figure 7.3: Rain water reuse

Components of Rain Barrels, Cisterns, and Tanks

Rain barrels, cisterns, and tanks all require the following basic components:

- a roof leader or other means of conveying roof runoff to the storage element,
- a screen to prevent debris and mosquitoes from entering,
- a storage element,
- a slow release mechanism or pump, a reuse opportunity, or infiltration area, and
- an overflow mechanism to bypass larger storms.



Adapted from Composters.com

Figure 7.4: Components of a rain barrel

Roof Leader

The gutter and roof leader system collects rooftop runoff and conveys it to the rain barrel, cistern, or other storage element. In most cases conventional roof leaders and downspouts can be used for this purpose.

Screen

A screen keeps leaves and other debris from entering and clogging the storage element. A screen also prevents mosquitoes from breeding in the rain barrel. A screen is typically placed at the end of the roof leader, before flow enters the rain barrel. A leaf strainer may also be placed where the gutter connects to the roof leader.



District of Columbia Water and Sewer Authority

Storage Element

The storage element is the barrel, cistern, or tank itself. Rain barrels are typically made of plastic. Underground cisterns may be poured concrete or prefabricated plastic tanks similar to septic tanks. Proprietary products that store water in a variety of structures are also available. Some of these are designed to bear the weight of vehicles. With the addition of an impervious liner, many of the designs discussed in the section Subsurface Infiltration (such as gravel beds) can be modified to serve as subsurface storage elements. Tanks larger than rain barrels may be used above or below ground.

Slow Release Mechanism or Pump

For the storage element to serve its stormwater control function, it must be completely drained between most wet weather events. Rain barrels are typically drained in one of two ways. A gardener may use the barrel to fill a watering can; however, this must be done on a regular basis and completely drain the storage element to provide effective stormwater management. Another solution is to use a soaker hose to slowly release stored water to a garden or infiltration area. Larger surface tanks may drain by gravity or may be pumped.



District of Columbia Water and Sewer Authority

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Subsurface systems and systems where stormwater is reused for needs other than irrigation are typically pumped. To perform effective stormwater control, the rate of use must be sufficient to empty the storage between most storms.

Reuse Opportunity or Infiltration Area

For rain barrels, cisterns, and other tanks to provide effective stormwater management, an opportunity for reuse or infiltration of the stormwater must exist. This opportunity might be provided by a garden or landscaped area that needs to be watered, or an opportunity to reuse stormwater for non-potable uses. Water stored for emergency purposes, such as fire protection is not a suitable reuse opportunity, because the storage volume will not be emptied between each storm.

Overflow Mechanism

The storage capacity of rain barrels, cisterns, and other tanks will be exceeded in large storms. In rain barrels, a flexible hose is provided at an elevation near the top of the barrel. The diameter of the hose is at least equal in size to the roof leader to allow runoff to flow unimpeded during large events. The overflow from cisterns and larger tanks can occur through a hose, weir, pipe, or other mechanism.

The discharge from the overflow is directed to the same place flow from the roof leader would be directed if there were no rain barrel, cistern, or storage tank.



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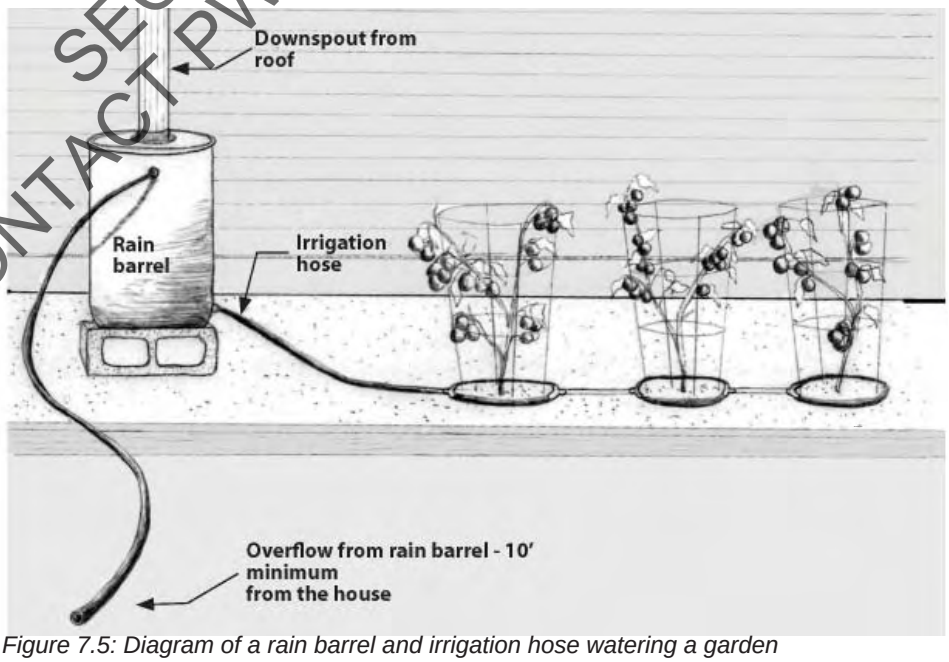

Figure 7.5: Diagram of a rain barrel and irrigation hose watering a garden

Recommended Design Procedure

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater. Small sites that are installing rain barrels voluntarily may skip this step.

- Identify opportunities and areas where water can be reused for irrigation, released to an infiltration area, or meet indoor use needs. Estimate the rate at which water can be reused. If the process of reuse is proposed to meet the Water Quality requirement, the water quality volume must be use in the first 72 hours after the storm event. For irrigation or garden use, determine the water needs of the plants; an assumption of 1 inch per week over the soil area may be used for approximate results. Identify potential infiltration areas where water may be discharged to at a slow rate. For toilet use, calculate volume based on number of flushes per day times 1.6 gallons per flush (new toilet). If a small rain barrel is discharging to a lawn through a soaker hose, detailed calculations are not necessary.

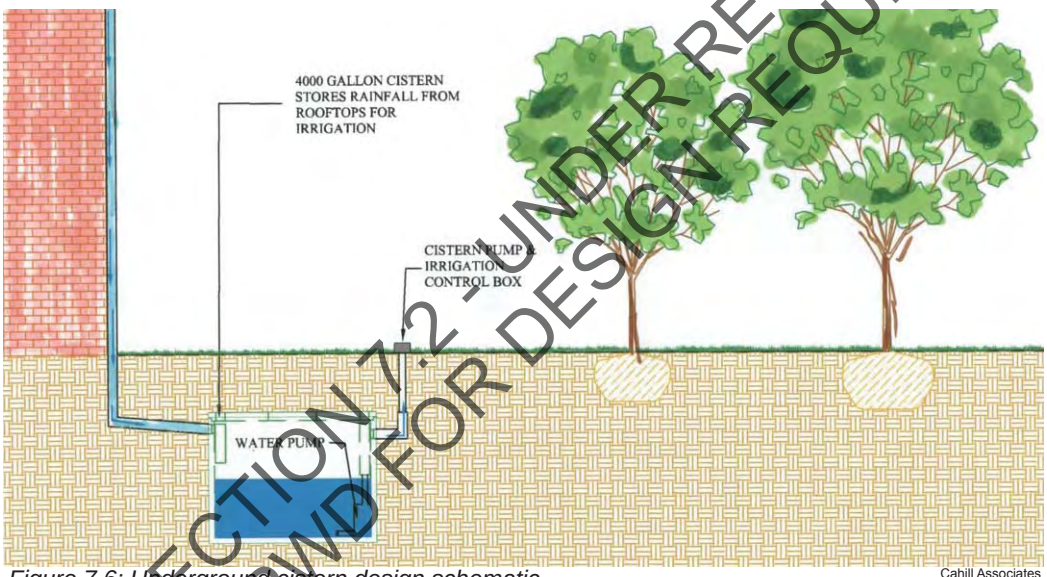

Figure 7.6: Underground cistern design schematic

Cahill Associates

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- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements will be met by rain barrels, cisterns, or storage tanks (see **Section 4.0**: Site Design). Consider more than one tank if additional storage is required, making sure that there is sufficient demand for the water. For small sites installing rain barrels voluntarily, skip this step.

Table 7.2: Suggested Storage Design Values for Rain Barrels	
Rain Barrel	50 – 135 gallons
Cistern	500 – 7,000 gallons
Larger Above Ground Tank	3,000 – 12,000 gallons

Rain Barrels



- Identify roof leaders where rain barrels can be installed.
- Decide whether to purchase commercial rain barrels or construct rain barrels. If constructing a rain barrel, follow one of the references listed at the end of this section.
- Choose between a faucet and a soaker hose. Position the outlet as low on the barrel as the design will allow to maximize storage volume. It is recommended that the design allow retention of 1 to 2 inches at the bottom of the barrel to help trap sediment and provide stability.
- Consider placing the barrel on cinder blocks to increase head at ground level.
- It is easiest to install soaker hoses on the ground surface. The hoses can then be easily reconfigured and moved whenever necessary. However, underground soaker hoses provide greater irrigation benefits for gardens, because the water does not evaporate. If buried, soaker hoses should be placed 2-4 inches under soil or 1-2 inches under mulch. Soaker hoses that are buried too deep can be difficult to monitor and are more prone to damage from root growth.
- If emptying the barrel manually, develop a plan so that it is completely emptied on average every 72 hours or less. This is necessary so that the entire storage capacity is available at the beginning of most storms.
- Position the overflow hose to discharge larger storms. The overflow should be discharged to a pervious area if possible. However, roof leaders might need to be connected to a storm sewer or gutter to prevent flooding or property damage in some cases.

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Cisterns (Subsurface or Surface)



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- Identify which roof leaders can drain to the cistern, and the area of roof draining to each leader.
- Estimate the storage needed. A rough estimate may be obtained by performing a weekly water balance of rainfall and water reuse. The table below lists average monthly rainfall amounts at the Philadelphia International Airport. Estimate the difference on a weekly basis between rainfall depth and water depth needed. Multiply this deficit by the roof drainage area to obtain an estimate of the cistern volume needed. The Design Professional may choose to do a more rigorous analysis using a long-term daily or hourly rainfall record, or using a dryer than average year.

Table 7.3: Average Monthly Rainfall at the Philadelphia International Airport				
	Average Precipitation	Average Temperature		Potential Evaporation
		High	Low	
Month	(in)	(°F)	(°F)	(in/month)
January	3.3	39.2	24.4	2.1*
February	2.9	42.1	26.1	2.1*
March	3.6	50.9	33.1	2.1
April	3.4	63	42.6	4.5
May	3.5	73.2	52.9	5.4
June	3.6	81.9	61.7	6.3
July	4.1	86.4	67.5	6.6
August	4.3	84.6	66.2	5.7
September	3.4	77.4	58.6	4.2
October	2.8	66.6	46.9	2.7
November	3.0	55	37.6	2.1
December	3.3	43.5	28.6	2.1*

- Determine the pumping requirements or design a gravity system to meet water reuse requirements. The cistern must drain within 72 hours to maximize available storage at the beginning of each storm. A detailed discussion of pumping and outlet hydraulics is beyond the scope of this manual.

- Complete construction plans and specifications.

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Materials and Construction Guidelines

Rain Barrels

- Rain barrels are commonly pre-fabricated structures constructed with plastic, wood or steel.

- The container should be made of a opaque material to prevent algae growth in the stored water.

- Debris screen to keep leaves and other debris from entering and clogging the storage element.

- For a detailed list of materials and methods used to construct a rain barrel at home, see the references at the end of this section.

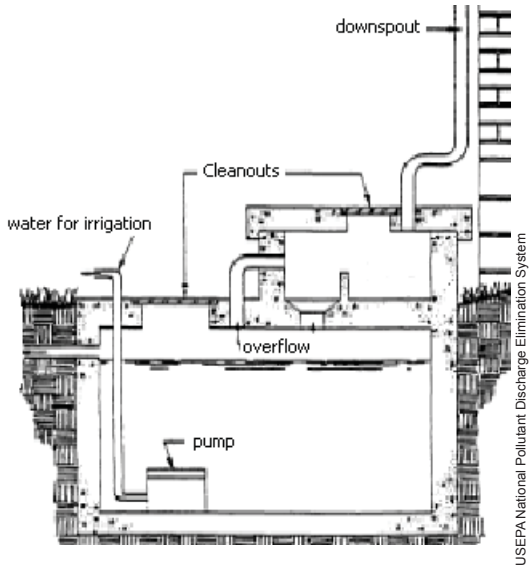

Figure 7.7: Runoff cistern

Cisterns

- Cisterns may be constructed of fiberglass, concrete, plastic, brick, or other materials.

- For a detailed discussion of cistern materials and construction, see one of the references at the end of this section.

Maintenance Guidelines

As with other stormwater management practices (SMPs), these stormwater storage systems require regular maintenance to ensure a prolonged life. The following table suggests maintenance activities to perform on rain barrels, cisterns, or vertical storage.

Table 7.4: Rain Barrels & Cisterns Maintenance Guidelines

Activity	*Schedule*
• Occasional cleaning may be necessary to remove debris, such as leaves, coming off the drainage area.	As needed
• Flush cisterns to remove sediment. • Brush the inside surfaces and thoroughly disinfect. • To avoid structural damage, the rain barrel should be drained prior to freezing weather.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

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Note:
Design of rain barrels and cisterns is not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Do-it yourself Rain Barrels:
Low Impact Development Center. 2005. Website: http://www.lid-stormwater.net/index.html (February 14, 2005).

Maryland Environmental Design Program. "Build a Simple Rain Barrel." http://www.dnr.state.md.us/ed/rainbarrel.html. (April 27, 2005).

South River Federation. August 2002. "How to Build and Install a Rain Barrel." University of Wisconsin. Website: http://www.cwp.org/Community_Watersheds/brochure.pdf. (April 27, 2005).

Tookany/Tacony-Frankford Watershed Partnership. "Rain Barrel Implementation Assistance Resource Center." Website: http://www.phillywater.org/Tacony-Frankford/Rain%20Barrel%20Project%20Web/Rain_Barrel_Project.html.

Whatcom County Master Composter Recycler Program. "Make you own rain barrel." Washington State University.. Website: http://whatcom.wsu.edu/ag/compost/rainbarrel.html. (April 19, 2005).

Commercially Available Rain Barrels:
Aaron's Rain Barrels and More. 2005. Irrigations Systems. Website: http://www.ne-design.net/rain-barrel-irrigation.html. (March 11, 2005).

Composters.com. April 16, 2005. Rainbarrels Website: http://www.composters.com/docs/rainbarrels.html. (April 19, 2005).

Stormwater Manager's Resource Center. April 19, 2005. "Pollution Prevention Fact Sheet: Rain Barrels." http://www.stormwatercenter.net/Pollution_Prevention_Factsheets/rain_barrels.html. (April 27, 2005).

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7.3 Filter strips

are densely vegetated lands that treat sheet flow stormwater from adjacent pervious and impervious areas. They function by slowing runoff, trapping sediment and pollutants, and in some cases infiltrating a portion of the runoff into the ground. Filter strips are a sensible and cost-effective stormwater management pretreatment option applicable to a variety of development sites including roads and highways.



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key elements :

- Filters strips are only considered a viable pretreatment option for other SMPs.
- Sheet flow across the vegetated filter strip is mandatory for proper filter strip function.
- Filter strip length is a function of slope, vegetation type, soil type, drainage area, and desired amount of pretreatment.
- Level spreading devices are recommended to provide uniform sheet flow conditions at the interface of the filter strip and the adjacent land cover.
- The longest flow path to a filter strip, without the installation of energy dissipaters and/or flow spreaders, is 75 feet for impervious ground covers and 150 feet for pervious ground covers.
- Filter strip slope should never exceed 8%. Slopes less than 5% are generally preferred.
- Maximum contributing drainage area is less than 5 acres, and should also never exceed a drainage area to filter strip area ratio of 6:1.
- Maximum contributing drainage area slope is generally less than 5%, unless energy dissipation and/or flow spreaders are provided.
- Construction of filter strips shall entail as little disturbance to existing vegetation at the site as possible.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes*
Ultra Urban:	Limited*
Industrial:	Limited*
Retrofit:	Yes
Highway Road:	Yes

*if designed without an underdrain

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	No
Channel Protection:	N/A
Flood Control:	N/A

acceptable forms of pre-treatment

N/A

Filter Strips in the Urban Landscape

Filter strips are effective at slowing runoff velocities, removing pollutant loads, and promoting infiltration of runoff produced by both impervious and pervious areas.

Filter strips are suitable for many types of development projects. Filter strips can be used as pretreatment facilities for other SMPs in residential, commercial, and light industrial development; roads and highways; and parking lots.

Filter strips are recommended for use as a pretreatment component of other SMPs including but not limited to: bioretention, constructed wetlands, detention, filters, ponds/wet basins, porous pavement, and vegetated swales. The use of a properly maintained filter strip extends the life of the associated SMPs and decreases its hydraulic residence time. It also increases the amount of time before these structures need maintenance.



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Figure 7.8: Filter strip in forested area

Components of a Filter Strip System

Inlet Control

Filter strips are typically combined with a level spreader or flow control device. A flow control device functions to lessen the flow energy of stormwater prior to entering the filter strip area. Concentrated flow rates can have an erosive effect that can damage the filter strip, rendering the strip ineffective. Curb openings combined with a gravel level spreader are a common type of flow control. See **Section 7.15**: Inlet and Outlet Controls for more information. Slotted or depressed curbs installed at the edge of the impervious area should ensure a well-distributed flow to the filter strip. These slotted openings should be spaced along the length of the curb.



Filter strip providing pretreatment from a parking lot to a bioretention system at Villanova University

Vegetation

The vegetation for filter strips may be comprised of turf grasses, meadow grasses, shrubs, and native vegetation. It can include trees or indigenous areas of woods and vegetation. Vegetation adds aesthetic value as well as water quality benefits. The use of indigenous vegetated areas that have surface features that disperse runoff is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. The use of turf grasses will increase the required length of the filter strip compared to other vegetation options.

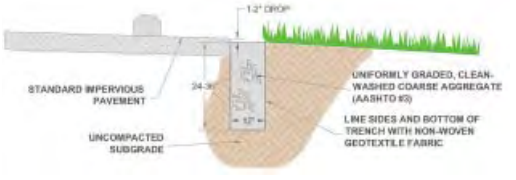

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Figure 7.9: Filter strip with gravel trench level spreader

Retentive Grading

Filter strip effectiveness may be enhanced by installing retentive grading perpendicular to the flow path. A pervious berm allows for a greater reduction in both runoff velocity and volume, thus improving pollutant removal capabilities by providing a temporary (very shallow) ponded area. The berm should be constructed according to the design provided in **Section 7.7**: Berms and Retentive Grading.

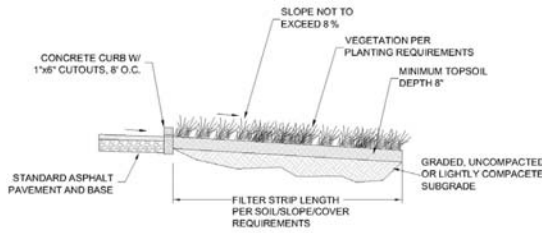

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Figure 7.10: Filter strip with curb opening

Check Dams

Filter strips with slopes that exceed 6% should implement check dams to encourage ponding and prevent scour and erosion of the filter strip area. More information on check dams is available in **Section 7.15**: Inlet and Outlet Controls.



Virginia Stormwater Management Manual

Check dams
**Note channel storage capacity created by check dams. Notched center allows safe overflow without scour around sides.*

Recommended Design Procedure

- Determine the Water Quality, Channel Protection, and Flood Control requirements for the site. See **Section 4.3**: Manage Remaining.
- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements filter strips will accommodate (for pretreatment purposes). See **Section 4.0**: Integrated Site Design.
- Investigate the feasibility of infiltration according to soil and vegetative conditions in the area proposed for the filter strip. If infiltration is feasible, determine the of saturated vertical infiltration rate. See **Appendix B**: Soil Infiltration Testing Procedures.
- Examine size and slope of the drainage area. The maximum contributing drainage area to a filter strip area shall never exceed 5 acres, and should also never exceed a drainage area to filter strip area ratio of 6:1.
    - If the slope of the filter strip parallel to the proposed flow path is ≥ 5%, energy dissipater and/or flow spreaders must be installed.
- Design an inlet control to meet energy dissipation requirements. See **Section 7.15**: Inlet and Outlet Controls.
    - A flow spreader which stretches the entire length (perpendicular to flow path) of the contributing drainage area should be designed to limit flow velocity to prevent erosion and to spread the flow equally across the filter strip. If necessary, a bypass should be installed to prevent excessive, damaging flows.
- Create a conceptual design for the pretreatment filter strip.

Table 7.5: Suggested Starting Design Values for Filter Strip Length

Strip Length Perpendicular to Flow Path	Largest feasible on site
Strip Length Parallel to Flow Path	4* - 150 feet

* The minimum pretreatment filter strip value is based on the length of the receiving flow path. The graph below shows how the minimum length requirement changes as both flow path and filter strip slope change.

- Determine the longest flow path length for the contributing drainage area.
- For contributing drainage areas with flow paths < 30 feet use the following graph to help determine the filter strip length parallel to the flow path.

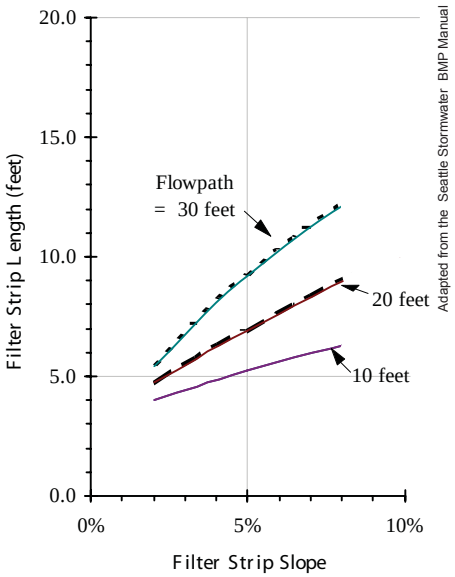


Figure 7.11: Suggested Design Specifications for Narrow Pretreatment Filter Strips with Flow Paths < 30 feet
Note: The filter strip length requirements reflected in the above graph are scaled from dimensions of a grassy vegetative swale for the same slope and flow conditions mention in the table above.

- For filter strips with contributing flow paths > 30 feet, use the suggested flow characteristics for maximum velocity and depth as design restrictions. When choosing an initial filter strip length, the suggested minimum starting design value is 10 feet.

Table 7.6: Suggested Maximum Velocities and Water Depths for Filter Strip Area	
Maximum Velocity (ft/s)	1.0, Less than 0.5 preferred
Maximum Water Depth (in.)	1.0, Less than 0.5 preferred
The values for both maximum Velocity and Water depth were taken from the US DOT Stormwater Best Management Practices (BMPs)in an Ultra-Urban Setting: Selection and Monitoring and the Seattle BMP Manual.	

- Adjust filter strip design characteristics to provide desired amount of pretreatment.

- When considering retentive grading, use the infiltration area and the saturated vertical infiltration rate of the native soil to estimate how long the surface ponding will take to drain. The maximum drain down time for the ponded volume is 72 hours, but a drain down time of 24 – 48 hours is recommended. If ponded water does not drain in the time allowed, adjust water surface depth, soil depth, and/or surface area. Adjust the design until the volume and drainage time constraints are met.
- All retentive grading techniques should encourage soil stabilization and erosion control with vegetative growth. See **Section 7.7**: Berms and Retentive Grading.

- Choose plants and trees appropriate and compatible with the site conditions. See **Section 8**: Landscape Guidance.

- Filter strips may not be used in high use areas unless precautions are taken to minimize disturbance (i.e. signage, placement of sidewalks or paths to minimize disturbance of the filter strip).

- Determine final contours of the filter strip.

- Complete construction plans and specifications.

Materials

• Recommendations for plant materials and soils can be found in **Section 8**: Landscape Guidance.

Construction Guidelines

• Areas for filter strips shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

    • In areas where soil is compacted, tilling to depths of 12-18 inches is necessary. A minimum of 6 inches of top soil must be added into the tilled soil column, and small trees and shrubs with capabilities for deep root penetrations should be introduced to maximize the soil infiltrative capacity. See **Section 8**: Landscape Guidance, for more specification on soil types and preferred plantings.

• Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed filter strip location.

• Complete site elevation and retentive grading, if proposed. Stabilize the soil disturbed within the limit of earth disturbance.

• Install energy dissipaters and flow spreaders. Refer to **Section 7.15**: Inlet and Outlet Controls for more detailed construction information.

    • The slope (parallel to the flow path) of the top of the filter strip, after the flow spreading device, should be very small (less than 1 %) and gradually increase to designed value to protect from erosion and undermining of the control devise.

• Construct inlet protection as specified in the design.

• Seed and plant vegetation (plants, shrubs, and trees) as indicated on the plans and specifications listed in **Section 8**: Landscape Guidance.

• Once site vegetation is stabilized, remove erosion and sediment control protection.

Maintenance Guidelines

All areas of the filter strip should be inspected after significant storm events for ponding that exceeds maximum depth and duration guidelines. Corrective measures should be taken when excessive ponding occurs.

Table 7.7: Filter Strips Maintenance Guidelines

Activity	*Schedule*
• Mowing and/or trimming of vegetation (not applicable to all filter strips). Filter strips that need mowing are to be cut to a height no less than 4 inches. Greater than 5 inches is preferred.	As needed
• Inspect all vegetated strip components expected to receive and/or trap debris and sediment for clogging and excessive debris and sediment accumulation; remove sediment during dry periods.	Quarterly
• Vegetated areas should be inspected for erosion, scour, and unwanted growth. This should be removed with minimum disruption to the planting soil bed and remaining vegetation. • Inspect all level spreading devices for trapped sediment and flow spreading abilities. Remove sediment and correct grading and flow channels during dry periods.	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

- When correcting grading of a flow spreading device, use proper erosion and sediment control precautions in the concentrated area of disturbance to ensure protection of the remaining portion of the filter.

- Disturbance to filter strips should be minimal during maintenance. At no time should any vehicle be driven on the filter strip. In addition, foot traffic should be kept to a minimum.

- If the filter strip is of the type that needs mowing (i.e., turf grass and possibly other native grasses), the lightest possible mowing equipment (i.e., push mowers, not riding mowers) should be used. The filter strip should be mowed perpendicular to the flow path (however not exactly the same path every mowing) to prevent any erosion and scour due to channeling of flow in the maintenance depressions.

- When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. For more information on vegetative maintenance, refer to **Section 8**: Landscape Guidance.

- Bi-weekly inspections of erosion control and flow spreading devices should be performed until soil settlement and vegetative establishment has occurred.

Note:
Design of filter strips are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.4 Filters

are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other filter media. They reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants. Filtered stormwater may be infiltrated or released to a sewer or receiving water. Depending on design, the filter media may provide significant detention time or may be combined with an outlet control.

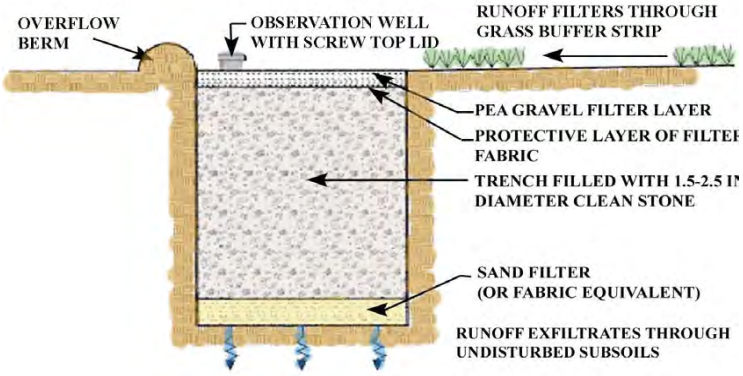


Figure 7.12: Filter with infiltration

key elements:

- Acceptable technique on sites where vegetated systems are impractical.
- Surface ponding that drains down in no more than 72 hours.
- Filter medium (typically sand, peat, or a mixture) removes pollutants and provides some travel time.
- Underdrain allowed on sites where infiltration is infeasible, or where a filter is used in combination with other practices.
- Flow splitter or positive overflow bypasses large storms.
- Maintenance required to maintain capacity of system.

potential applications

Residential Subdivision:	Limited
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	Low/Medium
Flood Control:	Low/Medium

acceptable forms of pre-treatment

- Filter strips
- Appropriate prefabricated and proprietary designs
- Swales
- Sediment forebays
- Bioretention
- Planter boxes

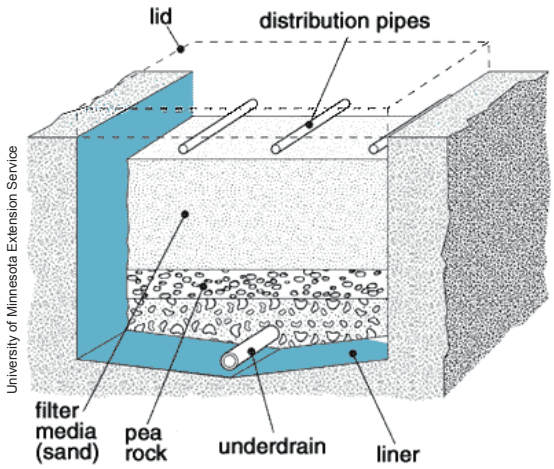


Figure 7.13: Sand filter with underdrain. Underdrains and liners should only be used when infiltration is not possible or prohibited.

Stormwater Filters in the Urban Landscape

Stormwater filters are suitable for sites without sufficient surface area available for vegetated bioretention basins. Filters are designed to either infiltrate or to treat and convey runoff to a disposal point. The only difference between a filter and a bioretention basin, as defined in this manual, is surface vegetation. Vegetated basins often include a filtering layer that may be designed according to the guidelines in this section. Filters are recommended as a viable SMP for use in:

- Parking lots
- Roadways and Highways
- Light Industrial sites
- Marina areas
- Transportation facilities
- Fast food and shopping areas
- Waste Transfer Stations
- Urban Streetscapes

Filters may be visible from the surface, for example in photograph below, or completely subsurface as shown in Figure 7.16. They may be designed as a single large chamber (often with a smaller chamber for pretreatment) or as a long, narrow trench at the perimeter of a parking lot (Figure 7.15).

Components of a Stormwater Filter System

Stormwater filters can be designed to infiltrate all or some of the flow. Components of stormwater filter system include:

- Excavation or container
- Pretreatment
- Flow entrance/inlet
- Surface storage (ponding area)
- Filter media
- Underdrain, if required
- Positive overflow



Pennsylvania Stormwater BMP Manual, 2004

Excavation or Container

The filter media may be contained in a simple trench lined with a geotextile, or it may be contained in a more structural facility such as concrete. In either case, the container may be designed either to allow infiltration or to collect flow in an underdrain system.

Flow Entrance/Inlet

Flow may be introduced to a filter through any of the controls discussed in **Section 7.15**: Inlet and Outlet Controls. If stormwater does not enter as sheet flow, a flow spreader is required.

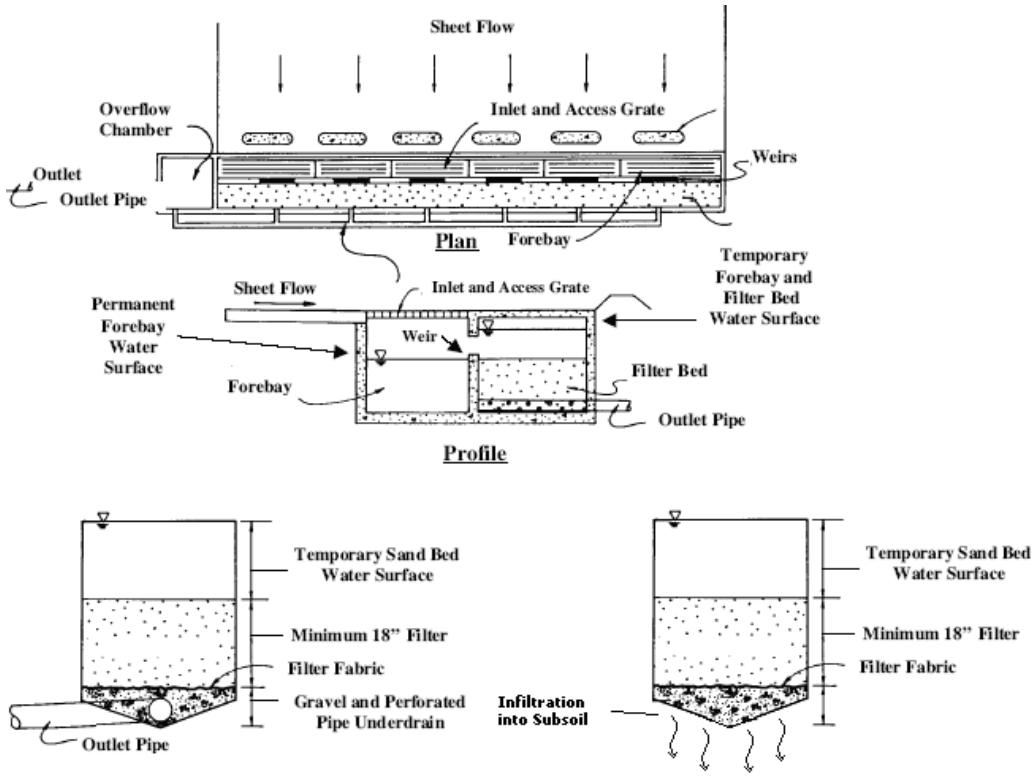


Figure 7.14: Surface sand filter

Adapted from City of Boise



Stormwater Management, Inc.

Left to right: Granular leaf compost, perlite and granular activated carbon (GAC)



Vegetated peat filter in Carlisle, PA

Surface Storage (ponding area)

The filter allows water to pond during intense storms as water flows slowly through the filter media.

Filter Media

Stormwater flows onto filter media where sediments and other pollutants are separated from the stormwater. Filter materials such as sand, peat, granular activated carbon (GAC), leaf compost, pea gravel and others are used for water quality treatment. Coarser materials allow faster transmission, but finer media filters particles of a smaller size. Sand has been found to be a good balance between these two criteria (Urbonas, 1999), but different types of media remove different pollutants. While sand is a reliable material to remove TSS, (Debusk and Langston, 1997) peat removes slightly more TP, Cu, Cd, and Ni than sand. Depending on the characteristics of the stormwater runoff, a combination of these filter materials will provide the best quality results. In addition to determining the degree of filtration, media particle size determines travel time in the filter and plays a role in meeting release rate requirements.

Underdrain (if required)

Infiltration is required where feasible unless the filter is combined with another facility that provides infiltration. Filters that do not infiltrate collect water through an underdrain system.


Georgia Stormwater Management Manual

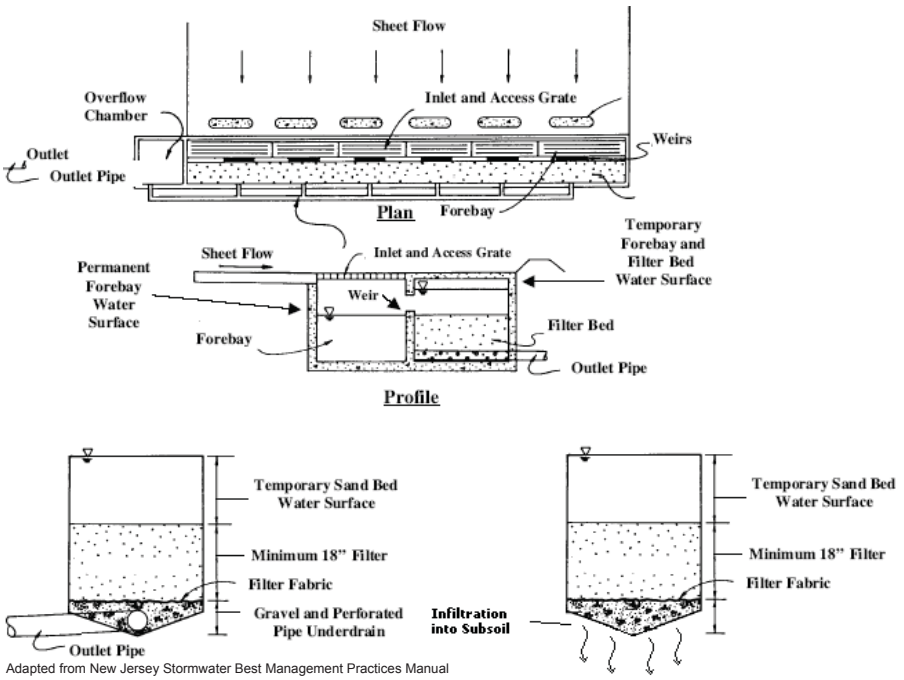
Perimeter filter inspection

Positive Overflow

Filters must be designed to allow overflow or bypass of larger storm volumes. Flow splitters, diversion chambers, or proprietary devices can be used to divert a portion of flow to a filter in an off-line design. A design that is considered on-line allows water to flow across the surface of the filter before being discharged over a weir or other control.

Recommended Design Procedures

- Determine the Water Quality, Channel Protection, and Flood Control requirements for the site. See **Section 4.3**: Manage Remaining Stormwater.
- Create a Conceptual Site Plan for the entire site and determine what portion of the stormwater control requirements the filters will meet. See **Section 4.0**: Integrated Site Design.
- Investigate the feasibility of infiltration in the area proposed for the stormwater filter. If infiltration is feasible, determine the saturated vertical infiltrate rate. See **Appendix B**: Soil Infiltration Testing Procedures. Design proceeds differently depending on the feasibility of infiltration.
- Create a conceptual design for the stormwater filter.



Adapted from New Jersey Stormwater Best Management Practices Manual

Figure 7.15: Typical schematic of perimeter filter design. Note filters can be designed to infiltrate or to treat and convey via an outlet pipe.

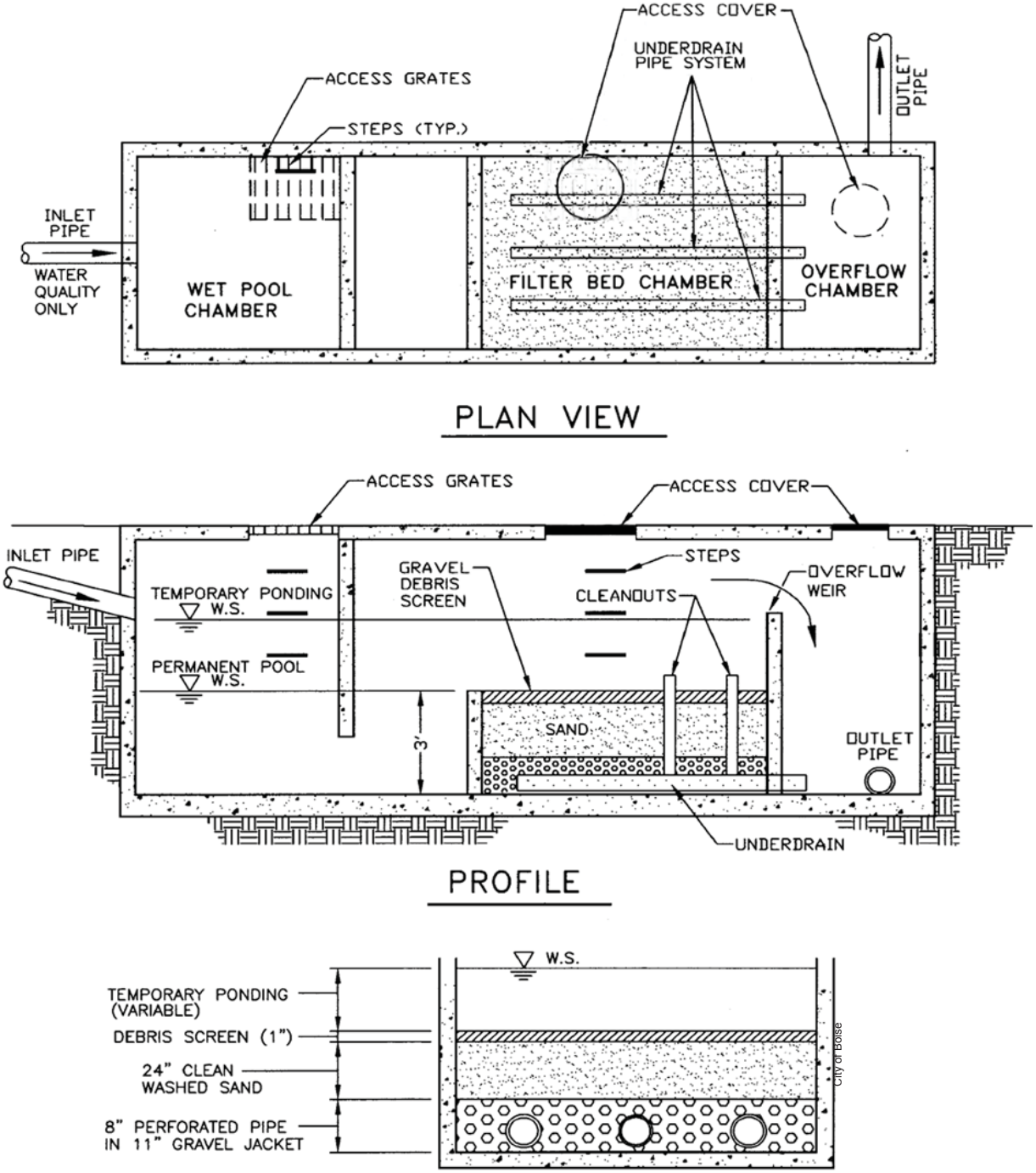


Figure 7.16: Large subsurface filter. Note this system can also be designed to infiltrate directly into the soil or to connect to another infiltration BMP.

• The filter area may be estimated initially using Darcy's Law, assuming the soil media is saturated.

Af = (V x d) / [k x t (h + d)]
Af = Surface area of filter (square feet)
V = Volume to be managed (cubic feet)
d = Depth of filter media (feet)
t = Drawdown time (days)
h = Head (average in feet)
k = Saturated hydraulic conductivity (feet/day)
k Design values: sand = 3.5 feet/day; peat = 2.5 feet/day; leaf compost = 8.7 feet/day

• For filters designed for infiltration, estimate the total storage volume and adjust area and/or depths as needed to provide required storage.

Table 7.8: Suggested Starting Design Values for Ponding and Media Depths	
Average Ponding Depth	3 – 6 inches
Filter Media Depth	18 – 30 inches

• Using stormwater filter area and the saturated vertical infiltration rate of the filter media, estimate the drainage time for ponded surface water. The saturated vertical infiltration rate may be based on the estimated saturated hydraulic conductivity of the proposed filter materials. The maximum drain down time for the entire storage volume is 72 hours, but a surface drain down time of 24-48 hours is recommended. If storage does not drain in the time allowed, adjust pretreatment depth, filter media depth, and surface area. Adjust the design until the volume and drainage time constraints are met.

• Consider an underdrain only under one of the following conditions:

  • in areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible (See **Appendix B**: Soil Infiltration Testing Procedures) and the filter system is needed only to provide water quality treatment;
  • in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
  • in combination with other SMPs where the system as a whole meets storage and release criteria.

• Design underdrains to minimize the chances of clogging. Pea gravel filters can be used for this purpose. Pea gravel filters should include at least 3 inches of gravel under the pipe and 6 inches above the pipe.

• In areas where infiltration is infeasible due to a hotspot or unstable fill that threatens an existing structure, specify an impervious liner.

  • Check that any release rate requirements (including release through any underdrain) are met by the system as designed. For filters with underdrains, release rate is a function of travel time. See **Section 5.3**: Acceptable Calculation Methods, for a discussion of travel time calculations in porous media.

• Design a pretreatment facility.

• Design an inlet control for the filter media chamber to meet energy dissipation requirements. See **Section 7.15**: Inlet and Outlet Controls.

• Design a bypass or overflow control for larger storms.

• Design any structural components required.

• Complete construction plans and specifications.

Materials

Stone Storage (if used)

• Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.

• Stone shall be separated from filter medium by a non-woven filter fabric or a pea gravel filter.

Filter Media

• Peat shall have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

• Sand shall be clean, medium to fine sand, and have organic material meeting specifications of AASHTO M-6 (0.02" – 0.04") or ASTM-C-33.

• Prefabricated filter media shall meet filter design and water quality specifications.

Piping

• Pipe shall have continuous perforations, smooth interior, and minimum diameter of 6 inches. High-density polyethylene (HDPE) pipe shall meet specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

• Areas for stormwater filters shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

• Permanent filters should not be installed until site is stabilized. Excessive sediment generated during construction can clog filter and prevent its function prior to post-construction benefits.

• Structures such as inlet boxes, reinforced concrete boxes, inlet controls, and outlet structures should be constructed in accordance with manufacturer's guidelines or Engineer's guidance.

• Excavated filters or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the sub-base. Structures should be set on a layer of clean, lightly compacted gravel specified as AASHTO No. 57.

• A layer of permeable non-woven geotextile should underlie infiltration filters.

• Place underlying gravel/stone in minimum 6 inch lifts and lightly compact. Place underdrain pipes in gravel during placement (if applicable).

• Wrap and secure non-woven geotextile to prevent gravel/stone from clogging with sediments.

Maintenance Guidelines

For filters located entirely underground, unobstructed access for must be provided over the entire sand filter, including inlet and outlet pipe structures, by either doors or removable panels. Ladder access is required for vault heights greater than 4 feet.

Table 7.9: Filter Maintenance Guidelines

Activity	Schedule
• Rake filter media surface for the removal of trash and debris from control openings. • Repair of leaks from the sedimentation chamber or deterioration of structural components.	As needed
• Inspect filter for standing water (filter drainage is not optimal) and discoloration (organics or debris have clogged filter surface).	Quarterly
• Removal of the top few inches of filter media and cultivation of the surface when filter bed is clogged. • Clean out accumulated sediment from filter bed chamber. • Clean out accumulated sediment from sedimentation chamber.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all State and Federal Regulations.

Winter concerns

Pennsylvania's low temperature dips below freezing for about four months out of every year, and surface filtration may not take place as well in the winter. Peat and compost may hold water, freeze, and become impervious on the surface. Design options that allow direct sub-surface discharge into the filter media during cold weather may help overcome this condition.

Note:

Design of stormwater filters are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.5 Bioinfiltration / Bioretention

systems use surface storage, vegetation, a select growing medium, flow controls, and other components to meet stormwater management goals. These systems may be referred to by a variety of names such as bioinfiltration areas, biofilters, rain gardens, or recharge gardens. On a small scale, these systems may be contained inside planter boxes. This section will refer to all these systems as bioretention.



R. Traver

key elements:

- Preferred stormwater management design that replicates natural hydrologic processes.
- Flexible in size and configuration; can be used for a wide variety of applications.
- Water Quality volume that drains down in no more than 72 hours.
- Modified soil that provides temporary stormwater storage and enhances plant growth.
- Native plantings that provide evapotranspiration of stormwater, remove pollutants, and enhance the landscape.
- Positive overflow limits inundation depth.
- Maintenance of vegetation is required.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

acceptable forms of pre-treatment

- Energy dissipation to prevent erosion and scour of SMP

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction:	Yes
(no infiltration)	
Channel Protection:	Medium
Flood Control:	Low/Medium

*if designed without an underdrain

Bioretention in the Urban Landscape

Bioretention systems are shallow, vegetated depressions used to promote absorption and infiltration of stormwater runoff. This management practice is very effective at removing pollutants and reducing runoff volume. Stormwater flows into the bioretention area, ponds on the surface, infiltrates into the soil bed, and is used by plants and trees in the system.

Bioretention areas are suitable for many types and sizes of development, from single-family residential to high-density commercial projects. Bioretention areas are generally capable of managing stormwater from areas of up to about 1 acre, but they can also be integrated throughout a site to manage larger areas. Flexible and easy to incorporate in landscaped areas, bioretention facilities are ideal for placement in roadway median strips and parking lot islands. They can also provide water quality treatment from pervious areas, such as golf courses.

In highly urbanized watersheds, bioretention is often one of the few retrofit options that can be cost-effectively employed by modifying existing landscaped areas, converting islands or under-used parking areas, or integrating into the resurfacing of a parking lot. Applications of bioretention systems in urban environments include planter boxes, residential on-lot landscaping, parking lots, roadways, and industrial and commercial applications, which can capture both site and roof runoff. The application of bioretention systems is not limited to this list; however, examples for each of these alternatives are provided below.

Planter Boxes

A flow-through the planter box is designed with an impervious bottom or is placed on an impervious surface. Pollutant reduction is achieved as the water filters through the soil. Flow control is obtained by storing the water in a reservoir above the soil and detaining it as it flows through the soil. This planter can be used adjacent to a building if the box is properly lined.

Residential On-lot

Landscaped garden areas can be designed with bioretention systems to create decorative features, habitat, and stormwater treatment at a residential site. The design can be as simple as incorporating a planting bed into the lowest point on a site. It is recommended that downspouts be directed into these systems after appropriate pre-treatment.

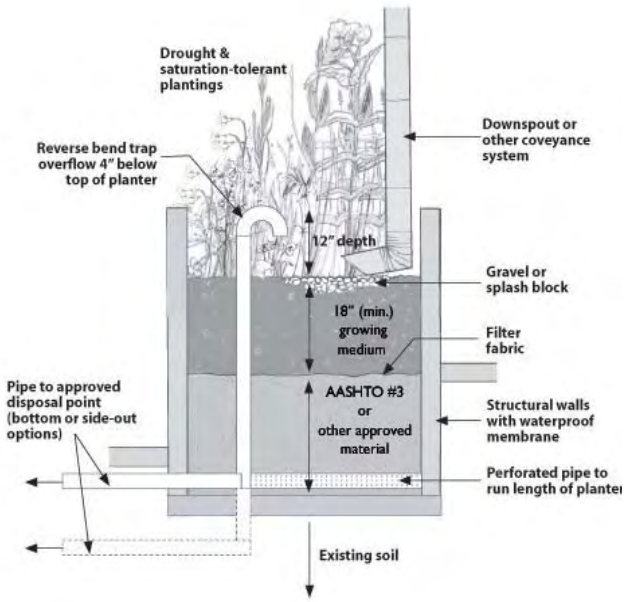


Figure 7.17: Profile of flow-through planter box

highlights:

- Can store and treat runoff.
- Can be used for infiltration or to meet the Water Quality requirements where infiltration is not feasible.
- Use vegetation to filter and transpire.
- Contribute to better air quality, water quality and help reduce urban heat island impacts.
- Can improve property value through attractive landscaping.



City of Portland, OR

Parking lot recharge garden

Tree Wells

Bioretention principles can be incorporated into a tree well design to create mini-treatment areas throughout a site. Care should be taken to ensure that the ponding area depth is appropriate to the tree size and species.

Parking Lots

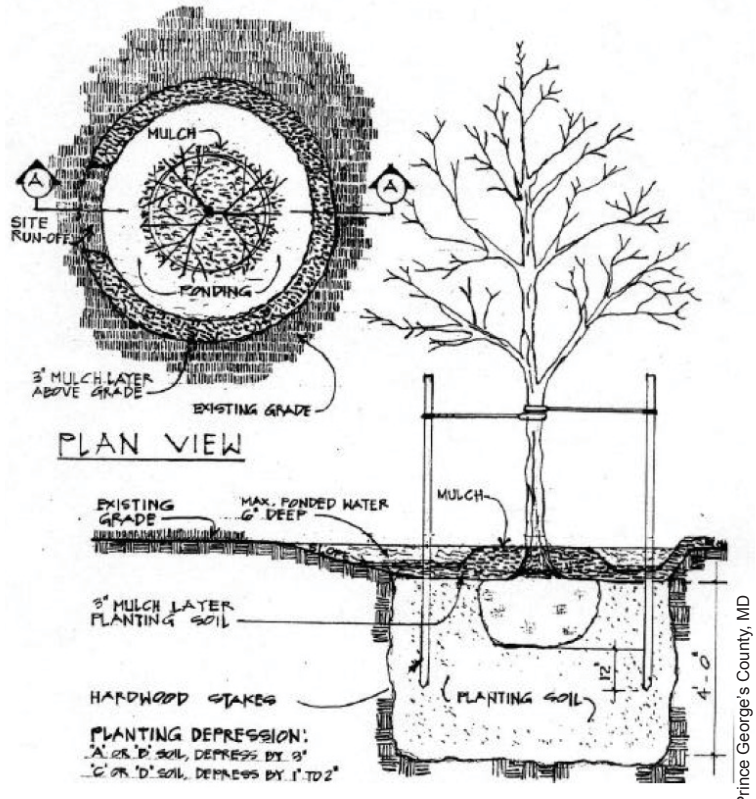
Parking lots are an ideal location for bioretention systems. Bioretention can be incorporated as an island, median, or along the perimeter of the parking area. Bioretention areas can enhance the aesthetics of a parking lot while managing stormwater from the site. Site grading must not result in erosive velocities.

Roads and Highways

Linear bioretention basins can be constructed alongside roads or highways, in roadway medians, or in bump-outs that double as traffic calming devices. The system will manage runoff from the street and help to control automotive pollutants. The systems can also help to control roadway flooding.

Commercial/Industrial/Institutional

At commercial, industrial, and institutional sites, areas for stormwater management and green space are often limited. At these sites, bioretention systems serve the multiple purposes of stormwater management and landscaping. Bioretention areas can be used to manage runoff from impervious site areas such as parking lots, sidewalks, and rooftops.



Prince George's County, MD

Figure 7.18: Tree Pit Bioretention

Components of a Bioretention System

Bioretention systems can be designed to infiltrate all or some of the flow that they treat. The primary components of a bioretention system are:

- Pretreatment if the site will generate high sediment loads
- Flow entrance/inlet
- Surface storage (ponding area)
- Organic layer or mulch
- Planting soil and filter media
- Native plantings
- Sand bed or stone filter and underdrain, if required
- Stone storage for additional storage, if needed
- Positive overflow

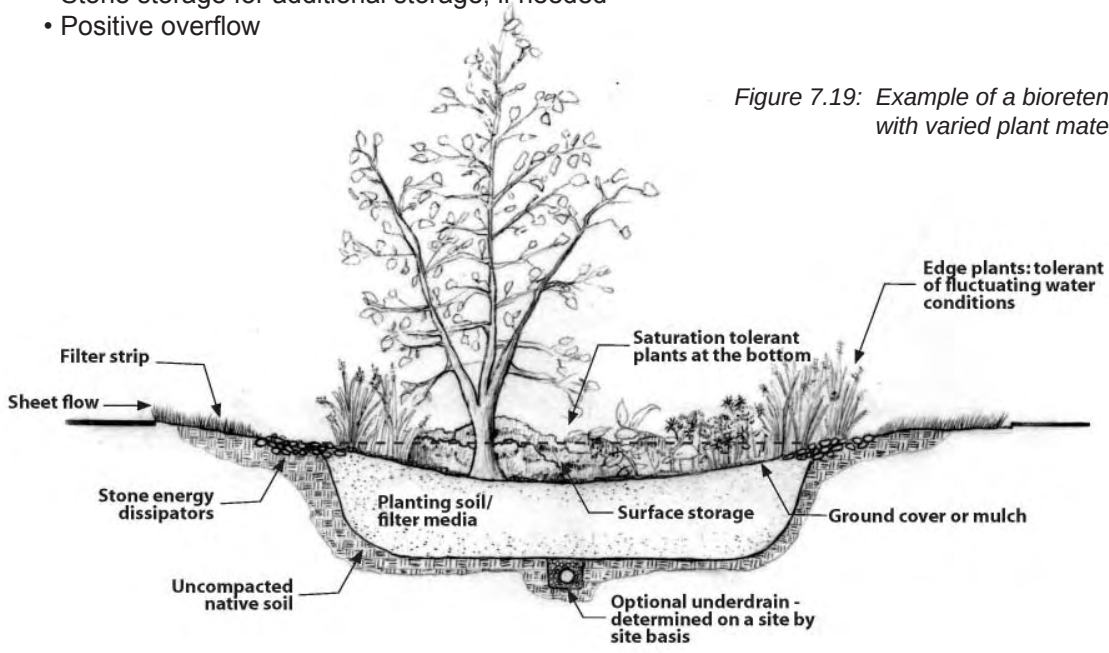


Figure 7.19: Example of a bioretention system with varied plant materials

Pretreatment

Pretreatment is not required for all bioretention systems because the soil-plant system provides treatment. However, pretreatment is recommended for bioretention systems on sites that generate high sediment loads. Additional pretreatment may prolong the life of the system by reducing sediment and other pollutant loads.

Flow Entrance / Inlet

It is recommended that runoff is conveyed to a curbless bioretention area via sheet flow over a grass or gravel filter strip. This is not always possible due to site constraints or space limitations. On sites where curb removal is not an option or where flow is concentrated by the time it reaches the bioretention area, curb openings coupled with energy dissipaters provide an alternative runoff inlet.

Roof leaders that flow into bioretention areas also require energy dissipaters to prevent erosion in the bed. Refer to **Section 7.15**: Inlet and Outlet Controls for details about energy dissipaters.



Flow enters the bioretention system via a curb opening inlet that is protected with an energy dissipater (stones).

Surface Storage (Ponding Area)
Surface storage provides temporary storage of stormwater runoff before infiltration, evaporation, and uptake can occur within the bioretention system. Ponding time provides water quality benefits by allowing larger debris and sediment to settle out of the water. Recommended ponding design depths are provided in order to reduce hydraulic loading of underlying soils, minimize facility drainage time, and prevent standing water.

Planting Soil and Filter Media
The planting soil acts as a filter between the surface storage and the native soil. The prepared planting soil provides additional storage while the water infiltrates into the native soil. Storage area is a function of both soil depth and bioretention surface area. The planting soil also provides a medium suitable for plant growth. (see **Section 8:** Landscape Guidance for planting soil specifications.)

Native Plantings
The plant material in a bioretention system removes nutrients and stormwater pollutants through vegetative uptake, removes water through evapotranspiration, and creates pathways for infiltration through root development and plant growth. A varied plant community is recommended to avoid susceptibility to insect and disease infestation and to ensure viability. A mixture of groundcover, grasses, shrubs, and trees is recommended to create a microclimate that can ameliorate urban stresses as well as discourage weed growth and reduce maintenance. **Section 8**: Landscape Guidance contains information on native plant and tree selection and landscape design. Do not use invasive species listed in **Section 8**.

Organic layer or mulch
The organic layer or mulch provides a medium for biological growth, decomposition of organic material, adsorption, and binding of heavy metals. The mulch layer can also serve as a sponge that absorbs water during storms and retains water for plant growth during dry periods.

Sand bed or stone filter and Underdrain (if necessary)
An underdrain is a perforated pipe that collects water at the bottom of the system and conveys it quickly to the system outlet. Underdrains eliminate most infiltration because they provide a preferential pathway for flow. A sand layer or gravel filter should surround the underdrain to filter sediment and facilitate flow to the underdrain. If a sand layer is used, the underdrain should be surrounded by a non-woven filter fabric to prevent clogging.

Stone Storage (if necessary)
A stone storage layer can be included to provide higher void space storage if needed in addition to the surface and soil storage.

Positive Overflows
A positive overflow must be provided at the maximum ponding depth. When runoff exceeds system storage capacity, the excess flow leaves the system through the positive overflow. If additional stormwater controls are required on the site, the overflow can connect to a system that will provide channel protection or peak rate control. If no additional stormwater controls are required, the overflow can be connected to storm sewer, combined sewer, or receiving water, as appropriate for the site. Types of overflow structures are discussed in **Section 7.15**: Inlet and Outlet Controls.



Surface inlet

Recommended Design Procedures

Design of bioretention systems is somewhat flexible. The area, depth, and shape of the system can be varied to accommodate site conditions and constraints. The following design procedures are general guidelines that designers can follow.

- Determine the Water Quality, Channel Protection, and Flood Control requirements for the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site and determine what portion of the stormwater management requirements bioretention will meet and what the drainage area will be. See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration in the area proposed for bioretention. If infiltration is not feasible, consider an underdrained bioretention system or an alternate location for the bioretention area. If infiltration is feasible, determine the saturated vertical infiltration rate. See **Appendix B**: Soil Infiltration Testing Procedures.

- Create a conceptual design for the bioretention basin.

Table 7.10: Suggested Starting Design Values for Areas and Depths

Area (surface area and infiltration area)	Largest feasible on site
Typical Ponding Depth*	6-12 inches
Soil Depth	2 – 3 feet

* Note pond depth may not exceed 2 feet

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage.

- Estimate how long the surface ponding and soil storage will take to drain based on the infiltration area and the saturated vertical infiltration rate of the native soil. The maximum drain down time for the entire storage volume (surface, planting soil, and gravel if used) is 72 hours, but a surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust surface depth, soil depth, and/or surface area. Adjust the design until the volume, drainage time, and site constraints are met.

- Consider an underdrain only under one of the following conditions:

    - In areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible (See **Appendix B**: Soil Infiltration Testing Procedures) and the bioretention system is being designed to provide only water quality treatment;
    - In areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
    - In combination with other SMPs where the system as a whole meets storage and release rate criteria.
    - If soil depth is a minimum of 3 feet.

- Design underdrains to minimize clogging. Pea gravel filters can be used for this purpose. Pea gravel filters should include at least 3 inches of gravel under the pipe and 6 inches above the pipe.

- In areas where infiltration is infeasible due to a hotspot or unstable fill that threatens an existing structure, specify an impervious liner.

- Check that any release rate requirements (including release through any underdrain) are met by the system as designed. See **Section 7.15**: Inlet and Outlet Controls.

- Choose plants, trees, and either mulch or seeding appropriate to the site. (See **Section 8**)

- Choose a soil mix and depth appropriate for plant growth. Soil depth shall be the larger of what is needed for storage or healthy plant growth.

Table 7.11: Suggested Minimum Soil Depths for Plant Growth	
Soil Depth for Herbaceous Species	24 inches
Soil Depth for Woody Species	4 inches deeper than largest root ball

- Design an inlet control to meet energy dissipation requirements and provide pretreatment if required. See **Section 7.15**: Inlet and Outlet Controls.

- Design a positive overflow for large storms.

- Given the design area and average depths, determine the final contours of the basin.

*Table 7.12: Suggested Maximum Ponding Depths and Side Slopes**	
Maximum Ponding Depth	2 feet
Side Slopes	3 horizontal to 1 vertical recommended; 2:1 maximum
*These decisions affect safety and appearance rather than stormwater function; acceptable dimensions are ultimately a decision to be made jointly by the Engineer and Owner.	

- Complete construction plans and specifications.

Materials

Planting Soil
- See **Section 8**: Landscape Guidance for soil specifications

Mulch
- Organic mulch shall be aged, double-shredded hardwood bark mulch or composted leaf mulch.

- Mulch shall be free of weeds.

- Organic mulch shall be placed on bioretention surface to a depth of 2-3 inches.

Plants
- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select bioretention plants from the list of native species in **Section 8**: Landscape Guidance. Take ponding depth, drain down time, sunlight, salt tolerance, and other conditions into consideration when selecting plants from this list. Although plants will be subject to ponding, they may also be subject to drought especially in areas that get a lot of sunlight or are in otherwise highly impervious areas.

Storage Stone (if used)
- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.

- Stone shall be separated from soil medium by a non-woven filter fabric or a pea gravel filter.

Construction Guidelines

- Areas for bioretention shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.
- Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed bioretention location. Proposed bioretention areas may only be used as sediment traps during construction if at least two feet of soil are removed and replaced.
- Complete site elevation grading and stabilize the soil disturbed within the limits of disturbance. Do not finalize bioretention excavation and construction until the drainage area is fully stabilized.
- Excavate bioretention area to proposed invert depth and manually scarify the existing soil surfaces. Do not compact in-situ soils. Heavy equipment shall not be used within the bioretention basin. All equipment shall be kept out of the excavated area to the maximum extent possible.
- If using an underdrain and/or a gravel storage bed, place filter fabric or pea gravel filter, then place the rock, and set the underdrain according to the plans.
- If an underdrain and/or gravel storage are not used, rototill 2-3 inches of sand into the base of the facility, then rototill 3-4 inches of planting soil into the sandy subgrade to create a gradation zone.
- Backfill the excavated area as soon as the subgrade preparation is complete to avoid accumulation of debris. Place bioretention soil in 12-18 inches lifts and tamp lightly. Slight overfilling might be necessary to account for settlement. Presoak soil at least one day prior to final grading and landscaping to allow for settlement.
- After allowing for settlement, complete final grading within about 2 inches of the proposed design elevations, leaving space for top dressing of mulch or mulch/compost blend.
- Seed and plant vegetation as indicated on the plans and specifications.
- Place mulch and hand grade to final elevations.
- Install bioretention energy dissipaters as specified on the plans (if applicable).
- Water vegetation at the end of each day for two weeks after planting is completed.
- Water vegetation regularly during first year to ensure successful establishment.



Landscape maintenance of a bioretention basin

Maintenance Guidelines

Properly designed and installed bioretention systems require little maintenance. During periods of extended drought, bioretention systems may require watering approximately every 10 days.

Table 7.13: Bioinfiltration/Bioretention Maintenance Guidelines

Activity	Schedule
• Water vegetation at the end of each day for two weeks after planting is completed. • Water vegetation regularly to ensure successful establishment.	First year after installation
• Remulch void areas. • Treat diseased trees and shrubs. • Keep overflow free and clear of leaves.	As needed
• Inspect soil and repair eroded areas. • Remove litter and debris. • Clear leaves and debris from overflow.	Monthly
• Inspect trees and shrubs to evaluate health, replace if necessary. • Inspect underdrain cleanout. • Verify drained out time of system.	Biannually
• Add additional mulch. • Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

Note: Design of bioretention systems are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.



City of Portland, OR

Glencoe Elementary's newly planted bioretention garden

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7.6 Detention Basins

are constructed to provide temporary storage of runoff and function hydraulically to attenuate stormwater runoff peaks. Detention basins provide temporary storage on the surface or subsurface either by impoundment of a natural depression of excavation of soil. Traditional detention basins function primarily to provide water quantity control. The designer should note that detention basins can also be configured to provide water quality treatment. These designs are referred to as dry extended detention basins. More information on dry extended detention basins can be found in the Pennsylvania Stormwater BMP Manual.



Virginia Stormwater Manual

key elements :

- Detention basins should completely drain in 72 hours.
- Most basins are designed to provide Channel Protection and Flood Control only.
- A sediment forebay helps decrease maintenance and prolong design life of the basin.
- Vegetation stabilizes the soil in the basin.
- Outlet structure design is critical and determines how the basin meets stormwater control requirements.

potential applications

Residential Subdivision:	Limited
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Limited

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	No
Channel Protection:	High
Flood Control:	High

acceptable forms of pre-treatment

- Sediment forebays
- Filter strips
- Vegetated swales

Detention Basins in the Urban Landscape

Detention basins are suitable for large developments and high-density commercial projects. They require substantial open space; however, they can often be designed for use between storm events, creating an open space available for recreational purposes.

Components of a Detention Basin

Detention basins are typically comprised of the following components:

- Sediment forebay
- Vegetation
- Micropool
- Outflow structure



Pennsylvania Stormwater BMP Manual

Sediment forebay

Sediment Forebay
Supplementing a dry pond design with a sediment forebay is required to increase the treatment efficiency. The sediment forebay improves pollutant reduction by trapping larger particles near the inlet of the pond. The forebay should include a permanent pool to minimize the potential for scour and re-suspension. A sediment forebay will enhance the removal rates of particulates, decrease the velocity of incoming runoff, and reduce the potential for control structure failure due to clogging. Sediment forebays should be designed for ease of maintenance. Forebays must be accessible to heavy machinery. Those constructed with a bottom made or concrete or other solid materials make sediment removal easier and more accessible by heavy machinery.



Pennsylvania Stormwater BMP Manual

Athletic field to be used as a detention basin

Vegetation
Surface vegetation in the basin provides erosion control and sediment entrapment. Side slopes, berms, and basin surface should be planted with appropriate native species. Appropriate species can be found in **Section 8**: Landscape Guidance.

Micropool at the Outlet (Optional)
Applying a micropool design to a detention basin can maximize water quality performance. The micropool is typically shallow and permanently inundated. Its function is to concentrate finer sediment and reduce re-suspension. The micropool is normally planted with wetland vegetation species such as cattails.

Outflow Structure
The outlet structure determines the performance of the basin. By installing a multi-stage riser, the basin can be designed to meet both Water Quality and Flood Control requirements.

A gate valve or orifice plate should regulate the drawdown time. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the structure. See **Section 7.15**: Inlet and Outlet Controls for more information.

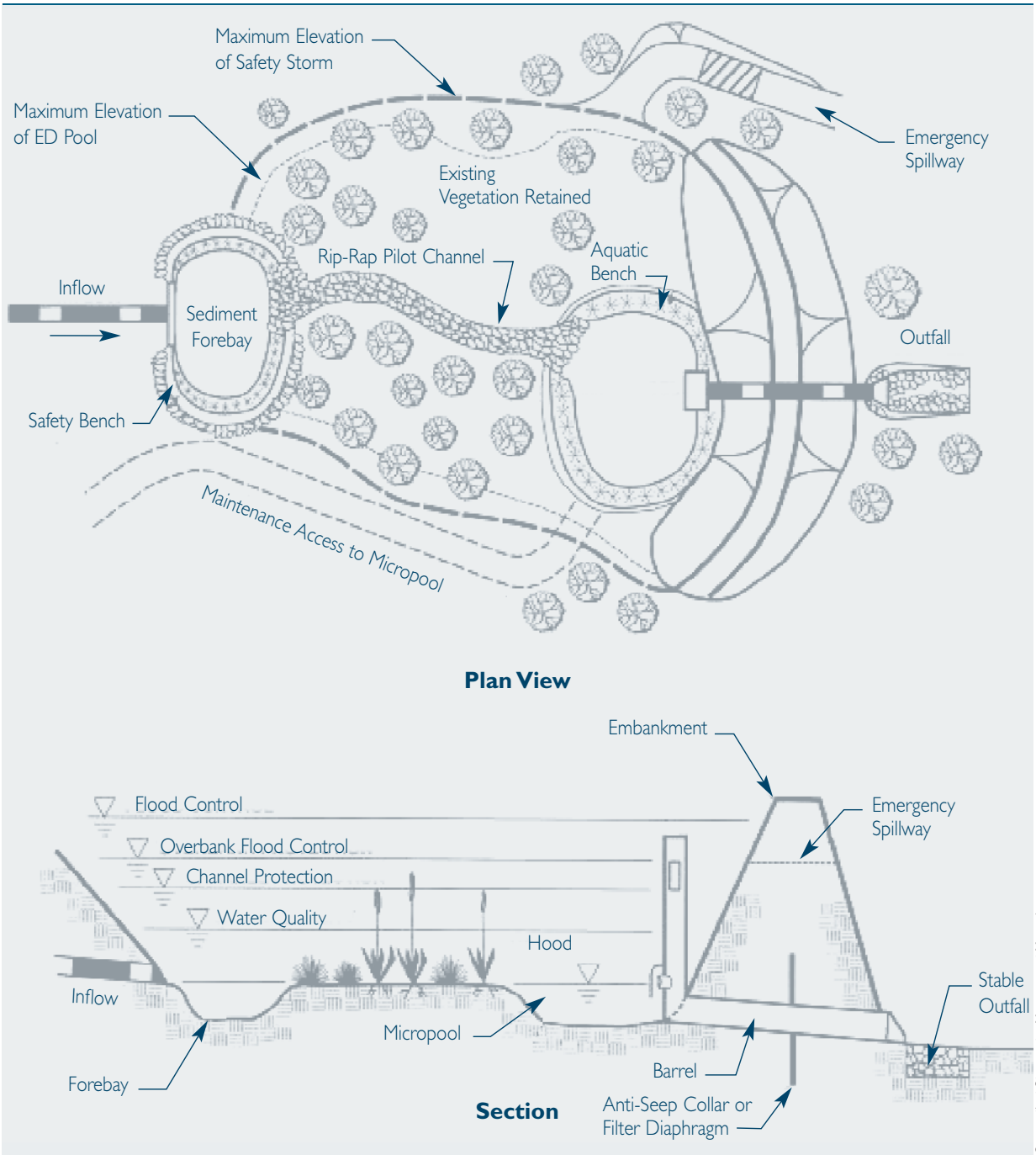

Figure 7.20: Extended detention basin schematic

Recommended Design Procedure

- Determine the stormwater management requirements for the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site and determine what portion of the control requirements the detention basin will meet.

  - Consider a dry extended detention basin to provide water quality treatment if infiltration is infeasible on the site.

  - Detention basins may not be built on steep slopes. Slopes may not be significantly altered or modified to reduce the steepness of the existing slope. See **Section 4.0**: Integrated Site Design.

  - Extended detention basins shall not be constructed within jurisdictional waters, including wetlands.

- Create a conceptual design for the basin. Estimate required basin size according to an approved calculation method in **Section 5.3**: Acceptable Methods for Calculations.

Table 7.14: Starting Design Parameters for Detention Basins

Detention time for water quality volume	24-hour minimum
Water depth	10 feet (Maximum)
Width	10 feet (Minimum)
Shape	• To maximize length of stormwater flow pathways. • To minimize short-circuited inlet-outlet systems.
Length to width ratio	2:1 (Minimum - recommended to maximize sedimentation)

- Design an outlet structure (or multiple structures) that provides the level of control required. (A multi-stage outlet structure will be required in most cases.)

  - Energy dissipaters are to be placed at the end of the primary outlet to prevent erosion.

  - If the basin discharges to a channel with dry weather flow care shall be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel.

  - The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.

  - The primary and low flow outlet shall be protected from clogging by an external trash rack.

  - On sites that have the potential for accidental spills, the outflow structure should be fitted with a valve so that discharge from the basin can be halted. This same valve also can be used to regulate the rate of discharge from the basin.

- The detention basin must provide an emergency overflow capable of passing the 100-year design storm. This spillway may not direct emergency flows toward neighboring properties.

- Determine the final contours of the basin.

Table 7.15: Contour Design Parameters for Detention Basins	
Lowest basin elevation	2 feet above seasonal high water table (Minimum)
Basin shape	Irregularly shaped to appear more natural
Low flow channels	Only use where there is a concern for severe ponding due to native soils Always vegetate with a maximum slope of 3% to encourage sedimentation Consider other SMPs such as wet ponds, constructed wetlands or bioretention
Vegetated embankments	Less than or equal to 3 feet in height (Recommended) 15 feet in height (Maximum)* Maximum slope 3:1 (Horizontal to vertical)
Basin freeboard	Minimum 1 foot above the 100-yr design storm
*15 feet or higher or that which will impound more that 50 acre-feet of runoff during high-water condition will be regulated as dams by PADEP. Consult chapter 105 on the Pennsylvania State Code.	

- Design an inlet control and a sediment forebay. The sediment forebay volume may be considered to meet a portion of the water quality volume.

Table 7.16: Inlet Control and Sediment Forebay	
Forebay length	10 feet (Minimum)
Storage	Designed to trap sediment over a period of 2 to 10 years

- Verify that the basin meets all control requirements concurrently as designed.
- Choose appropriate vegetation using the guidelines in **Section 8**: Landscape Guidance. Fertilizers and pesticides shall not be used.
- Complete construction plans and specifications.

Materials

Basin Soil

- A minimum of 6 inches of planting soil is recommended. Soil shall be a high-quality topsoil with a loam or sandy loam texture.
- Clay cores may be necessary in basins designed to withstand excessive pressures and seepage forces.

Plants

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in **Section 8**: Landscape Guidance.
- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.
- Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.
- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

Construction Guidelines

- Install all temporary erosion and sedimentation controls. The area immediately adjacent to the basin must be stabilized in accordance with the Pennsylvania Department of Environmental Protection (PADEP) *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) prior to basin construction.
- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain if feasible and shall only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area to be excavated of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area.
- Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade subsoil in bottom of basin, taking care to prevent compaction. Compact surrounding embankment areas and around inlet and outlet structures.
- Apply and grade planting soil.
- Apply geotextile and other erosion-control measures.
- Seed, plant, and mulch according to Planting Plan.

Maintenance Guidelines

- Maintenance is required for the proper operation of detention basins. Plans for detention basins should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule for extended storage detention basins.

Table 7.17: Detention Basin Maintenance Guidelines

Activity	*Schedule*
• Remove trash and debris. • Remove invasive plants. • Grassed areas require periodic prudent fertilizing, dethatching and soil conditioning. • Trees, shrubs, and other vegetative cover will require periodic maintenance such as fertilizing, pruning, and pest control. • Mow / trim detention basin vegetation.	As needed
• Sediment should be removed from the basin.	As needed (at least once every 5 to 25 years)*
• Inspect outlet control structure for clogging.	Quarterly and after every storm greater than 1 inch
• Inspect detention basin for potential problems including: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

* The frequency of sediment removal depends on site conditions such as soil type and maintenance of site stabilization which influence the sediment load on the basin.

- In most cases, no specific limitations have been placed on disposal of sediments removed from detention basins. Studies to date indicate that pond sediments are likely to meet toxicity limits and can be safely landfilled. On-site sediment disposal is always preferable as long as the sediments are deposited away from the shoreline to prevent their re-entry into the pond and away from recreation areas where people could inhale resulting dust. Sediment disposal should be included in the Operations and Maintenance (O & M) Plan and will be evaluated on a site by site basis.

- Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the drainage area include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.

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7.7 Berms

and retentive grading techniques use a site's topography to manage stormwater and avoid erosion. They may function alone in grassy areas or may be incorporated into the design of other stormwater control facilities such as bioretention and constructed wetlands. They are landscaped features placed parallel to existing contours that direct runoff while promoting retention and infiltration of stormwater.

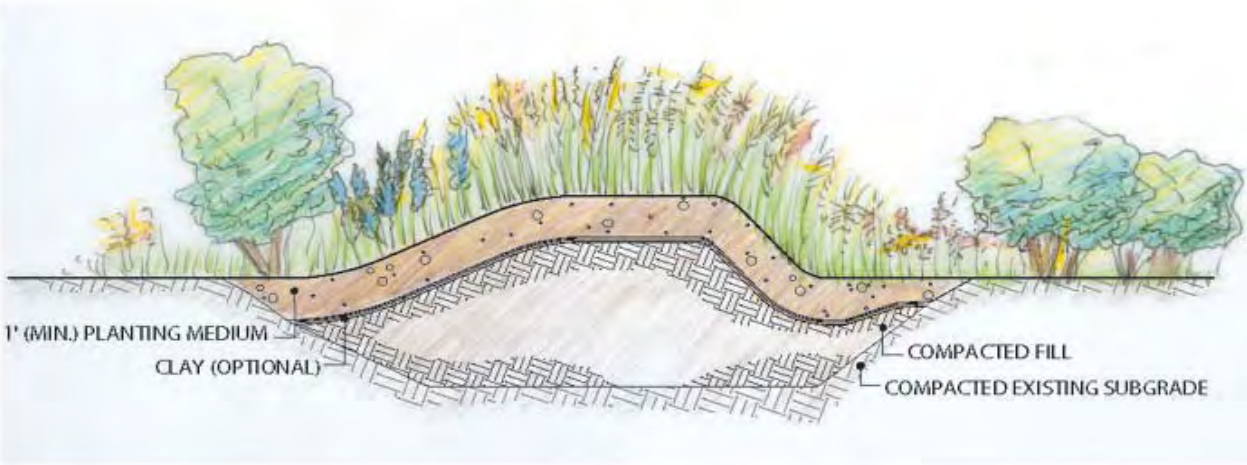


Figure 7.21: Berm cross-section

key elements :

- High quality topsoil in outer layer of berm that provides growing medium for plants (minimum 4 inches).
- Inner layer of berm constructed of a stable fill material.
- Established vegetation to prevent erosion and improve appearance.
- An overflow weir or runoff bypass mechanism.

potential applications

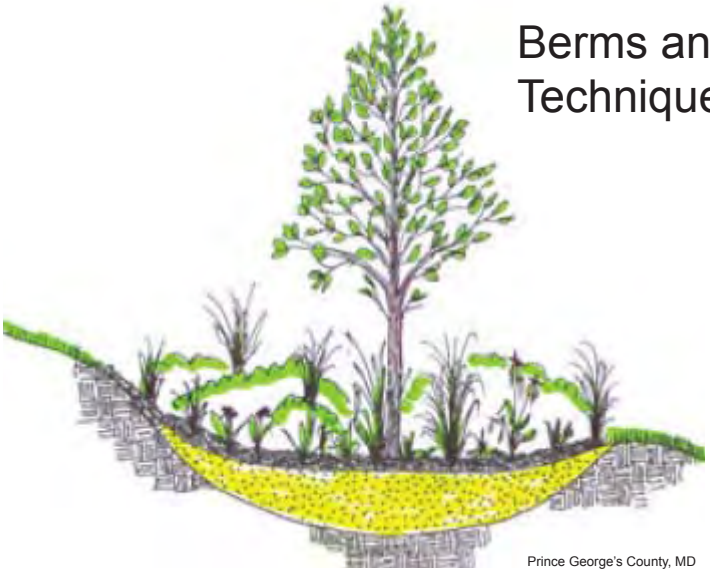
Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Limited
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	N/A
Flood Control:	N/A

acceptable forms of pre-treatment

N/A



Prince George's County, MD

Figure 7.22: Example of retentive grading used to create a small bioretention basin which can be vegetated to various extents

Berms and Retentive Grading Techniques in the Urban Landscape

Berms are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, residential developments, and vacant lots. Berms and shallow depressions are well suited for both small and large projects. It can be an inexpensive method of reusing soil on site to manage stormwater.

Pretreatment for other Facilities
A berm and small depression can act as a sediment forebay before stormwater enters a bioretention basin, subsurface infiltration facility, or other facility.

Retention and Increased Capacity for other Facilities
A berm placed on the downslope side of a bioretention basin or other facility built on a mild slope can help retain stormwater in that facility and increase its capacity without additional excavation.

Retention and Infiltration in a Shallow Depression
A shallow depression can be created behind a berm to provide an infiltration area without the need for a more complex stormwater facility.

Flow Diversion
A berm can be placed across a slope to divert water to a nearby channel or facility.

Berms in Series
A series of small berms and depressions can be placed along a slope to provide infiltration and detention while stabilizing the slope.

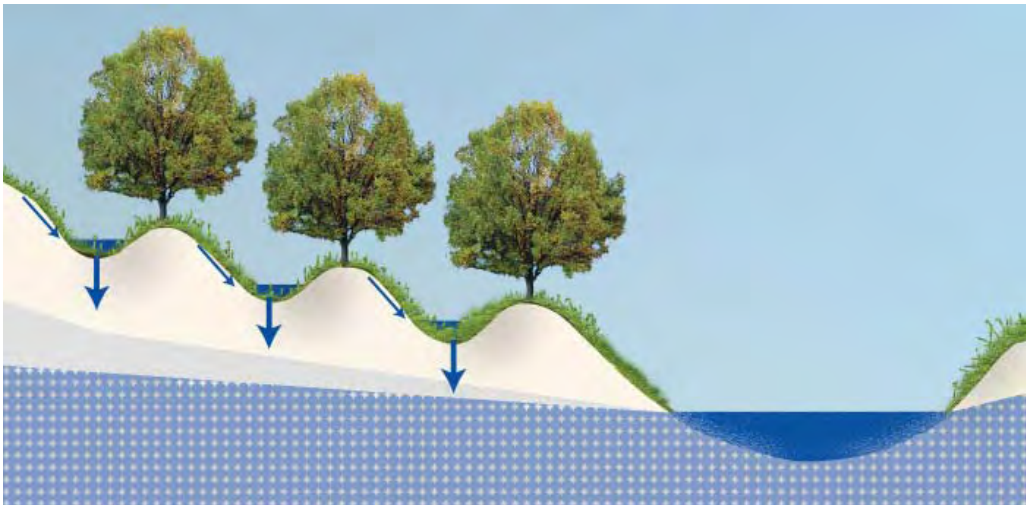


Figure 7.23: Woodland infiltration berms in series

Components of Berms and Retentive Grading Techniques

Berms and retentive grading systems are designed to convey and infiltrate all of the stormwater they receive in small storms. These systems often include the following components:

- Topsoil
- Fill
- Vegetation
- Weir or Bypass Mechanism

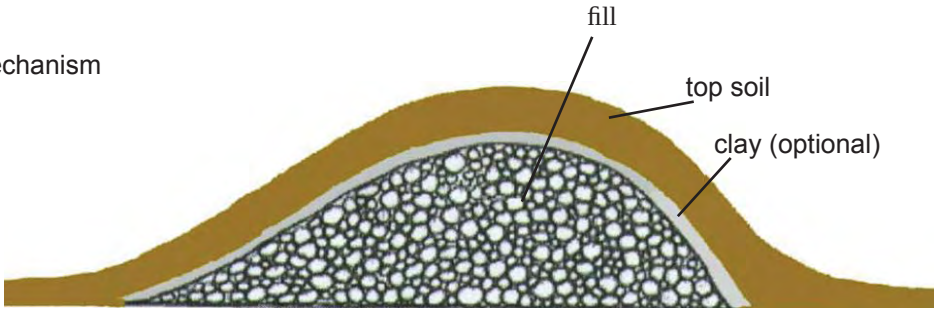


Figure 7.24: Ideal substrate components of a berm Pennsylvania Stormwater BMP Manual

Topsoil
The outer portion of the berm consists of high quality topsoil to provide a barrier to flow and act as a growing medium for plants. A berm may consist entirely of high quality topsoil. To reduce cost, only the top 4 to 8 inches needs to consist of high quality topsoil, with well-drained soil making up the remainder of the berm.

Fill
A berm may consist entirely of high quality topsoil. However, cost may be reduced by constructing the inner portion of the berm of a stable fill material. In many cases, soil may be reused from elsewhere on the site.

Vegetation
Vegetation stabilizes and prevents erosion of the soil layer. Native trees and grasses are encouraged for aesthetic reasons and because of their deeper root systems, but turf is acceptable.

Weir or Bypass Mechanism
The berm may not be able to retain all flow during large events. An overflow weir may be designed to allow flow to overtop the berm without causing erosion. In other cases, the contours of the site may allow excess flow to bypass around the end of the berm.



Traver

The sediment forebay at Villanova University uses a rock and soil berm as pretreatment for their constructed wetland

Recommended Design Procedure

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements berms and retentive grading will help meet. Determine the general location of these features and the role they will play on the site. See **Section 4.0**: Integrated Site Design.

- Create a conceptual design for the berm (or berms), including height of berm and depth of depression.

Table 7.18: Starting Design Values for Berm Areas and Depths	
Area (surface area and infiltration area)	Largest feasible on site (Minimum of 1 square foot of infiltration area for every 5 square feet of contributing DCIA recommended.)
Average Ponding Depth	6 – 12 inches
Berm Height	6 – 24 inches

- For a berm-depression system intended to promote infiltration, investigate the feasibility of infiltration in the proposed location. See **Appendix A**: Hotspot Investigation Procedures, **Appendix B**: Soil Infiltration Testing Guidelines, and **Appendix C**: Geotechnical Investigation Procedures for more guidance on requirements. Infiltration testing must be within 25 feet of the infiltration footprint.

- Estimate runoff reaching the system during the design storm and the maximum water level reached at the berm.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. A surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust berm height and depression depth. Adjust the design until the volume and drainage time constraints are met.

- Design an overflow or bypass mechanism for large storms.

- Consider maintenance activities when choosing berm materials and shape. Figure 7.25 illustrates the recommended shape.

- If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid “scalping” by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 to 7:1 ratio. Other herbaceous plants, which do not require mowing, can tolerate slopes of 3:1, though this may promote increased runoff rate and erosive conditions. Berm side slopes should never exceed a 2:1 ratio.

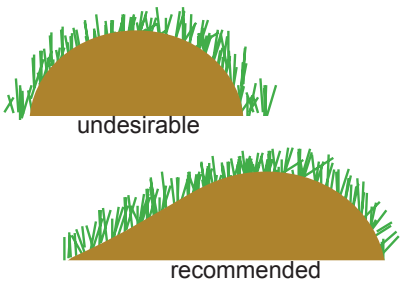


Figure 7.25: Recommended berm shape

- To minimize cost, check the volume of cut and fill material. Berm height and depression depth may be adjusted to more closely balance the two.

- Choose vegetation as recommended in **Section 8**: Landscape Guidance.

Materials

Soil

- Satisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GW, GP, GM, SM, SW, and SP.

- Unsatisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GC, SC, ML, MH, CL, CH, OL, OH, and PT.

- Topsoil stripped and stockpiled on the site should be used for fine grading. Topsoil is defined as the top layer of earth on the site, which produces heavy growths of crops, grass or other vegetation.

- Soils excavated from on-site may be used for berm construction provided they are deemed satisfactory as per the above recommendations or by a soil scientist.

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Native trees and grasses are strongly recommended but turf grass is acceptable. Select native plants from the list in **Section 8**: Landscape Guidance. Take ponding depth, drain down time, sunlight, and other conditions into consideration when selecting plants from this list. Although plants will be subject to ponding, they may also be subject to drought.

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.

- Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.

- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

- A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

Construction Guidelines

- Areas for infiltration berms shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- Provide erosion and sedimentation control protection on the site such that construction runoff is directly away from the proposed infiltration berm location.

- Complete site elevation grading and stabilize the soil disturbed within the limit of disturbance. Do not finalize berm excavation and construction until the drainage area is fully stabilized.

- Manually scarify the existing soil surfaces of the proposed infiltration berm locations. Do not compact in-situ soils. Heavy equipment shall not be used within the berm area.

- Backfill the excavated area as soon as the subgrade preparation is complete to avoid accumulation of debris. Place berm soil in 8 inch lifts and compact after each lift is added according to design specification. Grade berm area as fill is added.

- Protect the surface ponding area at the base of the berm from compaction. If compaction occurs scarify soil to a depth of at least 8 inches.
- After allowing for settlement, complete final grading within 2 inches of proposed design elevations. The crest and base of the berm should be level along the contour.
- Seed and plant vegetation as indicated on the plans and specifications.
- Place mulch to prevent erosion and protect establishing vegetation and manually grade to final elevations.
- Water vegetation at the end of each day for two weeks after planting is completed.

Maintenance Guidelines

Infiltration berms have low to moderate maintenance requirements, depending on the design.

Table 7.19: Berm & Grading Maintenance Guidelines

Activity	*Schedule*
• Remove trash and debris. • Remove invasive plants. • If desired, mow grass to maintain 2 – 4 inch height.	As needed
• Inspect soil for erosion and repair eroded areas.	Monthly
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
Design of berms and grading techniques are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site. Berms may be used within larger basins (e.g., wetlands, wet ponds) to lengthen flow paths; these applications are discussed in **Section 7**: SMP Design Guidance for each type of basin.

7.8 Swales

A swale is an open channel vegetated with a combination of grasses and other herbaceous plants, shrubs, and trees. A traditional swale reduces peak flow at the discharge point by increasing travel time and friction along the flow path. A swale provides some infiltration and water quality treatment; these functions can be enhanced by adding check dams periodically along its length. Swales planted with turf grass provide some of these functions but turf grass is not as effective as deeper-rooted vegetation at decreasing peaks, allowing infiltration, and decreasing erosion. A swale can be more aesthetically pleasing than a concrete or rock-lined drainage system and is generally less expensive to construct.



key elements :

- Open channel design that balances storage, treatment, and infiltration with peak flow conveyance needs
- Check dams often used to increase storage, dissipate energy, and control erosion
- Native vegetation increases friction and stabilizes soil
- Designed to fit into many types of landscapes in an aesthetically pleasing manner

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	No
Industrial:	Limited
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction:	Yes
(no infiltration)	
Channel Protection:	Medium
Flood Control:	Medium

acceptable forms of pre-treatment

Filter strips (Optional)
Sediment Forebay (Optional)

Swales in the Urban Landscape

Swales are landscaped channels that convey stormwater and reduce peak flows by increasing travel time and friction. Depending on design, they can effectively reduce runoff volume and improve water quality. Check dams increase these functions by providing ponding areas where settling and infiltration can occur. As the number of check dams increases, a swale may resemble a series of bioinfiltration/ bioretention basins while still being designed to convey peak flows. The first ponding area may be designed as a sediment forebay and function as a pretreatment practice for the remainder of the swale or other stormwater management facilities.



Curbless driveway drains to stone and vegetated swales



Curb opening to grass swale in residential development

Swales are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, and residential developments. For instance, a swale is a practical replacement for roadway median strips and parking lot curb and gutter.

Commercial, Light Industrial, and Institutional Sites

These facilities often have landscaped or grassed areas that can also function as drainage pathways and infiltration areas.

Roads and Highways

Swales can be installed in some median strips and shoulders. In some cases, these systems may replace costly curb and gutter systems.

Residential Development

With approved property agreements, swales can be constructed parallel to the sidewalks and streets. Alternatively they can collect stormwater from multiple properties and convey it to a shared facility.

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Components of a Swale

Swale systems often include the following components:

- Inlet Control
- Pretreatment (Optional)
- Excavated Channel
- Soil
- Outlet Control
- Check dams
- Stone (Optional)
- Underdrain (Limited Application)
- Vegetation

Inlet Control
Runoff can enter the swale through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road and down a swale slope in a diffuse manner.

Pretreatment (Optional)
Pretreatment is optional but can extend the life of the design. Vegetated or stone filter strips are options for pretreatment. A sediment forebay may be constructed at the swale inlet, or the first swale segment and a check dam may be designed as a sediment forebay.

Excavated Channel
The channel itself provides the storage volume and conveyance capacity of the swale. Swale design balances needs for infiltration and treatment during small storms with needs for conveyance during large storms.

Soil
The soil provides a growing medium for plants and allows for infiltration. Growing medium may consist of amended native soils or imported soil.

Check Dams
It is recommended that swale designs include check dams. Ponding behind check dams provides storage, increases infiltration, increases travel time, reduces peaks, and helps prevent erosion by dissipating energy.

Stone
A crushed stone layer may be added beneath the soil to increase storage and promote infiltration. Stone will perform this function most effectively when placed in ponded areas.

Underdrain
In some cases, an underdrain and piping system may be designed to prevent prolonged ponding of stormwater or to collect and convey water to another facility such as an infiltration trench. Underdrained systems may be appropriate in locations where conditions are not ideal for infiltration.

Outlet Control
A swale may have an outlet control to convey water to a sewer or receiving water.



River rock swale with structural check dams that manages runoff from sloped street

Recommended Design Procedures

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site, and determine what portion of the requirements the vegetated swale will meet. Consider the site's natural topography in siting the swale; if possible, locate the swale along contours and natural drainage pathways with slopes of 2-3%. See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration according to conditions in the area proposed for the vegetated swale. If infiltration is feasible, determine the saturated vertical infiltration rate. See **Appendix B**: Soil Infiltration Testing Procedures.

- Create a conceptual design for the vegetated swale.



Vegetated swales at Swarthmore University

Table 7.20: Suggested Swale Starting Design Values	
Bottom Width	2-8 feet
Side Slopes	3-4 horizontal to one vertical recommended; 2:1 maximum•
Check Dams	Evenly spaced, 6-12 inches high••
•Swales may be trapezoidal or parabolic in shape. Recommended widths and slopes in this table may be used as a general guide for parabolic channels	
••Check dams are recommended for most applications to improve infiltration and water quality. They are strongly recommended for swales in which flow in combination with soil, slope, and vegetation may result in erosive conditions	

- Consider an underdrain only under one of the following conditions:
  - in areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible (See **Appendices B**: Soil Infiltration Testing Procedures) and the vegetated swale is needed only to provide water quality treatment;
  - in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
  - in combination with other SMPs where the system as a whole meets storage and release criteria.

- Estimate the portion of Infiltration, Water Quality, Channel Protection, and Flood Control requirements met by the design. See **Section 4.3**: Manage Remaining Stormwater for guidance on these calculations.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long storage behind check dams will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. A surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust channel shape, number of check dams, or check dam height. Adjust the design so that performance and drainage time constraints are met concurrently.

- Check the peak flow capacity of the swale. It is recommended that the swale convey the 10-year, 24-hour design storm with 6 inches of freeboard, an average ponding depth of 12 inches or less, and a maximum ponding depth of 18 inches or less. Flow over check dams may be estimated using a weir equation. For rock weirs that allow flow through the weir, an equation is suggested in **Section 7.15**: Inlet and Outlet Controls. Ultimately, the level of service provided on the site during large events is a joint decision of the Engineer and Owner based on safety, appearance, and potential property damage.

- Choose soil mix and swale vegetation. A minimum of 6 inches of prepared soil is recommended for the channel bottom and slopes.

- Check resistance of the swale to erosion. It is recommended that the swale convey the 2-year, 24-hour design storm without erosion. The PADEP *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) is recommended as a reference for these calculations. Adjust soil mix, vegetation, and temporary or permanent stabilization measures as needed.

- Design inlet controls, outlet controls, and pretreatment if desired.

- Check that the design meets all requirements concurrently, and adjust design as needed.

- Complete construction plans and specifications.

Materials

Soil

- Swale soil shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle.

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in species in **Section 8**: Landscape Guidance. Take ponding depth, drain down time, sunlight, salt tolerance, and other conditions into consideration when selecting plants from this list. Turf grass is generally not recommended but may be acceptable provided the designer can show it meets all requirements.

Check Dams

- Check dams can be constructed from natural wood, concrete, stone, boulders, earth, or other materials.
- If a stone check-dam is designed to be overtopped, appropriate selection of aggregate will ensure

stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

Storage Stone

- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.

- Stone shall be separated from soil medium by a non-woven geotextile or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

  - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
  - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
  - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
  - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
  - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used for an underdrain shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

- Begin vegetated swale construction only when the up gradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized very early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. (Erosion and sediment control methods shall adhere to the PADEP *Erosion and Sediment Pollution Control Program Manual*, March 2000 or latest edition).

- Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be rototilled into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

- Construct check dams, if required.

- Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow conditions.

- Seed and vegetate according to final planting list. Seeding with an annual turf grass is recommended to provide temporary stabilization. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

- Concurrent with the previous step, stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established. Erosion and sediment control methods shall adhere to the PADEP's *Erosion and Sediment Pollution Control Program Manual*, March 2000 or latest edition.

- Once the swale is sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving stormwater flow.

Maintenance Guidelines

The following schedule of inspection and maintenance activities is recommended:

Table 7.21: Swale Maintenance Guidelines

Activity	*Schedule*
• Remulch void areas. • Treat or replace diseased trees and shrubs. • Keep overflow free and clear of leaves.	As needed
• Inspect soil and repair eroded areas. • Remove litter and debris. • Clear leaves and debris from overflow.	Monthly
• Inspect trees and shrubs to evaluate health.	Biannually
• Add additional mulch. • Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

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7.9 Constructed Wetlands
can be found in the
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7.10 Ponds and Wet Basins
can be found in the
Pennsylvania Stormwater BMP Manual

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7.11 Subsurface vaults

are underground structures designed primarily to reduce peak stormwater flows, although in some cases they may allow infiltration. They are usually constructed of either concrete or corrugated metal pipe (CMP) and must account for the potential loading from vehicles. Pretreatment structures can be used at the inlet to treat stormwater runoff and remove debris. A permanent pool can also be incorporated to dissipate energy and improve the settling of particulate stormwater pollutants. Dry systems are primarily used for volume control or in combination with pretreatment, whereas wet systems include a permanent pool and provide water quality treatment.

key elements :

- Effective for urban areas with limited space for SMPs.
- More effective in areas of combined sewer than in areas of separate sewers.
- Provides peak rate control.
- Pretreatment may be included to remove sediment and pollutants associated with sediment.
- Traffic loading capabilities.
- Maintenance required periodically to remove sediment and debris.

potential applications

Residential Subdivision:	Limited
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	No
Channel Protection:	Medium / High
Flood Control:	Medium / High

acceptable forms of pre-treatment

- Sediment chamber
- Sediment forebay
- Appropriate prefabricated and proprietary designs

Subsurface Vaults in the Urban Landscape

Subsurface vault systems are suitable for projects where space is limited and other stormwater management systems are not feasible. Subsurface vaults may be used for commercial, industrial, or roadway projects. The presence of a subsurface vault in most cases does not alter the intended land use at the surface. The subsurface vault must meet structural requirements for overburden support and traffic loading to be applicable in urban settings. Some applications of subsurface vaults are provided; however, examples are not limited to this list.

Components of a Subsurface Vault

Subsurface vault systems contain a combination of the following components:

Inlet Control
The inlet control of a subsurface vault should be connected to the stormwater catchment area. The subsurface vault should be sized according to the area entering into the system. Parking lots, roadways, and large rooftop areas are typically the drainage areas contributing to the subsurface vault system. The inlet control may include a flow splitter to regulate the rate and volume of water entering the vault.

Pretreatment
Pretreatment can include a forebay/grit chamber, sand filter, or water quality inlet. It may also include features to trap floatables and an oil/water separator. A baffle inserted within the subsurface vault separates the entire volume into two chambers. A sedimentation chamber is created using a baffle wall. Storage volume present in a pretreatment structure may be considered part of the total storage volume required.

Storage Structure
Storage often provided by a concrete structure, a large pipe, or a group of pipes.

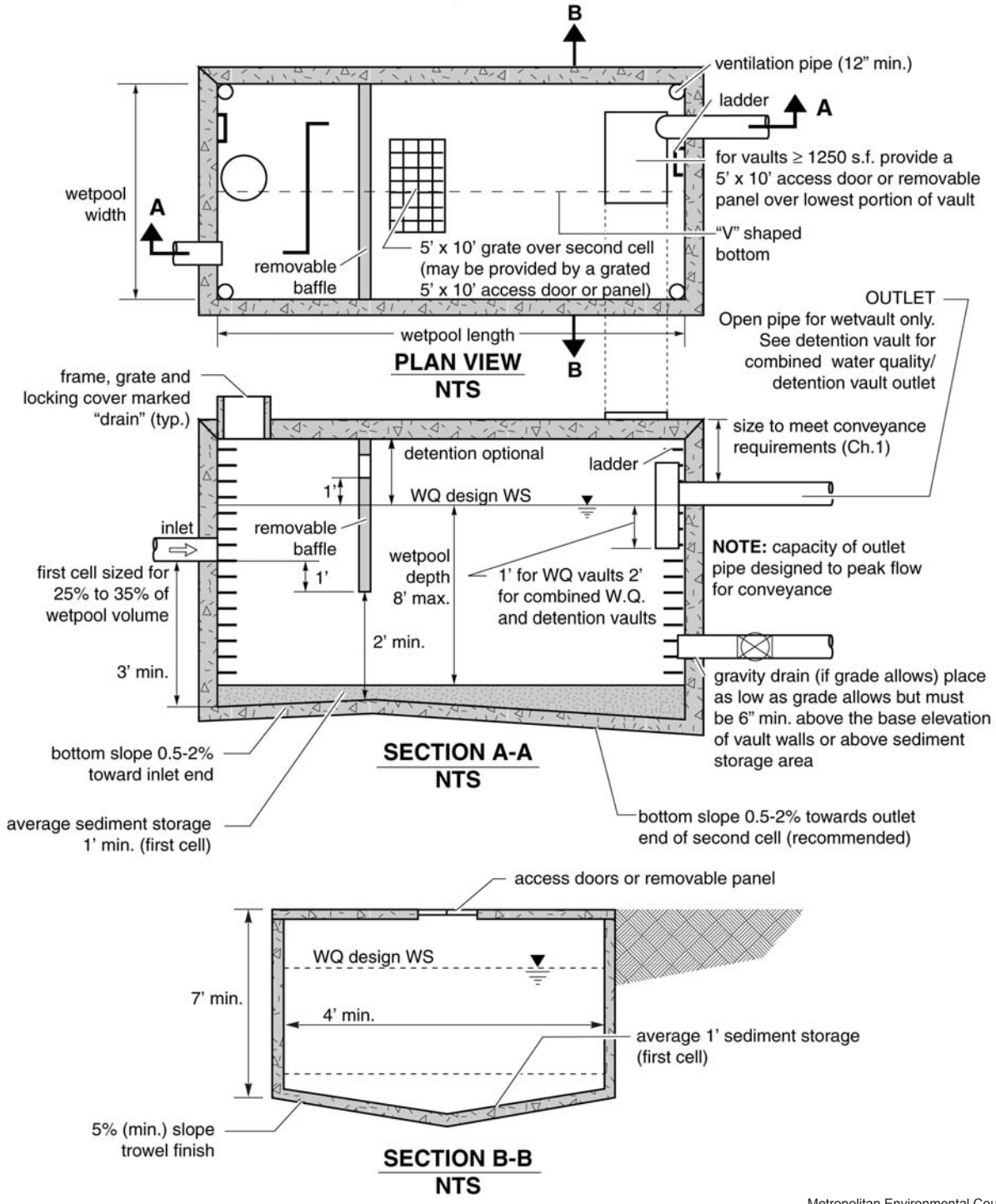
Infiltration Feature
Infiltration is typically not a major function of a subsurface vault; however, some designs may allow it. The designer must consider soil conditions and maximize the ratio of infiltration area to drainage area. For more information on subsurface infiltration design see **Section 7.12**: Subsurface Infiltration.

Permanent Pool
A permanent pool of water may be incorporated to dissipate energy and improve the settling of particulate pollutants. When a permanent pool is incorporated in a design, the design may be referred to as a "wet vault". This design provides a benefit similar to that of a surface wet pond, with the exception of evaporation and functions improved by vegetation.

Slow Release Structure
The slow release structure regulates the rate of outflow for storms up to the design capacity. The storage volume and slow release together allow a subsurface vault to meet channel protection and peak release rate criteria.

Overflow Structure
An overflow structure allows storms in excess of the design storm to pass through the structure without being detained or receiving treatment. An overflow structure at the outlet, a flow splitter at the inlet, or a combination may be used to safely convey large storms.

Access Feature
This feature is used for maintenance and inspection purposes and most commonly consists of a panel leading to the storage area.



Metropolitan Environmental Council

Figure 7.26: Schematic of a subsurface wet vault

Recommended Design Procedure

- Determine the water quality/recharge, stream bank protection, and peak rate control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements the subsurface vault will meet. See **Section 4.0**: Integrated Site Design.

- Create a conceptual design for the subsurface vault, including enough volume to meet storage requirements.

- Estimate the total storage volume and adjust facility sizing as needed to provide required storage. Any permanent pool areas should not be included in the storage volume estimation.

- Decide whether to include pretreatment, a permanent pool, or a combination. This decision may be based on which option is more cost-effective; frequency and ease of maintenance desired by the Owner; land use and expected stormwater constituents.

- Choose and design pretreatment as appropriate. The pretreatment volume is part of the total volume. By maximizing the flowpath and stabilizing the flow rate from inlet to outlet, residence time and treatment effectiveness are increased. A baffle oil/water separator can be used to treat incoming flow from industrial sites or parking lots. In this case, the subsurface vault should include a baffle to create two chambers within structure. If a baffle is used, the following design is recommended:

    - The baffle should extend from a minimum of 1 foot above the design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
    - The lowest point of the baffle should be a minimum of 2 feet from the bottom of the vault, and greater if feasible.

- Permanent pool sizing follows the same procedure explained in the BMP 6.14: Wet Ponds / Retention Basin of the Pennsylvania Stormwater BMP Manual (PA SBMPM). A minimum depth of 3 feet is recommended to minimize disturbance of sediment. The shape of the permanent pool should be designed to promote adequate mixing as follows:

    - Maximize the flowpath between inlet and outlet, including the vertical path, to enhance treatment by increasing residence time.
    - The ratio of flowpath length to width from the inlet to the outlet should be at least 3:1.
    - All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.
    - Refer to the references for additional shape recommendations.

- Decide whether to design for infiltration. The procedure followed is similar to that in **Section 7.12**: Subsurface Infiltration.

- Design a slow release structure. If a gate valve is used, it should be close to the bottom of the vault but above the sediment storage level. A check valve or other backflow prevention device is often incorporated. Check that any release rate requirements are met by the system as designed. See **Section 7.15**: Inlet and Outlet Controls.

- Design a positive overflow or bypass system for large storms. The outlet structure and design head should provide adequate flow to avoid overtopping the vault. See **Section 7.15**: Inlet and Outlet Controls.

- Design a maintenance access door or grate to connect to ground level. A grated access panel is ideal for air flow. A minimum of 50 square feet of grate is recommended for permanent pool designs. For vaults in which the surface area is larger than 1250 square feet, 4 percent of the top should be grated.

- Complete construction plans and specifications. At a minimum, plans should include plan view, cross-sections, and inlet and outlet details.

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Maintenance Guidelines

The systems must be designed so that the vault can have easy access for inspection and maintenance. Vault maintenance procedures must meet OSHA confined space entry requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Table 7.22: Subsurface Vaults Maintenance Guidelines

Activity	*Schedule*
• Removal of sediment and debris from subsurface vault sedimentation chamber when the sediment zone is full. Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if indications of pollution are noticed.	As needed
• Inspection of subsurface vault and control structures. • Floating debris and accumulated petroleum products should be removed.	Quarterly
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
The designs of subsurface vaults are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.



Ejector truck used for maintenance of subsurface vaults

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7.12 Subsurface infiltration

systems are designed to provide temporarily below grade storage infiltration of stormwater as it infiltrates into the ground. Dry wells, infiltration trenches and beds are a few examples of these types of systems.



City of Portland, OR

key elements :

- Infiltration testing is required for this SMP.
- Reduce volume of runoff from a drainage area by promoting infiltration though uncompacted subgrade.
- Flexible design can be sited beneath lawns, parking areas, and recreational areas.
- Maintain minimum distance from building foundation (typically 10 feet down-gradient).
- Open-graded aggregate or other approved material provides storage.
- System must be designed to drain down in less than 72 hours.
- Greater than 2 feet from any limiting zone such as groundwater or bedrock.
- Pre-treatment is required.
- Positive overflow required for large storms.
- Areas of soil contamination or areas of unstable soils should be avoided.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	Low/Medium
Flood Control:	Low/Medium

acceptable forms of pre-treatment

- Filter
- Bioretention
- Filter strips
- Appropriate prefabricated and proprietary design
- Sumped inlets with traps

Subsurface Infiltration in the Urban Landscape

Subsurface infiltration systems are typically stone-filled beds or trenches beneath landscaped or paved surfaces. Stormwater flows into the subsurface infiltration system collects within the aggregate void space, and slowly infiltrates into surrounding soils.

Subsurface infiltration is a versatile management practice suitable for many different types of land uses. Both high-density development and individual residences can implement subsurface infiltration systems for stormwater control. Their flexibility also makes them an option for a stormwater retrofit. Several example uses for subsurface infiltration are provided below.

Parking Lots and Roadways
Stormwater inlets in parking lots or streets can be directly connected to subsurface infiltration systems. Sumped or trapped inlets prevent sediment and debris from migrating into the infiltration bed. The inlets can be connected to subsurface infiltration systems located underneath landscaped areas, recreation areas, or under the impervious surfaces themselves.

Lawns and Recreational Areas
Open green spaces can collect, store, and infiltrate runoff from impervious surfaces.

Direct Connection of Rooftops
Downspouts can be connected to subsurface infiltration beds at both residential and commercial sites. Small subsurface infiltration areas that manage roof runoff from residential roofs or that are distributed around a larger building to manage runoff from smaller sections of roof are often called dry wells. Although roofs do not often generate high sediment loads, sumped cleanouts should be located between the roof and the infiltration area. The roof leader connects to perforated piping when it reaches the subsurface infiltration area.

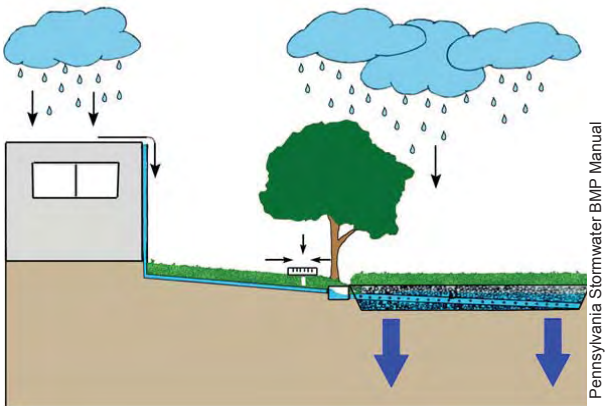


Villanova University

Subsurface infiltration occurs beneath this picnic area



Subsurface infiltration beds were installed at the Penn-Alexander School in Philadelphia



Pennsylvania Stormwater BMP Manual

Figure 7.27: Direct connection of a roof into a subsurface infiltration bed

Components of a Subsurface Infiltration System

There are many variations of subsurface infiltration systems, but they are often comprised of these components:

- Inflow/Pretreatment
- Storage
- Observation well
- Infiltration/Outflow

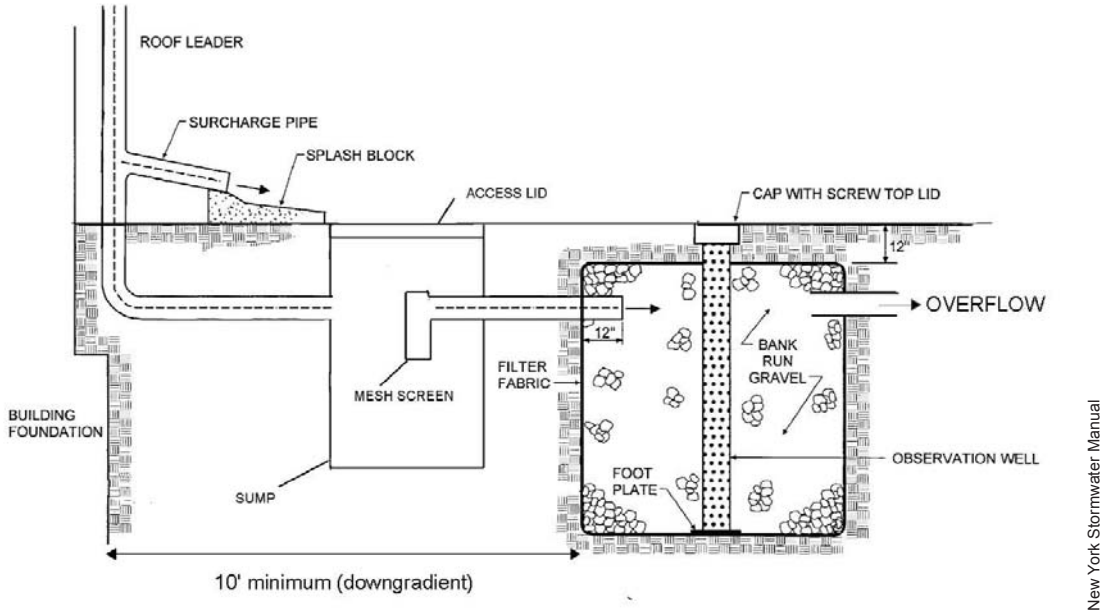


Figure 7.28: Intermediate sump box and dry well

Inflow/Pretreatment

Subsurface infiltration systems are capable of intercepting stormwater inflow from many sources, including rooftops, parking lots, roads, sidewalks, and driveways. It is important to prevent coarse sediments and debris from entering subsurface infiltration systems, because they could contribute to clogging and failure of the system. The following are acceptable forms of pretreatment.

- Roof leader sump, or an intermediate sump box
- Roof gutter guard (may required additional sump unit depending on structure design).
- Filter Strips, see Section 7.3
- Vegetated Swales, See Section 7.8

Storage

The storage component of a subsurface infiltration area is typically provided by a stone filled, level-bottomed bed or trench. The void spaces between the stones stores stormwater until it can percolate into surrounding soils.

Alternative subsurface storage products may also be used to provide temporary storage. These include a variety of proprietary, interlocking plastic units with much greater storage capacity than stone fill (up to 96% void space). Perforated pipe in a stone bed can also increase the effective void space of the system. The higher void ratio requires a smaller footprint and can allow more flexibility in an urban environment, but proper analysis should be completed to ensure that the in-situ soils will adequately drain with the additional loading and that loading ratio and effective head maximums are not exceeded.



Prefabricated storage

Observation Well
An observation well should be located at the center of the trench to monitor water drainage from the system. In a subsurface infiltration system, the water level is the primary means of measuring infiltration rates and drain-down times. A lockable above ground cap is recommended. Adequate inspection and maintenance access to the observation well should be provided. Observation wells not only provide necessary access to the system, but they also provide a means through which pumping of stored runoff can be accomplished in a failed system.

Infiltration/Outflow
Outflow occurs via infiltration through subsurface soil surrounding the infiltration storage area. A bypass system should be implemented for all infiltration systems to convey high flows around the system to downstream drainage systems. Depending on the level of stormwater management required at the site, overflows can connect to an approved discharge point or other SMPs.

Recommended Design Procedure


Infiltration testing

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.
- Must be greater than 10 feet down-gradient and 100 feet up-gradient.
- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements subsurface infiltration will meet. See **Section 4**: Integrated Site Design.
- Investigate the feasibility of infiltration in the area proposed for a subsurface infiltration system. See **Appendix A**: Hotspot Investigation Procedures, **Appendix B**: Soil Infiltration Testing Guidelines, and **Appendix C**: Geotechnical Investigation Procedures for more guidance on requirements. Infiltration testing must be within 25 feet of the infiltration footprint.
- Create a conceptual design for the subsurface infiltration system.

Table 7.23: Starting Design Values for Subsurface Infiltration Areas and Depths

Area (surface area and infiltration area)	Largest feasible in moderately sloped areas of the site (Minimum of 1 square foot of infiltration area for every 5 square feet of contributing DCIA recommended.)
Maximum Storage Depth	2 feet of effective head. (2 cubic feet of storage volume per square foot of infiltration area.)
Minimum distance above limiting zone	2 feet
Maximum drain down time	72 hours

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Open-graded aggregate sub-base may be assumed to have 40% void space for storage.
- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. If storage does not drain in the time allowed, adjust the depth and/or surface area. Adjust the design until the volume and drainage time constraints are met.

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- Design a positive overflow or bypass system for larger design storms. All systems must design overflow structures and pipes to convey at least the 10-year storm.

- Include acceptable form(s) of pretreatment into design.

- Observation well to be designed with 4 inch diameter perforated plastic pipe, and placed at the invert of inflation bed with a lockable above-ground cap.

- Complete construction plans and specifications.

Materials

Storage Stone

- Stone used for subsurface storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3.

- Stone shall be separated from soil by a non-woven geotextile filter fabric or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

  - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
  - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
  - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
  - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
  - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used within the subsurface system shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

- Any pipe materials outside the SMP are to meet City Plumbing Code Standards.



Installation of a subsurface infiltration trench

Construction Guidelines

- Areas for proposed subsurface infiltration systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction. If areas are compacted during construction additional infiltration testing may be required.

- Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed subsurface infiltration system.

- If the infiltration area is being used as a sediment basin during construction the bottom elevation of the sediment basin must be a minimum of 2 feet above the infiltration bed invert elevation.

- Complete site elevation grading and stabilize the soil disturbed within the limit of disturbance. Do not finalize the subsurface infiltration system's excavation and construction until the drainage area is fully stabilized.

- Excavate subsurface infiltration area to proposed invert depth and manually grade and scarify the existing soil surface. The bottom of the infiltration bed shall be at a level grade.

- Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. If it is essential that equipment be used in the excavated area, all equipment must be approved by the Engineer. Use of equipment with narrow tracks or tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction and shall not be used. Should the subgrade be compacted during construction additional testing of soil infiltration rates and system redesign may be required.

- Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.

- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of bed.

- Install aggregate course in lifts of 6-8 inches. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.

- Complete surface grading above subsurface infiltration system, using suitable equipment to avoid excess compaction.

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Maintenance Guidelines

As with all infiltration practices, subsurface infiltration systems require regular and effective maintenance to ensure prolonged functioning. The following table describes minimum maintenance requirements for subsurface infiltration systems.

Table 7.24: Subsurface Infiltration Maintenance Guidelines

Activity	Schedule
• Regularly clean out gutters and catch basins to reduce sediment load to infiltration system. Clean intermediate sump boxes, replace filters, and otherwise clean pretreatment areas in directly connected systems.	As needed
• Inspect and clean as needed all components of and connections to subsurface infiltration systems. • Evaluate the drain-down time of the subsurface infiltration system to ensure the drain-down time of 24-72 hours.	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
Design of subsurface infiltration systems are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

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7.13 Porous pavement

provides the structural support of conventional pavement, but allows stormwater to drain directly through the surface into the underlying base and soils, thereby reducing stormwater runoff. There are porous varieties of asphalt, concrete, and interlocking pavers. Porous pavements are designed with an open graded subbase that allows water to pass through to the native soil and provides temporary storage



key elements :

- Pervious structural surface with high infiltration rate.
- Porous surface and stone sub-base suitable for design traffic loads. Can be used on most travel surfaces with slopes less than 5%.
- Uncompacted, level sub-grade allows infiltration of stormwater.
- Open-graded aggregate sub-base provides storage.
- Additional storage and control structures can be incorporated to meet channel protection and flood control.
- Positive overflow prevents system flooding.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Limited

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	Low/Medium
Flood Control:	Low/Medium

acceptable forms of pre-treatment

- Maintenance

Porous Pavement in the Urban Landscape

Porous pavement systems are used to promote infiltration of stormwater runoff. This technique is very effective in removing pollutants and reducing the volume of stormwater entering a sewer system. During a rain event, stormwater flows through the porous surface, drains into the crushed stone subbase beneath the pavement, and remains stored until stormwater can infiltrate into the soil. Porous asphalt and concrete mixes are similar to their impervious counterparts, but do not include the finer grade particles. Interlocking pavers have openings that are filled with stone to create a porous surface.

Porous pavement systems are suitable for any type of development. They are especially well suited for parking lots, walkways, sidewalks, basketball courts, and playgrounds. Proper training of maintenance staff will help to prolong the life of the system.


Pennsylvania Stormwater BMP Manual

Porous pavement parking lot in Radnor Township

Alternate for Paved Surfaces

Almost any surface that is traditionally paved with an impervious surface can be converted to a porous pavement system. Porous surfaces are particularly useful in high density areas where there is limited space for other stormwater management systems. Porous pavement can be used for parking lots, basketball courts, playgrounds, and plazas. Interlocking porous pavers can be used to provide an interesting aesthetic alternative to traditional paving. Porous pavement can be designed to meet the loading requirements for most parking lots and travel surfaces. However, for lots or loading areas that receive a high volume of heavy traffic, porous pavement can be used for parking stalls and conventional asphalt for travel lanes if the impervious surfaces are graded toward the porous surfaces.


Pennsylvania Stormwater BMP Manual

Porous asphalt playground at the Penn-Alexander Partnership

Direct connection of roof leaders and/or inlets

The subbase storage of porous pavement systems can be designed with extra capacity, and roof leaders and inlets from adjacent impervious areas can be tied into the subbase to capture additional runoff. These beds can be sized to accommodate runoff from rooftops via direct connection or to supplement other SMPs. Pretreatment may be necessary to prevent particulate materials from these surfaces from clogging the subbase of the porous pavement system. If roof leaders or inlets are connected into the bed, the porous asphalt cannot be considered disconnected and a positive overflow must be provided.

Direction of Impervious Runoff to Porous Pavement

Adjacent impervious surfaces can be graded so that the flow from the impervious area flows over the porous pavement and into the subbase storage below if sufficient capacity is created. If impervious runoff is directed onto porous pavement, it cannot be considered disconnected and a positive overflow must be provided.


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Porous pavement at Pennsylvania State University, Berks Campus

Components of a Porous Pavement System

Different porous surfaces are used for porous pavement systems, but all rely on the same primary components:

- Inflow/Surfacing
- Storage
- Infiltration/Outflow



Porous Concrete

Inflow/Surfacing

There are many different types of structural surfaces that allow water to flow through void spaces in the surface. Any of these alternatives serve as a form of conveyance and filtration for the storage bed below. Several of the most commonly used porous structural surfaces are described below, but this does not represent an exhaustive list of the porous surfaces appropriate for stormwater management applications.

Porous concrete

Porous concrete was developed by the Florida Concrete Association and has seen the most widespread application in Florida and other southern areas. Like porous asphalt, porous concrete is produced by substantially reducing the number of fines in the mix in order to establish voids for drainage. Porous concrete has a coarser appearance than its conventional counterpart.

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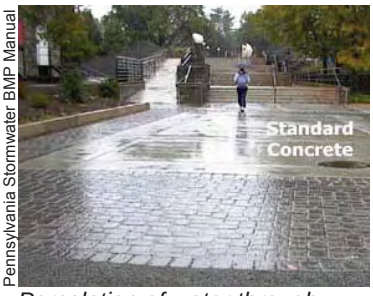

Percolation of water through porous concrete at Villanova University

Porous asphalt

Porous asphalt pavement was first developed in the 1970s and consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through very small voids. Recent research in open-graded mixes for highway application has led to additional improvements in porous asphalt through the use of additives and binders. Porous asphalt is very similar in appearance to conventional, impervious asphalt.

City of Portland, OR



Porous pavers

Permeable pavers

Permeable pavers are interlocking units (often concrete) with openings that can be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, small parking areas, etc. There are also plastic grids that can be filled with gravel to create a fully gravel surface that is not as susceptible to rutting and compaction as traditional gravel lots. Gravel used in interlocking concrete pavers or plastic grid systems must be well-graded to ensure permeability.



Rag Flats in Philadelphia, where grass pavers filter stormwater before it flows into subsurface storage and infiltrates

Reinforced turf

Reinforced turf consists of interlocking structural units with openings that can be filled with soil for the growth of turf grass and are suitable for traffic loads and parking. They are often used in overflow or event parking. Reinforced turf grids are made of concrete or plastic and are underlain by a stone and/or a sand drainage system for stormwater management. While both plastic and concrete units perform well for stormwater management and traffic needs, plastic units may provide better turf establishment and longevity, largely because the plastic will not absorb water and diminish soil moisture conditions.

Storage
In addition to distributing mechanical loads, coarse aggregate laid beneath porous surfaces is designed to store stormwater prior to infiltration into soils. The aggregate is wrapped in a non-woven geotextile to prevent migration of soil into the storage bed and resultant clogging. The storage bed also has a choker course of smaller aggregate to separate the storage bed from the surface course. The storage bed can be designed to manage runoff from areas other than the porous surface above it, or can be designed with additional storage and control structures that meet the Channel Protection requirements and/or meet the Flood Control requirements.

Positive Overflow
Positive overflow must be provided for porous pavement systems that manage runoff from additional impervious surfaces. Positive overflow conveys runoff from larger storms out of the system and prevents flooding. A perforated pipe system can convey water from the storage bed to an outflow structure. The storage bed and outflow structure can be designed to control the Channel Protection and/or Flood Control requirement. Inlets can be used to provide positive overflow if additional rate control is not necessary. More information about large underground storage systems can be found in **Section 7.12**: Subsurface Infiltration.

Recommended Design Procedure

Design of porous pavement systems is somewhat flexible. The area and shape are dependent on the site design and selection of the surface material is dependent on intended site uses and desired appearance. The depth of the stone base can be adjusted depending on the management objectives, total drainage area, traffic load, and soil characteristics. The following design procedures are general guidelines that designers can follow.

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements porous pavement will meet. See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration in the area proposed for a porous pavement. See **Appendix A**: Hotspot Investigation Procedures, **Appendix B**: Soil Infiltration Testing Guidelines, and **Appendix C**: Geotechnical Investigation Procedures for more guidance on requirements. Infiltration testing must be within 25 feet of the infiltration footprint..

- Create a conceptual design for the porous pavement system.

Table 7.25: Suggested Starting Porous Pavement Design Values	
Area (surface area and infiltration area)	Largest feasible on site
Choker/Aggregate Bed Depth	8 - 36 inches

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Assume a void ratio of approximately 40% for AASHTO No 3 stone.

- Design system with a level bottom; use a terraced system on slopes.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. If storage does not drain in the time allowed, adjust aggregate depth and/or surface area. Adjust the design until the volume and drainage time constraints are met.

- Consider an underdrain only under one of the following conditions:
  - in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
  - in combination with other SMPs where the system as a whole meets storage and release criteria.
  - in systems that manage runoff from surrounding impervious areas.

- Design distribution and overflow piping to minimize chance of clogging.

- Check that any release rate requirements (including release through any underdrain) are met by the system as designed. See **Section 7.15**: Inlet and Outlet Controls.

- Complete construction plans and specifications.

Materials

Subsurface Storage Beds

- All aggregates within infiltration beds shall meet the following:

  1. Maximum wash loss of 0.5%
  2. Minimum Durability Index of 35
  3. Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions.

- Choker course aggregate shall meet the specifications of AASHTO No. 57.

Table 7.26: Required Choker Course Gradation	
U.S. Standard Sieve Size	***Percent Passing***
1 ½" (37.5 mm)	100
1" (25 mm)	95 – 100
½" (19 mm)	25 – 60
4 (4.75 mm)	0 – 10
8 (2.36 mm)	0 – 5

- Storage stone should meet the specifications of AASHTO No. 3. Additional storage materials are further discussed in **Section 7.12**: Subsurface Infiltration.

Table 7.27: Required Stone Storage Gradation	
U.S. Standard Sieve Size	***Percent Passing***
2 ½ " (63 mm)	100
2" (50 mm)	90 – 100
1 ½" (37.5 mm)	35 – 70
1" (25 mm)	0 – 15
½" (12.5 mm)	0 – 5

Porous Bituminous Asphalt

- Bituminous surface shall be laid with a bituminous mix of 5.75% to 6% by weight dry aggregate. In accordance with ASTM D6390, drain down of the binder shall be no greater than 0.3%. Aggregate grain in the asphalt shall be a minimum 90% crushed material and have the following gradation.

Table 7.28: Porous Bitumainous Aggregate Gradation	
U.S. Standard Sieve Size	**Percent Passing**
½ (12.5 mm)	100
3/8 (9.5 mm)	92 - 98
4 (4.75 mm)	34 – 40
8 (2.36 mm)	14 – 20
16 (1.18 mm)	7 – 13
30 (0.60 mm)	0 - 4
200 (0.075 mm)	0 - 2

- Neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22 as specified in AASHTO MP-1. The elastomer polymer shall be styrene-butadiene-styrene (SBS), or approved equal, applied at a rate of 3% by weight of the total binder.

- Hydrated lime should be added at a dosage rate of 1% by weight of the total dry aggregate to mixes containing granite. Hydrated lime shall meet the requirements of ASTM C 977. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a required tensile strength ratio (TSR) of at least 80% on the asphalt mix when tested in accordance with AASHTO T 283. The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-1664. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

- The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-3625. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

Porous Concrete

- Portland Cement Type I or II conforming to ASTM C 150 or Portland Cement Type IP or IS conforming to ASTM C 595:

- No. 8 coarse aggregate (3/8 to No. 16) per ASTM C 33 or No. 89 coarse aggregate (3/8 to no. 50) per ASTM D 448.

- An aggregate/cement ratio range of 4:1 to 4.5:1 and a water/cement ratio range of 0.34 to 0.40 should produce pervious pavement of satisfactory properties in regard to permeability, load carrying capacity, and durability characteristics.

Paver and Grid Systems

- Paver and grid systems shall conform to manufacturer specifications.

- A minimum flow through rate of 5 in/hr or a void percentage of no less than 10%.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

    - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
    - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
    - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
    - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
    - Heat-set or heat-calendared fabrics are not permitted

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Pipe

- Distribution pipe within bed shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

The construction guidelines for the installation of the subsurface infiltration beds are applicable to all porous pavement systems. Guidelines are also provided specifically for porous asphalt.

- Areas for porous pavement systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- Excavate porous pavement subsurface area to proposed depth. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.

- Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. If it is essential that equipment be used in the excavated area, all equipment must be approved by the Engineer. Use of equipment with narrow tracks or tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction and shall not be used.

- Bring subgrade of stone infiltration bed to line, grade, and elevations indicated in the Drawings. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before placing the stone. The bottom of the infiltration bed shall be at a level grade.

- Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.

- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile can be cut back to the edge of the bed.

- Install aggregate course in lifts of 6-8 inches. Compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.

Guidelines for Installation of Porous Asphalt

- Install and compact choker course aggregate evenly over surface of stone bed. Choker base course shall be sufficient to allow for even placement of asphalt, but no thicker than 1-inch in depth.

- Appropriate vehicles with smooth, clean dump beds shall be used to transport the asphalt mix to the site. Control cooling of asphalt by covering mix. Porous asphalt mix shall not be stored for more than 90 minutes before placement.


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Aggregate is placed in the infiltration bed


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Unexcavated earthen berms between terraced bottoms

- The porous bituminous surface course shall be laid in one lift directly over the storage bed and stone base course and compacted to a 2½-inch finished thickness.
- Compaction of the surface course shall take place when the surface is cool enough to resist a 10-ton roller. One or two passes is all that is required for proper compaction. More rolling could cause a reduction in the surface porosity and permeability, which is unacceptable
- After rolling asphalt, no vehicular traffic is permitted on the surface until cooling and hardening has taken place (minimum 48 hours).
- After hardening, test pavement surface by applying clean water at a rate of at least 5 gpm over surface. The water applied to the surface should infiltrate without creating puddles or runoff.
- Do not use the porous pavement area for equipment or materials storage; no soil shall be deposited on porous pavement surfaces.

Maintenance Guidelines

As with most SMPs, porous pavement systems require regular maintenance to extend their life. The following table displays maintenance recommendations for porous pavement systems.

Table 7.29: Porous Pavement Maintenance Guidelines

Activity	*Schedule*
• Mow grass in paver or grid systems that have been planted with grass.	As needed
• Vacuum porous asphalt or concrete surface with commercial cleaning unit (pavement washing systems and compressed air units are not recommended). • Clean out inlet structures within or draining to the subsurface bedding beneath porous surface	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

Sediment Control

Superficial dirt does not necessarily clog the voids in porous surfaces. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. Furthermore, all construction or hazardous materials carriers should be prohibited from entering a porous pavement lot.

Winter Maintenance

Winter maintenance for a porous parking lot may be necessary, but is usually less intensive than that required for a standard asphalt lot. By its very nature, a porous pavement system with subsurface aggregate bed has better snow and ice melting characteristics than standard pavement. Once snow and ice melt, they flow through the porous pavement rather than refreezing. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms. Abrasives such as sand or cinders shall not be applied on or adjacent to the porous pavement. Snow plowing is acceptable, provided it is done carefully (i.e. by setting the blade about one inch higher than usual). Salt is acceptable for use as a deicer on the porous pavement, though non-toxic, organic deicers, applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable. Any deicing materials should be used in moderation.

Repairs

Potholes are not common; though settling might occur if a soft spot in the subgrade is not removed during construction. Damaged areas that are smaller than 50 square feet can be patched with a porous or standard asphalt mix, depending on the location within the porous area. In many cases the loss of porous surface will be insignificant. If an area greater than 50 square feet is in need of repair, approval of patch type must be sought from either the engineer or owner. Porous pavement must never be seal coated under any circumstances. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

Note:

Design of porous pavement systems are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

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7.14 Prefabricated and Proprietary Designs can be found in the Pennsylvania Stormwater BMP Manual

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7.15 Inlet &Outlet Controls



are the structures or landscape features that manage the flow into and out of a stormwater management facility. Flow splitters, level spreaders, curb openings, energy dissipaters, traditional inlets, and curbless design are all examples and elements of inlet controls. Outlet controls regulate the release of stormwater from a management facility. Examples of outlet controls include risers and orifices, underdrains, permeable weirs, positive overflows, and impervious liners. Outlet control structures limit flow to meet release rate requirements and bypass larger flows to prevent re-suspension of sediment, hydraulic overload, or erosion of management practices.

key elements :

- Inlet Controls: Flow splitters divert a portion of the storm hydrograph to a management facility, while allowing the remainder of the flow to bypass the facility.
- Inlet Controls: Curbless roads, streets, and parking lots allow stormwater to sheet flow into a SMP.
- Inlet Controls: Curb openings allow water to flow through a curb that would otherwise block the flow.
- Inlet Controls: Level spreaders spread out concentrated flow and release it as low-velocity, non-erosive diffuse flow.
- Inlet Controls: Large-scale energy dissipaters slow down and spread flow from culverts and steeper slopes.
- Outlet Controls: Risers and orifices release ponded water at a reduced rate.
- Outlet Controls: Positive overflows allow stormwater to safely flow out of an SMP.
- Outlet Controls: Underdrains collect water that has filtered through a porous medium and convey it to an outlet.
- Outlet Controls: Impervious liners prevent water from infiltrating the soil where infiltration is not desirable.
- Outlet Controls: Permeable weirs allow water to flow slowly through smaller openings and more quickly over the top of the weir.

Inlet Controls

Flow Splitter

Flow splitting devices are used to direct a fraction of runoff into a stormwater management facility, while bypassing excess flows from larger events around the facility into a bypass pipe or channel. The bypass typically connects to another stormwater management facility or to the receiving drainage system, depending on the design and management requirements. This type of inlet control can also serve as the positive overflow for the SMP.

Flow splitters can be constructed by installing diversion weirs in stormwater control structures such as inlets and manholes. On a larger scale, they can be constructed using concrete baffles in manholes. Example designs for larger-scale flow splitters are shown in Figures 7.30 and 7.31. Smaller-scale designs operate using a similar concept.

Design Criteria

There are two basic components involved in the design of flow splitters: the elevation of the bypass weir, which is based on the maximum ponding elevation in the SMP, and capacity of the pipe to and from the SMP, which controls the maximum flow the SMP can receive and discharge.

Bypass Elevation:

The elevation of the bypass baffle or weir dictates the maximum elevation of the water in the SMP. The bypass elevation can be selected by setting it equal to the design storage elevation in the SMP. Flow will only start to bypass the SMP once it exceeds the design storage level of the SMP. The water level in the SMP may exceed the design level for large infrequent storms that utilize the bypass, so the SMP should provide adequate freeboard to prevent overflow.

Pipe Capacity:

The capacity of the influent and effluent pipes can also limit flow into and out of the SMP. Controlling flows in this fashion can help to minimize erosion and scour in the SMP and at the outlet structure. At a minimum, all pipes must convey the peak runoff from the 10-year, 24-hour rainfall with an NRCS (Natural Resources Conservation Service) Type II distribution without surcharging (as specified within §14.1603.1 Stormwater controls, of the Philadelphia Code). Adequate bypass capacity should be provided for conveyance of larger storms.

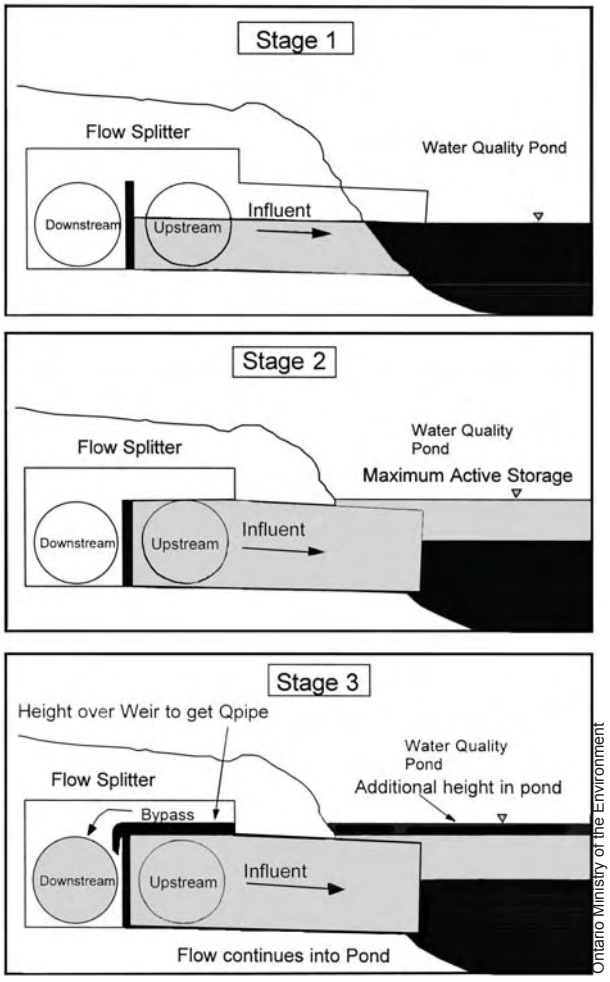
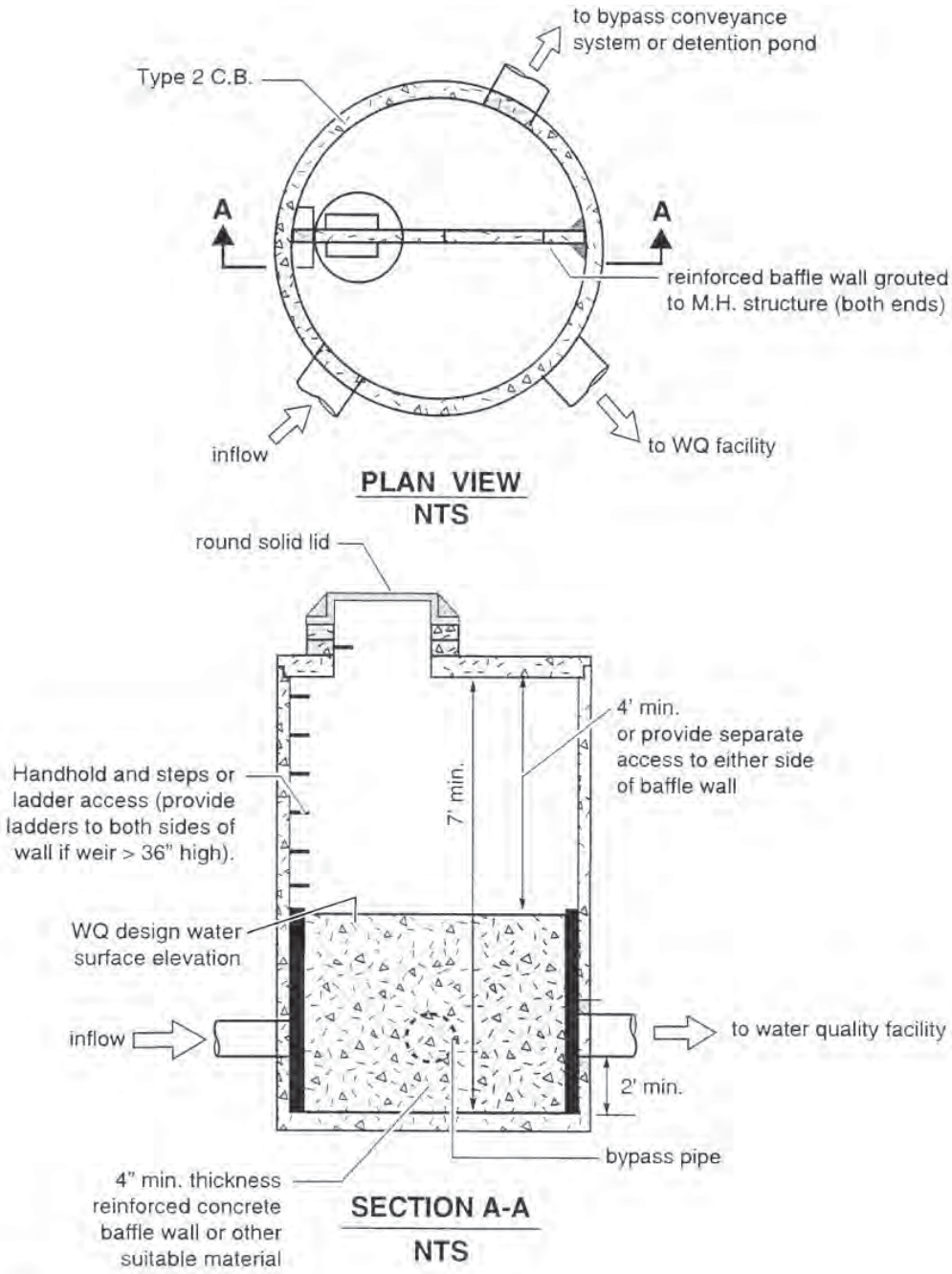


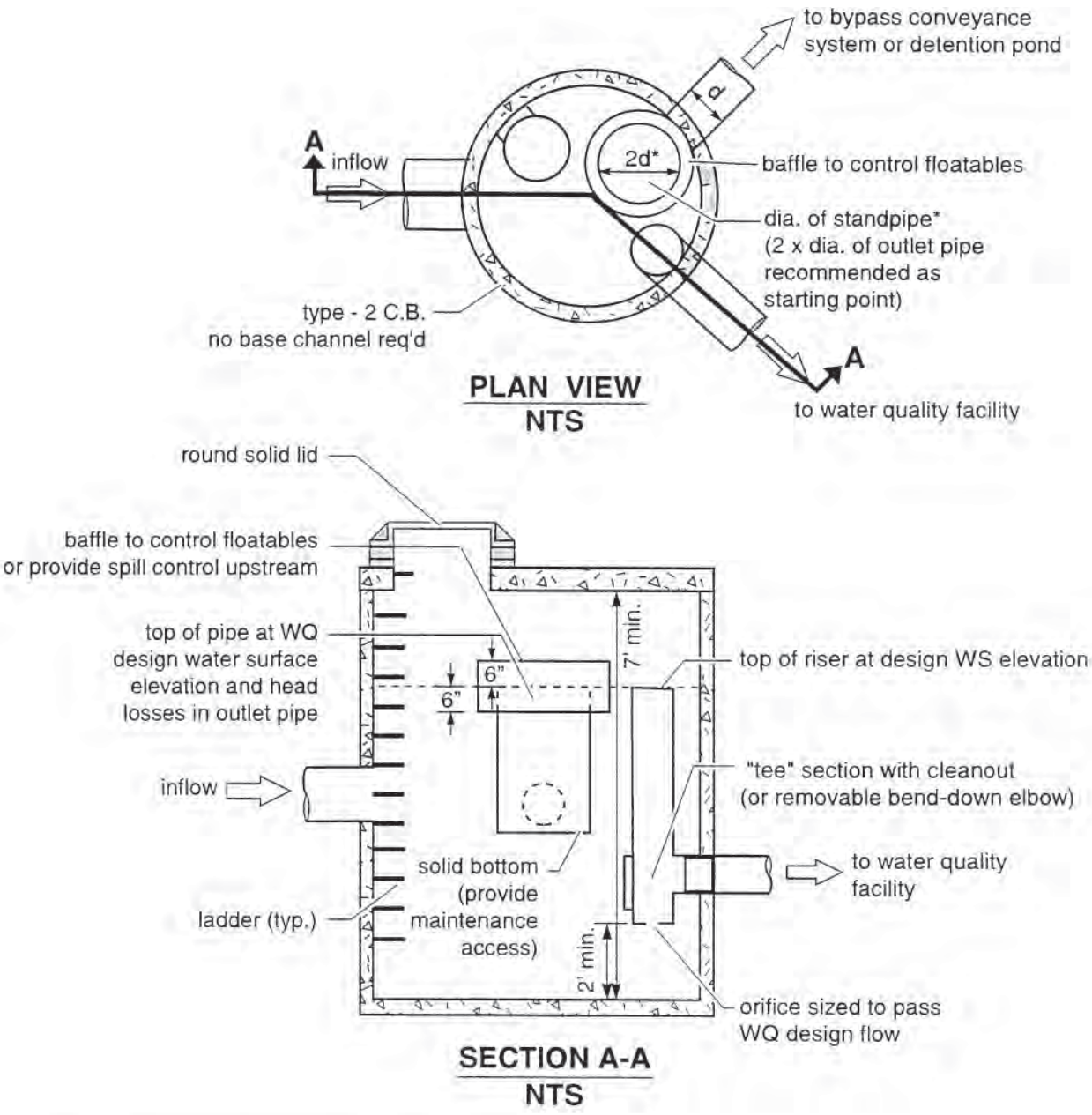
Figure 7.29: Flow splitting device



Note: The water quality discharge pipe may require an orifice plate be installed on the outlet to control the height of the design water surface (weir height). The design water surface should be set to provide a minimun headwater/diameter ratio of 2.0 on the outlet pipe.

King County Department of Natural Resources

Figure 7.30: Schematic of a flow splitter (1 of 2)



*NOTE: Diameter (d) of standpipe should be large enough to minimize head above WQ design WS and to keep WQ design flows from increasing more than 10% during 100-year flows.

King County Department of Natural Resources

Figure 7.31: Schematic of a flow splitter (2 of 2)

Curbless Design

Curbless designs allow stormwater to flow directly from the impervious source to the SMP. This type of design discourages concentration of flow and reduces the energy of stormwater entering a management facility. Curbless designs are often used with bioretention islands or roadside swales.


City of Seattle, WA

Curbless street design in Seattle, WA.

Curb Openings

Curb openings provide an alternative inlet control when a curbless design is not possible. Bioretention and landscaped islands in curbed parking lots or roadways often use curb openings as inlet controls.

If flow is to be introduced through curb openings, the pavement edge should be slightly higher than the elevation of the vegetated areas. Curb openings should be at least 12 -18 inches wide to prevent clogging (CA Stormwater Manual). Small rock or stone should be used at the inlet of the curb openings to provide erosion protection.


Prince George's County, MD

Flow enters the bioretention system via a curb opening inlet


City of Portland, OR

Curb openings allow flow to enter the bioretention system in the choker


City of Portland, OR

Curb openings in a parking lot allow flow to enter a bioretention island

Level Spreaders

Level spreaders are inlet controls that are designed to uniformly distribute concentrated flow over a large area. There are many types of level spreaders that can be selected based on the peak rate of inflow, the duration of use, and the site conditions. Level spreaders help reduce concentrated flow, thereby reducing erosion and increasing the design life of many stormwater facilities.

All level spreader designs follow the same principles:

- Concentrated flow enters the spreader at a single point such as a pipe, swale, or curb opening.
- The flow is slowed and energy is dissipated.
- The flow is distributed throughout a long linear shallow trench or behind a low berm.
- Water then flows over the berm or edge of trench uniformly along the entire length.

The following considerations are important when designing and constructing level spreaders:

- It is critical that the edge over which flow is distributed is exactly level. If there are small variations in height on the downstream lip small rivulets will form. Experience suggests that variations of more than 0.25 inches can cause water to re-concentrate and potentially cause erosion downstream of the level spreader. The site selected for the installation of a level spreader must be nearly level before construction. Changes in ground elevation greater than 4 inches across the entire length of the level spreader can begin to make level construction difficult.

• The downslope side of the level spreader should be clear of debris. After construction, debris such as soil, wood, and other organic matter might accumulate immediately downstream of the level spreader. This effectively blocks water as it flows out of the level spreader, forcing it to re-concentrate.

• The downstream side of the level spreader should be fully stabilized before the level spreader is installed. If a level spreader is installed above a disturbed area without sufficient vegetative cover or other ground cover such as mulch or construction matting, erosion rills will quickly form. Even sheet flow can cause significant downstream erosion on disturbed areas.

• Do not construct level spreaders in newly deposited fill. Undisturbed earth is much more resistant to erosion than fill. Erosion is even likely to occur over a well-established young stand of grass planted on fill.

• Level spreaders should not be considered to be sediment removal facilities. Significant sediment deposition in the spreader can render it ineffective.

Types of Level Spreaders

Rock lined Channel

Rock-lined channels function as level spreaders when the lower (downslope) lip of the channel is level. The channel must be dug along an elevation contour, which helps make the downstream lip level. Rock-lined channel depths and widths are typically about 6-12 inches. The depth of the channel depends on the flow. Rock-lined channels do not serve as detention devices.

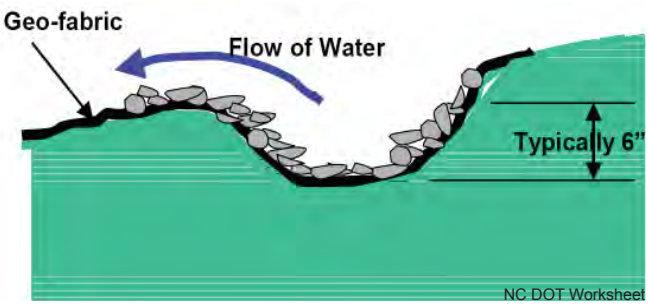


Figure 7.32: Cross-section of rock-lined channel

Concrete Troughs and Half Pipes

Concrete troughs 4-12 inches deep can be used as level spreaders. Half sections of pipe can also be used for the same function. The depths of the trough or pipe will depend on the flow. Concrete troughs are a more expensive level spreader alternative; however, they are easy to maintain and have a longer design life. If sediment or debris accumulates in the trough or pipe, it can be easily removed. Concrete level spreaders have design lives of up to 20 years while other level spreader designs may be able to effectively function for a period of 5-10 years. Accordingly, long term maintenance and replacement costs should be lower if installed properly.

Treated Lumber

Treated lumber is not recommended as a level spreading device dues to issues with deformation and decomposition.

Level Spreader System Configuration

A typical level spreader system consists of pre-treatment (e.g., a forebay), principal treatment (e.g., a level spreader with grassed buffer), and emergency treatment (e.g., a reinforced grassy swale downslope of spreader). A stilling area such as a forebay is particularly useful upstream of a level spreader, because flow energy should be dissipated before the flow enters a level spreader. The forebay will periodically fill with sediment, which must be removed. A detailed design example for a level spreader, by Hunt, et al. from North Carolina State University, can be found at the following website: www.bae.ncsu.edu/cont_ed/main/handouts.html (Current June 17, 2007)

Energy Dissipaters
Energy dissipaters are large-scale engineered devices such as rip-rap aprons or concrete baffles designed to reduce the velocity, energy, and turbulence of the flow. These structures can be employed when highly erosive velocities are encountered at the end of culverts or at the bottom of steep slopes where aesthetics are not a concern. A standard reference for design of these structures is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 14 (HEC-14).

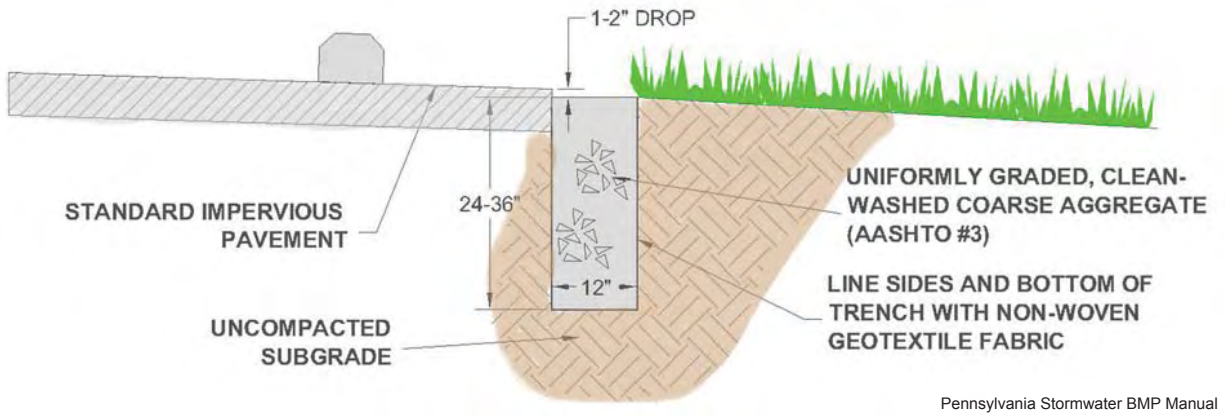


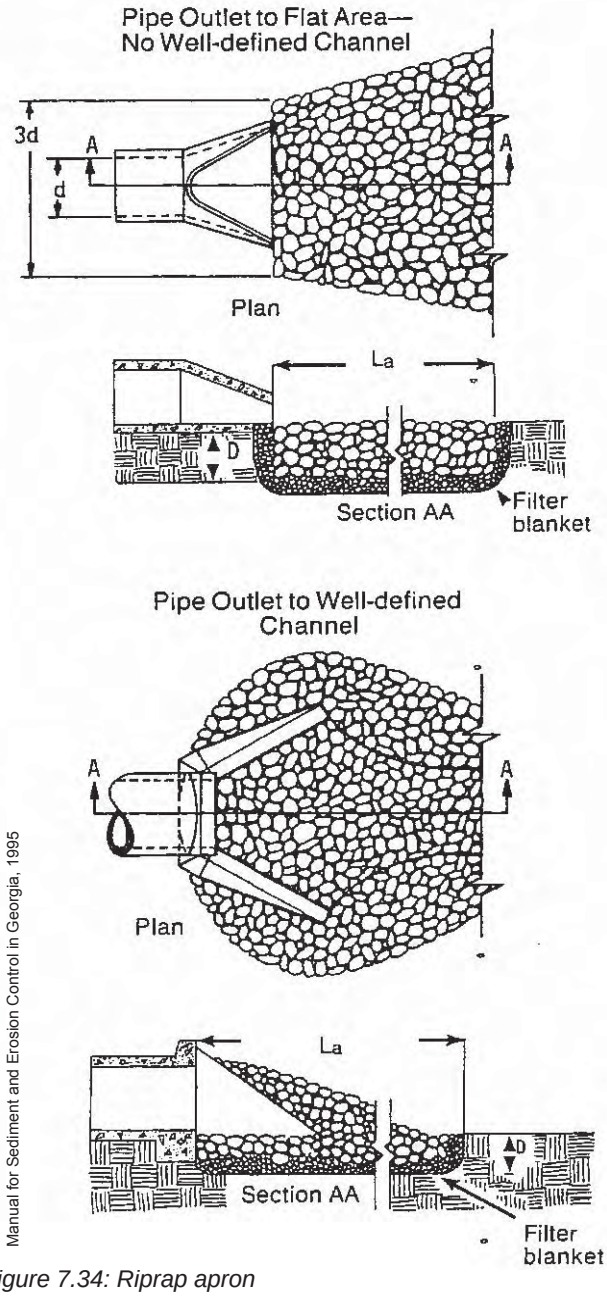
Figure 7.33: Filter strip with gravel trench level spreader.

Riprap Aprons
Riprap aprons are commonly used for energy dissipation, due to their relatively low cost and ease of installation. A flat riprap apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Riprap aprons will provide adequate protection if there is sufficient length and flare to dissipate energy by expanding the flow.

Riprap Basins
A riprap outlet basin is a pre-shaped scour hole lined with riprap that functions as an energy dissipater.

Baffled Outlets
A baffled outlet is a boxlike structure with a vertical hanging baffle and an end sill, as shown in Figure 7.36. Energy is dissipated primarily through the impact of the water striking the baffle and through the resulting turbulence.

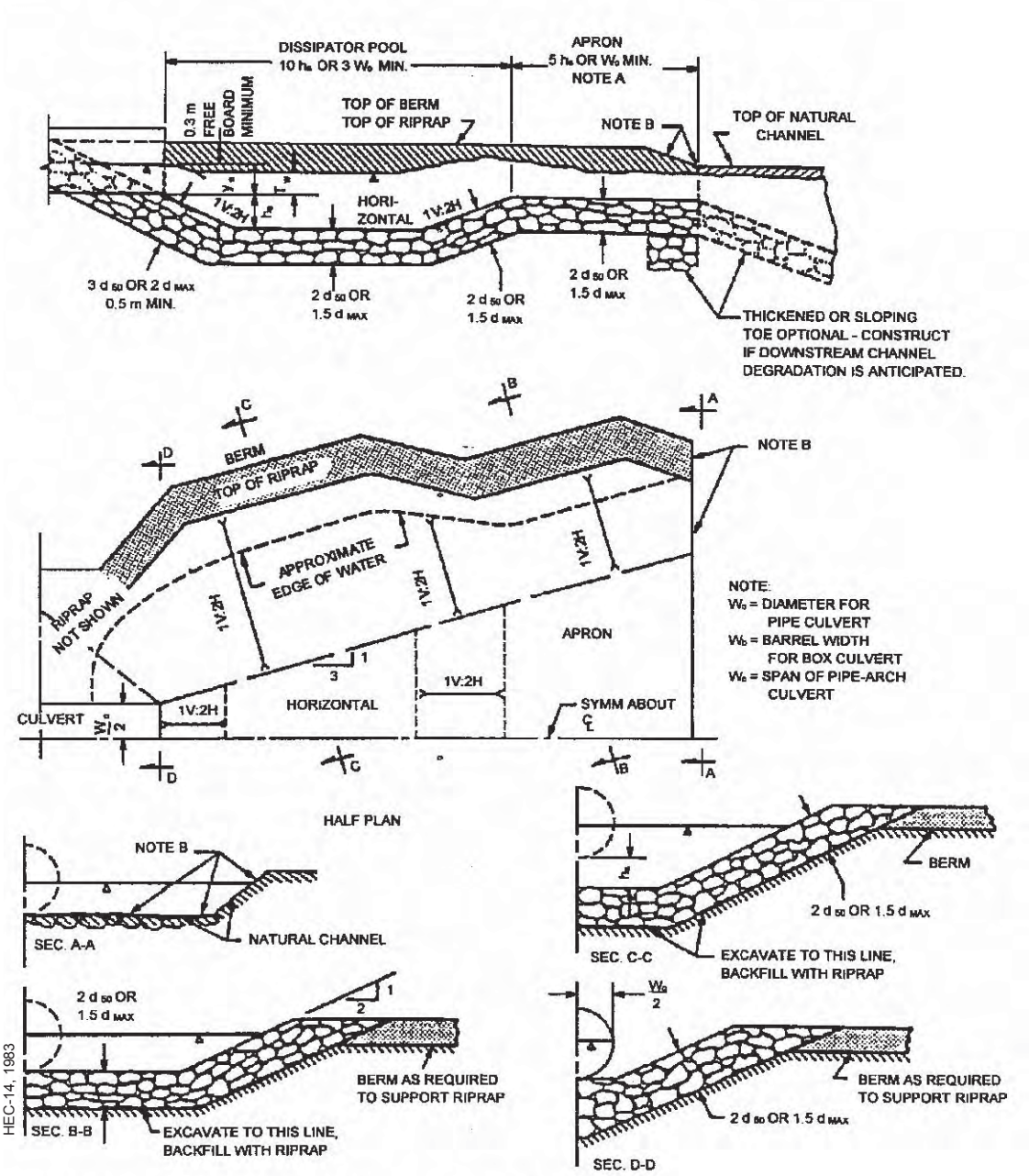
Inlets and Catch Basins
Traditional inlets and catch basins may be used as an inflow device for stormwater facilities where curb and gutter design is desired or required. The disadvantage of traditional inlets is that the inverts of the outlet pipes are relatively deep, and excavation of stormwater facilities may need to be deeper than with curb openings or a curbless design. A standard reference for designing traditional drainage systems is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 22 (HEC-22). Any inlet or catch basin that connects to a SMP must have at least a one (1) foot sump.



Notes

1. L_a is the length of the riprap apron.
2. D = 1.5 times the maximum stone diameter but not less than 6".
3. In a well-defined channel extend the apron up the channel banks to an elevation of 6" above the maximum tailwater depth or to the top of the bank, whichever is less.
4. A filter blanket or filter fabric should be installed between the riprap and soil foundation.

Figure 7.34: Riprap apron



NOTE A - IF EXIT VELOCITY OF BASIN IS SPECIFIED, EXTEND BASIN AS REQUIRED TO OBTAIN SUFFICIENT CROSS-SECTIONAL AREA AT SECTION A-A SUCH THAT Q/(CROSS SECTION AREA AT SEC. A-A) = SPECIFIED EXIT VELOCITY.

NOTE B - WARP BASIN TO CONFORM TO NATURAL STREAM CHANNEL. TOP OF RIPRAP IN FLOOR OF BASIN SHOULD BE AT THE SAME ELEVATION OR LOWER THAN NATURAL CHANNEL BOTTOM AT SEC. A-A.

Figure 7.35: Details of riprap outlet basin

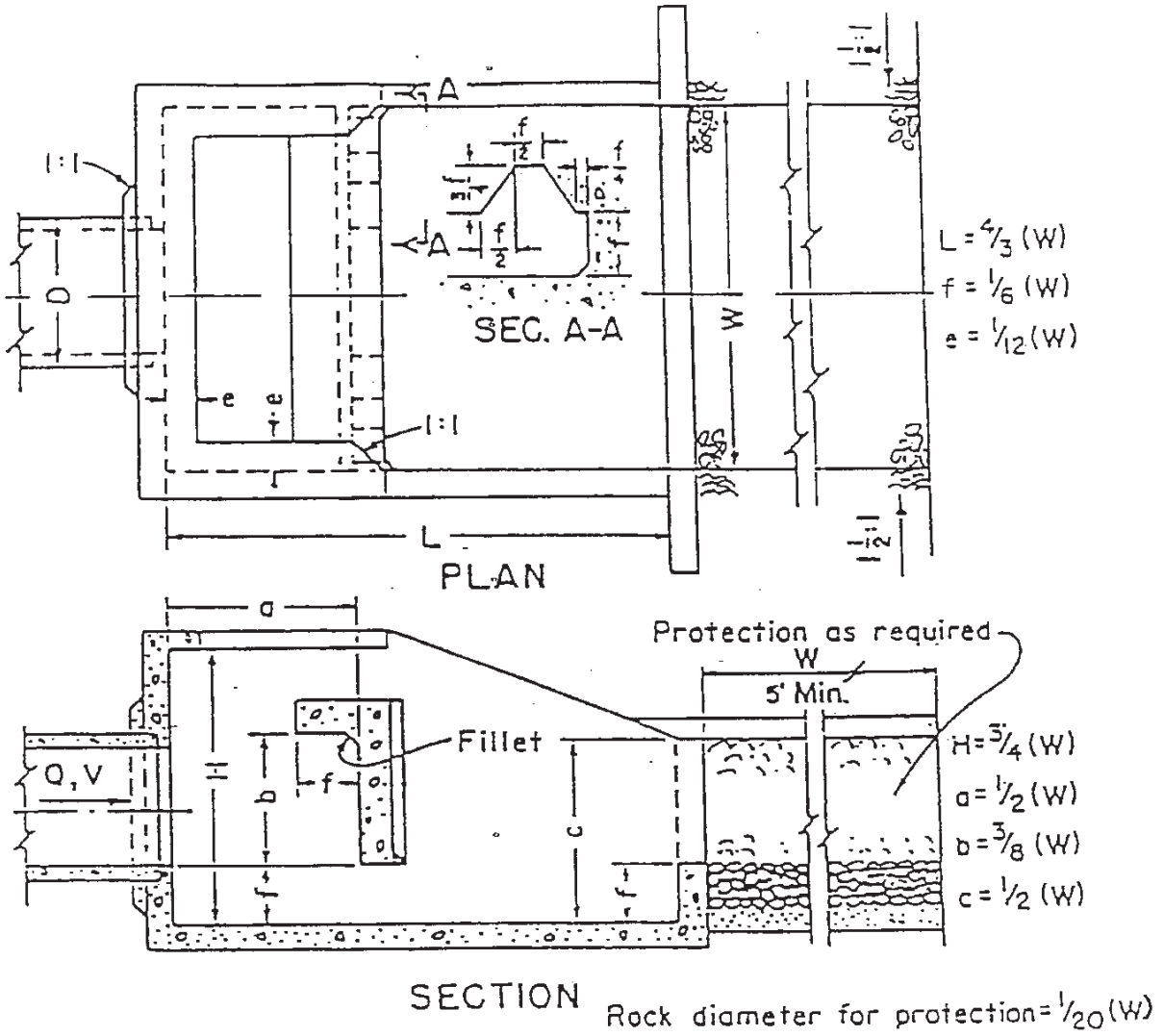


Figure 7.36: Schematic of a baffled outlet

U.S. Dept. of the Interior

Maintenance Concerns for Inlet Controls

Table 7.30: Inlet Maintenance Guidelines	
Activity	***Schedule***
• Inlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion problems developing. • Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed
• Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. • Clean out leaves, trash, debris, etc.	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

Outlet Controls

Risers and Orifices

An orifice is a circular or rectangular opening of a prescribed shape and size that allows a controlled rate of outflow when the orifice is submerged. When it is not submerged, the opening acts as a weir. The flow rate depends on the height of the water above the opening and the size and edge treatment of the orifice. A riser is a vertical structure with one or more orifices that provide the controlled release in combination. A standard reference for discharge through a submerged orifice is Brater and King's Handbook of Hydraulics (1996).

Control structures may consist of several orifices and weirs at different elevations to meet stormwater management requirements. Multiple orifices may be necessary to meet the channel protection and flood protection performance requirements for a detention system. Orifices may be located at the same elevation if necessary to meet performance requirements.

Flow through multiple orifices, such as the perforated plate shown in Figure 7.37, can be computed by summing the flow through individual orifices. For multiple orifices of the same size and under the influence of the same effective head, the total flow can be determined by multiplying the discharge for a single orifice by the number of openings.

Design of a control structure with multiple orifices is an iterative process. An orifice is designed and positioned to meet each control requirement independently (e.g., channel protection and flood control). Calculations are then performed on the two orifices together, and the design is adjusted to meet all requirements concurrently without oversizing the basin. The Outlet Structures section of the Georgia Stormwater Management Manual at www.georgiastormwater.com/ (current August 12, 2005) is recommended for detailed instructions on design of multi-stage outlet structures.

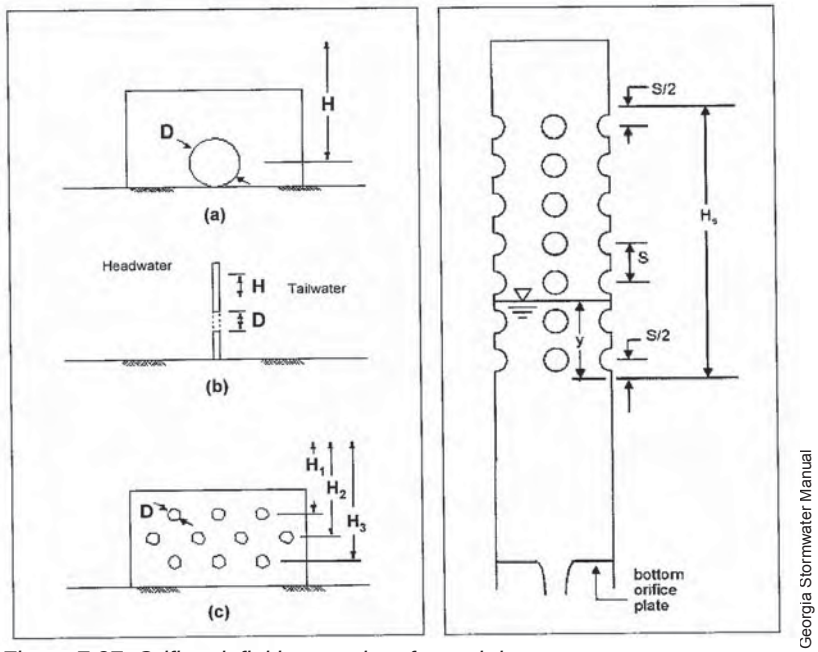


Figure 7.37: Orifice definitions and perforated riser

Small orifices are sometimes needed when a stormwater management systems must meet low flow rate requirements. Control structures with small orifices must meet the following requirements:

- The orifice diameter should always be greater than the thickness of the orifice plate.
- The minimum recommended diameter for an orifice is 3 inches. A waiver must be submitted for use of an orifice smaller than 3 inches in diameter. The required waiver form can be found in **Appendix F.4**: Special Circumstances and Waiver Requests or downloaded at www.PhillyRiverInfo.org/PWDDevelopmentReview.
- Protection from clogging is required for any orifice smaller than 3 inches in diameter.

Protection from Clogging

Small orifices used for slow release applications can be susceptible to clogging, which prevents the structural control from performing its function and potentially causing adverse impacts. Design measures can be taken to prevent clogging. These measures are most effective when used in combination with periodic inspection and maintenance. These measures are summarized below; the Design Professional is encouraged to consult the original sources for more information.

Since sediment will tend to accumulate around the lowest stage outlet, the inside of the outlet structure for a dry basin should be depressed below the ground level to minimize clogging due to sedimentation. Depressing the outlet bottom to a depth below the ground surface at least equal to the diameter of the outlet is recommended.

The Georgia Stormwater Management Manual recommends the following measures:

- The use of a reverse slope pipe attached to a riser for a stormwater pond or wetland with a permanent pool. The inlet is submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. See Figure 7.38 for an example.
- The use of a hooded outlet for a stormwater pond or wetland with a permanent pool. See Figure 7.39 for an example.
- Internal orifice protection through the use of an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wire cloth and a stone filtering jacket. See Figure 7.40 for an example.
- Use of trash racks on larger outlets. See Figure 7.41 for an example.

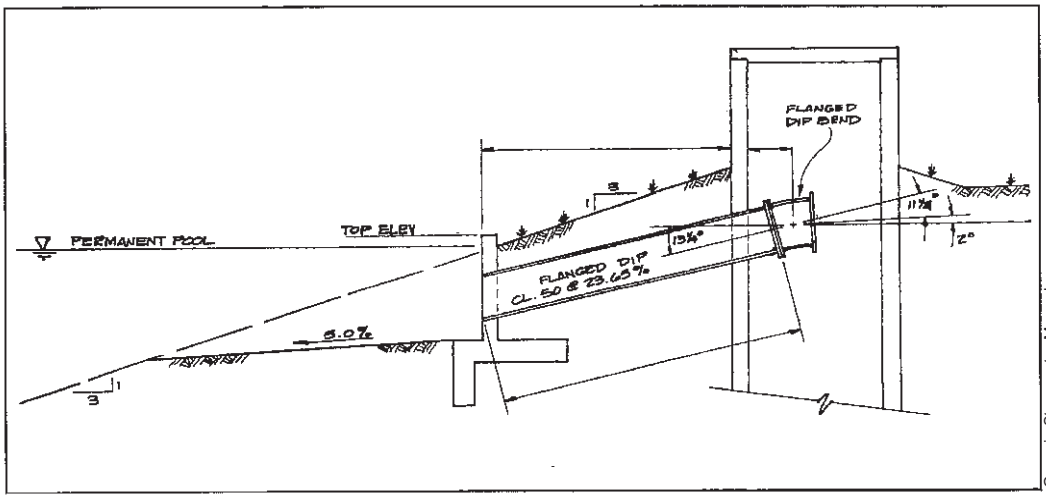


Figure 7.38: Reverse slope pipe outlet

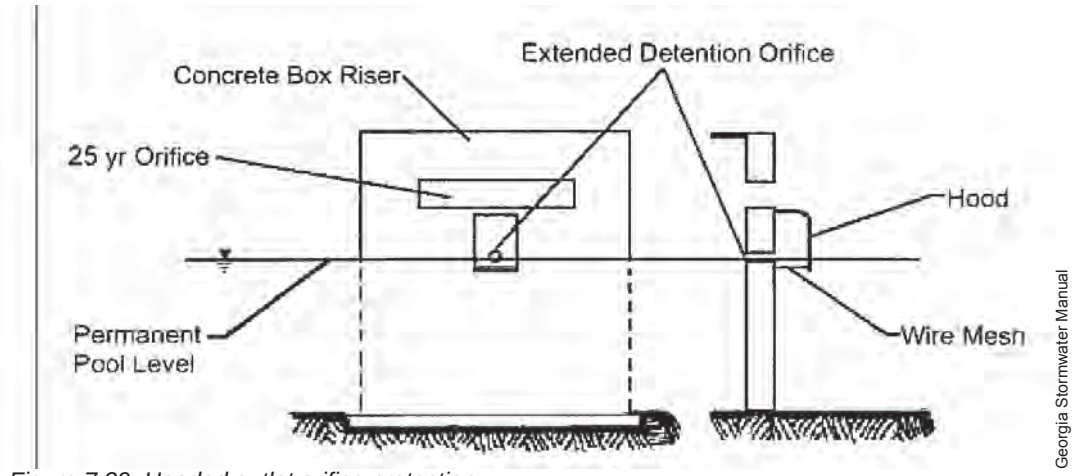


Figure 7.39: Hooded outlet orifice protection

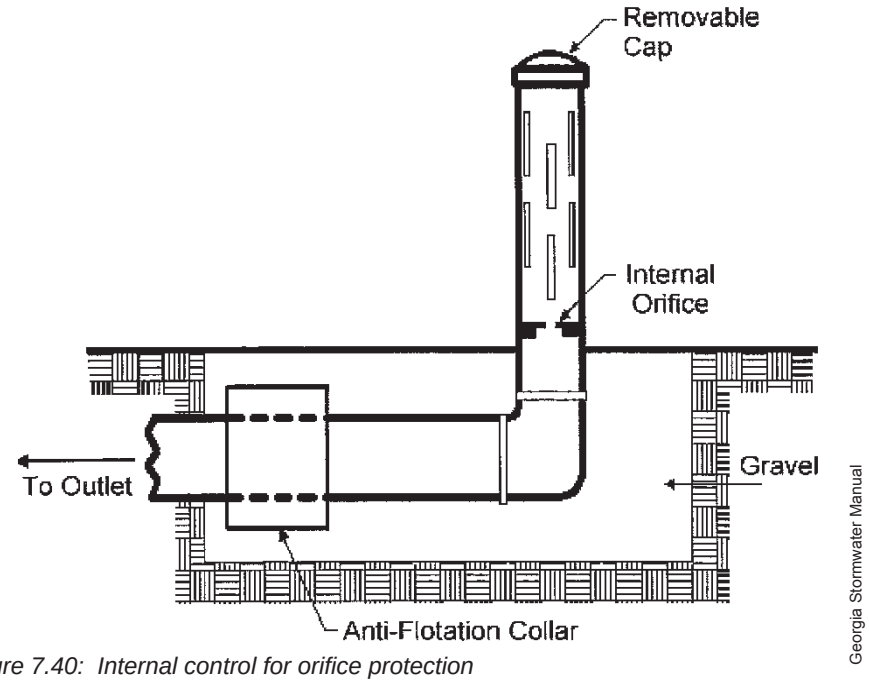


Figure 7.40: Internal control for orifice protection

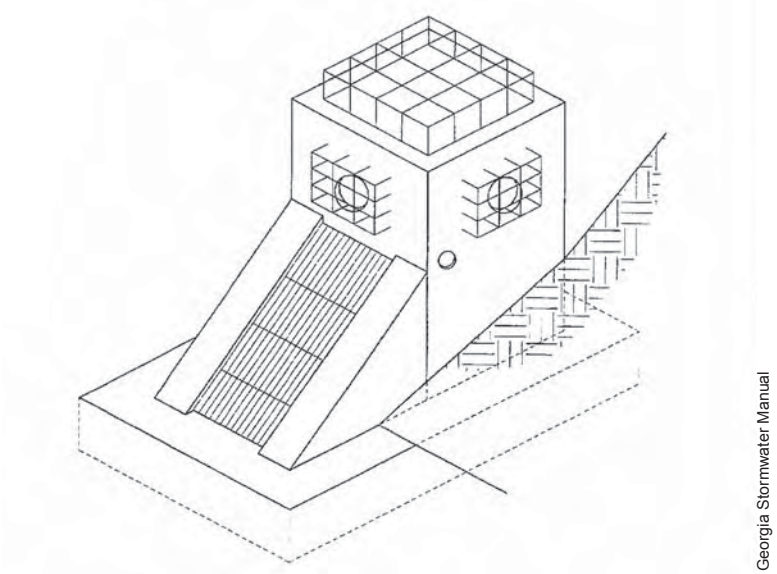


Figure 7.41: Trash racks

Positive Overflows

A positive overflow permits stormwater to flow out of the SMP when the water level reaches a maximum design elevation in a subsurface feature or a maximum ponding depth in a surface feature. Flow through the positive overflow can either connect to another SMP or an approved point of discharge. A multi-stage outlet control may include a number of orifices for controlled flow and a positive overflow to quickly pass flow during extreme events. Overflow structures should be sized to safely convey larger storms from the SMP. If flow reaches the SMP via a flow splitter, this structure can provide the positive overflow.



City of Portland, OR

Surface inlet for overflows in a bioretention system.

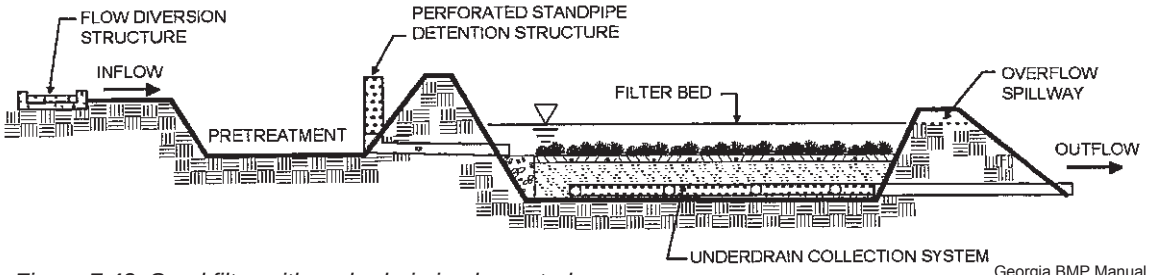
Underdrains

Underdrains are conduits, such as perforated pipes and/or gravel filled trenches that intercept, collect, and convey stormwater that has percolated through soil, a suitable aggregate, and/or geotextile. Perforated underdrains are an outlet control because they collect water and convey it to a system outlet. Underdrains may be used in combination with other techniques such as layering of porous media to regulate outflow. They can also be connected to an outlet structure that then controls the ponding elevation or release rate through weirs or orifices. Design of underdrains must meet the follow criteria:

• A permeable filter fabric is placed between the gravel layer and surrounding soil to prevent sediment contamination.

• Clean out access must be provided for all underdrain systems.

• Underdrain pipes are spaced a maximum of 10 feet on center.



Georgia BMP Manual

Figure 7.42: Sand filter with underdrain implemented

Impervious Liners

Impervious liners are considered an outlet control because they prevent water from infiltrating and thus crossing a system boundary. Impervious liners may be selected from the following four types: compacted till liners, clay liners, geomembrane liners, and concrete liners.

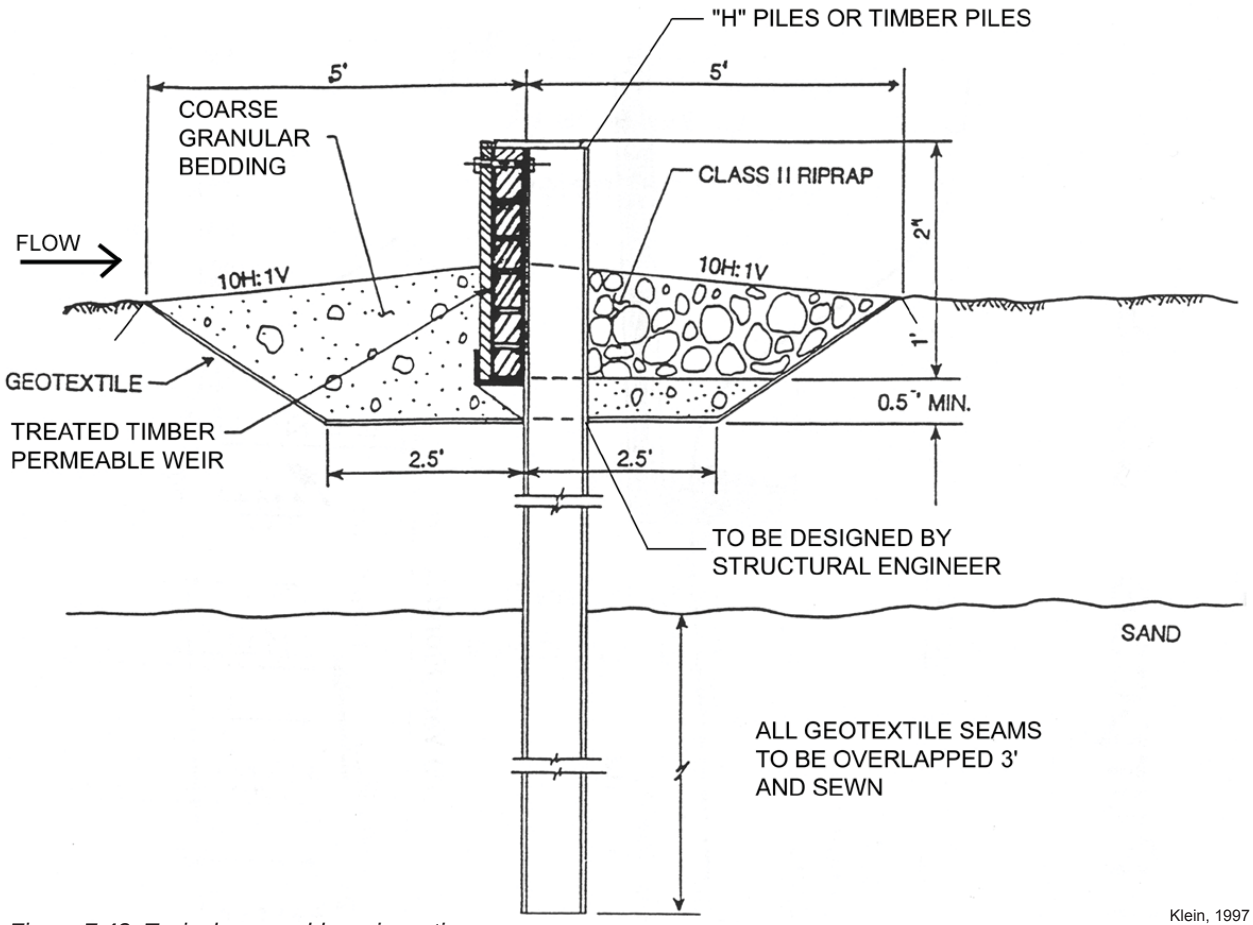
The Stormwater Management Manual for Western Washington is recommended for more information on choosing and designing impervious liners.

Permeable Weirs

Permeable weirs are typically constructed from treated lumber stacked with spaces between each timber to provide long, narrow openings that slowly pass stormwater. They have the appearance of a wooden fence. Under low flow conditions, water ponds behind the permeable weir and slowly seeps through the openings between the timbers, functioning like a dry extended storage pond. Under high flow conditions, water flows both over and through the weir.

Permeable weirs are generally used in wetland areas or constructed water quality treatment ponds. They promote sedimentation by slowing flow velocities as water ponds behind the weir. They also provide a means of spreading runoff as it is discharged, helping to decrease concentrated flow and reduce velocities as the water travels downstream.

Permeable weirs are most often used in large drainage areas as regional SMPs. The permeable weir concept could be applied to smaller sites, where the permeable weir would act as a wooden check dam, placed in a ditch or swale.



Klein, 1997

Figure 7.43: Typical permeable weir section

Maintenance Concerns for Outlet Controls

Table 7.31: Outlet Maintenance Guidelines	
Activity	***Schedule***
• Outlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion problems developing • Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed
• Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. • Clean out leaves, trash, debris, etc.	Biannually (Quarterly for small orifice designs)
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:

Design of inlet and outlet controls are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the drainage area include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.

8 Landscape Guidance

8.0 Introduction

8.1 Planting Recommendations / Guidelines

8.2 Facility Specific Landscaping Guidance

8.3 Native and Recommended Non-invasive Plants

8.4 Prohibited Non-native and Invasive Plants

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8.0 Introduction

Landscaping is a critical element to improve both the function and appearance of stormwater management practices (SMPs). Integrated stormwater landscapes can provide many benefits such as construction cost savings, reduced maintenance, aesthetic enhancement, and the improved long-term functionality. A well-designed and established landscape will also prevent post-construction soil erosion. Additionally, these approaches can help mitigate urban heat island effects, improve air quality, and reduce atmospheric carbon levels.

Vegetated stormwater management systems are a preferred practice. SMPs can be integrated within planned landscape areas, with minor modifications to conventional landscape design. It is essential that impervious surfaces be graded toward the vegetated areas that are used as SMPs and that these SMPs are depressed to allow for flow and/or surface ponding. Guidance for the design of inlets to vegetated SMPs can be found in **Section 7.15**: Inlet and Outlet Controls. Since these design approaches are still new to many construction contractors it is advisable to clearly show these details in cross section and plan view drawings. Additional guidance can be found in **Section 4.0**: Integrated Site Design as well as in **Section 7**: SMP Design Guidelines of this Manual.

This section provides landscaping criteria and plant selection guidance for effective SMPs and is organized as follows: **Section 8.1**: Planting Guidance contains general guidance that should be considered when landscaping any SMP. **Section 8.2**: SMP Specific Landscaping Requirements includes specific planting and site preparation information for selected SMPs. **Section 8.3**: Native and Recommended Non-invasive Plants lists appropriate plants for use in SMPs in this region. Key information useful for the selection of plant material for stormwater landscaping is presented, including National Wetland Indicator Status, preferred hydrologic zones, and aesthetic considerations. Finally, **Section 8.4**: Prohibited Non-native Invasive Plants lists prohibited invasive plants.

8.1 Planting Recommendations / Guidelines

General guidance for all SMP plantings:

Plant selection and arrangement

- Existing native and non-invasive vegetation should be preserved where possible.
- Noxious weeds and invasive species shall not be specified or used.
- Plant stream and water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade. This will help to reduce thermal warming, reduce erosion, increase roughness and protect habitat.
- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area). Use low maintenance ground cover as an alternative to turf.
- Stressors (e.g. wind, exposure, exposure to deicing salt, salt tolerance, insects, drought and inundation tolerance, and disease), micro-climates, and sunlight conditions should also be considered when laying out the planting plan.
- Aesthetics and visual characteristics should be a prime consideration. Plant form, texture, color, bloom time and fragrance are important to the overall feel of the site. Plants can be used to enhance and frame desirable views or screen undesirable views. Care should be taken to not block views at entrances, exits, or along difficult road curves.
- Trees and shrubs should be placed in a manner that restricts pedestrian access to steep pools or slopes without blocking maintenance access.

• Existing and proposed utilities must be identified and considered.

Maintenance considerations

• The designer should carefully consider the long-term vegetation management strategy for the SMP, keeping in mind the maintenance legacy for the future owners. The SMP maintenance agreement must include requirements to ensure vegetation cover in perpetuity.

• Provide signage to help educate the public about SMPs and to designate limits of mowing (wildflower areas, meadows, etc.).

Embankments, spillways, dams, and orifices

• Planting of trees, shrubs, and/or any type of woody vegetation is not allowed on structural embankments.

• All emergency spillways should be stabilized with plant material that can withstand strong flows. Root material should be fibrous and substantial but lack a taproot.

• Trees or shrubs known to have long taproots should not be planted within the vicinity of an earthen dam or subsurface drainage facilities.

• Plant trees and shrubs at least 25 feet away from a principal spillway structures.

• Plant trees and shrubs at least 15 feet away from the toe of slope of a dam.

Soils

SMP soils should provide adequate infiltration rates and be suitable for healthy tree and vegetation growth. Soil analysis shall be conducted within the SMP area to determine appropriate levels and types of soil amendments.

If topsoil exists on site and is stockpiled for re-use, appropriate erosion control measures as required by the Pennsylvania Department of Environmental Protection (PADEP) *Erosion and Sediment Pollution Control Manual*, shall be used. Soil analysis tests shall be performed on stockpiled soil if it will be used within the SMP area. See **Section 7** for SMP specific soil requirements.

Site Selection, Preparation and Grading

When selecting a location for the SMP, take into consideration the physical variables of the site and the effects they will have on the SMP. Some variables to consider include amount of sunlight received and solar orientation, wind speed and direction, temperature gain and surface character. For example: sites facing northeast receive morning sun and tend to be cooler and wetter than those facing southwest; runoff from asphalt will be hotter than that from concrete; etc. Combinations of these variables create different micro-climates and should be taken into account when placing the SMP and selecting plants.

Unwanted vegetation in the SMP area shall be removed during site preparation with equipment appropriate for the type of material encountered and site conditions. It is recommended that the maximum amount of pre-existing native vegetation be retained and protected.

No material storage or heavy equipment is allowed within the SMP area after site clearing and grading has been completed, except to excavate and grade as needed to build the SMP. No compaction of infiltration areas should occur during this excavation.

After the SMP area is cleared and graded, any necessary soil amendments should be added and tilled into the existing soil to the depth specified for each SMP. No tilling shall occur within the drip line of existing trees. After tilling is complete, no other construction traffic shall be allowed in the area, except for planting and related work. Where topsoil is needed, (for example swales and dry detention basins) it should be spread to a depth of 4-8 inches and lightly compacted to minimum thickness of 4 inches. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

Mulch

The mulch layer helps maintain soil moisture and avoid surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. Approved mulching materials include organic materials such as compost, bark mulch, leaves, as well as small river gravel, pumice, or other inert materials. Grass clippings should not be used as mulch. For ground cover plantings, the mulch shall be applied to cover all soil between plants. Care should be exercised to use the appropriate amount of mulch – any more than 3-4 inches can negatively impact growing conditions and cause excessive nutrients to leach into the SMP. Mulch shall be weed-free. Manure mulching and high-fertilizer hydroseeding are prohibited in a SMP area during and after construction.

Irrigation

Newly installed plant material requires water in order to recover from the shock of being transplanted. Be sure that some source of water is provided during establishment of the SMP, especially during dry periods. This will reduce plant loss and provide the new plant materials with a chance to establish root growth.

Permanent irrigation systems are allowed, but designers are encouraged to minimize the need for permanent irrigation. Innovative methods for watering vegetation are encouraged, such as the use of cisterns and air conditioning condensate.

SMP Screening

SMP elements such as chain link fences, concrete bulkheads, outfalls, rip-rap, gabions, large steel grates, steep side slopes, manhole covers/vault lids, berm embankments planted only with grasses, exposed pipe, banks, retaining walls greater than 2 feet high, and access roads are generally not aesthetically pleasing. When these elements face public right-of-way or other private property, The Philadelphia Water Department (PWD) recommends that they be screened with plant materials. Designers are strongly encouraged to integrate aesthetically pleasing landscape design with SMPs.

Pollution Prevention

Stormwater pollution prevention practices related to landscaping can be categorized into two broad categories: Toxic Substance Use Reduction and Pollutant Source Reduction.

Toxic Substance Use Reduction

Projects shall be designed to minimize the need for toxic or potentially polluting materials such as herbicides, pesticides, fertilizers, or petroleum based fuels within the SMP area before, during, and after construction. Use of these materials creates the risk of spills, misuse, and future draining or leaching of pollutants into facilities or the surrounding area.

Pollutant Source Reduction
Materials that could leach pollutants or pose a hazard to people and wildlife shall not be used as components of a SMP. Some examples of these materials are chemically treated railroad ties and lumber and galvanized metals. Many alternatives to these materials are available.

SMP Establishment and Maintenance

Establishment procedures should include: control of invasive weeds, prevention of damage from animals and vandals, use of erosion control mats and fabrics in channels, temporary diversion of flows from seeded areas until stabilized, mulching, re-staking, watering, and mesh or tube protection replacement, to the extent needed to ensure plant survival. To ensure landscape plant survival and overall stormwater facility functional success, the design and construction documents must include elements that help achieve these results. Construction specifications and details need to include staking, irrigation schedule, soil amendments, plant protection, over planting, and potentially mycorrhizal inoculation.

Table 8.1: Planting Specifications

Specification Element	Elements
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean-up.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering amount and schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	All systems should contain a 2 year warranty. Specifications should contain the warranty period, the required survival rate, and expected condition of plant species at the end of the warranty period.

8.2 Facility Specific Landscaping Guidance

The planting recommendations shown under this section are based on research, local experience and/or standard landscape industry methods for design and construction. It is critical that selected plant materials are appropriate for soil, hydrologic, and other site conditions. SMPs shall use appropriate native and recommended non-invasive species from the Recommended Plant Lists in Table 8.2.
The design for plantings shall minimize the need for herbicides, fertilizers, pesticides, or soil

amendments at any time before, during, and after construction and on a long-term basis. Plantings should be designed to minimize the need for mowing, pruning, and irrigation. Grass or wildflower seed shall be applied at the rates specified by the suppliers. If plant establishment cannot be achieved with seeding by the time of substantial completion of the SMP portion of the project, the contractor shall plant the area with wildflower sod, plugs, container plants, or some other means to complete the specified plantings and protect against erosion.

Green Roof Landscaping Requirements

Plantings used on green roofs shall be self-sustaining, with little to no need for fertilizers or pesticides. Shrubs, herbs, succulents, and/or grasses shall be used to cover most of the green roof. See **Section 7.1**: Green Roofs for more specific information on green roof requirements.

Planter Box Landscaping Requirements

The following quantities per 100 square feet of planter box area are suggested:

- 4 - Large shrubs/small trees 3-gallon containers or equivalent.
- 6 - Shrubs/large grass-like plants 1-gallon containers or equivalent
- Ground cover plants: 1 per 12 inches on center, triangular spacing. Minimum container: 4-inch pot. Spacing may vary according to plant type.

Note: Container planting requires that plants be supplied with nutrients that they would otherwise receive from being part of an ecosystem. Since they are cut off from these processes they must be cared for accordingly.

Note: Tree planting is not required in planters, but is encouraged where practical. Tree planting is also encouraged near planters.

Infiltration and Filter System Recommendations

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for water quality and groundwater recharge volume. In some instances where permeability is high, these facilities may be used for the Channel Protection requirement as well. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters. When properly planted, vegetation will thrive and enhance the

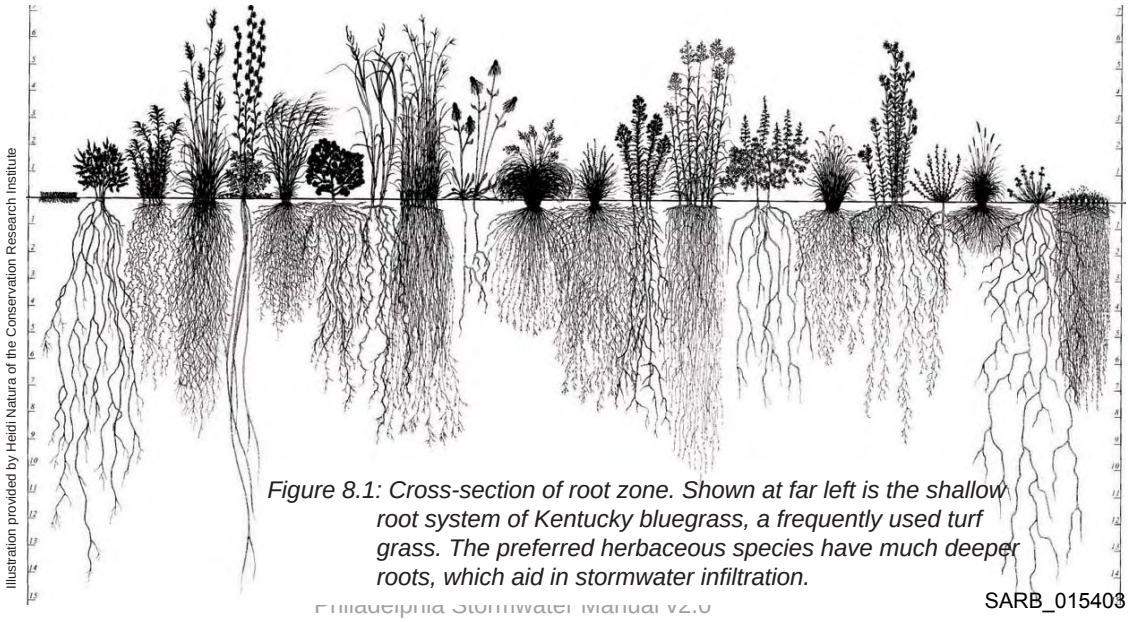

Illustration provided by Heidi Natura of the Conservation Research Institute

Figure 8.1: Cross-section of root zone. Shown at far left is the shallow root system of Kentucky bluegrass, a frequently used turf grass. The preferred herbaceous species have much deeper roots, which aid in stormwater infiltration.

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functioning of these systems. For example, pre-treatment buffers will trap sediment that is often bound with phosphorous and metals. Vegetation planted in the SMP will aid in nutrient uptake and water storage. Additionally, plant roots will create macropores for stormwater to permeate soil for groundwater recharge (see Figure 8.1). Finally, successful plantings provide aesthetic value and wildlife habitat, making these facilities more desirable to the public.

Design Constraints:
Along with the guidelines listed at the start of this section, the following should be adhered to:

- Determine areas that will be saturated with water and water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see Figure 8.2 and associated tables for planting material guidance).
- Plants shall be located so that access is possible for structure maintenance.

Vegetated Swale Landscaping Requirements

The following quantities per 200 square feet of swale area are suggested:

- 1 Evergreen or Deciduous tree:
  - Evergreen trees: Minimum height: 6 feet.
  - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
  - Multi-stem trees: Minimum root ball diameter: 20 inches
- Grass: Seed or sod is required to completely cover the swale bottom and side slopes.
- (Shrubs are optional)

Vegetation or ground cover within the swale should be suitable for expected velocities. For the swale flow path, approved native grass mixes are preferable. The applicant shall have plants established at the time of SMP completion (at least 3 months after seeding). No runoff should be allowed to flow in the swale until grass is established. Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas. These type of landscape can be designed to require mowing only once or twice annually.

Vegetated Infiltration Basin and Dry Detention Pond Landscaping Requirements

Vegetation increases evapotranspiration, helps improve infiltration functions, protects from rain and wind erosion and enhances aesthetic conditions. The following quantities per 300 square feet of basin area are suggested:

- 1 Evergreen or Deciduous tree:
  - Evergreen trees: Minimum height: 6 feet.
  - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
  - Multi-stem trees: Minimum root ball diameter: 20 inches
- 4 Large shrubs/small trees 3-gallon containers or equivalent.
- 6 Shrubs/large grass-like plants 1-gallon containers or equivalent
- Ground cover plants: 1 per 12 inches on center, triangular spacing, for the ground cover planting area only, unless seed or sod is specified. Minimum container: 4-inch pot. At least 50 percent of the SMP shall be planted with grasses or grass-like plants.

Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas.
These type of landscape can be designed to require mowing only once or twice annually.

Appropriate plants should be selected based on ponding depth and drain-down time in the basin. Infiltration systems will be dry much of the time and should be vegetated with drought tolerant species especially if they will not be irrigated.

Bioretention Landscaping Requirements

Planting Soil Bed Characteristics

The characteristics of the soil for the bioretention system are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground. Planting soil should meet the following specifications:

- Clay content: less than 5%
- Sand content: 50 – 60%
- Leaf compost or aged leaf mulch: 20 – 30%
- High quality topsoil: 20 – 30%
- Bioretention soil can be created by amending existing soil. Depending on the quality of the soil, combine 20-30% native soil with 20-30% compost and 50% sand.
- Have a permeability of at least 1.0 feet per day (0.5 inches per hour).
- Be free of stones, stumps, roots, or other woody material over 1 inch in diameter. It should also be free of brush or seeds from noxious weeds. Placement of the planting soil should be in lifts of 12-18 inches, loosely compacted (tamped lightly with a dozer or backhoe bucket).

Planting Plan Guidance

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.

- Perennials, grass-like plants, and ground-cover plants shall be healthy, well-rooted specimens.

- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

The following quantities per 100 square feet of bioretention area are suggested:

- 1 large tree per 100 square feet of bioretention area
- 2-4 small trees or shrubs per 100 square feet of bioretention area
- 6 ferns or grass-like plants per 100 square feet of bioretention area (1-gallon containers)
- Groundcover plantings and wildflower plugs on 12 inch centers with triangular spacing.
- A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention system (Figure 8.2). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. However, plants in all the zones should be drought tolerant. Plants should also have high salt tolerance if bioretention area receives runoff from ground level impervious surfaces.

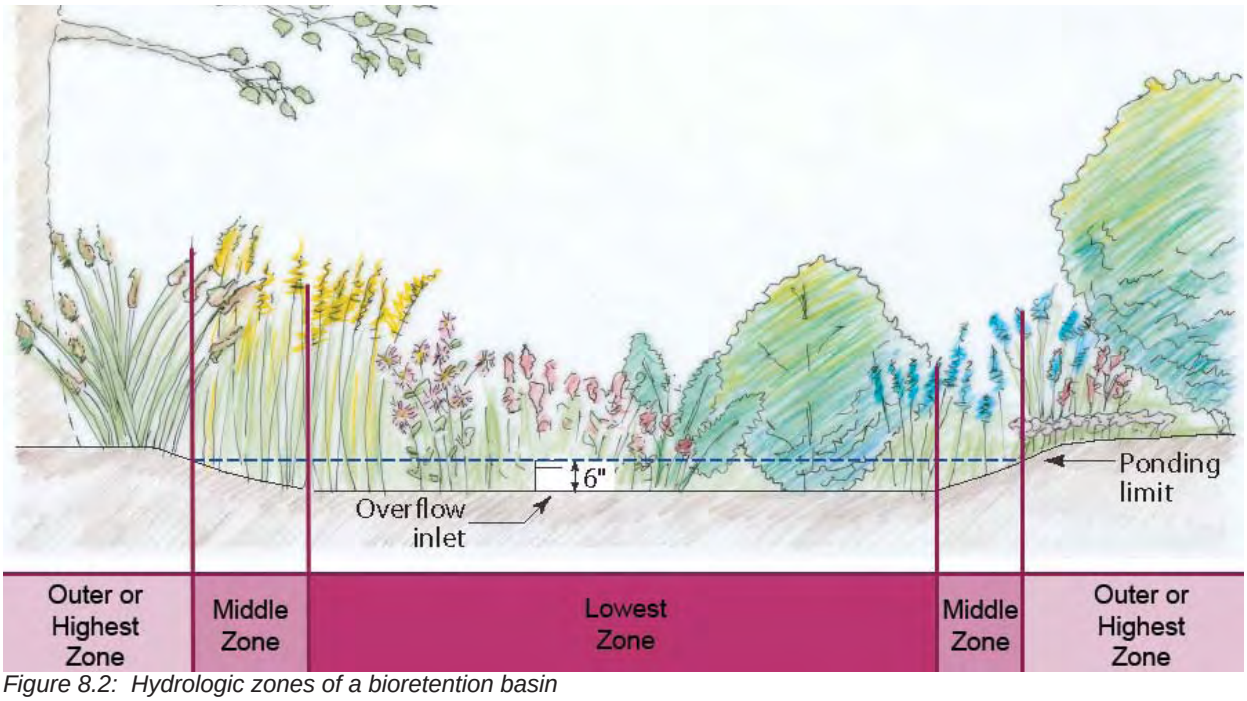

Figure 8.2: Hydrologic zones of a bioretention basin

Lowest Zone (Hydrologic zones 2-4):
Plant species adapted to standing and fluctuating water levels. Frequently used native plants include*:

asters (*Aster spp.*)	winterberry (*Ilex verticillata*)
goldenrods (*Solidago spp.*)	arrowwood (*Viburnum dentatum*)
bergamot (*Monarda fistulosa*)	sweet pepperbush (*Clethra alnifolia*)
blue-flag iris (*Iris versicolor*)	bayberry (*Myrica pensylvanica*)
sedges (*Carex spp.*)	buttonbush (*Cephalanthus occidentalis*)
ironweed (*Vernonia noveboracensis*)	swamp azalea (*Rhododendron viscosum*)
blue vervain (*Verbena hastata*)	elderberry (*Sambucus canadensis*)
joe-pye weed (*Eupatorium spp.*)	green ash (*Fraxinus pennsylvanica*)
swamp milkweed (*Asclepias incarnata*)	river birch (*Betula nigra*)
switchgrass (*Panicum virgatum*)	sweetgum (*Liquidambar styraciflua*)
shrub dogwoods (*Cornus spp.*)	northern white cedar (*Juniperus virginiana*)
swamp rose (*Rosa palustris*)	red maple (*Acer rubrum*)

* Refer to the plant list for a complete listing

Middle Zone (Hydrologic zones 4-5):
This zone is slightly drier than the lowest zone, but plants should still tolerate fluctuating water levels. Some commonly planted native species include*:

black snakeroot (*Cimicifuga racemosa*)	spicebush (*Lindera benzoin*)
switchgrass (*Panicum virgatum*)	hackberry (*Celtis occidentalis*)
spotted joe-pye weed (*Eupatorium maculatum*)	willow oak (*Quercus phellos*)
cutleaf coneflower (*Rudabeckia lacinata*)	winterberry (*Ilex verticillata*)
frosted hawthorn (*Crataegus pruinosa*)	slippery elm (*Ulmus rubra*)
marginal wood fern (*Dryopteris marginalis*)	viburnums (*Viburnum spp.*)
ironwood (*Carpinus caroliniana*)	witch-hazel (*Hamamelis virginiana*)
serviceberry (*Amelanchier canadensis*)	steeplebush (*Spiraea tomentosa*)
obedient plant (*Physostegia virginiana*)	blueberry (*Vaccinium spp.*)

* Refer to the plant list for a complete listing

Outer Zone (Hydrologic zones 5-6):
Generally supports plants adapted to drier conditions. Examples of commonly planted native species include*:

many grasses & wildflowers	juniper (*Juniperus communis*)
basswood (*Tilia americana*)	sweet-fern (*Comptonia peregrina*)
white oak (*Quercus alba*)	eastern red cedar (*Juniperus virginiana*)
scarlet oak (*Quercus coccinea*)	smooth serviceberry (*Amelanchier laevis*)
black oak (*Quercus velutina*)	american holly (*Ilex opaca*)
american beech (*Fagus grandifolia*)	sassafras (*Sassafras albidum*)
black chokeberry (*Aronia melanocarpa*)	white pine (*Pinus strobus*)

* Refer to the plant list for a complete listing

Constructed Wetlands and Wet Ponds Landscaping Requirements

Refer to the *Pennsylvania Stormwater Management Best Management Practices Manual* for additional guidance regarding constructed wetlands and wet ponds.

Filter Strip Landscaping Requirements

It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select vegetation from the list of native species found in this section (Table 8.2). Take soil infiltration capacities, sunlight, pollution tolerances, root structure, and other considerations into account when selecting plants from this list.

Filter strips should be planted with meadow grasses, shrubs, and native vegetation (including trees) from the list provided in **Section 8.3**: Native and Recommended Non-invasive Plants.

For the filter strip, approved native grass mixes are preferable. Seed shall be applied at the rates specified by the supplier. The applicant shall have plants established at the time of SMP completion (at least 3 months after seeding). No runoff shall be allowed to flow across the filter strip until the vegetation is established. Trees and shrubs may be allowed in the flow path if the filter strip exceeds the minimum length and widths specified.

Filter strips often make a convenient area for snow storage. Therefore, filter strip vegetation should be salt-tolerant, and the maintenance schedule should involve removal of sand build-up at the toes of the slope. If the filter strip cannot provide pretreatment in the winter due to snow storage or vegetation choice, other pretreatment should be provided.

Vegetation cover should be maintained at 85 percent. If vegetation is damaged, the damaged areas should be reestablished in accordance with the original specifications or according to a new design approved by the Water Department. In all design cases where vegetation is to be established, the planting regime should be as dense as the soil conditions can sustain. This is especially true at the top portions of the filter strip where the highest sheet flow velocities are found. Soils that can sustain higher quantities and qualities of vegetation may need to be added to insure thick vegetative densities needed for sustainable filter strip performance. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides if possible.

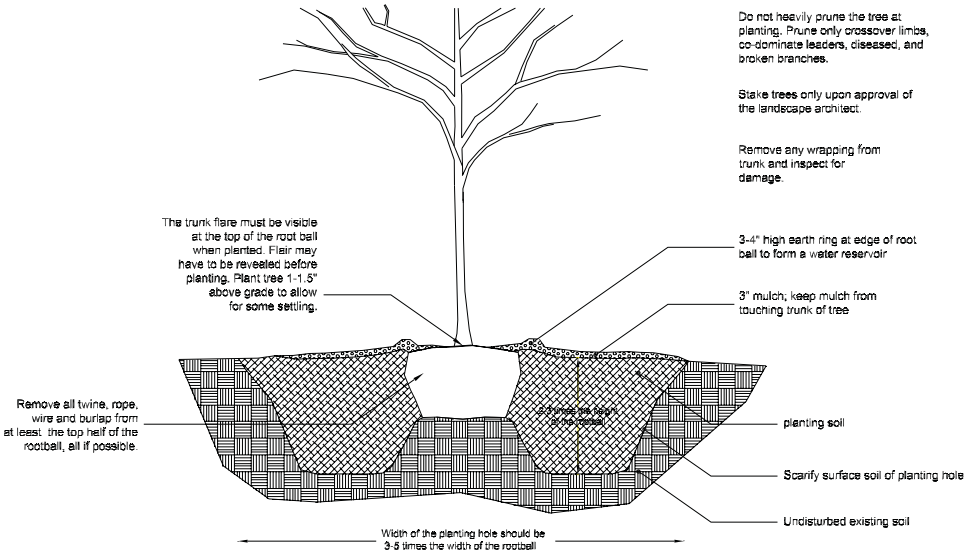

Figure 8.3: Balled & Burlapped (B&B) tree and shrub planting diagram

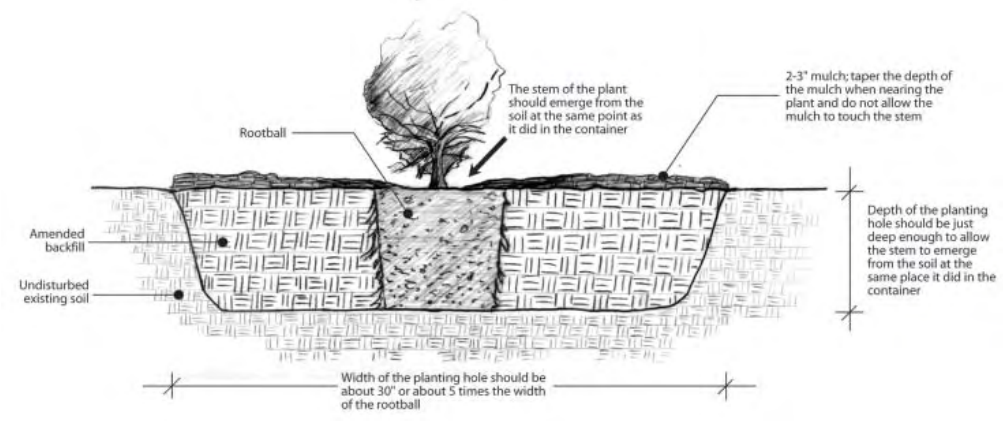

Figure 8.4: Containerized tree and shrub planting diagram

8.3 Native and Recommended Non-invasive Plants

Native plant species are recommended over exotic foreign species because they are well adapted to local climate conditions. This will result in less replacement and maintenance, while supporting the local ecology.

The pages at the end of this section present a list of herbaceous, tree and shrub plants native to Philadelphia and Pennsylvania and suitable for planting in stormwater management facilities (Table 8.2). The list is intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology. Because individual plants often have unique growing requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.

Table 8.2 lists native and recommended plants, trees, shrubs, and grasses and is organized by Type and Latin name. Additional information given for each species includes: Common name, National Wetland Indicator Status, hydrologic zone, inundation tolerance, drought tolerance, salt tolerance, mature canopy spread, mature height, light requirements, nativity, commercial availability, and notes to provide guidance for application and selection. For example, some trees are well suited to landscaped areas that will receive stormwater runoff, while others may not tolerate the additional moisture.

Hydrologic Zones

For planting within a SMP, it is necessary to determine what hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water (see Figure 8.2 for an example of hydrologic zones in a bioretention basin). Plants have differing tolerances to inundation and as an aid to landscape designers, these tolerance levels have been divided into six zones and corresponding plant species have been identified. In Table 8.2 each plant species has a corresponding hydrologic zone provided to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrologic conditions. Just as plants may, on occasion, be found outside of their hardiness zone, they may also be found outside of their hydrologic zone. Additionally, hydrologic conditions in a SMP may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, thus exposing the soil and increasing the chance for erosion.

Wetland Indicator Status

The Wetland Indicator Status (from Region 1, Reed, 1988) has been included to show "the estimated probability of a species occurring in wetlands versus non-wetlands" (Reed, 1988). Reed defines the indicator categories as follows:

- Obligate wetland (OBL): Plants, which nearly always (more than 99% of the time) occur in wetlands under natural conditions.
- Facultative Wetland (FACW): Plants, which usually occur in wetlands (from 67 to 99% of the time), but occasionally found in non wetlands.
- Facultative (FAC): Plants, which are equally likely to occur in wetlands and non wetlands and are found in wetlands from 34 to 66% of the time.
- Facultative Upland (FACU): Plants, which usually occur in non wetlands (from 67 to 99% of the time), but occasionally found in wetlands.
- Upland (UPL): Plants, which almost always (more than 99% of the time) under natural conditions occur in non wetlands.
- A given indicator status shown with a "+" or a "-" means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the "+" or "-" designation.

Inundation Tolerance

Since the Wetland Indicator Status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the "Inundation tolerance" column is designed to provide further guidance. If a plant is capable of withstanding permanent saturation, the depth of this saturation is listed (for example, "saturated" indicates the soil can be moist at all times, "sat, 0-6"" indicates that the species can survive in constantly moist soil conditions with up to 6" of standing water). Conversely, a plant may only tolerate seasonal inundation – such as after a storm event – or may not tolerate inundation at all. This type of plant would be well suited for an SMP that is expected to drain quickly or in the drier zones of the SMP.

Drought Tolerance (N=none; L=low; M=medium; H=high)

The drought tolerance column is meant to provide a way for SMP designers to select appropriate native plants that can survive in hot summer conditions, with a minimum of irrigation. Drought tolerance is defined as the relative tolerance of the plant to drought conditions compared to other plants in the same region (USDA, 2005).

Salt Tolerance (N=none; L=low; M=medium; H=high; U=unknown)

This column ranks the relative tolerance of a species to salt content in the soil. If U (unknown) is displayed, no research was found for that particular species.

Mature Canopy Spread

This column gives the SMP designer a rough estimate of the diameter (or spread) of a tree species' branching when it has matured. This information indicates what the light conditions will be like beneath the tree for understory plantings; how much space should be left open between the tree planting pit and any vertical structures, such as buildings; how far apart the trees should be planted; and it gives an idea, along with the mature height of the species, of the tree's growth habit. The mature canopy spread also provides a rough idea for how much leaf surface area will be available to intercept stormwater before it reaches the ground.

Mature Height

This column provides the approximate mature height of plant species in optimal growing conditions. This height may be reduced dramatically in the urban environment where light, space, and other factors may not be as readily available as in a forest or field setting. However, by providing as much space as possible for a plant to grow and by choosing appropriate species for a planting area, improved – if not optimal - growing conditions can be achieved. For example, a tree planted in a sidewalk pit measuring 4 feet x 4 feet may only reach half its mature height, while a tree planted in a 4 foot wide "trough" style planting bed will grow taller and live longer, because it will have greater access to air and water.

Light Requirement

The light requirements for each species are listed as ranges between full shade and full sun. At the bottom of the range – full shade – plants thrive in conditions where they receive filtered, or dappled, light for the entire day (such as under an oak tree). In the middle of the range are plants that grow best in part shade, where they are in full shade for 2-3 hours during midday. Plants that require full sun should be sited so that they receive 5 or more hours of direct sun during the growing season. Some plants requiring full sun may still do well in a part shade environment, depending on the quality and duration of the light the plants receive when they are not in the shade.

Nativity

A native plant is an indigenous species that occurred in the region prior to settlement by the Europeans. In this column, each species is located within a range of nativity to Philadelphia. Plants known to have existed in Philadelphia County are native to Philadelphia, while a wider geographic range lists plants native to the state, but not necessarily to the county. The widest geographic range lists a few species native to the United States, but not necessarily to Pennsylvania. The plants listed that are not specifically native to Philadelphia are included because of their demonstrated success within SMPs.

Commercial Availability (C=container; P=plug; S=seed)

Wildflower and grass species often come in a form known as a plug. These are often grown and sold in trays of 50 of the same species. They are essentially very small container plants, with a root/soil mass about an inch wide and 2-4 inches long. Most species available in plug form are also sold as seed. Often, a combination of plugs and seed will be used to establish a SMP quickly and provide immediate visual interest and stabilization.

Container-grown plants include trees, shrubs, wildflowers, ferns, grasses, and sedges. This is an excellent alternative to the far more expensive balled-and–burlapped (B&B) form of trees and shrubs, although the size of the tree is almost always smaller. Nurseries often provide a few container sizes for each species.

Notes

PWD has included the recommendations for street trees in the notes section of the native plant list and recommended non-invasive plants, trees, shrubs, and grasses list to assist designers in selection of vegetation most appropriate for the harsh conditions which are often associated in close proximity to streets. It is likely that most these areas will be hot in summer months until the trees become established.

Table 8.2: Native and Recommended Non-invasive Plants

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
fern	Adiantum pedatum	maidenhair fern	FAC-	4, 5, 6	no	L	N		1-3'	part shade-full shade	Philadelphia County	C	slightly acidic soils
fern	Dennstaedtia punctilobula	hayscented fern	UPL	4, 5, 6	no	L	U		1-2'	part sun-shade	Philadelphia County	C	groundcover; grows easily in poor soils
fern	Dryopteris marginalis	marginal wood fern	FAC+	4, 5, 6	no	L	U		1-2'	part sun-shade	Philadelphia County	C	evergreen
fern	Onoclea sensibilis	sensitive fern	FACW	(3, 4) 5	saturated	N	U		1-2'	sun-shade	Philadelphia County	P,S	groundcover; needs consistent moisture
fern	Osmunda cinnamomea	cinnamon fern	FACW	2 (3, 4)	saturated	M	N		2-4'	part-full shade	Philadelphia County	P,S	acidic soils
fern	Osmunda regalis	royal fern	OBL	2 (3, 4)	saturated	L	N		2-4'	part-full shade	Philadelphia County	P,S	groundcover; acidic soils
fern	Polystichum acrostichoides	christmas fern	FACU-	6	no	M	U		1-3'	part shade-full shade	Philadelphia County	C	groundcover; evergreen; silvery fiddleheads
fern	Thelypteris noveboracensis	new york fern	FAC	(3, 4) 5	saturated	M	N		1-2.5'	part shade-shade	Pennsylvania	C	groundcover; delicate fronds spread rapidly in moist areas
forb	Acorus americanus	sweet flag	OBL	3, 4	sat, 0-6"	L	M		4'	full sun	Pennsylvania	P,S	occurs in shallow water of ponds
forb	Anaphalis margaritacea	pearly everlasting		5, 6	no	M	N		1-3'	full sun-part shade	Philadelphia County	S	attractive white, globular flowers
forb	Aquilegia canadensis	columbine	FAC	(4, 5) 6	no	M	N		2'	part sun-shade	Philadelphia County	P,S	flowers with scarlet sepals and yellow petal blades; very adaptable
forb	Asarum canadense	wild ginger	FACU-	4, 5, 6	seasonal	L	N		1'	part-full shade	Philadelphia County	P,S	groundcover; semi-evergreen spreads rapidly; small purple/brown flowers
forb	Asclepias incarnata	swamp milkweed	OBL	2 (3, 4)	sat, 0-6"	N	N		2-6'	full sun-part shade	Philadelphia County	P,S	pink-rose purple flowers in several umbels
forb	Asclepias syriaca	common milkweed	FACU-	5, 6	no	M	N		2-6'	full sun	Philadelphia County	P,S	fragrant brownish-pink flowers in umbels
forb	Asclepias tuberosa	butterfly-weed		5, 6	no	H	N		2-3'	full sun	Philadelphia County	P,S	bright orange flowers in umbels
forb	Aster cordifolius	blue wood aster		5, 6	no	M	L		1.5-4'	part-full shade	Philadelphia County	P,S	blue-violet to rose disk and ray flowers
forb	Aster divaricatus	wood aster		4 (5, 6)	no	M	L		1-3'	part-full shade	Philadelphia County	P,S	white rays, center yellow and reddish-purple
forb	Aster novae-angliae	new england aster	FAC	(3, 4) 5	seasonal	M	L		2-8'	full sun-part shade	Philadelphia County	P,S	rays bright pink or purple
forb	Aster novi-belgii	new york aster	FACW+	(3, 4) 5	seasonal	L	N		1-4'	full sun	Philadelphia County	P,S	violet to blue rays with yellow disks
forb	Baptisia australis	blue false indigo		4, 5, 6	seasonal	H	N		3-6'	full sun	Pennsylvania	P,S	showy blue flowers; shrub-like; nitrogen fixer; adaptable
forb	Baptisia tinctoria	wild indigo		5, 6	no	H	N		2-3'	full sun-part shade	Philadelphia County	P,S	sandy, acidic soils; yellow pea-like flowers; dark blue-green leaves
forb	Bidens aristosa	tickseed sunflower	FACW-	4, 5, 6	seasonal	L	N		1-3'	full sun	US	S	daisy-like yellow flower
forb	Bidens cernua	bur marigold	OBL	3, 4, 5	saturated	L	N		1-3'	full sun	Philadelphia County	S	many flowers crowded together into a head
forb	Bidens frondosa	beggars-ticks	FACW	5, 6	no	L	N		1-4'	full sun	Philadelphia County	S	orange flowers; adaptable
forb	Caltha palustris	marsh marigold	OBL	2, 3, 4	sat, 0-6"	N	N		1-2'	full sun-part shade	Philadelphia County	P,S	ideal for wetland gardens; clump-forming
forb	Chamaecrista fasciculata	partridge-pea	FACU	4, 5, 6	no	M	L		to 3'	full sun	Philadelphia County	S	showy yellow flowers; found on stream banks
forb	Chelone glabra	white turtlehead	OBL	3, 4, 6	seasonal	L	N		2-3'	full sun-part shade	Philadelphia County	P,S	snapdragon-type white flowers
forb	Chrysogonum virginianum	green and gold		6	no	N	N		1'	part shade	Pennsylvania	P,S	groundcover; golden daisy-like flowers continue until frost; spreads easily
forb	Cimicifuga racemosa	black snakeroot		4, 5, 6	seasonal	L	N		3-8'	full sun-part shade	Pennsylvania	C	woodland edge plant; white, wand-like blooms
forb	Dicentra eximia	wild bleeding heart		5, 6	no	L	N		1.5'	part shade-shade	Pennsylvania	C	mound of finely-cut foliage; delicate pink hearts
forb	Dodecatheon media	shooting star	FACU	5, 6	no	L	N		1-2'	part shade	Philadelphia County	C	nodding white, pink, or lilac flowers in a terminal umbel
forb	Eupatorium coelestinum	mist flower	FAC	4, 5, 6	seasonal	M	N		2'	full sun-part shade	Pennsylvania	P,S	groundcover; blue flowers on neat foliage; spreads easily
forb	Eupatorium fistulosum	joe-pye-weed	FACW	(3, 4) 5	seasonal	L	N		to 10'	sun-shade	Philadelphia County	S	many white flowers in large, branching clusters
forb	Eupatorium hyssopifolium	hyssopleaf thoroughwort		5, 6	no	M	M		1-4'	full sun-part shade	Philadelphia County	P,S	white flowers in flat topped terminal clusters
forb	Eupatorium maculatum	spotted joe-pye-weed	FACW	(3, 4) 5	seasonal	L	N		to 5'	full sun-part shade	Pennsylvania	P,S	light purple flowers; attracts butterflies
forb	Eupatorium perfoliatum	boneset	FACW+	(2, 3) 4	seasonal	L	U		2-5'	full sun-part shade	Philadelphia County	P,S	clusters of grayish-white flowers
forb	Eupatorium purpureum	joe-pye-weed	FAC	3 (4, 5)	seasonal	L	U		6-8'	full sun-part shade	Philadelphia County	P,S	vanilla-scented flowers
forb	Eupatorium rugosum	white snakeroot		5, 6	no	M	M		1-5'	sun-shade	Philadelphia County	P,S	white flowers in large clusters
forb	Filipendula rubra	queen of the prairie	FACW	4, 5, 6	seasonal	N	U		4-6'	full sun-part shade	Pennsylvania	S	prefers well-drained moist soils; foamy clusters of blooms
forb	Geranium maculatum	wild geranium	FACU	5, 6	no	M	U		1-2'	full sun-part shade	Philadelphia County	P,S	groundcover; rose-purple flowers in small clusters
forb	Helenium autumnale	sneezeweed	FACW+	3, 4, 5	seasonal	L	N		3-5'	full sun-part shade	Philadelphia County	P,S	showy yellow daisy-like flowers; moist meadows; stream banks
forb	Helianthus angustifolius	swamp sunflower	FACW	3, 4, 5	seasonal	M	N		6-8'	full sun	Pennsylvania	S	yellow flowers with maroon centers
forb	Helianthus giganteus	swamp sunflower	FACW	3, 4, 5	seasonal	L	N		5-10'	full sun-part shade	Philadelphia County	S	yellow flowers on red-purple stems
forb	Heliopsis helianthoides	ox-eye		3, 4, 5, 6	seasonal	M	U		2-5'	full sun-part shade	Philadelphia County	P,S	pale yellow cone-shaped rays with yellow disks
forb	Heuchera americana	alumroot		5, 6	no	M	U		1-1.5'	full sun-part shade	Philadelphia County	P,S	groundcover; white airy flowers
forb	Hibiscus moscheutos	swamp mallow	OBL	2, 3	sat, 0-12"	N	M		3-7'	full sun-part shade	Philadelphia County	P,S	large pink, purplish, or white flowers with a dark center
forb	Houstonia caerulea	bluets	FACU	5, 6	no	M	U		2-8"	full sun-part shade	Philadelphia County	S	delicate pale blue flowers with yellow centers
forb	Iris versicolor	blue-flag iris	OBL	2 (3, 4)	sat, 0-6"	N	L		1-3'	full sun	Philadelphia County	P,S	blue-violet flowers
forb	Liatris spicata	spiked gay-feather	FAC+	4, 5	seasonal	L	L		4-5'	full sun	Philadelphia County	P,S	easy to grow; tall spikes of lavender blooms
forb	Lillium superbum	turk's cap-lily	FACW+	4, 5	seasonal	N	U		3-8'	full sun	Philadelphia County	S	nodding flowers, orange or orange-red with spots
forb	Lobelia cardinalis	cardinal flower	FACW+	3, 4	saturated	M	N		2-5'	part-full shade	Philadelphia County	P,S	brilliant scarlet red flowers

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
forb	Lobelia siphilitica	great-blue lobelia	FACW+	3, 4	saturated	N	U		1-3'	full sun-part shade	Philadelphia County	P,S	blue-white flowers
forb	Maianthemum racemosum	false-solomon's seal		5, 6	no	L	U		1-3'	shade	Philadelphia County	C	creamy-white flowers in branched, pyramidal clusters
forb	Mertensia virginica	virginia bluebells	FACW	5, 6	no	L	N		1-2'	full-part shade	Philadelphia County	C	woodland flower; entire plant dies back by mid-summer
forb	Mimulus ringens	allegheny monkey-flower	OBL	3, 4	saturated	N	U		1-3'	full sun-part shade	Philadelphia County	P	blue-violet flowers
forb	Monarda didyma	bee-balm	FAC+	(4, 5) 6	no	N	U		2-5'	full sun	Philadelphia County	C	red flowers, scented leaves
forb	Monarda fistulosa	wild bergamot	UPL	5, 6	no	N	L		2-4'	full sun-part shade	Philadelphia County	P,S	pink to lavender flowers, scented leaves
forb	Monarda punctata	horsemint	UPL	6	no	M	U		2-3'	full sun	Pennsylvania	P,C	pink, showy bracts and yellow flowers with purple spots
forb	Oenothera fruticosa	sundrops	FAC	5, 6	no	L	H		1-2'	full sun	Philadelphia County	P,S	bright yellow flowers in spike or racemes
forb	Peltandra virginica	arrow-arum	OBL	(1, 2) 3	sat, 0-1'	N	L		1-2'	full sun	Philadelphia County	P,S	emergent aquatic; resembles an arrowhead
forb	Penstemon digitalis	white beardtongue	FAC	5, 6	no	H	M		2-4'	full sun-part shade	Philadelphia County	P,S	white with purple tinged tubular flowers
forb	Phlox maculata	wild sweet-william	FACW	4, 5	seasonal	M	N		1-3'	full sun	Philadelphia County	P,S	deep pink to rose-purple flower clusters
forb	Phlox paniculata	summer phlox	FACU	4, 5, 6	no	M	U		2-6'	full sun-part shade	Philadelphia County	P	magenta pink flower clusters
forb	Phlox subulata	moss phlox		6	no	M	N		3-5"	full sun-part shade	Pennsylvania	C	groundcover; evergreen; forms mats; good for hillsides and rocky areas
forb	Physostegia virginiana	obedient plant	FAC+	4, 5	seasonal	L	U		1-5'	full sun-part shade	Philadelphia County	P,S	tall graceful plant with pink tubular flowers; very tolerant
forb	Polygonatum biflorum	solomon's seal	FACU	5, 6	no	L	U		1-3'	full-part shade	Philadelphia County	C	greenish bell-shaped flowers hang from leaf axils in pairs
forb	Polygonum pensylvanicum	pennsylvania smartweed	FACW	2 (3, 4)	sat, 0-6"	M	L		to 6'	full sun	Pennsylvania	S	attractive pink flowers; great species for disturbed sites and stream banks
forb	Pontederia cordata	pickerel-weed	OBL	(2, 3) 4	saturated	N	L		1-3'	full sun	Philadelphia County	P, C	heart-shaped leaves with purple flowers in a spike
forb	Rudbeckia fulgida	early coneflower	FAC	5, 6	no	M	U		1.5'	full sun-part shade	Pennsylvania	P,S	yellow flowers with black eyes
forb	Rudbeckia hirta	black-eyed susan	FACU-	4, 5, 6	no	M	N		1-3'	full sun-part shade	Pennsylvania	P,S	flowers from seed in the first year
forb	Rudbeckia laciniata	tall coneflower	FACW	4, 5	seasonal	H	N		5-10'	full sun-part shade	Pennsylvania	P,S	yellow flowers with drooping rays and green eyes; moist thickets; swamps
forb	Rudbeckia triloba	three-lobed coneflower	FACU	5, 6	no	M	U		1-3'	full sun-part shade	Pennsylvania	P,S	yellow flowers with large, black eyes; moist to dry soils
forb	Sagittaria latifolia	arrowhead	OBL	1, 2, 3	sat, 0-2'	N	N		1-4'	full sun	Philadelphia County	P,S	emergent aquatic, tubers are edible
forb	Saururus cernuus	lizard's tail	OBL	2, 3, 4	sat, 0-1'	N	U		2-4'	sun-part shade	Philadelphia County	P,S	emergent aquatic, fragrant white flowers
forb	Sedum ternatum	wild stone crop		6	no	M	U		3-8"	full sun-part shade	Philadelphia County	P,S	groundcover; likes rocky banks
forb	Senecio aureus	golden ragwort	FACW	4, 5	seasonal	L	N		1-3'	sun-shade	Philadelphia County	P,S	groundcover; flowers in terminal clusters with many golden rays
forb	Solidago bicolor	silver-rod		5, 6	no	M	U		1-3'	part sun	Philadelphia County	S	only native white goldenrod
forb	Solidago nemoralis	gray goldenrod		6	no	M	N		1-3'	full sun-part shade	Philadelphia County	S	dry, sterile soils; yellow flower clusters
forb	Solidago odora	sweet goldenrod		6	no	M	U		2-4'	full sun-part shade	Philadelphia County	S	leaves smell and taste like licorice
forb	Solidago rugosa	wrinkle-leaf goldenrod	FAC	3, 4, 5	no	M	N		3-7'	sun-part shade	Philadelphia County	P,S	yellow flowers
forb	Solidago sempervirens	sea-side goldenrod	FACW	3, 4, 5	seasonal	H	M		3-5'	full sun	Philadelphia County	P,S	showy yellow flowers
forb	Tiarella cordifolia	foamflower	FAC-	5, 6	no	L	U		1'	part sun-full shade	Pennsylvania	P,S	groundcover; spreads rapidly; leaves are evergreen; flowers are small and white
forb	Tradescantia virginiana	spiderwort	FACU	5, 6	no	M	N		1-3'	full sun-part shade	Philadelphia County	P,S	long blooming; deep blue-purple or white flower; dry to moist soils
forb	Vallisneria americana	wild celery	OBL	1	sat, 1' min.	N	N		1'	full sun-part shade	Pennsylvania	C	tolerant of murky water and high nutrient loads
forb	Verbena hastata	blue vervain	FACW+	3, 4	saturated	N	U		2-6'	full sun	Philadelphia County	P,S	violet blue flowers in erect spikes
forb	Veronia novaborescensis	new york ironweed	FACW+	3, 4	saturated	M	N		5-6'	full sun	Philadelphia County	P,S	30-50 small rose-purple flowers on a head
forb	Zizia aptera	golden alexander	FAC	5, 6	no	L	U		1-3'	full sun-part shade	Philadelphia County	C	umbels of yellow flowers; all leaves are compound
grass	Andropogon gerardii	big bluestem	FACW+	(4, 5) 6	no	H	M		3-6'	full sun	Philadelphia County	P,S	warm-season grass
grass	Andropogon virginicus	broom sedge	FACU	5, 6	no	H	N		3-8'	full sun-part shade	Philadelphia County	P,S	warm-season grass
grass	Chasmanthium latifolium	river oats	FACU	4, 5	seasonal	M	N		2-3'	full sun-part shade	Pennsylvania	P,S	groundcover; resembles bamboo; dangling "oats"
grass	Danthonia spicata	poverty grass		6	no	L	U		1-3'	full sun	Pennsylvania	P,S	usually found in poor, dry soils; very tolerant; cool-season
grass	Distichlis spicata	seashore saltgrass	FACW+	5, 6	no	M	H		1'	full sun	Philadelphia County	P,S	especially useful in saline wetlands; dense roots act as a pollutant filter
grass	Eleocharis palustris	creeping spike-rush	OBL	2, 3, 4	sat, 0-6"	L	L		1-2'	full sun	Pennsylvania	P,S	forms dense tufts; roots fix nitrogen; important food and cover for waterfowl
grass	Elymus canadensis	Canada rye	FACU+	4, 5, 6	seasonal	M	M		3-6'	full sun-part shade	Philadelphia County	S	cool season, clump-forming grass with wheat-like spikes that remain until winter
grass	Elymus virginicus	virginia wild rye	FACW-	4, 5	seasonal	M	N		2-3'	part shade-shade	Philadelphia County	P,C	spreads easily; good for erosion control; very tolerant
grass	Eragrostis spectabilis	purple lovegrass	UPL	5, 6	no	H	N		1-2.5'	full sun	Philadelphia County	P,S	groundcover; delicate purple flowers seem to float above the plant
grass	Glyceria grandis	american mannagrass	OBL	2, 3, 4	seasonal	N	U		to 5'	full sun	Philadelphia County	S	decorative cool-season bunchgrass; purple seed heads
grass	Glyceria striata	fowl mannagrass	OBL	(2, 3) 4	seasonal	L	N		2-4'	full sun-part shade	Philadelphia County	P,S	clump forming
grass	Hordeum jubatum	foxtail barley	FAC	5, 6	no	M	M		1-3'	full sun	Philadelphia County	S	soft and airy appearance; compaction resistant; often found on roadsides
grass	Leersia oryzoides	rice cutgrass	OBL	(2, 3) 4	sat, 0-6"	L	N		2-5'	full sun	Philadelphia County	P,S	single flower clusters slightly drooping
grass	Panicum dichotomiflorum	smooth panic-grass	FACW-	4, 5, 6	seasonal	N	M		5-7'	full sun-part shade	Philadelphia County	S	green or purple inflorescence
grass	Panicum virgatum	switch-grass	FAC	(4, 5) 6	seasonal	M	M		3-6'	full sun-part shade	Philadelphia County	P,S	groundcover; bluish-green foliage; purple panicle of flowers

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
grass	Schizachyrium scoparium	little bluestem	FACU	6	no	H	N		2-3'	full sun	Philadelphia County	P,S	warm-season grass, tolerates poor, dry soils
grass	Sorghastrum nutans	indian grass	UPL	5, 6	no	M	M		5-7'	full sun	Philadelphia County	P,S	warm-season grass
grass	Tridens flavus	purpletop	FACU	6	no	H	N		2-5'	full sun	Philadelphia County	P,S	groundcover; purple drooping branches
grass	Typha angustifolia	narrow-leaved cattail	OBL	1 (2, 3)	sat, 0-1'	L	M		to 6'	full sun	Pennsylvania	P,S	provides food and cover for geese, ducks, and spawning fish
grass	Typha latifolia	broad-leaved cattail	OBL	1, 2, 3	sat, 0-1'	N	L		to 10'	full sun-part shade	Pennsylvania	P,S	provides food and cover for geese, ducks, and spawning fish
grass	Zizania aquatica	wild rice	OBL	2, 3, 4	saturated	N	L		to 9'	full sun	Philadelphia County	S	yellow-red edible grains; found in tidal and nontidal marshes; requires still water
grass-like	Alisma subcordatum	southern water-plantain	OBL	2	sat, 0-1'	N	N		to 4'	full sun	Philadelphia County	S	emergent aquatic, slow moving water
grass-like	Carex crinita	finged sedge	OBL	2 (3, 4)	saturated	L	N		to 4'	full sun-part shade	Philadelphia County	P,C	groundcover; emergent aquatic, distinctive sedge
grass-like	Carex lurida	lurid sedge	OBL	2, 3, 4	saturated	L	N		to 3'	full sun-part shade	Philadelphia County	P, C	seed heads resemble small sweetgum fruits; remains attractive in warm temps.
grass-like	Carex pensylvanica	pennsylvania sedge		5, 6	seasonal	M	N		3-15"	part-full shade	Philadelphia County	P,C	slow-spreading
grass-like	Carex scoparia	broom sedge	FACW	3 (4) 5	sat, 0-6"	N	L		1-3'	full sun	Philadelphia County	P,S	green flowers in clusters at the top of the stem
grass-like	Carex stricta	tussock sedge	OBL	1 (2, 3) 4	sat, 0-6"	L	N		to 3'	full sun	Philadelphia County	P,C	emergent aquatic
grass-like	Carex vulpinoidea	fox sedge	OBL	1, 2 (3) 4	sat, 0-6"	L	N		to 3'	full sun-part shade	Philadelphia County	P,C	seed heads resemble a fox's tail
grass-like	Juncus effusus	soft rush	FACW+	(2, 3) 4	sat, 0-1'	M	L		2-3'	full sun	Philadelphia County	P,C	clump forming
grass-like	Juncus gerardii	black-grass	FACW+	3, 4	sat, 0-6"	N	H		1-2'	full sun-part shade	Philadelphia County	P,C	purplish to burgundy flower clusters
grass-like	Pontederia cordata	pickerel-weed	OBL	1, 2, 3	sat, 0-1'	N	L		1-3'	full sun	Philadelphia County	S	emergent aquatic, heart-shaped leaves, purple flowers
grass-like	Schoenoplectus (Scirpus) pungens	three-square	FACW+	2, 3, 4	sat, 0-6"	N	H		1-3'	full sun	Philadelphia County	P,S	good bank stabilizer; erosion control; spreads easily
grass-like	Scirpus cyperinus	wool-grass	FACW+	2 (3, 4)	saturated	L	N		to 6'	full sun	Philadelphia County	P,C	forms dense tussocks; large inflorescence
grass-like	Scirpus polyphyllus	bulrush	OBL	2, 3, 4	saturated	N	U		to 4'	shade	Philadelphia County	S	numerous leaves along stem, flowers at the top of the stem
grass-like	Sparganium americanum	bur-reed	OBL	(2, 3) 4	sat, 0-6"	N	N		1-3'	full sun	Philadelphia County	P,C	emergent aquatic
grass-like	Sparganium eurycarpum	giant bur-reed	OBL	1 (2, 3)	sat, 0-12"	N	N		2-4'	full sun	Philadelphia County	P,C	emergent aquatic
shrub	Alnus serrulata	smooth alder	OBL	(1, 2) 3	sat, 0-3"	L	N	6-10'	6-10'	full sun	Philadelphia County	C	stabilizes stream banks, roots fix nitrogen
shrub	Amelanchier canadensis	serviceberry	FAC	4, 5, 6	seasonal	L	H	15-20'	6-20'	full sun-part shade	Philadelphia County	C	compaction sensitive
shrub	Aronia arbutifolia	red chokeberry	FACW	3 (4, 5)	seasonal	L	M	3-4'	6-10'	full sun-part shade	Philadelphia County	C	compaction resistant, bank stabilizer, white flowers
shrub	Aronia melanocarpa	black chokeberry	FAC	3 (4, 5)	seasonal	M	M	3-6'	5-10'	full sun-part shade	Philadelphia County	C	compaction tolerant, white flowers
shrub	Baccharis halimifolia	groundsel-tree	FACW	4, 5, 6	seasonal	L	M	6-12'	6-12'	full sun	Philadelphia County	C	compaction resistant
shrub	Cephalanthus occidentalis	buttonbush	OBL	1 (2, 3)	sat, 0-3'	M	M	4-8'	3-6'	full sun	Philadelphia County	C	compaction tolerant, interesting flowers
shrub	Chionanthus virginicus	fringetree	FAC+	4, 5	seasonal	M	N	12-20'	12-25'	sun-shade	Philadelphia County	C	white, pendulous, fragrant flowers; gold fall color; very adaptable; acidic soils
shrub	Clethra alnifolia	sweet pepperbush	FAC+	3, 4, 5	seasonal	L	M	4-6'	3-8'	full sun-shade	Philadelphia County	C	compaction tolerant, acidic soils
shrub	Comptonia peregrina	sweet-fern		6	no	H	N	4-8'	2-5'	full sun-part shade	Pennsylvania	C	very adaptable; aromatic leaves; nitrogen fixer
shrub	Cornus amomum	silky dogwood	FACW	(3, 4) 5	seasonal	L	N	8'	6-10'	full sun-part shade	Philadelphia County	C	compaction tolerant, bank stabilizer, white flowers
shrub	Cornus racemosa	gray dogwood	FAC-	3 (4, 5)	seasonal	M	N	10-15'	10-15'	full sun-shade	Philadelphia County	C	compaction tolerant, very adaptable, white flowers
shrub	Cornus sericea	red-osier dogwood	FACW+	(3, 4) 5	seasonal	L	N	8-12'	7-9'	full sun	Philadelphia County	C	compaction tolerant, stream bank stabilizer, red bark
shrub	Corylus americana	hazelnut	FACU-	4 (5, 6)	no	M	N	8-13'	8-10'	full sun-light shade	Philadelphia County	C	compaction tolerant, edible nuts
shrub	Euonymus americanus	hearts-a-burstin'	FAC	4, 5, 6	seasonal	N	N	4-6'	4-6'	full sun-part shade	Philadelphia County	C	small brown flowers; fuchsia hearts; green stems add winter interest
shrub	Hamamelis virginiana	witch-hazel	FAC-	4 (5, 6)	no	L	N	15-20'	20-30'	full sun-shade	Philadelphia County	C	ornamental, unusual yellow flowers
shrub	Hydrangea arborescens	wild hydrangea	FACU	3, 4, 5	no	N	U	3-5'	3-5'	part-full shade	Philadelphia County	P,S	creamy white flowers; dry to moist soil
shrub	Ilex verticillata	winterberry	FACW+	(3, 4) 5	seasonal	L	N	3-12'	6-12'	full sun-part shade	Philadelphia County	C	compaction resistant, red berries persist through winter
shrub	Itea virginica	virginia sweet spire	OBL	3, 4, 5	seasonal	L	N	3-5'	3-9'	sun-shade	Pennsylvania	C	fragrant white tassels; good fall color
shrub	Juniperus communis	juniper		6	no	H	N	7-13'	5-10'	full sun	Philadelphia County	C	mounded shrub; deep taproot; high wildlife value; evergreen
shrub	Leucothoe racemosa	swamp sweetbells	FACW	3, 4, 5	seasonal	L	L	3-8'	3-8'	part-full shade	Pennsylvania	C	white drooping flowers; evergreen leaves; moist soil
shrub	Lindera benzoin	spicebush	FACW-	3, 4, 5	seasonal	L	M	6-12'	6-12'	full sun-shade	Philadelphia County	C	compaction tolerant, drought sensitive
shrub	Lonicera sempervirens	trumpet honeysuckle	FACU	6	no	L	N	3-6'	10-20'	full sun-part shade	Philadelphia County	P,S	vine with bright orange trumpet-shaped flowers; flood intolerant
shrub	Myrica pensylvanica	bayberry	FAC	(3, 4) 5	seasonal	H	M	5-9'	9'	full sun	Philadelphia County	C	compaction resistant, roots fix nitrogen, winter fruits
shrub	Parthenocissus quinquefolia	virginia creeper	FACU	4, 5, 6	seasonal	H	M	5-10'	30-50'	full sun-part shade	Philadelphia County	C	very adaptable vine; compaction resistant; beautiful red fall color
shrub	Physocarpus opulifolius	ninebark	FACW	3, 4, 5	seasonal	H	N	4-6'	5-10'	full sun	Philadelphia County	C	compaction resistant
shrub	Rhododendron maximum	Rosebay	FAC	3, 4, 5	seasonal	H	N	4-25'	4-25'	full sun-part shade	Philadelphia County	C	acidic soil, compaction sensitive
shrub	Rhododendron periclymenoides	pinxterbloom azalea	FAC	4, 5, 6	seasonal	M	N	4-7'	4-6'	full sun-part shade	Philadelphia County	C	pink flowers open before leaves are out; moist, acid, well-drained soil
shrub	Rhododendron viscosum	swamp azalea	FACW+	(3, 4) 5	saturated	M	N	6-12'	5-8'	full sun-part shade	Philadelphia County	C	compaction resistant, showy pink and white flowers
shrub	Rhus aromatica	fragrant sumac		5, 6	no	M	U	6-10'	2-4'	full sun-part shade	Pennsylvania	C	spicy smelling leaves; good fall color
shrub	Rhus copallina	winged sumac		6	no	H	M	10-20'	7-15'	full sun	Philadelphia County	C	compaction sensitive; flood intolerant

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
shrub	Rhus glabra	smooth sumac		4 (5, 6)	no	M	N	9-15'	9-15'	full sun	Philadelphia County	C	grows well in poor soils; flood and compaction intolerant
shrub	Rhus typhina	staghorn sumac		6	no	H	M	15-25'	15-25'	full sun	Philadelphia County	C	flood intol., compaction sensitive
shrub	Rosa carolina	pasture rose	UPL	5, 6	no	H	M	5-10'	4-6'	full sun	Philadelphia County	C	compaction tolerant; flood intolerant
shrub	Rosa palustris	swamp rose	OBL	2 (3, 4)	saturated	L	N	4-6'	6'	full sun	Philadelphia County	C	easy to establish
shrub	Rosa virginiana	wild rose	FAC	3 (4, 5)	seasonal	L	N	3-5'	4-6'	full sun	Philadelphia County	C	very pretty; low maint; tolerant of poor soils
shrub	Rubus allegheniensis	common blackberry	FACU-	4, 5, 6	no	H	N	6-12'	3-6'	full sun-part shade	Philadelphia County	C	compaction tolerant; edible fruit
shrub	Rubus occidentalis	blackcap raspberry		6	no	M	N	5-11'	3-4'	full sun-part shade	Pennsylvania	C	tasty fruits; purple & white stems provide winter interest; forms thickets
shrub	Salix discolor	pussy-willow	FACW	3, 4, 5	seasonal	L	N	10-12'	10-15'	full sun	Philadelphia County	C	compaction resistant, roots easily from cuttings
shrub	Salix exigua	sandbar willow	OBL	3, 4, 5	seasonal	M	L	10-15'	10'	full sun	Philadelphia County	C	found on sandy, gravelly bars or shores
shrub	Salix sericea	silky willow	OBL	3, 4, 5	seasonal	L	N	10-15'	10'	full sun-part shade	Philadelphia County	C	found in swamps, bogs, and on stream banks
shrub	Sambucus canadensis	american elder	FACW	(3, 4) 5, 6	seasonal	M	M	5-12'	5-12'	full sun-shade	Philadelphia County	C	compaction resistant
shrub	Spiraea tomentosa	steeplebush	FACW-	4, 5, 6	seasonal	M	N	3-6'	3-6'	full sun	Philadelphia County	C	compaction resistant
shrub	Vaccinium angustifolium	low-bush blueberry	FACU-	4, 5, 6	seasonal	H	N	2'	1-3'	full sun-part shade	Philadelphia County	C	compaction sensitive; very sweet berries; very flood tolerant; needs acidic soil
shrub	Vaccinium corymbosum	highbush blueberry	FACW-	3, 4, 5, 6	seasonal	L	H	8-12'	6-12'	full sun-part shade	Philadelphia County	C	compaction resistant, acidic soils
shrub	Vaccinium pallidum	early low blueberry	FACU-	4, 5, 6	seasonal	H	U	2-3'	1-3'	full sun-part shade	Philadelphia County	C	white flowers; sweet edible fruit; wildlife value; compaction sensitive, very flood tol
shrub	Vaccinium stamineum	deerberry	FACU	6	no	H	N	5-10'	5-10'	full sun-part shade	Pennsylvania	C	white flowers; edible fruit; high wildlife value; dry to moist soil
shrub	Viburnum acerifolium	maple-leaved viburnum	UPL	5, 6	no	H	N	2-4'	4-6'	full sun-part shade	Philadelphia County	C	creamy white flowers; blue berries; dry to moist soil; wildlife value
shrub	Viburnum dentatum	southern arrow-wood	FAC	3 (4, 5)	seasonal	M	M	6-12'	6-12'	full sun-part shade	Philadelphia County	C	compaction tolerant; heat resistant
shrub	Viburnum lentago	nannyberry	FAC	4, 5, 6	no	H	N	6-12'	15-18'	full sun-part shade	Philadelphia County	C	white flowers; sweet black berries; very adaptable; high wildlife value
shrub	Viburnum nudum	possum haw	OBL	3, 4, 5	seasonal	L	N	12-20'	12-20'	full sun-part shade	Philadelphia County	C	white flowers; glossy leaves; high wildlife value; compaction resistant
shrub	Viburnum prunifolium	black haw	FACU	4, 5, 6	no	M	N	6-12'	15-20'	full sun-part shade	Philadelphia County	C	white flowers; black berries; very adaptable; high wildlife value
shrub	Viburnum trilobum	american cranberry	FACW	3, 4, 5	seasonal	M	N	8-12'	8-12'	full sun-part shade	Philadelphia County	C	white flowers; edible red berries; moist to boggy soil; high wildlife value
tree	Acer rubrum	red maple	FACW	3 (4, 5)	seasonal	L	N	30-50'	40-60'	sun-shade	Philadelphia County	C	tolerant of many soils, tolerates acidic soil, rapid growth; suitable street tree
tree	Acer saccharinum	silver maple	FACW	3 (4, 5)	seasonal	L	N	35-70'	50-70'	full sun-part shade	Philadelphia County	C	very tolerant of poor soils
tree	Acer saccharum	sugar maple	FACU	4, 5, 6	no	M	N	30-60'	60-75'	full sun-part shade	Philadelphia County	C	intolerant of crowding, pollution, and drought
tree	Amelanchier laevis	smooth serviceberry		4, 5, 6	seasonal	M	M	15-40'	25'	full sun-part shade	Philadelphia County	C	compaction sensitive
tree	Asimina triloba	paw paw	FACU+	4, 5, 6	no	L	N	15-30'	15-20'	full sun-part shade	Philadelphia County	C	unusual maroon flower; very large leaves; moist soil; compaction sensitive
tree	Betula lenta	sweet birch	FACU	4, 5, 6	seasonal	M	N	40-60'	40-55'	full sun-part shade	Philadelphia County	C	sensitive to soil compaction
tree	Betula nigra	river birch	FACW	(3, 4) 5	seasonal	L	N	40-60'	40-70'	full sun	Philadelphia County	C	good bank stabilizer; acidic soils
tree	Betula populifolia	gray birch	FAC	(4, 5) 6	seasonal	M	N	10-20'	20-40'	full sun	Philadelphia County	C	poor soils, short lived tree, early successional species
tree	Carpinus caroliniana	hornbeam	FAC	3 (4, 5) 6	seasonal	L	N	20-35'	50-75'	heavy shade	Philadelphia County	C	compaction sensitive
tree	Carya cordiformis	bitternut hickory	FACU+	5, 6	seasonal	H	N	50-75'	50-75'	full sun-part shade	Philadelphia County	C	dry, moist, or wet soil; high wildlife value; good fall color; compaction tolerant
tree	Carya glabra	pignut hickory	FACU-	4 (5, 6)	no	H	N	35-50'	50-60'	full sun-part shade	Philadelphia County	C	compaction sensitive, warm south-facing slopes
tree	Carya ovata	Shagbark hickory	FACU	4 (5, 6)	no	M	N	50-70'	75-100'	full sun-part shade	Philadelphia County	C	compaction tolerant, distinctive peeling bark
tree	Celtis occidentalis	hackberry	FACU	4, 5, 6	no	H	M	40-60'	40-60'	full sun-part shade	Philadelphia County	C	fruit persists into winter; deep-rooting; good street tree
tree	Cercis canadensis	eastern redbud	FACU-	4, 5, 6	no	H	N	25-35'	20-30'	full sun-part shade	Philadelphia County	C	not good in acidic soils; nitrogen fixer
tree	Chamaecyparis thyoides	atlantic white cedar	OBL	(1, 2) 3, 4	saturated	N	N	20'	50'	part sun-shade	Pennsylvania	C	usually found in areas with fluctuating water tables
tree	Cornus florida	flowering dogwood	FACU-	4, 5, 6	no	M	N	15-30'	30-50'	sun-shade	Philadelphia County	C	understory tree; nice ornamental
tree	Crataegus crus-galli	cockspur hawthorn	FACU	5, 6	seasonal	H	M	20-25'	20-30'	full sun-part shade	Philadelphia County	C	keeps berries all winter; tolerant of many soils
tree	Crataegus pruinosa	frosted hawthorn		4, 5	seasonal	M	U	20-24'	24'	full sun-part shade	Pennsylvania	C	white flowers; adaptable; high wildlife value
tree	Fagus grandifolia	american beech	FACU	4 (5, 6)	no	H	N	40-80'	50-70'	sun-shade	Philadelphia County	C	compaction intolerant; intolerant of poorly-drained soils
tree	Fraxinus americana	white ash	FACU	4 (5, 6)	no	L	N	60-80'	50-80'	full sun-part shade	Philadelphia County	C	well-drained soils; compaction tolerant
tree	Fraxinus pennsylvanica	green ash	FACW	3, 4, 5	seasonal	M	L	35-50'	50-60'	full sun	Philadelphia County	C	good bank stabilizer, compaction resistant; good street tree, but may develop surface roots with age
tree	Gleditsia triacanthos	honeylocust		3, 4, 5	seasonal	H	L	50-75'	50-75'	full sun	Philadelphia County	C	gold fall color; very adaptable; compaction tolerant; taproot; good street tree
tree	Ilex opaca	american holly	FACU	4, 5, 6	no	M	L	10-20'	40-50'	full sun-part shade	Philadelphia County	C	acidic well drained soils; intolerant of wind
tree	Juglans nigra	black walnut	FACU	5, 6	seasonal	L	N	75-100'	50-75'	full sun	Philadelphia County	C	flood and compaction tolerant; yellow-green flowers give way to edible nuts
tree	Juniperus virginiana	eastern red cedar	FACU	4, 5, 6	no	H	M	8-25'	50-75'	full sun	Philadelphia County	C	flood and shade intolerant; very tolerant of many soils; beautiful reddish bark
tree	Liquidambar styraciflua	sweetgum	FAC	3, 4, 5	seasonal	L	M	20-30'	60-75'	full sun	Philadelphia County	C	heat and flood tolerant; outstanding fall color; good street tree
tree	Liriodendron tulipifera	tulip tree	FACU	4, 5, 6	no	M	L	30-50'	70-100'	full sun-part shade	Philadelphia County	C	heat and compaction sensitive; rapid growth
tree	Magnolia virginiana	sweetbay magnolia	FACW+	3, 4, 5	seasonal	N	M	10-20'	10-20'	sun-shade	Philadelphia County	C	sandy-peaty acidic soil; attractive, fragrant flowers

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
tree	Nyssa sylvatica	sourgum	FAC	2 (3, 4) 5	seasonal	L	M	20-30'	30-50'	full sun	Philadelphia County	C	compaction tolerant; heat resistant
tree	Pinus rigida	pitch pine	FACU	4, 5, 6	no	M	M	30-50'	40-60'	full sun	Philadelphia County	C	acidic soils; compaction sensitive; heat resistant
tree	Pinus strobus	white pine	FACU	4, 5, 6	no	N	N	20-40'	50-100'	full sun-part shade	Philadelphia County	C	heat and compaction sensitive; long-lived; tolerant of poor soils
tree	Pinus virginiana	scrub pine		5, 6	no	H	N	10-20'	15-40'	full sun	Philadelphia County	C	tolerant of poor sterile soils; beautiful golden foliage in winter
tree	Platanus occidentalis	sycamore	FACW-	3, 4, 5	seasonal	L	N	75-100'	75-100'	full sun-part shade	Philadelphia County	C	compaction resistant
tree	Populus deltoides	cottonwood	FACU-	3, 4, 5	seasonal	L	L	35-60'	75-100'	full sun	Philadelphia County	C	compaction resistant; pioneer species
tree	Populus grandidentata	large-toothed aspen	FACU-	4, 5, 6	no	L	N	20-30'	50-70'	full sun	Philadelphia County	C	compaction sensitive; pioneer species
tree	Populus tremuloides	quaking aspen	FACU	4, 5, 6	seasonal	L	N	20-30'	35-50'	full sun	Philadelphia County	C	compaction sensitive; pioneer species
tree	Prunus serotina	black cherry	FACU	4, 5, 6	no	M	N	30-60'	50-60'	full sun	Philadelphia County	C	compaction intolerant; pioneer species
tree	Quercus alba	white oak	FACU	4, 5, 6	no	M	M	50-80'	50-80'	full sun-part shade	Philadelphia County	C	compaction very sensitive; acidic soils; long lived
tree	Quercus bicolor	swamp white oak	FACW+	2, 3, 4, 5	seasonal	L	L	50-60'	50-60'	full sun-part shade	Philadelphia County	C	compaction resistant
tree	Quercus coccinea	scarlet oak		5, 6	no	M	N	40-50'	50-75'	full sun	Philadelphia County	C	compaction intolerant, long lived, nice fall color
tree	Quercus falcata	southern red oak	FACU-	6	no	H	N	50-60'	70-80'	full sun-part shade	Philadelphia County	C	high winter wildlife value; found in dry to moist woods
tree	Quercus marilandica	blackjack oak		5, 6	no	H	L	15-40'	30-40'	full sun	Philadelphia County	C	very flood intolerant; compaction sensitive
tree	Quercus palustris	pin oak	FACW	(3) 4, 5, 6	seasonal	L	N	40-60'	60-70'	full sun	Philadelphia County	C	acidic well drained soils; compaction resistant; good street tree
tree	Quercus phellos	willow oak	FACU-	(3, 4) 5	seasonal	N	N	25-50'	40-60'	full sun-part shade	Philadelphia County	C	acidic soils; tolerates poor drainage; compaction tolerant
tree	Quercus rubra	red oak	FACU-	5, 6	no	M	M	50-75'	60-75'	full sun	Philadelphia County	C	acidic soils; compaction and pollution tolerant
tree	Quercus velutina	black oak		5, 6	no	L	N	40-50'	50-60'	full sun-part shade	Philadelphia County	C	compaction intolerant; acidic soils
tree	Salix nigra	black willow	FACW+	(2, 3) 4	seasonal	L	N	20-35'	35-50'	full sun	Philadelphia County	C	compaction resistant
tree	Sassafras albidum	sassafras	FACU	6	no	H	N	25-40'	30-60'	full sun-part shade	Philadelphia County	C	compaction intolerant; pioneer species; flood intolerant
tree	Tilia americana	basswood	FACU	(4, 5) 6	no	M	N	30-50'	60-80'	full sun-part shade	Philadelphia County	C	compaction sensitive; fragrant pale yellow spring flowers
tree	Ulmus americana	american elm	FACW-	(3) 4, 5, 6	seasonal	H	H	50-75'	60-90'	full sun	Philadelphia County	C	rare due to Dutch elm disease; new resistant stock; graceful vase form
tree	Ulmus rubra	slippery elm	FAC-	(3) 4, 5, 6	seasonal	H	H	50-75'	60-90'	full sun-part shade	Philadelphia County	C	seeds are eaten by birds and small mammals; shade tolerant
	*** WETLAND INDICATOR (probability of occurring in a wetland):**												
	OBL	Obligate wetland species	99%										
	FACW	Facultative wetland species	67-99%										
	FAC	Facultative species	34-66%										
	FACU	Facultative upland species	1-33%										
	UPL	Upland species	1%										
	(+)	indicates that the species occurs in the higher portion of the range											
	(-)	indicates that the species occurs in the lower portion of the range											
	Those species with no wetland indicator are virtually intolerant of flooding or prolonged soil saturation during the growing season.												
	**** HYDROLOGIC ZONES**												
	Zone 1: Open water - Permanent pool (12 inches - 6 feet)												
	This zone is best colonized by submergent plants, if at all. This deep water												
	zone is not usually planted for several reasons: there are few species that can grow												
	in this zone, and many are not commercially available; open water areas provide												
	unique habitat; and deep water aquatic plants may clog the stormwater facility												
	outlet structure. The benefits of planting in this zone include the absorption of												
	nutrients in the water column; enhanced sediment deposition; improved oxidation;												
	and the creation of additional habitat.												
	Zone 2: Shallow water terrace/Aquatic bench (6 inches -1 foot)												
	This zone offers ideal conditions for a wide variety of emergent wetland plants. These												
	areas typically fringe the ponding area and are permanently inundated.												
	Zone 3: BMP Fringe - Low marsh (0-6 inches regular inundation)												
	This zone is typically the shoreline of a pond or wetland - its width determined by the												

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
	design slope. This zone is usually inundated except during periods of drought and is the												
	interface between the emergent wetland plantings and the upland plantings. Plants must												
	be able to withstand periods of inundation as well as periods of drought and should												
	have some capacity for slope stabilization.												
	Zone 4: BMP Fringe - High Marsh (periodic inundation, saturated soils)												
	This zone extends upslope from zone 3 and may be inundated after storms. It constitutes												
	the majority of the temporary extended detention area. Plants selected should be able												
	to withstand periodic inundation after storms as well as significant drought during the												
	summer.												
	Zone 5: Floodplain terrace (infrequent inundation, temporarily saturated soils)												
	Zone 5 is infrequently saturated by floodwaters that quickly recede in a day or less.												
	Plants should be able to withstand infrequent inundation as well as drought and should												
	offer some slope stabilization.												
	Zone 6: Upland (never inundated)												
	This zone extends above the maximum design water surface elevation. Plant												
	selection should be based on local soil and light conditions, and on the amount												
	of available space for plantings.												
	REFERENCES:												
	The Plants of Pennsylvania: An Illustrated Manual , Ann Rhoads, Timothy Block, Anna Anisko												
	Fairmount Park Commission: Selected Trees & Shrubs Native to Philadelphia County (brochure)												
	Fairmount Park Commission: Selected Wildflowers, Ferns, Grasses, Sedges, & Rushes Native to Philadelphia County (brochure)												
	Website: U.S. Department of Agriculture, Natural Resources Conservation Service: PLANTS Database http://plants.usda.gov/												
	Website: The Kemper Center for Home Gardening: PlantFinder http://www.mobot.org/gardeninghelp/plantfinder/Alpha.asp												
	Website: Plants of the North: http://www.rook.org/earl/bwca/nature/flora.html												
	Website: NC State University Plant Factsheets http://www.ces.ncsu.edu/depts/hort/consumer/factsheets/index.html												
	Website: University of Connectict Plant Database http://www.hort.uconn.edu/plants/index.html												
	Website: USDA Forest Service: Silvics of North America http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm												

8.4 Prohibited Non-native and Invasive Plants

Invasive non-native plants reproduce rapidly, degrade and take over natural ecosystems and have few, if any natural controls to keep them in check. Brought in to new areas by people for a specific purpose or by accident these species have characteristics that allow them to grow out of control and usually favor disturbed sites like areas of new construction. Under no circumstance should they be planted in a SMP. Because of appealing characteristics, some of these plants are available for sale and care should be taken not to purchase them. Additionally, the ability to identify and remove them before they can establish themselves is important as they almost always invade due to their gregarious reproductive strategies. They can be especially hard to get rid of once they take hold. Table 3 lists common invaders for the Mid-Atlantic region.

Table 8.3: Common Invasive Species of the Mid-Atlantic Region

Type	Latin Name	Common Name	Availability
forb	*Hemerocallis fulva*	Common daylily	commercially available
forb	*Alliaria petiolata*	Garlic mustard	
forb	*Polygonum cuspidatum*	Japanese knotweed	
forb	*Ranunculs ficaria*	Lesser celadine	
forb	*Lythrum salicaria*	Purple loosetrife	
forb	*Cirsium arvense*	Canada thistle	
forb	*Lespedeza cuneata*	Chinese lespedeza	
forb	*Heracleum mantegazzianum*	Giant hogweed	
forb	*Murdannia keisak*	Marsh dewflower	
forb	*Centaurea biebersteinii*	Spotted knapweed	
grass	*Bambusa, Phyllostachys, Pseudosassa*	Bamboo	commercially available
grass	*Microstegium vimineum*	Japanese stiltgrass	
grass	*Miscanthus sinensis*	Chinese silvergrass	
grass-like	*Phragmites australis*	Common reed	
grass-like	*Arundo donax*	Giant reed- wild cane	
shrub	*Berberis thunbergii*	Japanese barberry	commercially available
shrub	*Ligustrum spp.*	Privets	commercially available
shrub	*Euonymus alata*	Winged burning bush	commercially available
shrub	*Buddleja davidii*	Butterfly bush	commercially available
shrub	*Spiraea japonica*	Japanese spiraea - Japanese meadowsweet	commercially available
shrub	*Elaeagnus umbellata*	Autumn olive	
shrub	*Lonicera spp.*	Bush honeysuckles	commercially available
shrub	*Rosa multiflora*	Mulitflora rose	
shrub	*Rubus phoenicolasius*	Wineberry	
shrub	*Rhodotypos scandens*	Jetbead	
Tree	*Pyrus calleryana 'Bradford'*	Bradford pear	commercially available
Tree	*Acer platanoides*	Norway maple	commercially available
Tree	*Quercus acutissima*	Sawtooth oak	commercially available
Tree	*Paulownia tomentosa*	Princess tree	
Tree	*Ailanthus altissima*	Tree of Heaven	
Tree	*Albizia julibrissin*	Silk tree - mimosa tree	commercially available
Tree	*Broussonetia papyrifera*	Paper mulberry	
Tree	*Morus alba*	White mulberry	
Vine	*Hedera helix*	English Ivy	commercially available
Vine	*Wisteria sinensis, W. floribunda*	Wisteria, exotic	commercially available
Vine	*Eunonymus fortunei*	Creeping euonymus	commercially available
Vine	*Lonicera japonica*	Japanese honeysuckle	commercially available

Table 8.3: Common Invasive Species of the Mid-Atlantic Region (continued)			
Type	**Latin Name**	**Common Name**	**Availability**
Vine	*Vinca minor*	Periwinkle	commercially available
Vine	*Pueraria montana v. lobata*	Kudzu	
Vine	*Polygonum perfoliatum*	Mile-a-minute	
Vine	*Celastrus orbiculatus*	Oriental bittersweet	
Vine	*Ampelopsis brevipedunculata*	Porcelain berry	commercially available
Vine	*Akebia quinata*	Five-leaved akebia	
Vine	*Cynanchum louiseae*	Louis' swallowwort	

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Appendices

A. Hotspot Investigation Procedures

B. Soil Infiltration Testing Procedures

C. Geotechnical Investigation (Subsurface Stability) Procedures

D. Maps: Zones for Acceptable Practices

E. Worksheets and Checklists

F. Regulatory Guidance

- F.1 The Philadelphia Stormwater Management Regulations
- F.2 Local Permitting Requirements
- F.3 Federal and State Permitting Requirements
- F.4 Special Circumstances and Waiver Requests
- F.5 PWD Review Policies

G. Case Studies

H. Abbreviations & Acronyms

I. Glossary

J. References

K. Voluntary Small Sites Checklist

L. Homeowner's Guide to Stormwater Management

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A

Hotspot Investigation Procedures

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Appendix A: Hotspot Investigation Procedures

A.1 Justification

This policy is intended to encourage infiltration on most sites while addressing potential contamination of groundwater and surface water caused by infiltration on sites with contaminated soils.

A.2 Required Steps

Step 1: Determine the prior land use at the site to be developed, and review any data on soil or groundwater quality.

• For larger development sites, a formal Phase I site assessment is often required by the lender in order to determine if any environmental hazard exists on the site. A determination of prior land use is part of this assessment.

• On sites where a formal Phase I is not conducted, methods to determine prior land use may include a title search, aerial photographs, soil surveys, topographic maps, city and state regulatory databases, and a review of state and local records.

Step 2: Determine the potential for contamination based on available data and prior land use.

• The following land uses are considered to have a potential for contaminated soil which may adversely affect the quality of groundwater discharging to surface water. Infiltration is prohibited on these site unless the applicant can show that there is no potential for contaminant migration due to infiltration.

- Sites designated as CERCLA (Superfund) sites
- Auto recycler facilities and junk yards
- Commercial laundry and dry cleaning
- Commercial nurseries
- Vehicle fueling stations, service and maintenance areas
- Toxic chemical manufacturing and storage
- Petroleum storage and refining
- Public works storage areas
- Airports and deicing facilities, railroads and rail yards, marinas and ports
- Heavy manufacturing and power generation
- Metal production, plating and engraving operations
- Landfills and hazardous waste material disposal
- Sites on subsurface material such as fly ash known to contain mobile heavy metals and toxins

Step 3: For sites that do not qualify as hotspots, proceed with design of infiltration facilities including pre-treatment. For hotspots, proceed with design of water quality treatment facilities. For sites not identified as a hot spot under Step 2, an infiltration waiver can be requested if sufficient proof of soil contamination is provided based on soil sampling results.

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Soil Infiltration Testing Procedures

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Appendix B: Soil Infiltration Testing Procedures

B.1 Justification

This policy is intended to provide standard methods for use in determining the infiltration rate of liquid into soils.

B.2 Required Steps

Designers are required to use the soil infiltration testing procedures described by American Standard Testing Methods (ASTM) in their “Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer” or as set forth by the Pennsylvania Stormwater Best Management Practices Manual.

B.3 Summary of Acceptable Soil Infiltration Testing

The purpose of **Appendix B** is to provide potential field infiltration testing methods to be utilized for the design of infiltration facilities. In an effort to maintain congruency between the Pennsylvania Department of Environmental Protection (PADEP) and the Philadelphia Water Department (PWD) regarding stormwater/infiltration practices, **Appendix C**: Site Evaluation and Soil Testing of the Pennsylvania Stormwater Management Manual has been attached and is incorporated into this document.

There are a variety of field tests available to determine the design field infiltration rate at a given site. This Appendix outlines the procedures to perform two methods of infiltration: Double-Ring Infiltrometers and Percolation Tests.

A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area, while a percolation test allows water movement through both the bottom and sides of the test area. As such, double-ring infiltrometer tests are considered to more accurately model the potential infiltration capacity of a soil. However, it is understood that for a large site with multiple test locations, double-ring infiltrometer tests can be cost prohibitive.

Key points for the two methods are summarized below.

Double-Ring Infiltrometer

- Double-Ring infiltrometer testing methodology is provided in ASTM D 3385.
- Two concentric metal rings are driven into the ground and filled with water. The outer ring helps to reduce lateral movement of water in the soil while the inner ring is used to calculate an infiltration rate.
- Test holes must be presoaked immediately prior to testing. The presoaking procedure is intended to simulate saturated conditions in the environment and to minimize the influence of unsaturated flow.
- The test must be performed for at least 6 hours or a length of time adequate for the infiltration rate to stabilize.
- It is strongly advised that a double-ring infiltration test be performed instead of a percolation test for proposed infiltration basins.

Percolation Tests

- Percolation test methodology is based on the criteria written in Chapter 73 of the Pennsylvania Code. The procedure is also included in the Pennsylvania Stormwater Manual included with this Appendix.

- A percolation test allows water movement through both the bottom and sides of the test area. Percolation tests are generally utilized in areas where both horizontal and vertical infiltration is expected.

- Percolation tests carried out betwen June 1 and December 31 should use a 24 hour presoaking before the testing.

- All test holes should be presoaked immediately prior to testing. The presoaking procedure is intended to simulate saturated conditions in the environment and to minimize the influence of unsaturated flow.

- The test infiltration rate from a percolation test is obtained by dividing the percolation rate by the appropriate reduction factor. This calculation is explained in detail in the following section.

Generally, a minimum of two tests should be performed per infiltration area. At least one test should be conducted at the proposed bottom elevation of an infiltration BMP. More tests may be warranted if the results for the first two tests are substantially different. The highest infiltration rate from the test results should be discarded when more than two are employed for design purposes. The geometric mean should be used to determine the average rate following multiple tests.

The presence of massive rock in relatively close proximity to the point of infiltration may result in lateral, as opposed to vertical infiltration if the rock is not sufficiently jointed and/or fissured to infiltrate. This can potentially result in water migrating and then reappearing at topographic low areas. Therefore, if rock is present within 5 feet of the proposed base of the infiltration basin, the designer must provide adequate information to document that the water is infiltrating vertically and not traveling laterally along the top of rock surface.

Other testing procedures may be used if site conditions make double-ring infiltrometer and percolations tests infeasible. In such cases, a waiver requesting approval of an alternate testing procedure must be submitted. It is recommended that this waiver be submitted before the testing is performed. Refer to http://www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent waiver forms.

Pennsylvania Stormwater Best Management Practices Manual

Appendix C – Site Evaluation and Soil Testing



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Protocol 1
Site Evaluation and Soil Infiltration Testing

A. Purpose of this Protocol

The purpose of the *Site Evaluation and Soil Infiltration Testing Protocol* is to describe evaluation and field testing procedures to:

a. Determine if Infiltration BMPs are suitable at a site, and at what locations.
b. Obtain the required data for infiltration BMP design.

B. When to Conduct Testing

Designers are encouraged to conduct the Soil Evaluation and Investigation early in the site planning and design process. The Site Development process outlined in Chapters 4 and 5 of this Manual describe a process for site development and BMPs. Soil Evaluation and Investigation should be conducted early in the preliminary design of the project so that information developed in the testing process can be incorporated into the design. Adjustments to the design can be made as necessary. It is recommended that Soil Evaluation and Investigation be conducted following the development of an early Preliminary Plan. The Designer should possess a preliminary understanding of potential BMP locations prior to testing. Prescreening test may be carried out in advance to site potential BMP locations.

C. Who Should Conduct Testing

Qualified professionals who can substantiate by qualifications/experience their ability carry out the evaluation should conduct test pit soil evaluations. A professional, experienced in observing and evaluating soils conditions is necessary to ascertain conditions that might affect BMP performance, which can not be thoroughly assessed with the testing procedures. Such professionals must conduct these evaluations in risk areas, or areas indicated in the guidance as non-preferred locations for testing or BMP implementation.

D. Importance of Stormwater BMP Areas

Sites are often defined as unsuitable for Infiltration BMPs and soil based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas should be identified early in the design process and should not be subject to a building program that precludes infiltration BMPs. An exemption should not be provided for “full build-outs” where suitable soils otherwise exist for infiltration.

E. Safety

As with all field work and testing, attention should be given to all applicable OSHA regulations and local guidelines related to earthwork and excavation. Digging and excavation should never be conducted without adequate notification through the Pennsylvania One Call system (**PA OneCall** 1-800-242-1776 or www.paonecall.org). Excavations should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work.

INFILTRATION TESTING: A MULTI-STEP PROCESS

Infiltration Testing is a four-step process to obtain the necessary data for the design of the stormwater management plan. The four steps include:

1. Background Evaluation
    - Based on available published and site specific data
    - Includes consideration of proposed development plan
    - Used to identify potential BMP locations and testing locations
    - Prior to field work (desktop)
    - On-site screening test
2. Test Pit (Deep Hole) Observation
    - Includes Multiple Testing Locations
    - Provides an understanding of sub-surface conditions
    - Identifies limiting conditions
3. Infiltration Testing
    - Must be conducted on-site
    - Different testing methods available
    - Alternate methods for - additional-Screening and Verification testing
4. Design Considerations
    - Determination of a suitable infiltration rate for design calculations
    - Consideration of BMP drawdown
    - Consideration of peak rate attenuation

Step 1. Background Evaluation

Prior to performing testing and developing a detailed site plan, existing conditions at the site should be inventoried and mapped including, but not limited to:

- Existing mapped individual soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including the location of any dikes, faults, fracture traces, solution cavities, landslide prone strata, or other features of note.
- Existing streams (perennial and intermittent, including intermittent swales), water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters and 1st order streams.
- Existing topography, slope, and drainage patterns.
- Existing and previous land uses.
- Other natural or man-made features or conditions that may impact design, such as past uses of site, existing nearby structures (buildings, walls), etc.

A sketch plan or preliminary layout plan for development should be evaluated, including:

- The preliminary grading plan and areas of cut and fill.
- The location and water surface elevation of all existing and location of proposed water supply sources and wells.
- The location of all existing and proposed on-site wastewater systems.
- The location of other features of note such as utility right-of-ways, water and sewer lines, etc.
- Existing data such as structural borings, drillings, and geophysical testing.

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- The proposed location of development features (buildings, roads, utilities, walls, etc.). In Step 1, the Designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be located on the proposed development plan and should serve as the basis for the location and number of tests to be performed on-site.

Important: If the proposed development program is located on areas that may otherwise be suitable for BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the Designer is *strongly* encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary. Full build-out of areas suitable for infiltration BMPs should *not* preclude the use of BMPs for volume reduction and groundwater recharge.

Step 2. Test Pits (Deep Holes)

A Test Pit (Deep Hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. An extensive number of Test Pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for Test Pits strongly is discouraged, as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings. Borings and other procedures, however, might be suitable for initial screening to develop a preliminary plan for testing, or verification testing.

A Test Pit consists of a backhoe-excavated trench, 2-1/2 to 3 feet wide, to a depth of between 72 inches and 90 inches, or until bedrock or fully saturated conditions are encountered. The trench should be benched at a depth of 2-3 feet for access and/or infiltration testing.

At each Test Pit, the following conditions shall be noted and described. Depth measurements should be described as depth below the ground surface:

___ Soil Horizons (upper and lower boundary)

___ Soil Texture and Color for each horizon

___ Color Patterns (mottling) and observed depth

___ Depth to Water Table

___ Depth to Bedrock

___ Observance of Pores or Roots (size, depth)

___ Estimated Type and Percent Coarse Fragments

___ Hardpan or Limiting Layers

___ Strike and dip of horizons (especially lateral direction of flow at limiting layers)

___ Additional comments or observations

The Sample Soil Log Form at the end of this protocol may be used for documentation of each Test Pit.

At the Designer's discretion, soil samples may be collected at various horizons for additional analysis. Following testing, the test pits should be refilled with the original soil and the surface replaced with the original topsoil. A Test Pit should *never* be accessed if soil conditions are unsuitable for safe entry, or if site constraints preclude entry. OSHA regulations should always be observed.

It is important that the Test Pit provide information related to conditions at the bottom of the proposed Infiltration BMP. If the BMP depth will be greater than 90 inches below existing grade, deeper excavation will be required. However, *such depths are discouraged, especially in Karst topography.* Except for surface discharge BMPs (filter strips, etc.) the designer is cautioned regarding the proposal of systems that are significantly lower than the existing topography. The suitability for infiltration may decrease, and risk factors are likely to increase. *Locations that are not preferred* for testing *and* subsurface infiltration BMPs include swales, the toe of slopes for most sites, and soil mantels of less than three feet in Karst topography.

The designer and contractors should reducing grading and earthwork as needed to reduce site disturbance and compaction so that a greater opportunity exists for testing and stormwater management.

The number of Test Pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot BMPs, one test pit per lot is recommended, preferably within 25 feet of the proposed BMP area. Verification testing should take place when BMPs are sited at greater distances.
- For multi-family and high density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four (4) to six (6) tests per acre of BMP area.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction is not recommended.

Step 3. Infiltration Tests/Permeability Tests

A variety of field tests exist for determining the infiltration capacity of a soil. Laboratory tests are strongly discouraged, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Tests should not be conducted in the rain or within 24 hours of significant rainfall events (>0.5 inches), or when the temperature is below

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freezing. However, the preferred testing *is* between January and June, the wet season. This is the period when infiltration is likely to be diminished by saturated conditions. Percolation tests carried out between June 1 and December 31 should use a 24 hour presoaking before the testing. This procedure is not required for Infiltrometer testing, or permeometer testing

At least one test should be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per Test Pit is recommended. More tests may be warranted if the results for first two tests are substantially different. The highest rate (inches/hour) for test results should be discarded when more than two are employed for design purposes. The geometric mean should be used to determine the average rate following multiple tests.

Based on observed field conditions, the Designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting Infiltration Tests should be prepared to adjust test locations and depths depending upon observed conditions.

Methodologies discussed in this protocol include:

- Double-ring Infiltrometer tests.
- Percolation tests (such as for on-site wastewater systems and described in Pa Code Chapter 73).

There are differences between the two methods. A Double-ring Infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test must be adjusted to represent the discharge that is occurring on both the bottom and sides of the percolation test hole.

For *infiltration basins*, it is *strongly* advised that an Infiltration Test be carried out with an infiltrometer (not percolation test) to determine the saturated hydraulic conductivity rate. This precaution is taken to account for the fact that only the surface of the basin functions to infiltrate, as measured by the test. Alternatively, permeability test procedures that yield a saturated hydraulic conductivity rate can be used (see formulas developed by Elrick and Reynolds (1992), or others for computation of hydraulic conductivity and saturated hydraulic conductivity).

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer
- Testing as described in the Maryland Stormwater Manual Appendix D.1 using 5-inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093-90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph Permeameter
- Constant Head Permeameter (Amoozemeter)

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a. Methodology for Double-Ring Infiltrometer Field Test

A Double-ring Infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils. The diameter of the inner ring should be approximately 50% to 70% of the diameter of the outer ring, with a minimum inner ring size of 4-inches, preferably much larger. (Bouwer, 1986). Double-ring infiltrometer testing equipment that is designed specifically for that purpose may be purchased. However, field testing for stormwater BMP design may also be conducted with readily available materials.

Equipment for Double-Ring Infiltrometer Test:

___ Two concentric cylinder rings 6-inches or greater in height. Inner ring diameter equal to 50% - 70% of outer ring diameter (i.e., an 8-inch ring and a 12-inch ring). Material typically available at a hardware store may be acceptable.

___ Water supply

___ Stopwatch or timer

___ Ruler or metal measuring tape

___ Flat wooden board for driving cylinders uniformly into soil

___ Rubber mallet

___ Log sheets for recording data

Procedure for Double-Ring Infiltrometer Test

___ Prepare level testing area.

___ Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two inches.

___ Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of two inches. The bottom rim of both rings should be at the same level.

___ The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30 minute intervals for 1 hour. The minimum water depth should be 4-inches. The drop in the water level during the

last 30 minutes of the presoaking period should be applied to the following standard to determine the time interval between readings:

- If water level drop is 2-inches or more, use 10-minute measurement intervals.
- If water level drop is less than 2-inches, use 30-minute measurement intervals.

___ Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring shall be made from a fixed reference point and shall continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 1/4 inch or less of drop between the highest and lowest readings of four consecutive readings.

___ The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, shall represent the infiltration rate for that test location.

b. Methodology for Percolation Test

Equipment for Percolation Test:

___ Post hole digger or auger

___ Water supply

___ Stopwatch or timer

___ Ruler or metal measuring tape

___ Log sheets for recording data

___ Knife blade or sharp-pointed instrument (for soil scarification)

___ Course sand or fine gravel

___ Object for fixed-reference point during measurement (nail, toothpick, etc.)

Procedure for Percolation Test

This percolation test methodology is based largely on the Pennsylvania Department of Environmental Protection (PADEP) criteria for on-site sewage investigation of soils (as described in Chapter 73 of the Pennsylvania Code). This should include the 24 hour presoak procedure between June 1 and December 31. The presoak is done primarily to simulate saturated conditions in the environment (generally Spring) and to minimize the influence of

unsaturated flow. If a presoak procedure is not employed between June1 and December 31, than the rate reduction formula described by Elrick and Reynolds (1992), or Fritton, et.,al. (1986) is recommended to account for the influence of unsaturated conditions in the test.

Prepare level testing area.

___ Prepare hole having a uniform diameter of 6 to 10 inches and a depth of 8 to 12-inches. The bottom and sides of the hole should be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.

___ (Optional) two inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.

___ Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of 6 inches over the bottom and readjusted every 30 minutes for 1 hour.

___ The drop in the water level during the last 30 minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:

- If water remains in the hole, the interval for readings during the percolation test should be 30 minutes.
- If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.

___ After the final presoaking period, water in the hole should again be adjusted to a minimum depth of 6-inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.

___ Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 1/4 inch or less of drop between the highest and lowest readings of four consecutive readings.

___ The drop that occurs in the percolation hole during the final period, expressed as inches per hour, shall represent the percolation rate for that test location.

___ The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average/final percolation rate should be adjusted for each percolation test according to the following formula:

Infiltration Rate = (Percolation Rate) / (Reduction Factor)

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Where the Reduction Factor is given by**:

$$R_f = \frac{2d_1 - \Delta d}{DIA} + 1$$

With:

d_1	=	Initial Water Depth (in.)
Δd	=	Average/Final Water Level Drop (in.)
DIA	=	Diameter of the Percolation Hole (in.)

The Percolation Rate is simply divided by the Reduction Factor as calculated above or shown in the table below to yield the representative Infiltration Rate. In most cases, the Reduction Factor varies from about 2 to 4 depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower Reduction Factors because proportionately less water exfiltrates through the sides. For design purposes additional safety factors are employed (see Protocol 2, Infiltration Systems Design and Construction Guidelines)

*** The area Reduction Factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.*

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Table 1. Sample Percolation Rate Adjustments

Perc. Hole Diameter, DIA (in.)	Initial Water Depth, d_1 (in.)	Ave./Final Water Level Drop, Δd (in.)	Reduction Factor, R_f
6	**6**	0.1	3.0
		0.5	2.9
		2.5	2.6
	8	0.1	3.7
		0.5	3.6
		2.5	3.3
	10	0.1	4.3
		0.5	4.3
		2.5	3.9
8	**6**	0.1	2.5
		0.5	2.4
		2.5	2.2
	8	0.1	3.0
		0.5	2.9
		2.5	2.7
	10	0.1	3.5
		0.5	3.4
		2.5	3.2
10	**6**	0.1	2.2
		0.5	2.2
		2.5	2.0
	8	0.1	2.6
		0.5	2.6
		2.5	2.4
	10	0.1	3.0
		0.5	3.0
		2.5	2.8

Step 4. Design Considerations beginning with *Protocol 2 – Infiltration System Design and Construction Guidelines*

ADDITIONAL POSSIBLE TESTING - BULK DENSITY, OTHERS

Other testing methods are acceptable to assess a soil's suitability for infiltration for early screening and occasionally for verification. They can be especially helpful where consultants wish to cull out the better soils. Percolation testing can also be performed without presoaking as a *pre*-screening procedure.

Alternate tests or investigations can be used for verification. For instance, if the BMPs are not located precisely over the test locations, alternate testing or investigations can be used to verify that the soils are the same as the soils that yielded the earlier test results. However, consultants should document these verification test results or investigations. Professionals with substantiated qualifications should carry out verification procedures.

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Bulk Density Tests measure the level of compaction of a soil, which is an indicator of a soils' ability to absorb rainfall. Developed and urbanized sites often have very high bulk densities and therefore possess limited ability to absorb rainfall (and have high rates of stormwater runoff). Vegetative and soil improvement programs can improve, (i.e. lower), the soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Macropores occur primarily in the upper soil horizons and are formed by plant roots (both living and decaying), soil fauna such as insects, the weathering processes caused by the movement of water, the freeze-thaw cycle, soil shrinkage due to desiccation of clays, chemical processes, and other mechanisms. These macropores provide an important mechanism for infiltration prior to development, extending vertically and horizontally for considerable distances. It is the intent of good engineering and design practice to maintain these macropores in the installation of Infiltration BMPs as much as possible. Bulk Density Tests can help determine the relative compaction of soils before and after site disturbance and/or restoration and should be used at the discretion of the designer/reviewer.

Various procedures are available to conduct bulk density tests. The density measurements should be carried out in conjunction with a soil texture analysis. Sandy soils infiltrate well, but tend to have a somewhat higher bulk density than finer soils. Experienced personnel can do the texture analysis manually on site.

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Sample Soil Log

Tested by: _____ Date: _____ Elevation: _____ Equipment Used: _____

Test Pit: _____ Soil Type: _____ Land Use: _____ Weather: _____

Geology: _____

Additional comments: _____

Horizon	Upper Boundary	Lower Boundary	Soil Textural Class	Type, Size, Coarse Fragments, etc.	Soil Color	Color Patterns	Pores, Roots, Rock Structure	Depth to Bedrock	Depth to Water	Comments

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Protocol 2
Infiltration Systems Design and Construction Guidelines

Role of Infiltration BMPs

The phrase "infiltration BMPs" describes a wide range of stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon and eventually into deeper groundwater. In this manual the major infiltration strategies are grouped into four categories or types, based on construction and performance similarities:

- Surface Infiltration Basins
- Subsurface Infiltration Beds
- Bioretention Areas/Rain Gardens
- Other BMPs that support infiltration (vegetated filter/buffer strips, level spreaders, and vegetated swales)

Infiltration BMPs are one of the most beneficial approaches to stormwater management for a variety of reasons including:

- Reduction of the peak rate of runoff
- Reduction of the volume of runoff
- Removal of a significant portion of the particulate-associated pollutants and some portion of the solute pollutants.
- Recharge of groundwater and maintenance of stream baseflow.

Infiltration BMPs attempt to replicate the natural hydrologic regime. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events. During periods of reduced rainfall, this recharged water serves to provide baseflow to streams and maintain in-stream water quality. Qualitatively, infiltration BMPs are known to remove nonpoint source pollutants from runoff through a complex mix of physical, chemical, and biological removal processes. Infiltration promotes maintenance of the natural temperature regimes of stream systems (cooler in summer, warmer in winter), which can be critical to the aquatic ecology. Because of the ability of infiltration BMPs to reduce the volume of runoff, there is also a corresponding reduction in erosive "bankfull" conditions and downstream erosion and channel morphology changes.

Infiltration BMPs are designed to infiltrate some portion of runoff during every runoff event. During small storm events, a large percentage of the runoff may infiltrate, whereas during large storm events, the volume that infiltrates may only be a small portion of the total runoff. However, because most of the rainfall in Pennsylvania occurs in small (less than 1-inch) rainfalls, the annual benefits of an infiltration system may be significant.

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Purpose of Protocol 2: Infiltration Systems Guidelines
The purpose of this protocol is to provide the designer with specific guidelines for the successful construction and long-term performance of Infiltration BMPs. These guidelines fall into three categories:

1. Site conditions and constraints
2. Design considerations
3. Construction requirements

All of these guidelines are important, and successful infiltration is dependent on careful consideration of site conditions, careful design, and careful construction.

1. SITE CONDITIONS and CONSTRAINTS

a) It is desirable to **maintain a 2-foot clearance above regularly occurring seasonally high water table**. This reduces the likelihood that temporary groundwater mounding will affect the system, and allows sufficient distance of water movement through the soil to allow adequate pollutant removal. Some minor exceptions for very shallow systems and on grade systems, filter strips, buffers, etc.

b) **Maintain a minimum depth to bedrock of 2-feet to assure adequate pollutant removal**. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist.

c) It is desired that **soils underlying infiltration devices should have infiltration rates between 0.1 and 10 inches per hour**, which in most development programs should result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible but the surface area required could be large, and other volume reduction methods may be warranted. Undisturbed Hydrologic Soil Groups B and C often fall within this range and cover most of the state. Soils with rates in excess of 6.0 inches per hour may require an additional soil buffer (such as an organic layer over the bed bottom) if the Cation Exchange Capacity (CEC) is less than 5 and pollutant loading is expected to be significant. In carbonate soils, excessively rapid drainage may increase the risk of sinkhole formation, and some compaction or additional soil may be appropriate.

d) **Infiltration BMPs should be sited so that any risk to groundwater quality is minimized**, at least 50 feet from individual water supply wells, and 100 feet from community or municipal water supply wells. Horizontal separation distances or buffers may also be appropriate from Special Geologic Features, such as fractures traces and faults, depending on water supply sources.

e) **Infiltration BMPs should be sited so that they present no threat to sub-surface structures**, at least 10 feet down gradient or 100 feet up gradient from building basement foundations, and 50 feet from septic system drain fields unless specific circumstances allow for reduced separation distances.

In general, soils of Hydrologic Soil Group D will not be suitable for infiltration. Similarly, areas of floodplains and areas of close proximity to wetlands and streams will generally not be suitable

for infiltration (due to high water table and/or low permeability). In developing areas that were previously used for agricultural purposes, the designer should consider the past patterns of land use. Areas that were suitable for cultivation will likely be suitable for some level of infiltration. Areas that were left out of cultivation often indicate locations that are too wet or too rocky, and will likely not be suitable for infiltration.

2. DESIGN CONSIDERATIONS

a) **Do Not Infiltrate in Compacted Fill.** Infiltration in native soil without prior fill or disturbance is preferred but not always possible**.** Areas that have experienced historic disturbance or fill are suitable for infiltration provided sufficient time has elapsed and the Soil Testing indicates the infiltration is feasible. In disturbed areas it may be necessary to infiltrate at a depth that is beneath soils that have previously been compacted by construction methods or long periods of mowing, often 18-inches.

b) **A Level Infiltration Area (1% or less slope) is preferred.** Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. Infiltration areas should be flat, nearly so, or on contour.

c) **The soil mantle should be preserved to the maximum extent possible**, and excavation should be minimized. Those soils that do not need to be disturbed for the building program should be left undisturbed. Macropores can provide a significant mechanism for water movement in infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle also increases the pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

d) **Isolate "hot spot areas"**. Site plans that include 'hot spots' need to be considered. 'Hot spots' are most often associated with some industrial uses and high traffic – gasoline stations, vehicle maintenance areas, and high intensity commercial uses (fast food restaurants, convenience stores, etc.). These "hot spots" are defined in Section 3.3, Stormwater Standards for Special Areas. Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns. Pretreatment requirements need to be analyzed, especially for 'hot spots' and areas that produce high sediment loading. Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. The pollutants of greatest concern, site by site, should guide selection of pretreatment depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether the pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.

e) **The Loading Ratio of impervious area to bed bottom area must be considered**. One of the more common reasons for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration

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systems work best when the water is "spread out". The Loading Ratio describes the ratio of imperious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following Loading Ratio guidelines are recommended:

- Maximum Impervious Loading Ratio of 5:1 relating impervious drainage area to infiltration area.
- A Maximum Total Loading Ratio of 8:1 relating total drainage area to infiltration area.
- Maximum Impervious Loading Ratio of 3:1 relating impervious drainage area to infiltration area for Karst areas.

f) **The Hydraulic Head or Depth of Water should be limited**. The total effective depth of water should generally not be greater than two feet to avoid excessive pressure and potential sealing of the bed bottom. Typically the water depth is limited by the Loading Ratio and Drawdown Time and is not an issue.

g) **Drawdown Time must be considered**. In general, infiltration BMPs should be designed so that they completely empty within the time period specified in Chapter 3.

h) **All infiltration BMPs should be designed with a positive overflow** that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration in all situations.

i) **Geotextiles should be incorporated into the design as necessary in certain infiltration BMPs**. Infiltration BMPs that are subject to soil movement and deposition must be constructed with suitably well-draining non-woven geotextiles to prevent to movement of fines and sediment into the infiltration system. The designer is encouraged to err on the side of caution and use geotextiles as necessary at the soil/BMP interface.

j) Avoid severe slopes (>20%), and toes of slopes, where possible. Specific on-site investigations by experienced personnel need to be made to determined acceptability of each case.

3. CONSTRUCTION REQUIREMENTS

a) **Do not compact soil infiltration beds during construction**. Prohibit all heavy equipment from the infiltration area and minimize all other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as tracked vehicles.

b) **Protect the infiltration area from sediment until the surrounding site is completely stabilized.** Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Where geo-textile is used as a bed bottom liner, this should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed. Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be utilized as a temporary

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sediment basin, excavation should be limited to within 1 foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting the soil horizon, and final grade removed when the contributing site is fully stabilized. All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover.

c) **Provide thorough construction oversight.** Long-term performance of infiltration BMPs is dependent on the care taken during construction. Plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.

d) **Provide Quality Control of Materials.** As with all BMPs, the final product is only as good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

BMP Effectiveness

Infiltration BMPs produce excellent pollutant removal effectiveness because of the combination of a variety of natural functions occurring within the soil mantle, complemented by existing vegetation (where this vegetation is preserved). Soil functions include physical filtering, chemical interactions (e.g., ion exchange, adsorption), as well as a variety of forms of biological processing, conversion, and uptake. The inclusion of native vegetation for filter strips, rain gardens, and some vegetated infiltration basins, reinforces the work of the soil by reducing velocity and erosive forces, soil anchoring, and further uptake of nonpoint source pollutants. In some cases the more difficult-to-remove soluble nitrates can be reduced as well. It should be noted that infiltration BMPs tend to be excellent for removal of many pollutants, especially those that are in particulate form; however, there are limitations to the removal of highly solubilized pollutants, such as nitrate, which can be transmitted through the soil.

In addition to the removal of chemical pollutants, infiltration can address thermal pollution. Maintaining natural temperatures in stream systems is recognized as an issue of increasing importance for protection of overall stream ecology. Detention facilities tend to discharge heated runoff flows. The return of runoff to the groundwater through use of infiltration BMPs guarantees that these waters will be returned at natural groundwater temperatures, considerably cooler than ambient air in summer and warmer in winter, so that seasonal extreme fluctuations in stream water temperature are minimized. Fish, macroinvertebrates, and a variety of other biota will benefit as the result.

Although precise data on pollutant removal efficiencies is somewhat limited, infiltration BMPs have been shown to have excellent efficiencies for a wide range of pollutants. In fact, recent EPA guidance has suggested that infiltration BMPs can be considered 100 percent effective at removing pollutants from surface water for the fraction of water that infiltrates (EPA, 1999a). Other more conservative removals are reported in a variety of other sources. Estimated removals for all BMPs are contained in Section 9.

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Fate of Infiltrated Contaminants

The protection of groundwater quality is of utmost importance in any PA watershed. The potential to contaminate groundwater by infiltrating stormwater in properly designed and constructed BMPs with proper pretreatment is low, if come common sense rules are followed, as discussed above. Numerous studies have shown that stormwater infiltration BMPs have a minor risk of contaminating either groundwater or soil. Perhaps the most comprehensive research was conducted by the U.S. Environmental Protection Agency, summarized in "Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration" (Pitt et al., 1994). The publication presents a summary table that identifies the potential of pollutants to contaminate groundwater as either low, low/moderate, moderate, or high. Of the 25 physical pollutants listed, only one has a "high" potential (chloride), and only two have even "moderate" potential (fluoranthene and pyrene) for polluting groundwater through the use of shallow infiltration systems with some sediment pretreatment. While chloride can be found in significant quantities due to winter salting, relatively high concentrations are generally safe for both humans and aquatic biota (in fact, chloride is not even included in U.S. EPA's primary drinking water standards and the secondary standard concentration is given as 250 mg/L at http://www.epa.gov/safewater/mcl.html#mcls). Pentachlorophenol, cadmium, zinc, chromium, lead, and all the pesticides listed are classified as having a "low" contamination potential. Even nitrate which is soluble and mobile (discussed further below) is only given a "low/moderate" potential.

Legret et al. (1999) simulated the long term effects of heavy metals in infiltrating stormwater and concluded that the "long-term pollution risks for both soil and groundwater are low," and "metals are generally well retained in the upper layers of the soil (0-20 cm) [0-8 inches]…" Barraud et al. (1999) studied a thirty year-old infiltration BMP and found that both metal and hydrocarbon concentrations in the soil under the infiltration device decreased rapidly with depth "to a low level after a few decimeters down [3 decimeters = 1 foot]…" A study concerning the infiltration of highway runoff (Dierkes and Geiger, 1999) found that polycyclic aromatic hydrocarbons (PAH) were effectively removed in the upper 4 inches of the soil and that runoff that had passed through 14 inches of soil met drinking water standards for cadmium, zinc, and copper. This extremely high pollutant removal and retention capacity of soils is the result of a multitude of natural processes including physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake.

Several studies have also found that porous pavement and stone-filled subsurface infiltration beds can significantly reduce the pollutant concentrations (especially hydrocarbons and heavy metals) of stormwater runoff before it even reaches the underlying soil due to adsorption, filtering, sedimentation, and bio-degradation by a diverse microbial community in the pavement and infiltration beds (Legret and Colandini, 1999; Balades et al., 1995; Swisher, 2002; Newman et al., 2002; and Pratt et al., 1999).

Common Causes of Infiltration BMP "Failures"

The concept of failure is simple – a design no longer provides the benefit or performance anticipated. With respect to stormwater infiltration BMPs, the term requires some qualification, since the net result of "failure" may be a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of some pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration

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systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability to support surface vegetation, caused by too much or too little water.

The primary causes of reduced performance appear to be:

a) Poor construction techniques, especially soil compaction/smearing, which results in significantly reduced infiltration rates.
b) A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces.
c) Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates.
d) Lack of proper maintenance (erosion repair, re-vegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs.
e) Inadequate design

Infiltration systems should always be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.

Consideration of Infiltration Rate in Design and Modeling Application

For the purposes of site suitability, areas with tested soil infiltration rates as low as 0.1 inches per hour may be used for infiltration BMPs. However, in the design of these BMPs and the sizing of the BMP, the designer should incorporate a safety factor. Safety factors between 1 (no adjustment) and 10 have commonly been used in the design of stormwater infiltration systems, with a factor of two being recommended for most cases.

The minimum safety for design purposes that may used for any type of tests is two (2). For percolation tests this safety factor is only applicable for soils more coarse than a loam. It should be applied ***after*** (in addition to) using the reduction formula outlined in Protocol 1, Site Evaluation and Soil Infiltration Testing.

For Percolation tests in loams and finer soils (silty loam, clay loams, silty clay loams, sandy clay loams, clays) a minimum design safety factor of three (3) is recommended ***after*** using the reduction formula in Protocol 1, Site Evaluation and Soil Infiltration Testing. This higher factor is to account for the unwanted capillary suction force that can occur from *un*saturated conditions during percolation testing.

Therefore, a percolation rate of 0.5 inches per hour (***after*** reduction formula) should generally be considered as a rate of 0.25 inches per hour when designing an infiltration BMP for a sandy loam. The same rate for a loam would yield a *design* rate of 0.17 inches/hour.

For other test procedures a safety factor of 3 should also be considered for problem or less preferred locations, basins, swales, toe of slopes, loadings greater than 5:1 (drainage area to infiltration area) where saturated hydraulic conductivity rate (Ksat) was **not** determined (A raw infiltration rate was used. The Ksat rate will normally be less than the infiltration rate.)

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As discussed in Section 9 of this Manual, infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is convenient to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the Stage-Storage-Discharge table.

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C

Procedures for Determining Effects of Infiltration on Subsurface Stability in Areas of Historic Fill

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Appendix C: Procedures for Determining Effects of Infiltration on Subsurface Stability in Areas of Historic Fill

C.1 Justification

This policy is intended to address three potential problems involving stormwater control on sites built on structural fill.

1. Some fill material such as fly ash may contain mobile metals and toxins. This issue is addressed in the hotspot policy.

2. Concentrated infiltration can lead to extensive erosion and subsidence in fill containing very fine material, such as ash. Diffuse infiltration may still be possible under these conditions.

3. Minor subsidence under concentrated infiltration facilities may threaten structures that are very close to those facilities. Minor subsidence of the infiltration facility itself is not sufficient reason to avoid infiltration. In no case shall new structures included as part of the site development be considered cause for avoiding the use of an infiltration system.

C.2 Required Steps

Step 1: Complete a conceptual site design, including drainage area and estimated area of the proposed infiltration facility.

Step 2: Determine whether the site is in an area of historic fill.

- The Design Professional is responsible to rule out or detect the presence of historic fill. This investigation may rely on historic maps, records of previous construction, local knowledge, or test pits conducted at the site. If no historic fill is present, steps 3 through 7 are not necessary.

Step 3: If the site is in an area of historic fill, conduct an investigation to determine the type and condition of fill.

- The site investigation should conduct test pits or test borings to confirm the depth and nature of the fill at the site. The explorations should extend through any organic materials at the site, into the naturally deposited inorganic materials below the site. An assessment of permeability of each of the onsite stratums should be made by direct field testing, laboratory testing of samples collected during the investigation or correlation with grain size or other physical properties of representative samples of each stratum. At least one exploration, test boring or test pit should be conducted for every 2500 sq. feet of infiltration area planned at the site. Based on this information, the lateral extent of the zone of influence of the infiltration system should be determined.

- As part of the site investigation, the potential for drain lines, rubble fill, former building foundations or other man-made features which could facilitate the migration of fine material from the site should be evaluated from historic maps, records of previous construction, local knowledge or test pits conducted at the site.

Step 4: If the site is in an area of historic fill, rate existing structures based on susceptibility to subsidence.

- The foundation bearing condition of adjacent structures, utilities and other surface

features should be assessed. The depth of basement levels and anticipated foundation bearing soils should be determined. In particular, structures, utilities or other surface features which are suspected of bearing on historic fill soils must be identified.

• Low susceptibility are structures showing no signs of distress bearing on or in the naturally deposited inorganic strata below the fill and organic material or on prepared engineered fill after the removal of the historic fill and organic soils

• Moderate susceptibility are structures showing no signs of distress bearing on inorganic historic fill which are less than 10 feet in depth and contains little to no ash which was place directly over the naturally deposited inorganic stratums.

• High susceptibility are structures which either currently show signs of distress, are underlain by more than 10 feet of historic fill or historic fill containing significant amounts of ash or underlain by organic material. Any structure founded within the zone of influence as defined by a 1 vertical to 2 horizontal slope of an unfilled drain lines, rubble fill, former building foundations or other man-made features which could facilitate the migration of fine material from the site should be considered as a high susceptibility site.

Step 5: If the site is in an area of historic fill, determine feasibility of infiltration for the proposed design.

• Infiltrate for all cases where the adjacent structures of concern are outside of the zone of influence of the fluctuating water level caused by the infiltration system or where the support of the structures is rated as low susceptibility within the zone of influence.

• Strongly consider infiltration in areas affecting structures which can tolerate moderate subsidence where support of the structures is rated as moderate susceptibility within the zone of influence.

• Do not infiltrate in areas affecting structures in areas of high susceptibility within the zone of influence of the infiltration system unless special engineering evaluations indicate that the structures can tolerate the anticipated subsidence.

Step 6: If infiltration threatens existing structures, attempt to adjust the site design to remove any concerns.

• Determine whether the site can be redesigned to move infiltration facilities farther from structures.

• Determine whether the site can be redesigned to reduce the ratio of drainage area to infiltration area. Diffuse infiltration occurs when the infiltration area is equal in size to the impervious drainage area (for example, a gravel bed underlying the entire area of a parking facility). In this case, the infiltration facility will have no more effect on subsurface stability than if the site were completely pervious.

• As part of the submittal requesting a wavier from using an infiltration system on site, the Design Professional must evaluate the use of underpinning or other support of structures within the zone of influence illustrating that the cost of providing support below the depth of the fill and organic soils is prohibitive. In addition to evaluation of alternate locations of the infiltration system, the Design Professional will review the feasibility of using cut off barriers to limit the zone of influence adjacent to susceptible structure.

• In no case shall new facilities included as part of the site development be considered cause for avoiding the use of an infiltration system. All new structures and facilities shall be designed to tolerate the anticipated subsidence or be adequately founded on

non-susceptible engineered fill or on foundations extending though the historic fill and any organic soils.

Step 7: If, after completing steps 1 through 6, the Design Professional determines that there is no safe design for infiltration at the site, the Design Professional will proceed to design of water quality facilities. In this case, the Design Professional must provide sufficient data and calculations along with the Stormwater Management Control Plan to demonstrate that infiltration is infeasible.

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Maps: Zones for Acceptable Practices

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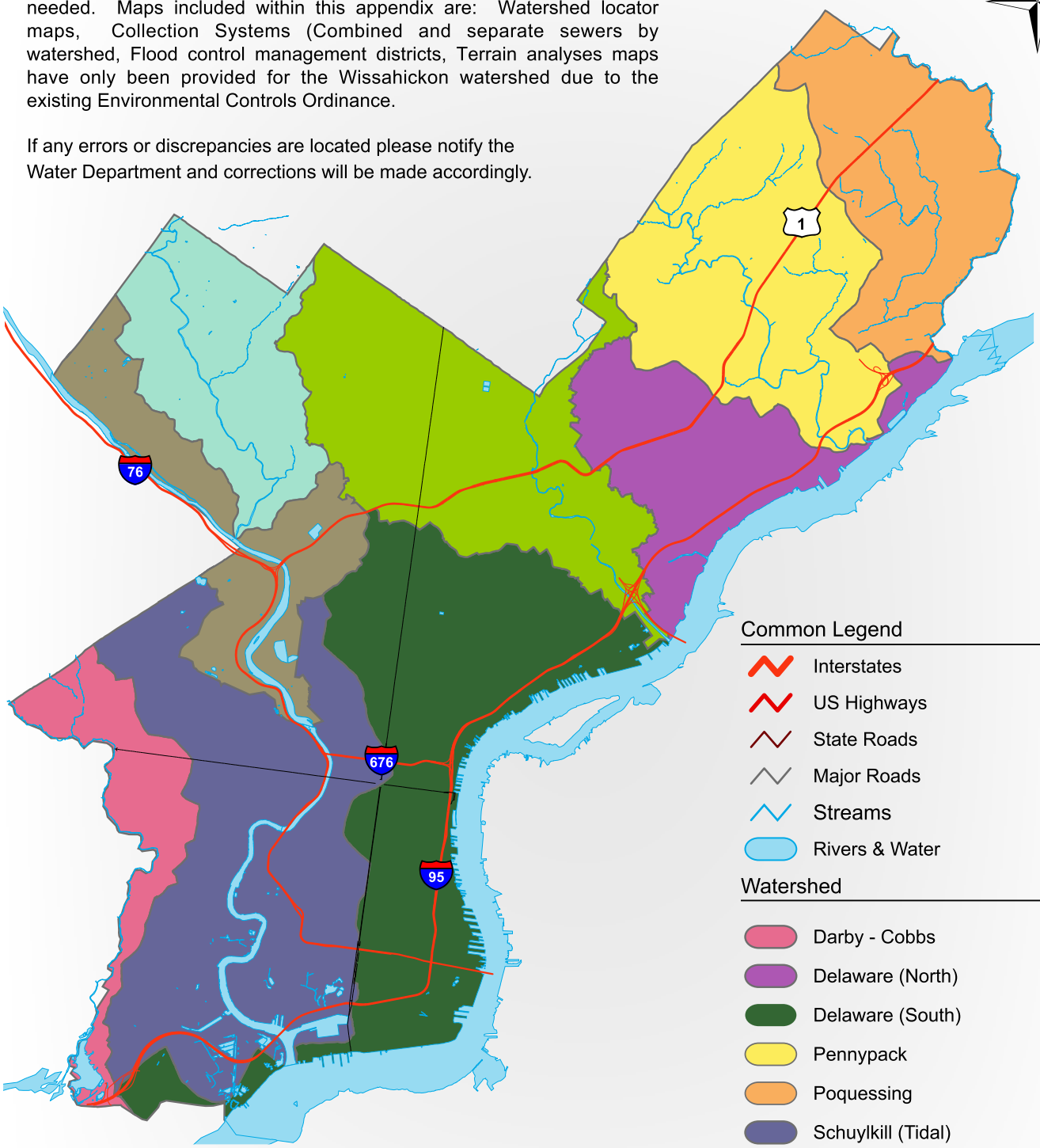
Philadelphia Watersheds

Watershed Information Maps

The following maps are provided as a reference for site planning and for determining if additional information regarding a development project is needed. Maps included within this appendix are: Watershed locator maps, Collection Systems (Combined and separate sewers by watershed, Flood control management districts, Terrain analyses maps have only been provided for the Wissahickon watershed due to the existing Environmental Controls Ordinance.

If any errors or discrepancies are located please notify the Water Department and corrections will be made accordingly.



Philadelphia Water Department
Office Of Watersheds

Disclaimer: The suite of maps provides general reference information only. By no means are the provided maps to be used in scientific calculations, in lieu of site location mapping or for submittal with required plans. Use of the maps is at the discretion of the owner and or developer and should not replace any of the standard data acquisition and research processes involved with development.

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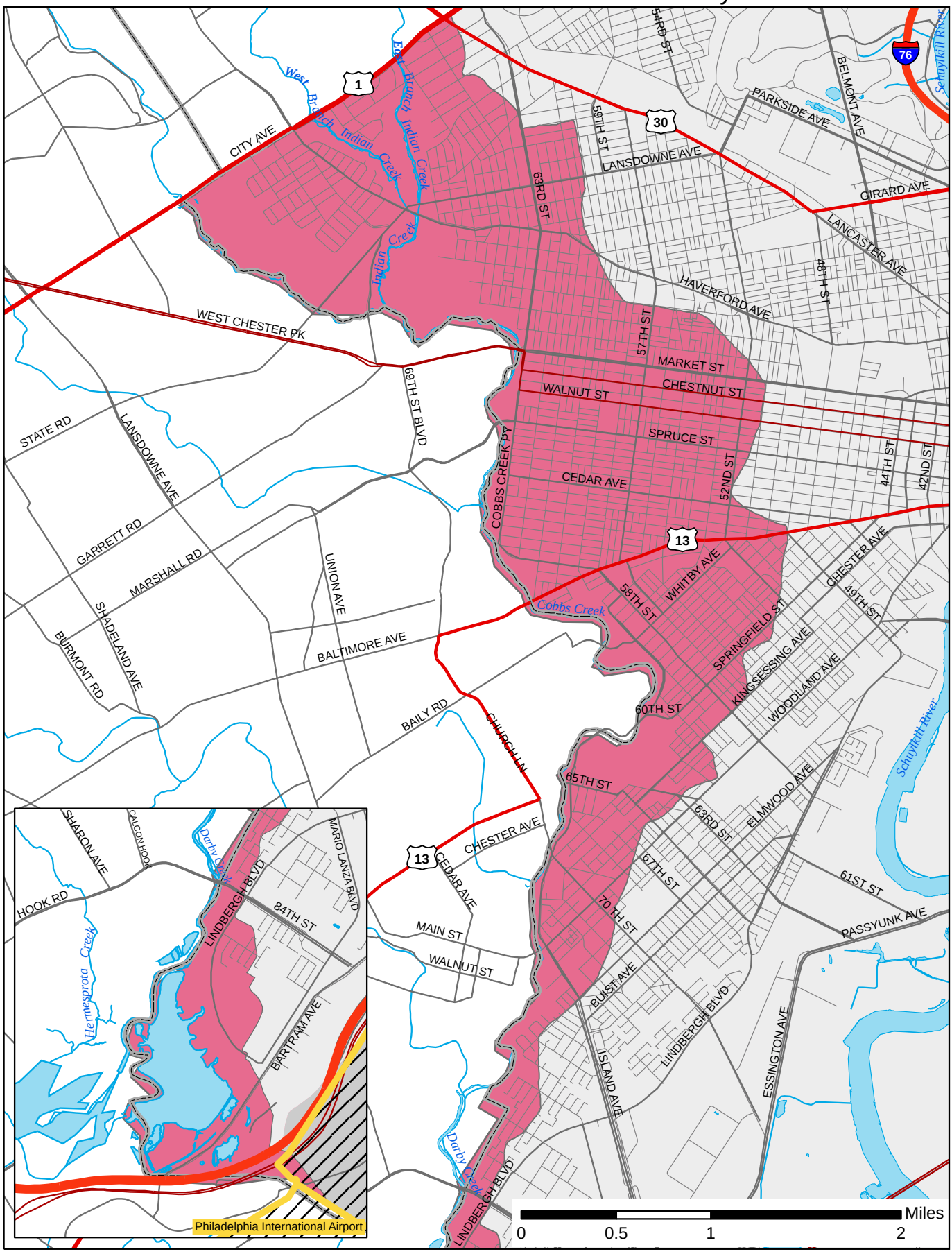

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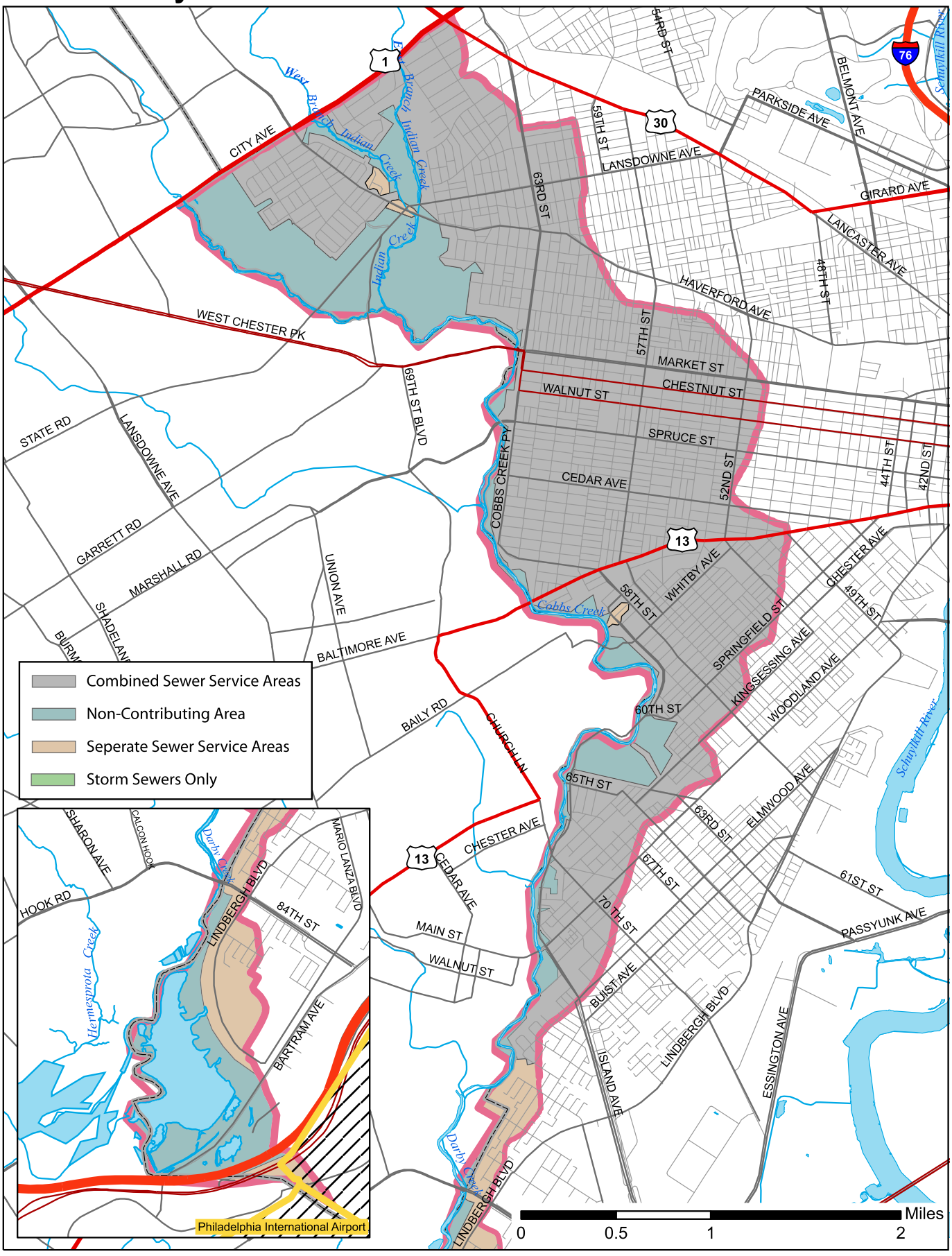

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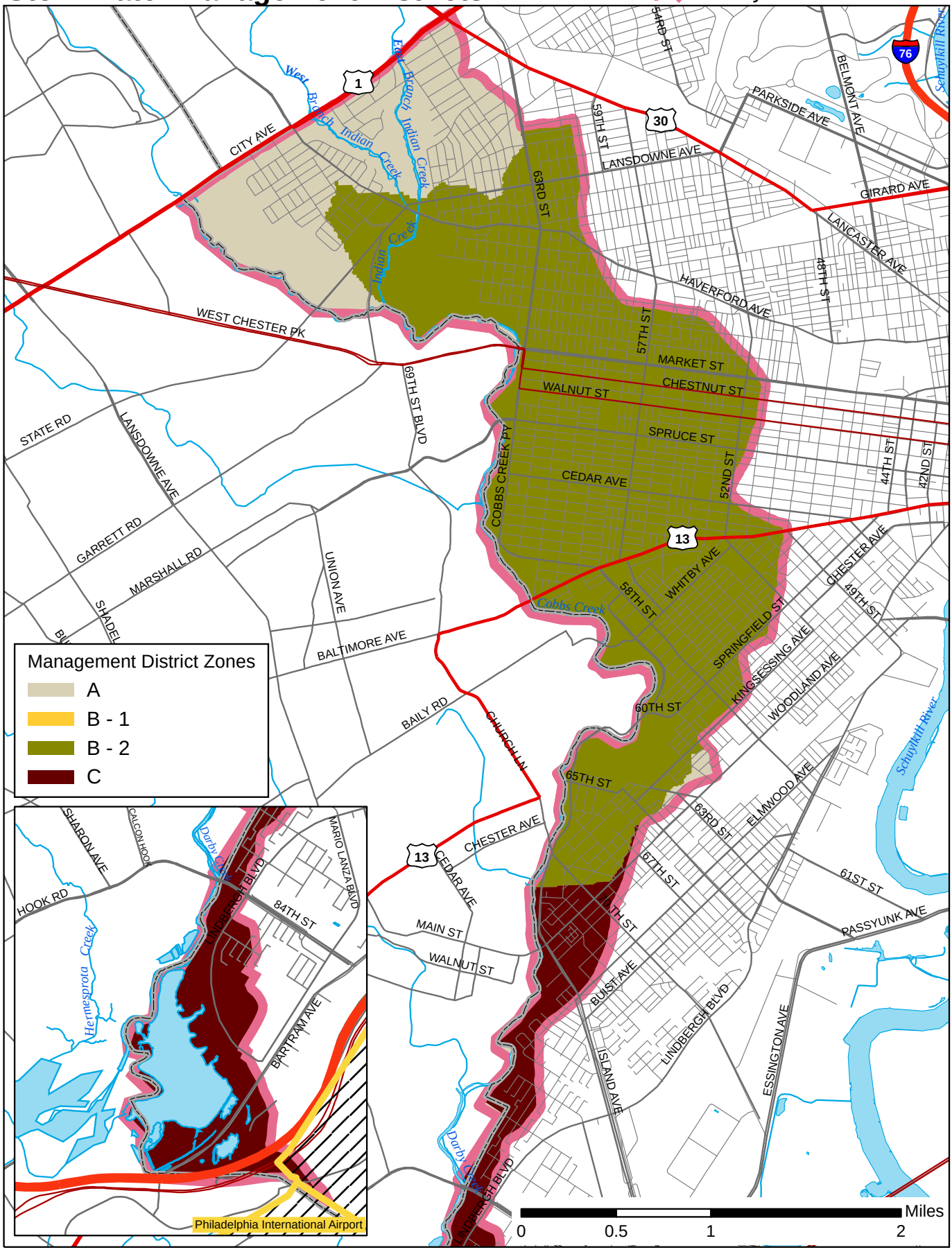
Stormwater Management Districts

Darby-Cobbs Watershed



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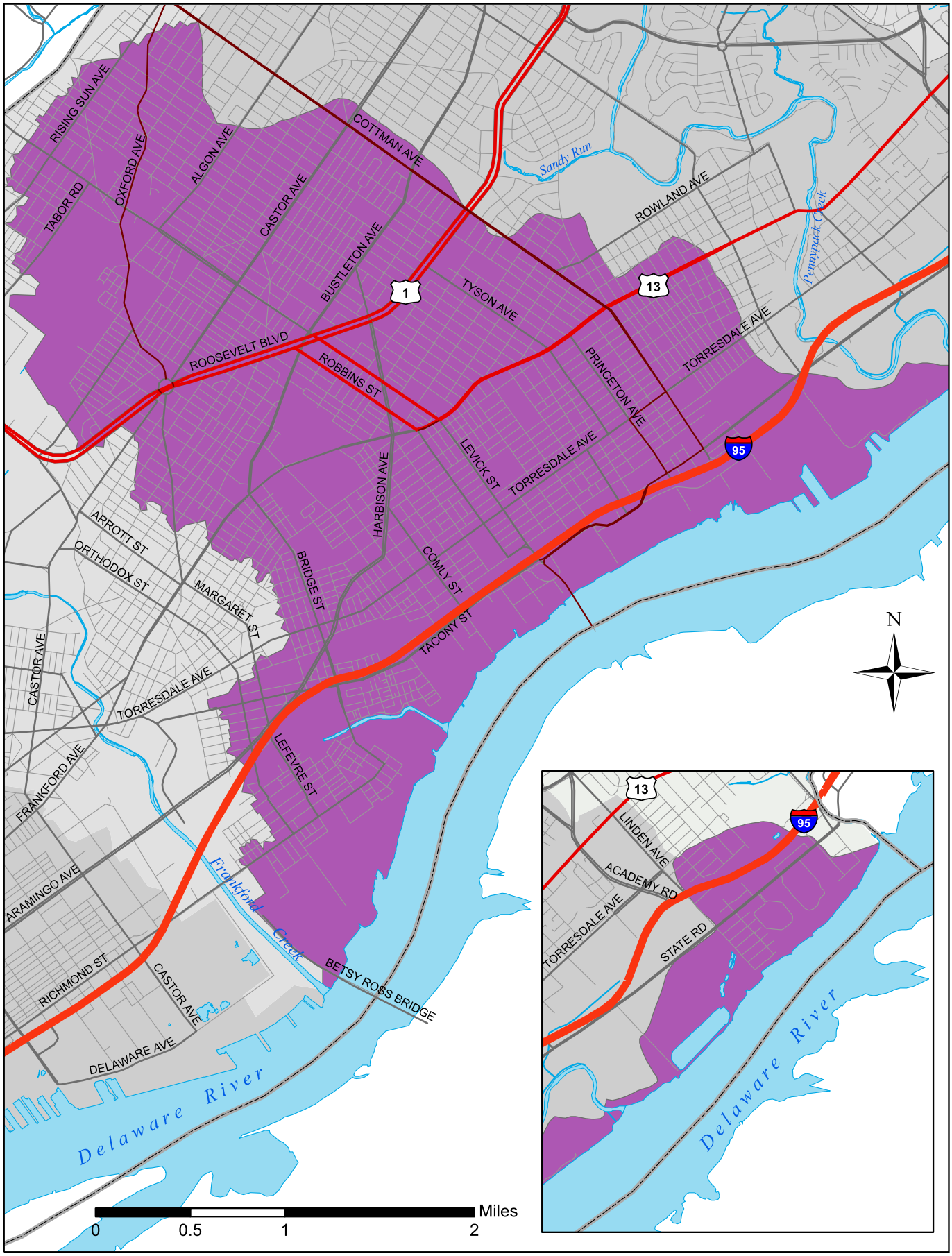

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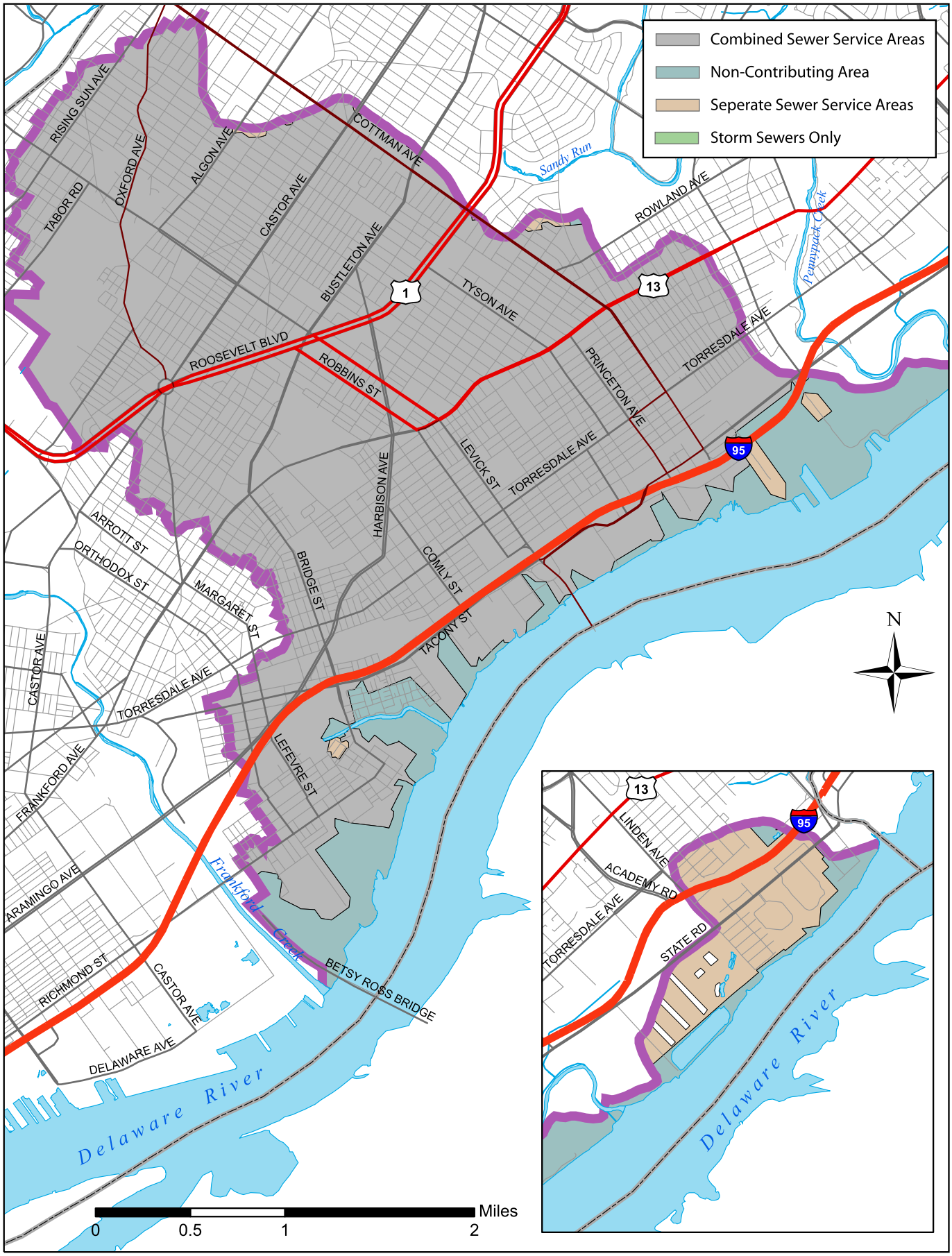

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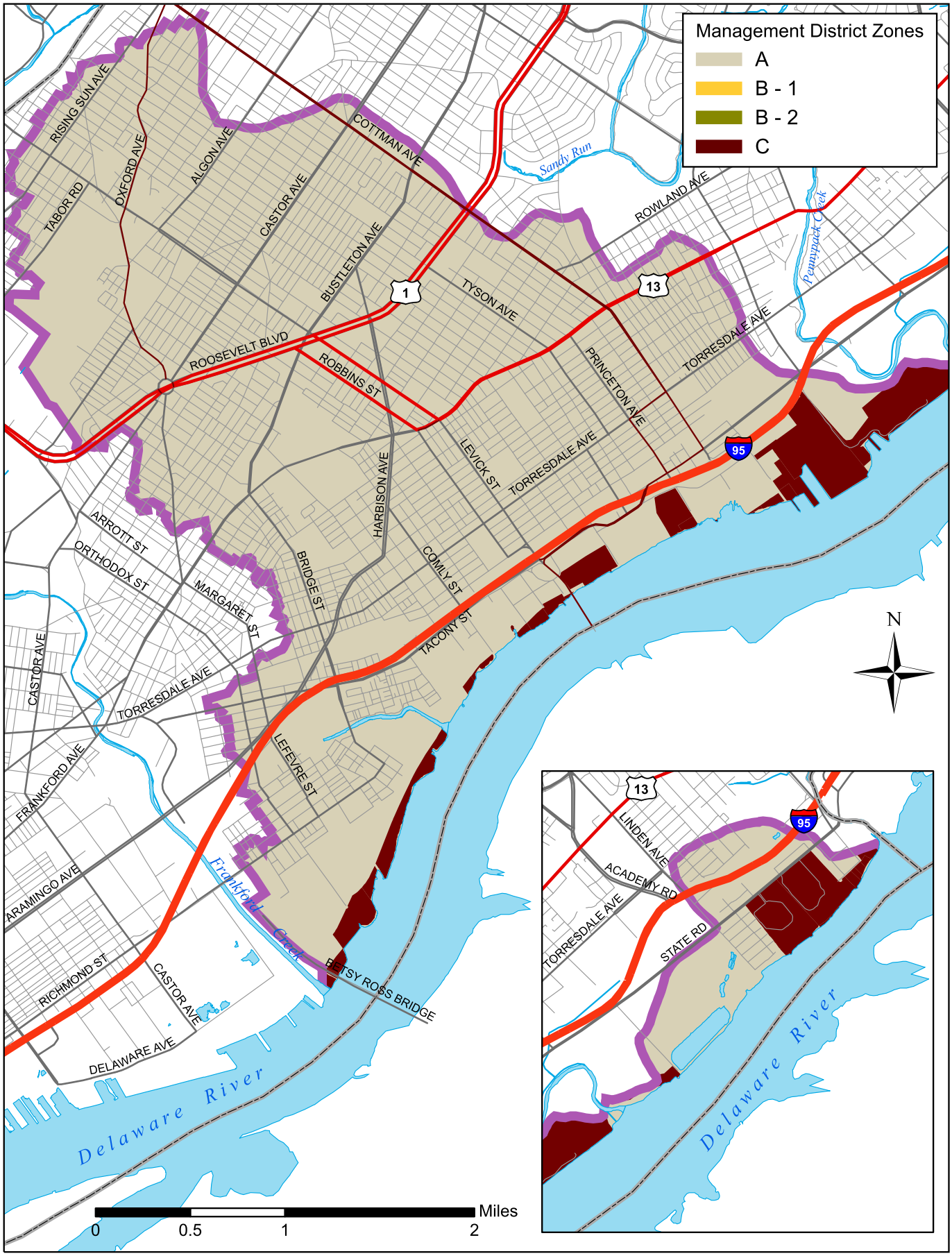
Stormwater Management Districts

Delaware Direct Watershed (North)



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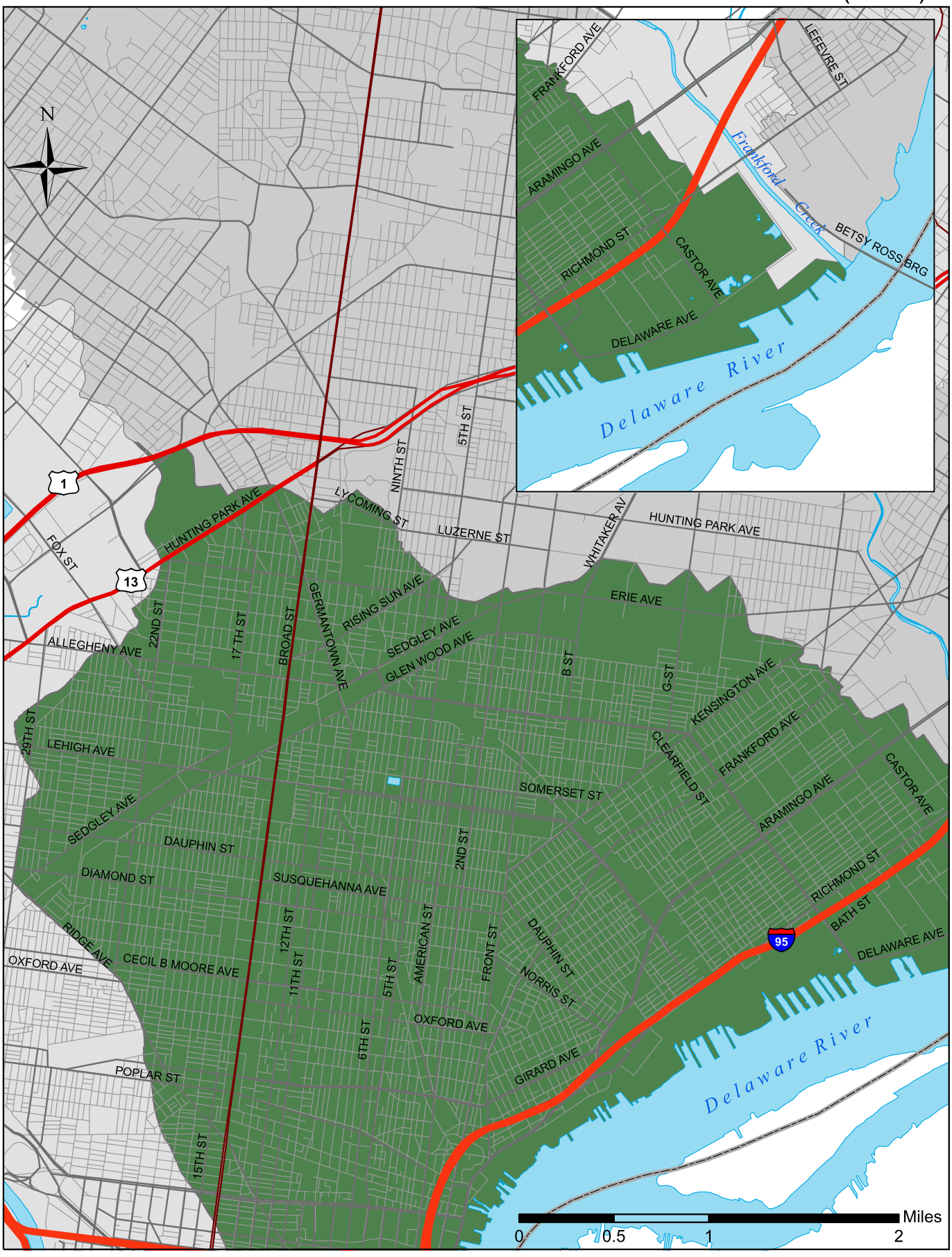

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Delaware Direct Watershed (South) A



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Stormwater Management Districts

Delaware Direct Watershed (South) A



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Watershed Locator

Delaware Direct Watershed (South) B



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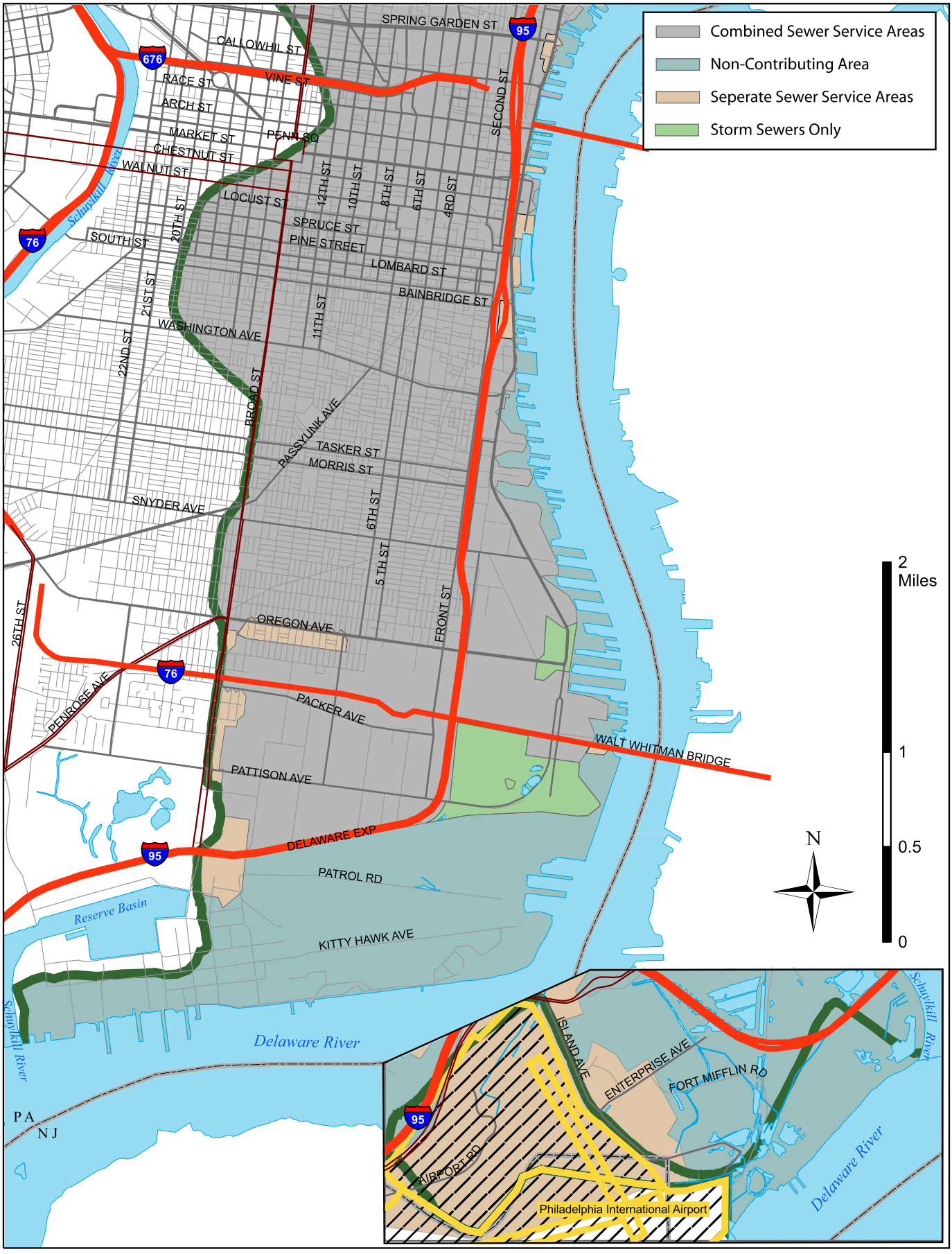
Delaware Direct Watershed (South) B



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Stormwater Management Districts

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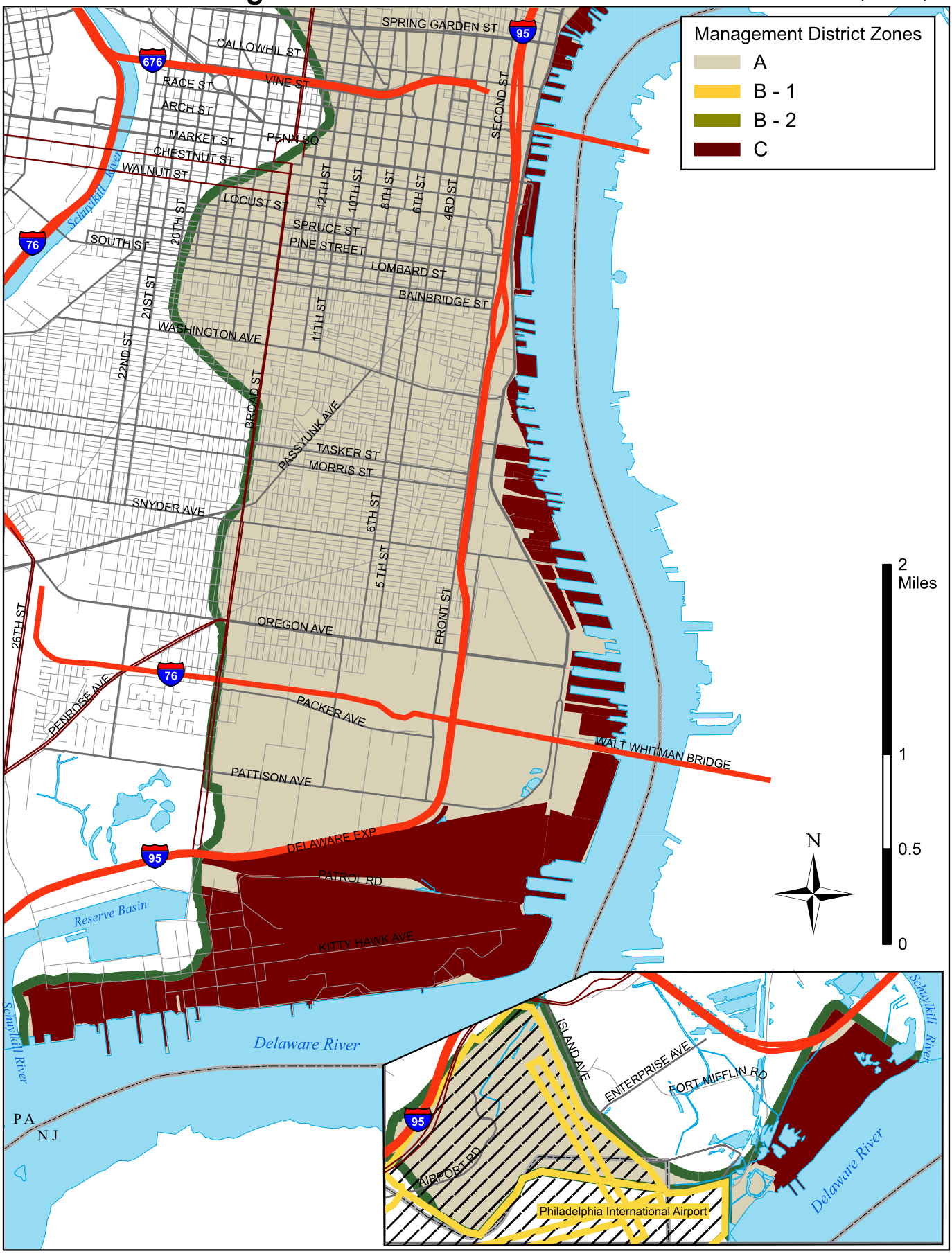

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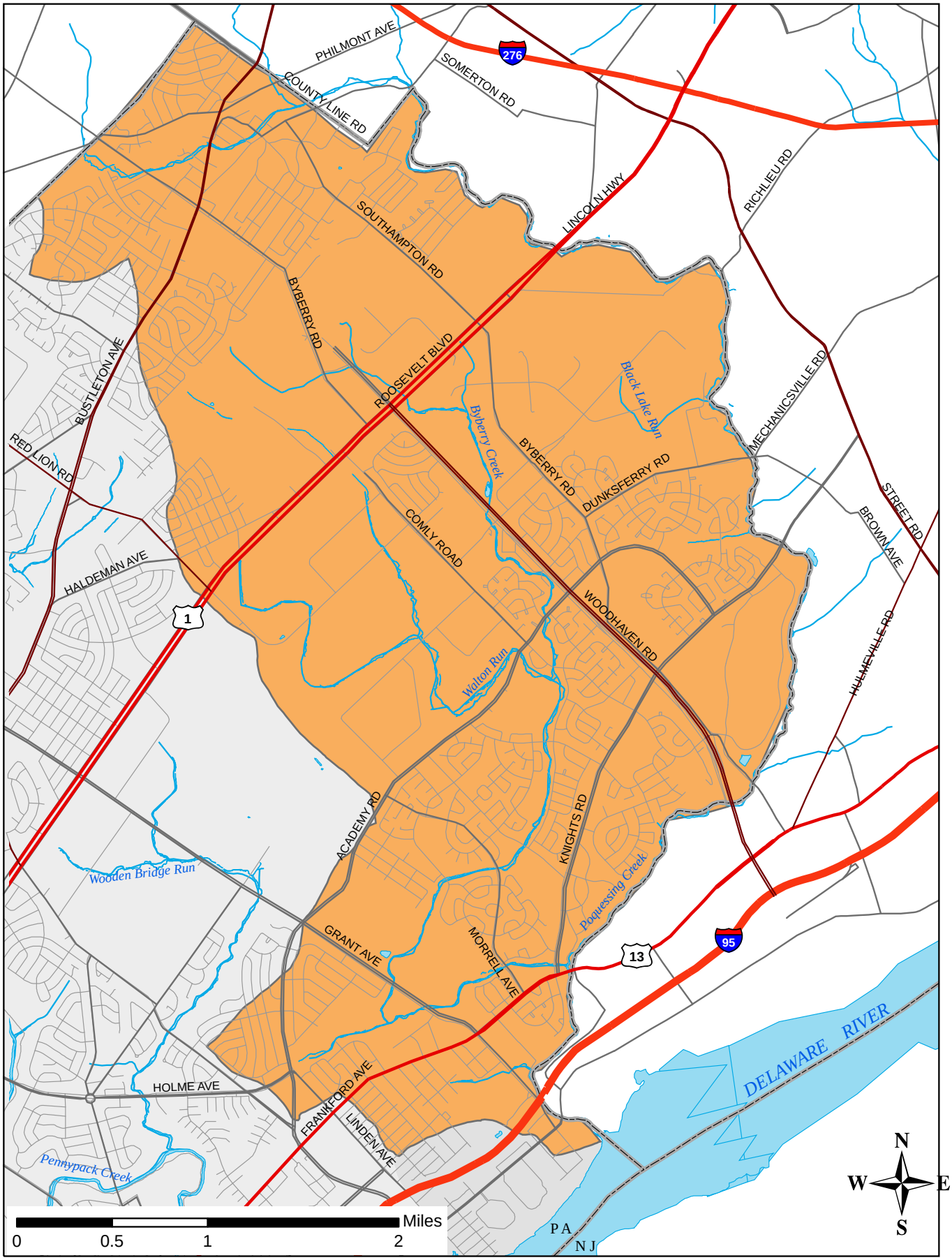
Watershed Locator

Poquessing Creek Watershed



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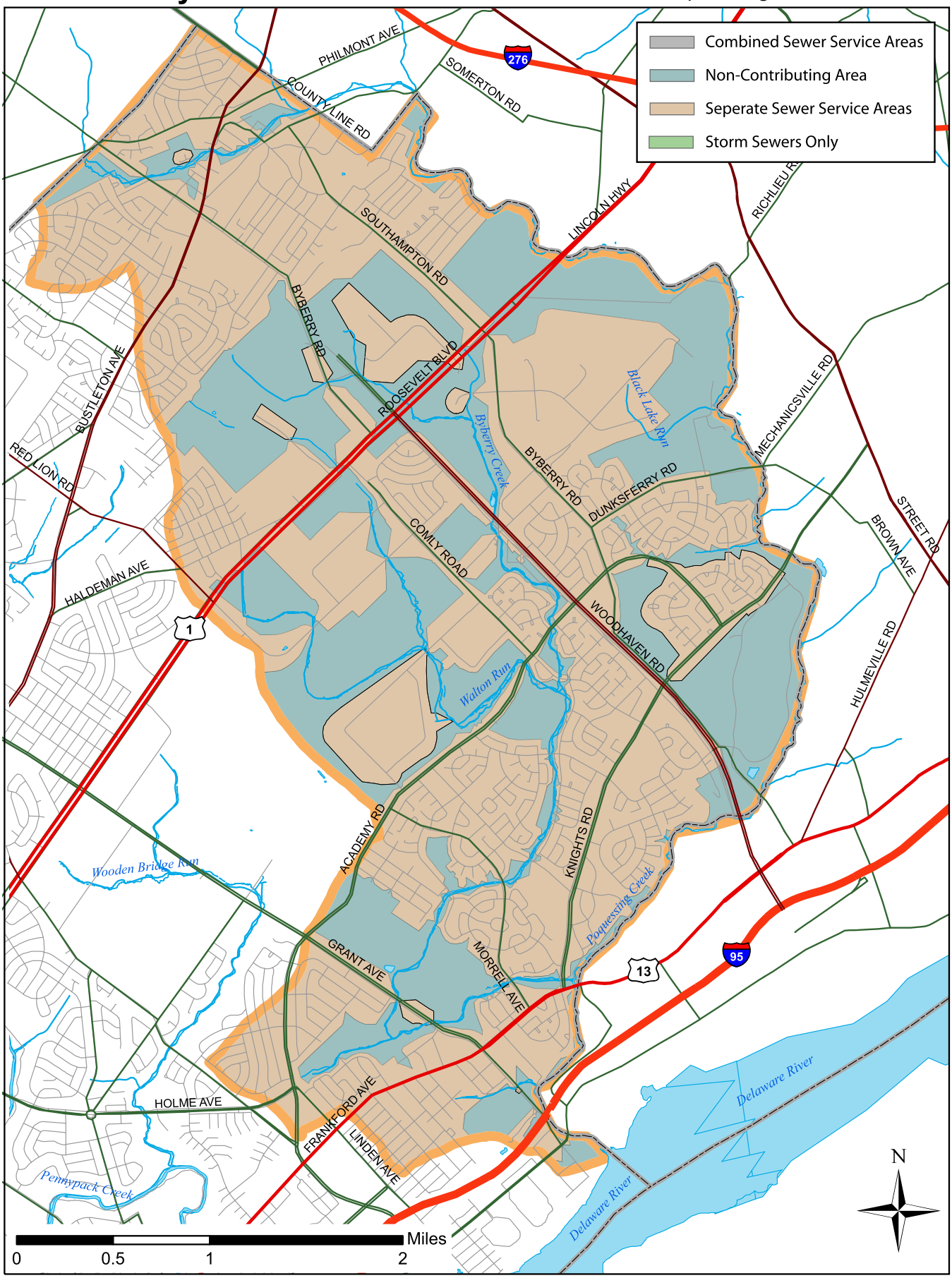
Poquessing Creek Watershed



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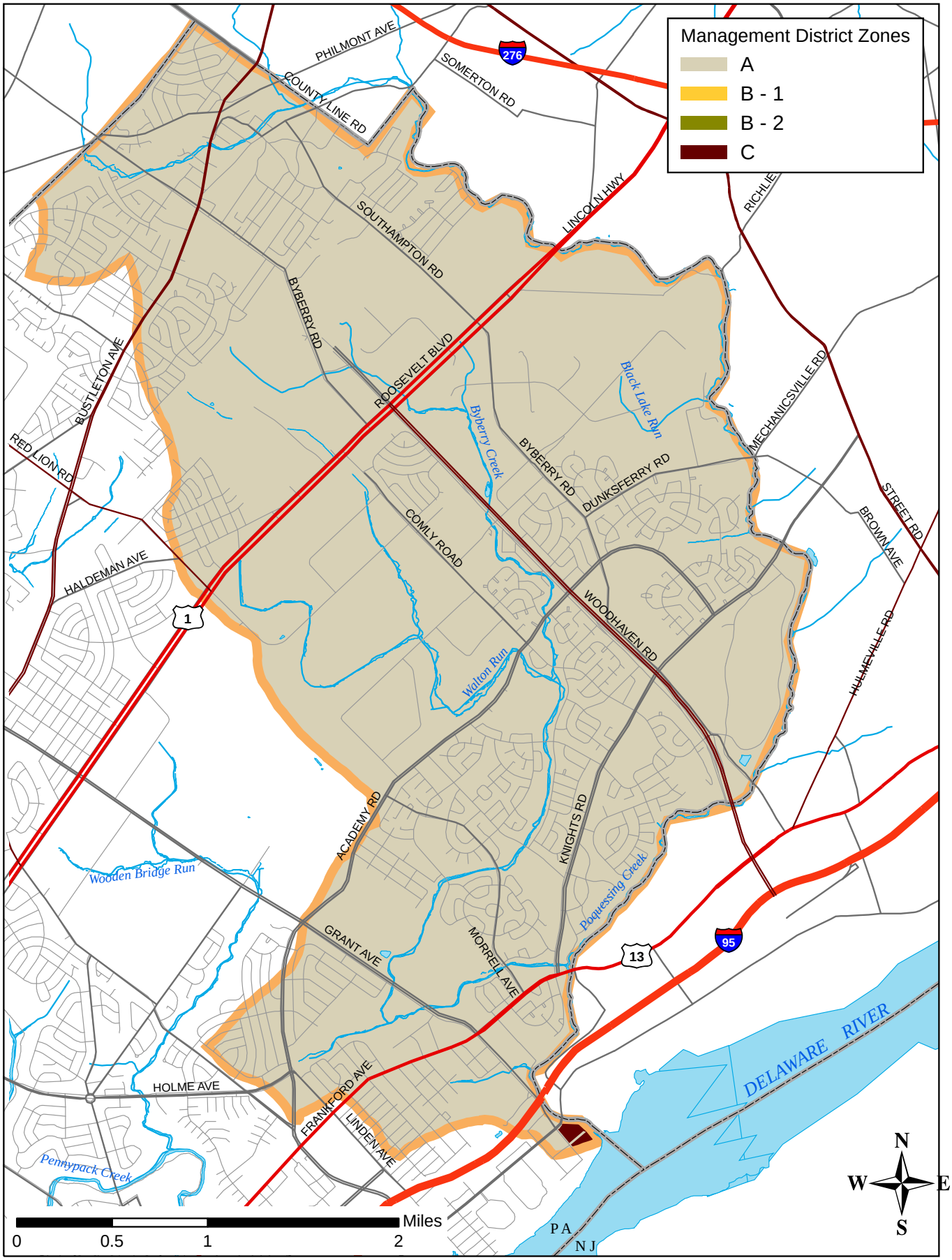
Stormwater Management Districts

Poquessing Creek Watershed



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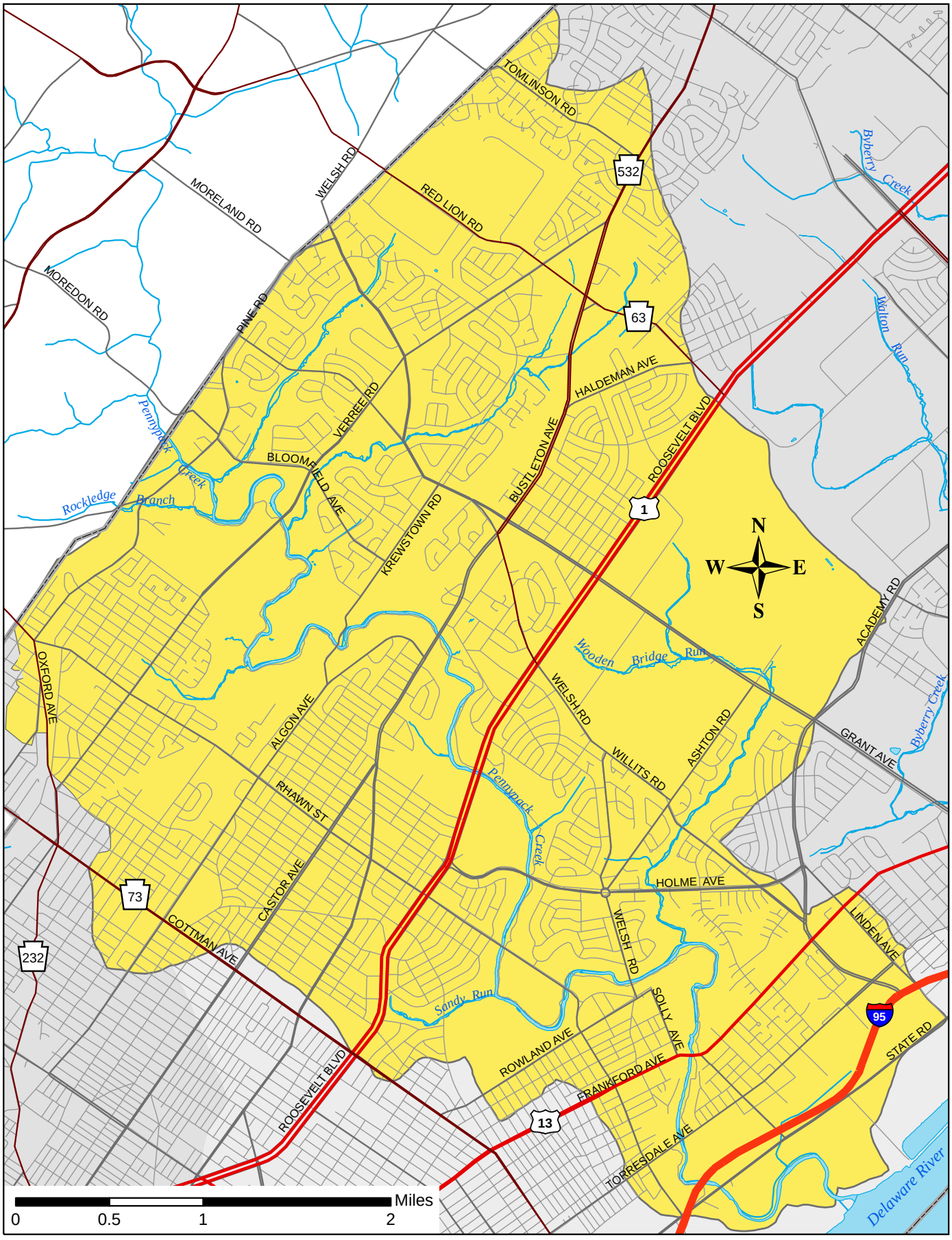
Watershed Locator

Pennypack Creek Watershed



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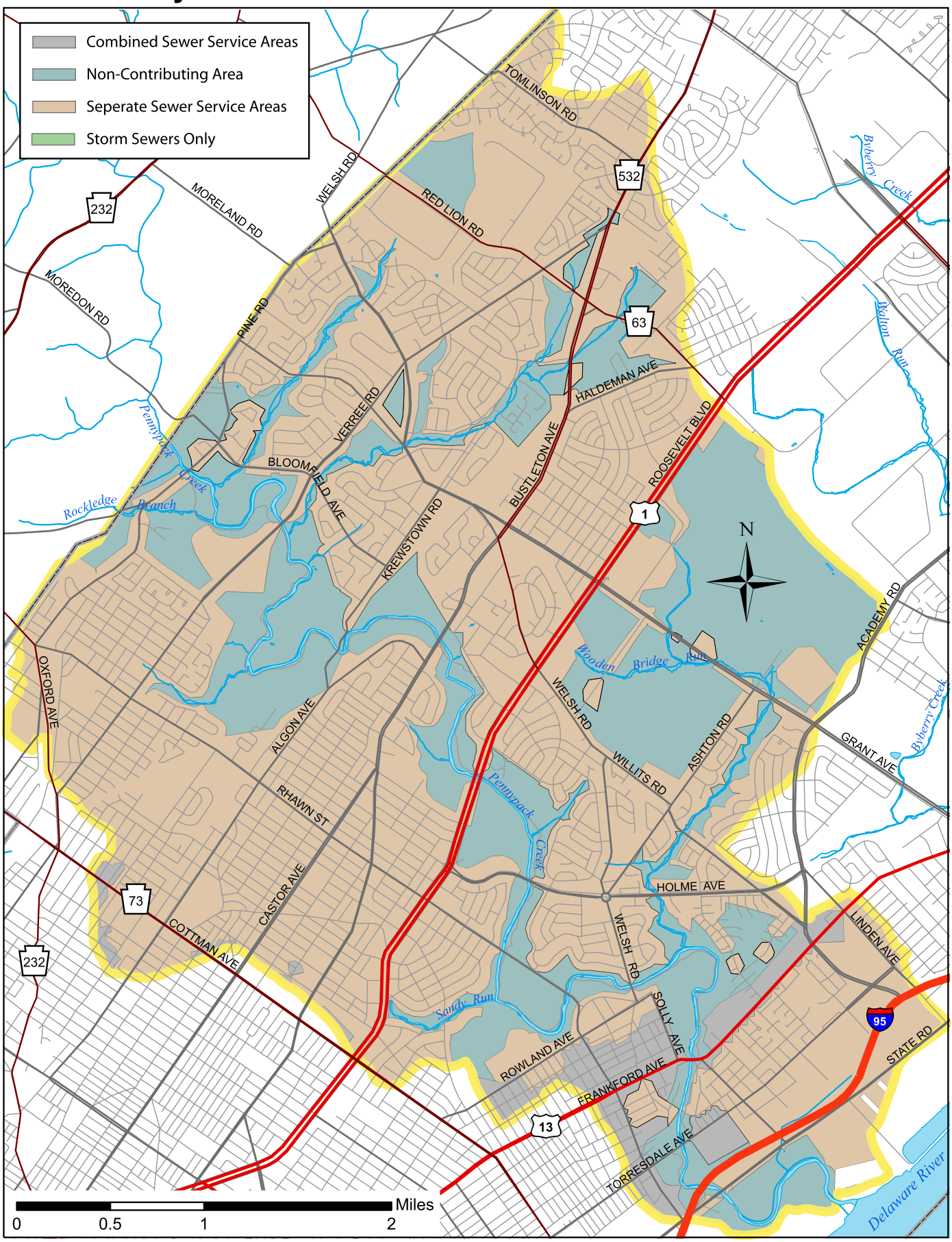

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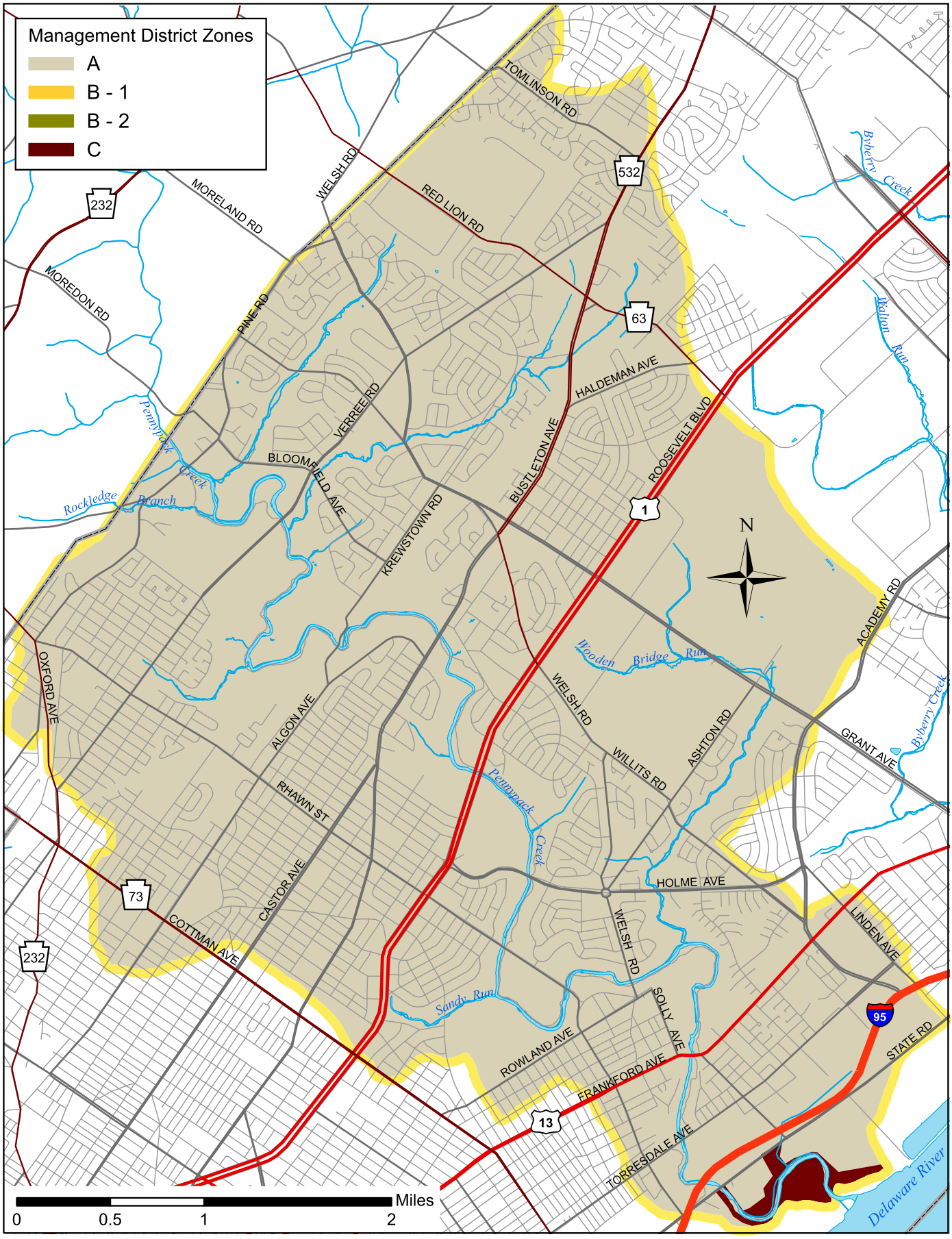
Stormwater Management Districts

Pennypack Creek Watershed



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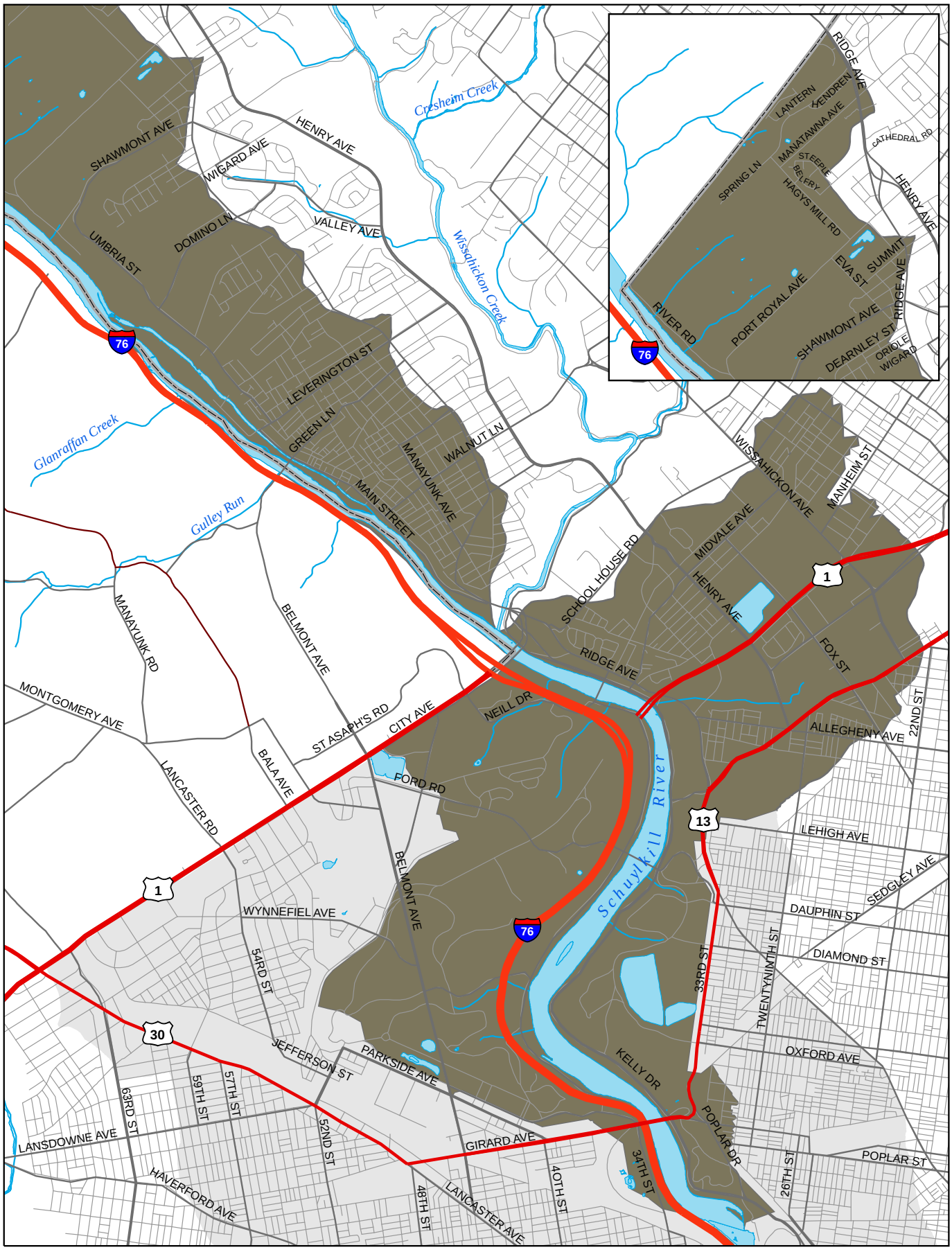
Stormwater Management Districts

Non-Tidal Schuylkill Watershed



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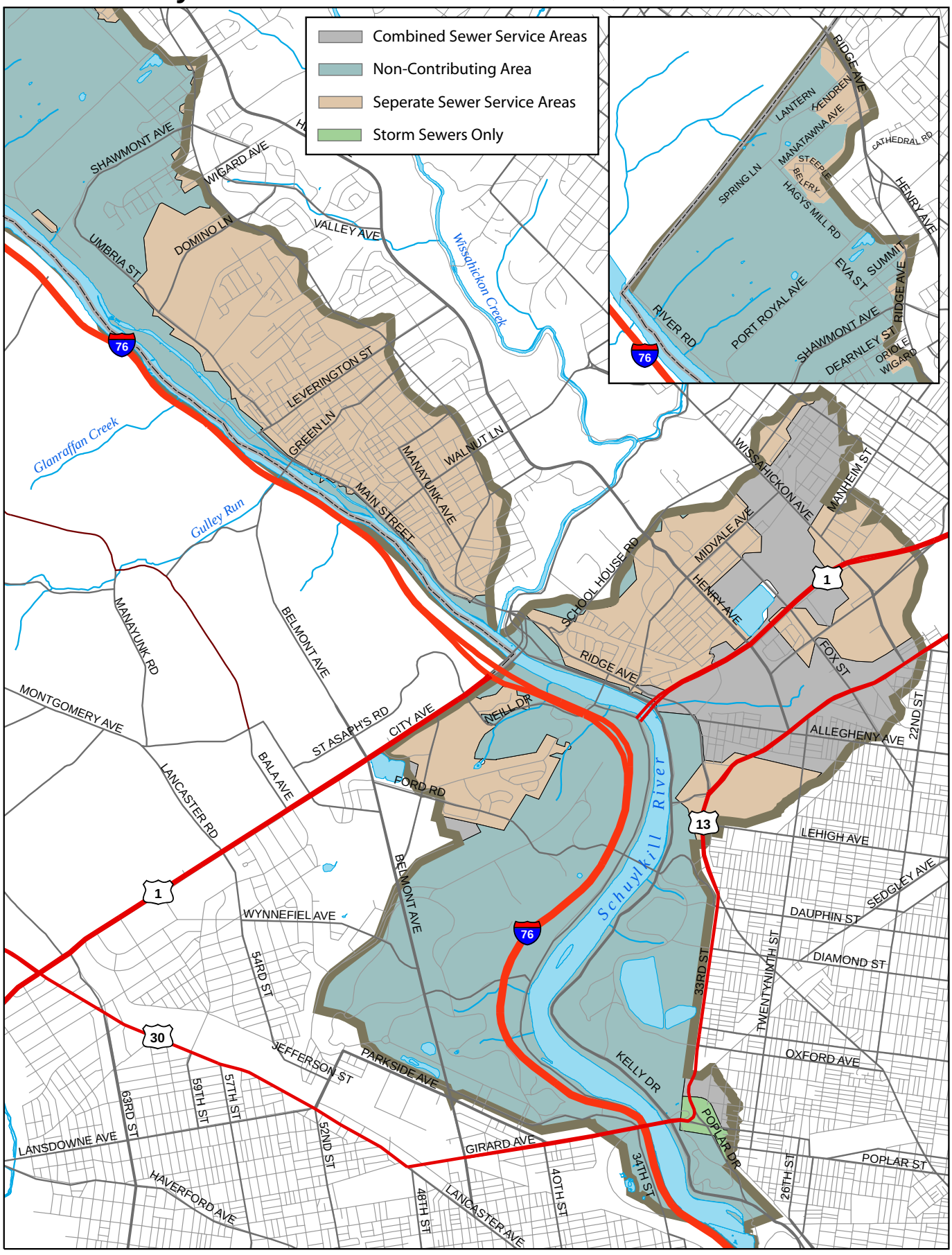
Non-Tidal Schuylkill Watershed



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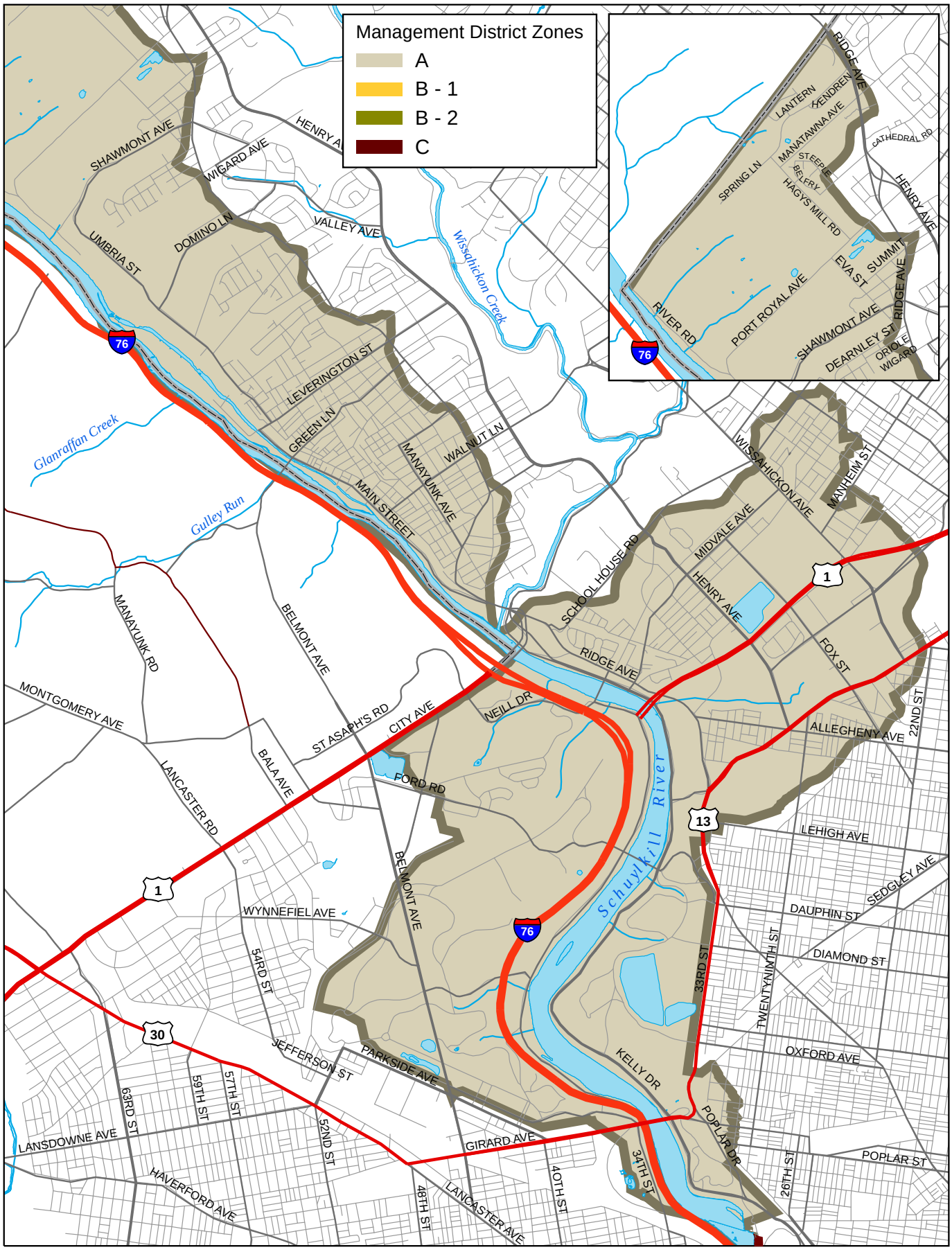
Stormwater Management Districts

Non-Tidal Schuylkill Watershed



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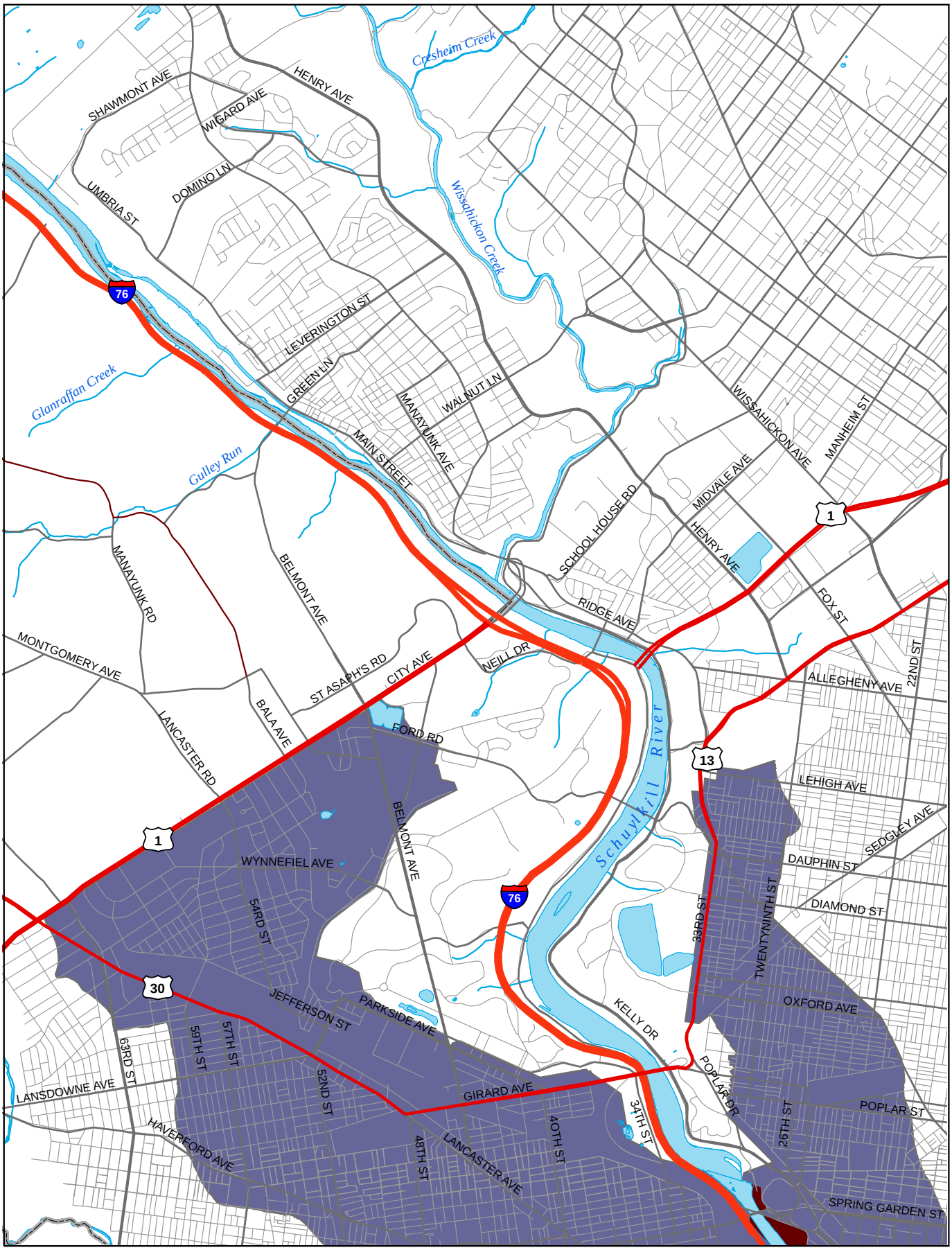
Watershed Locator

Tidal Schuylkill Watershed A



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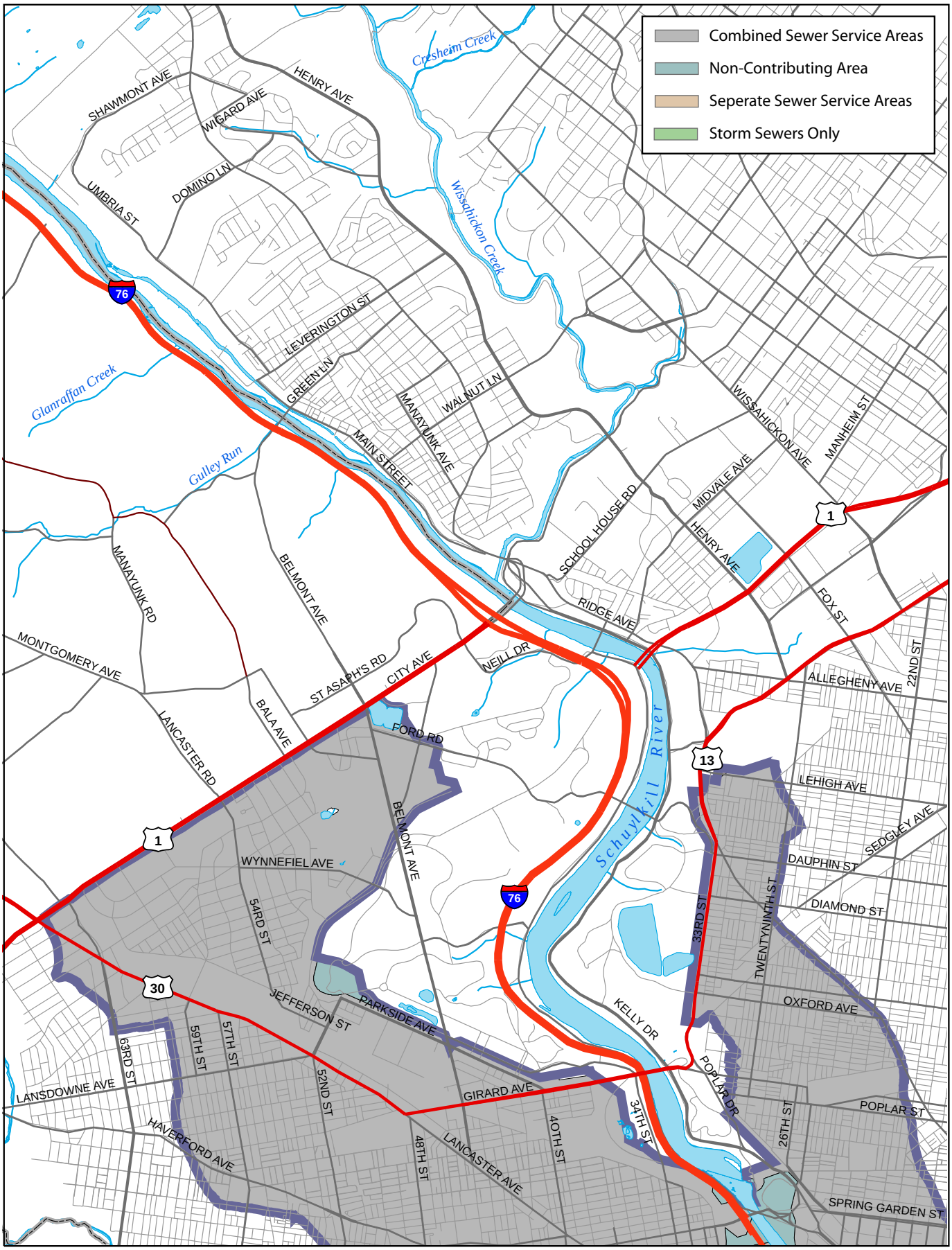
Tidal Schuylkill Watershed A



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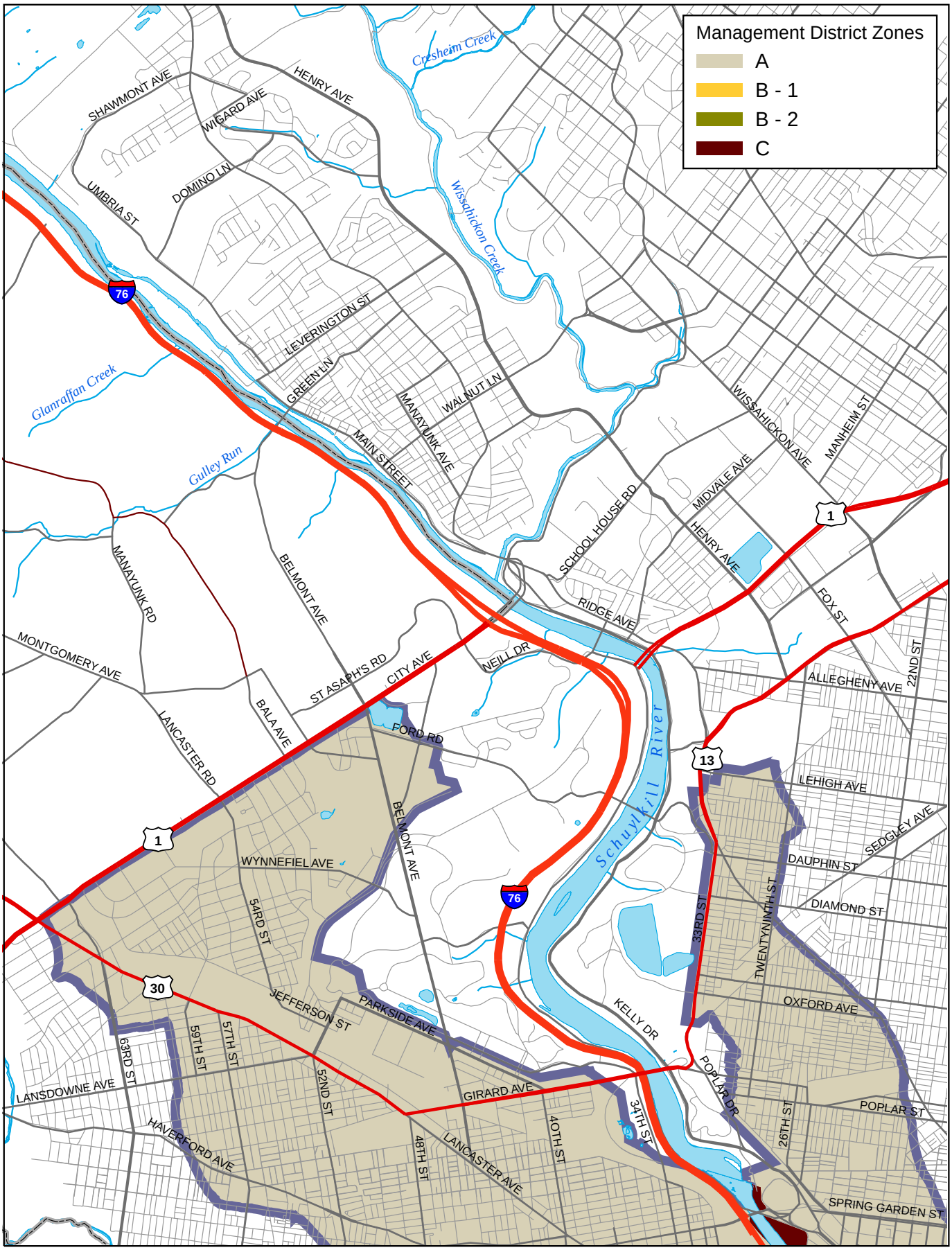
Stormwater Management Districts

Tidal Schuylkill Watershed A



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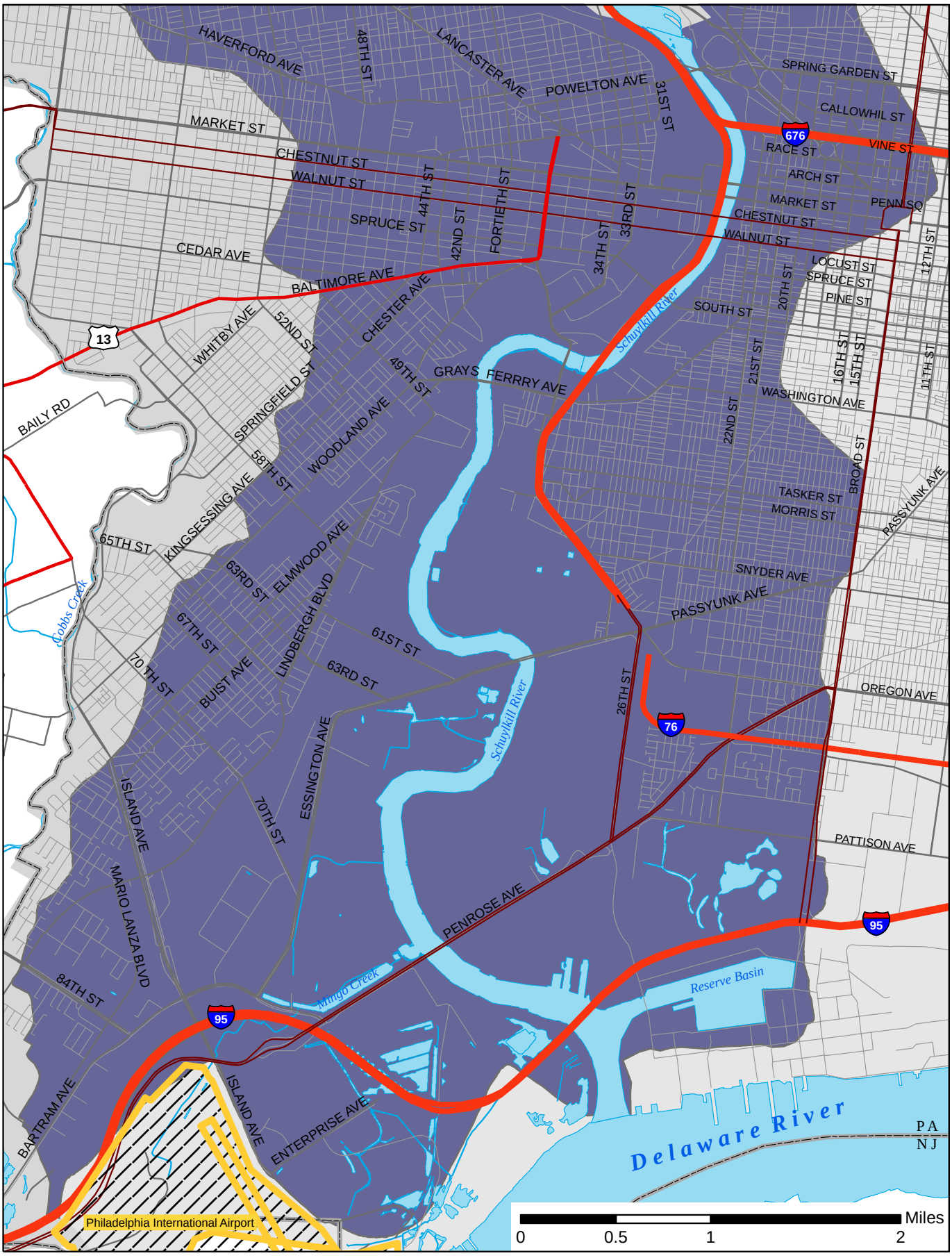

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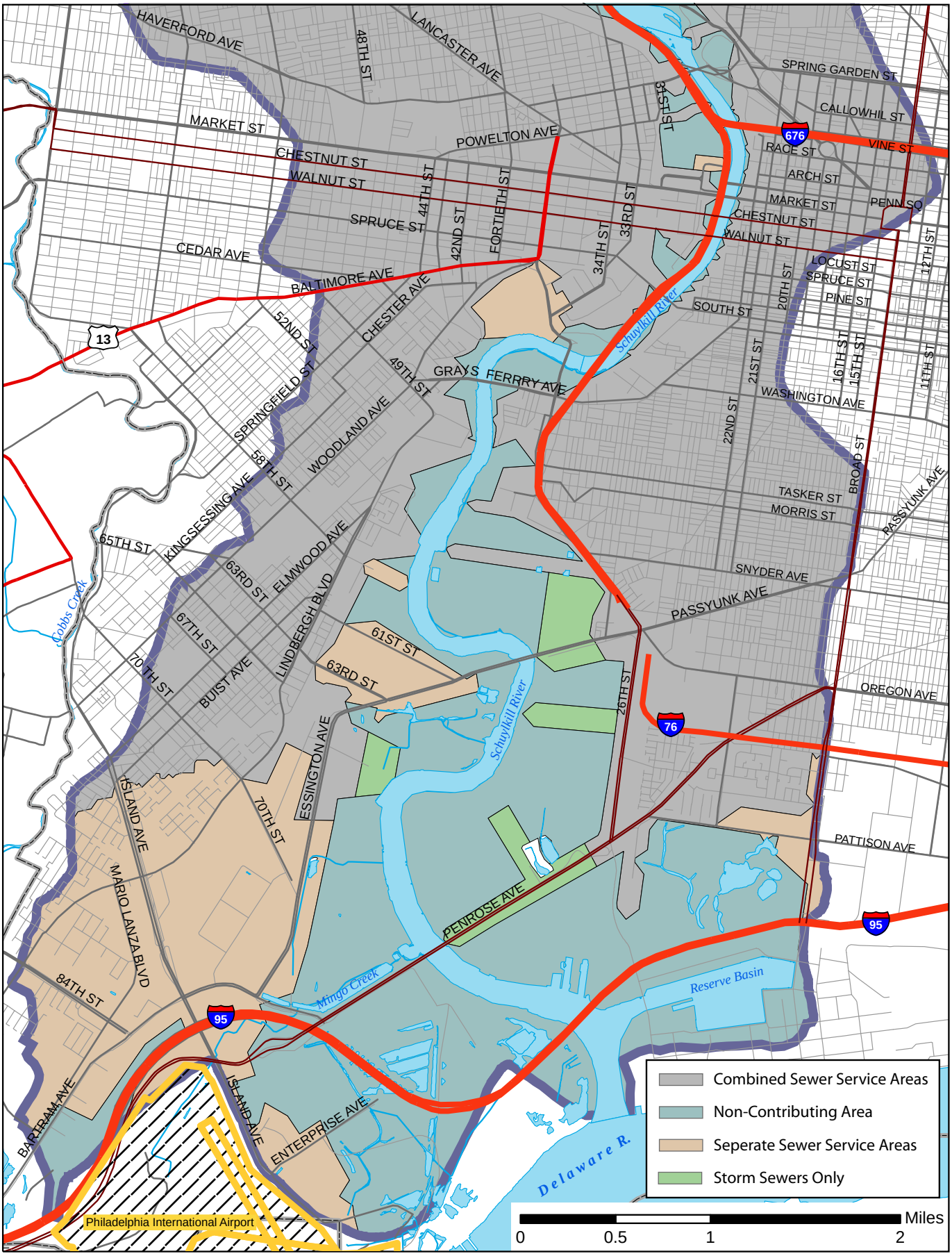

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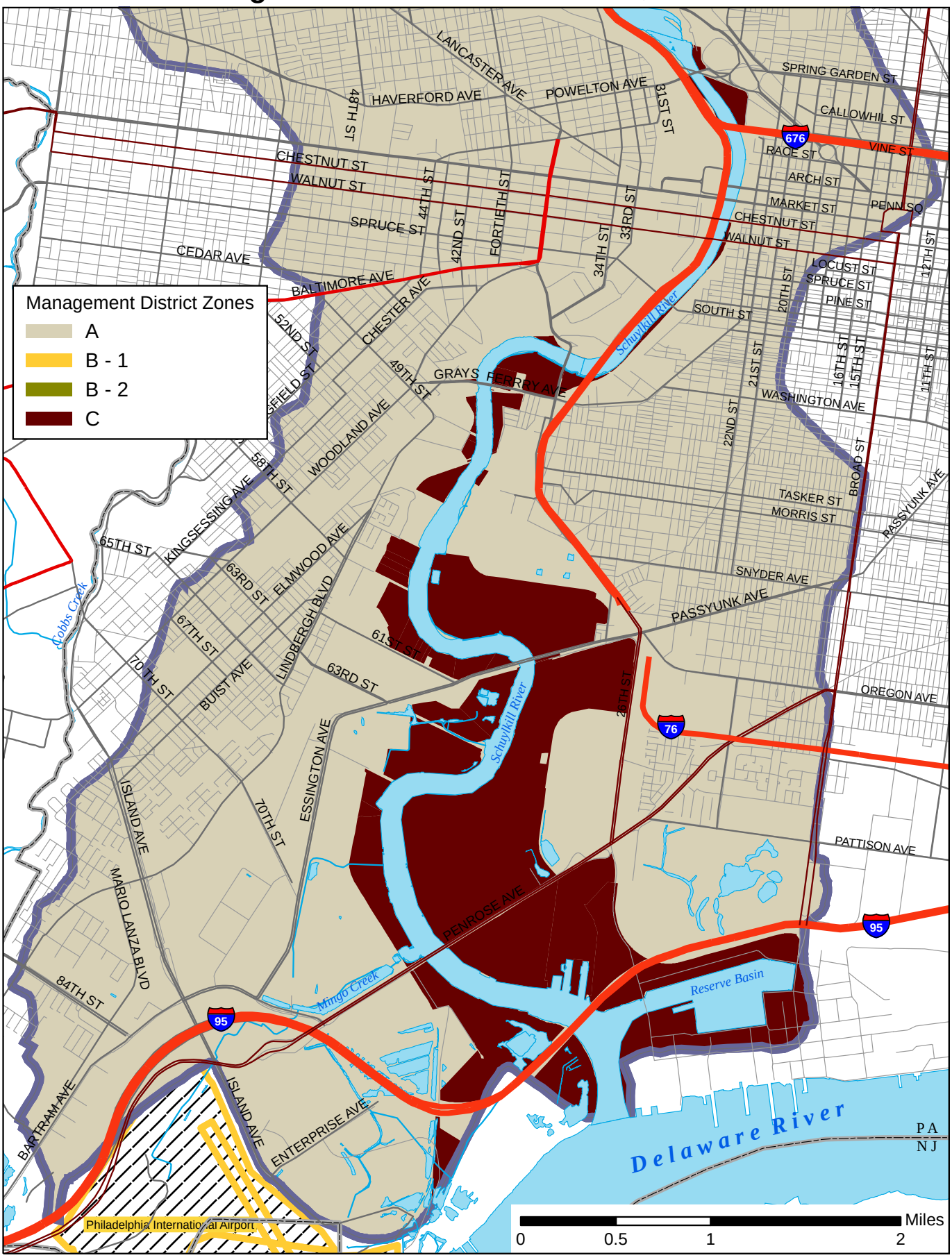
Stormwater Management Districts

Tidal Schuylkill Watershed B



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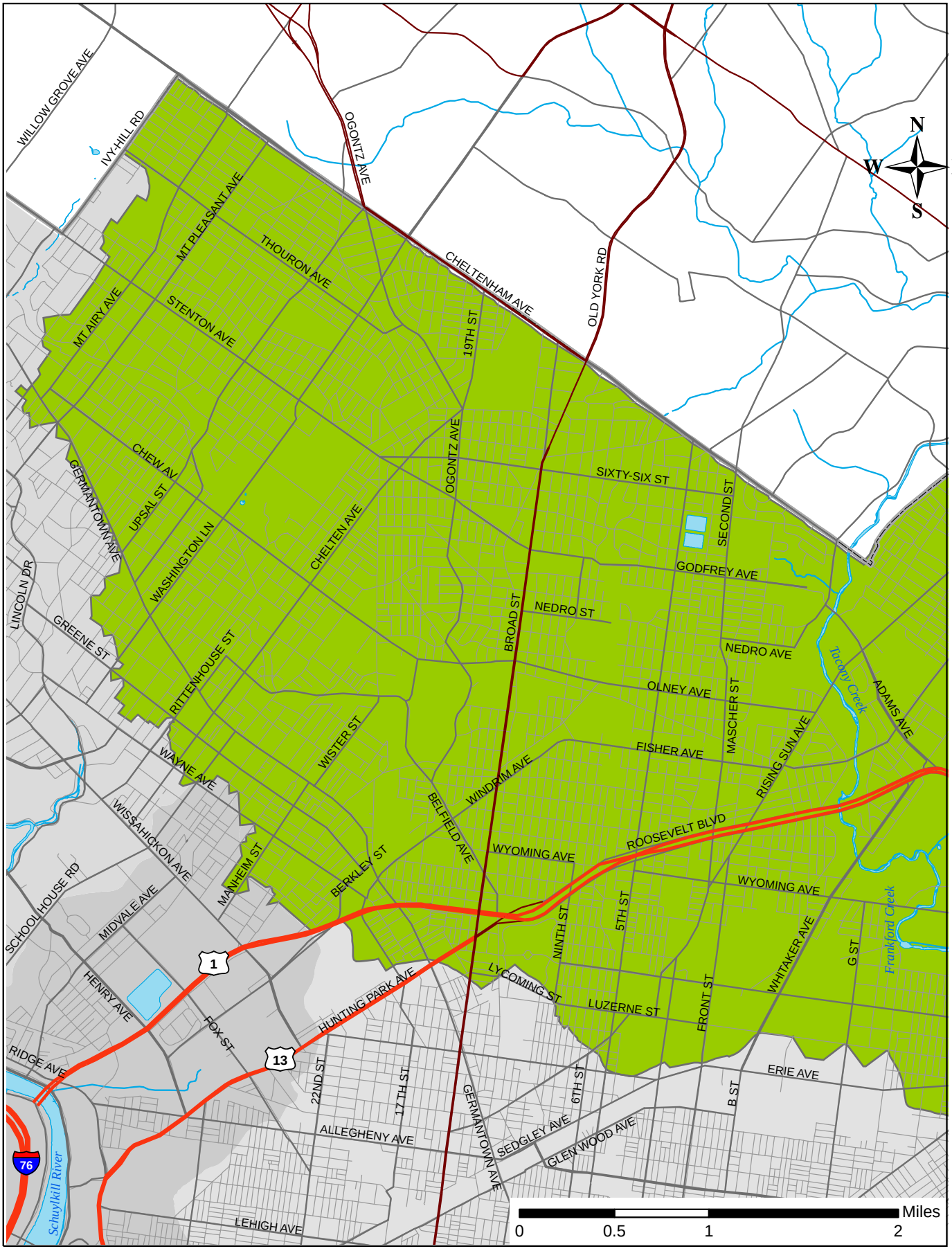
Watershed Locator

Tookany-Tacony Frankford Watershed A



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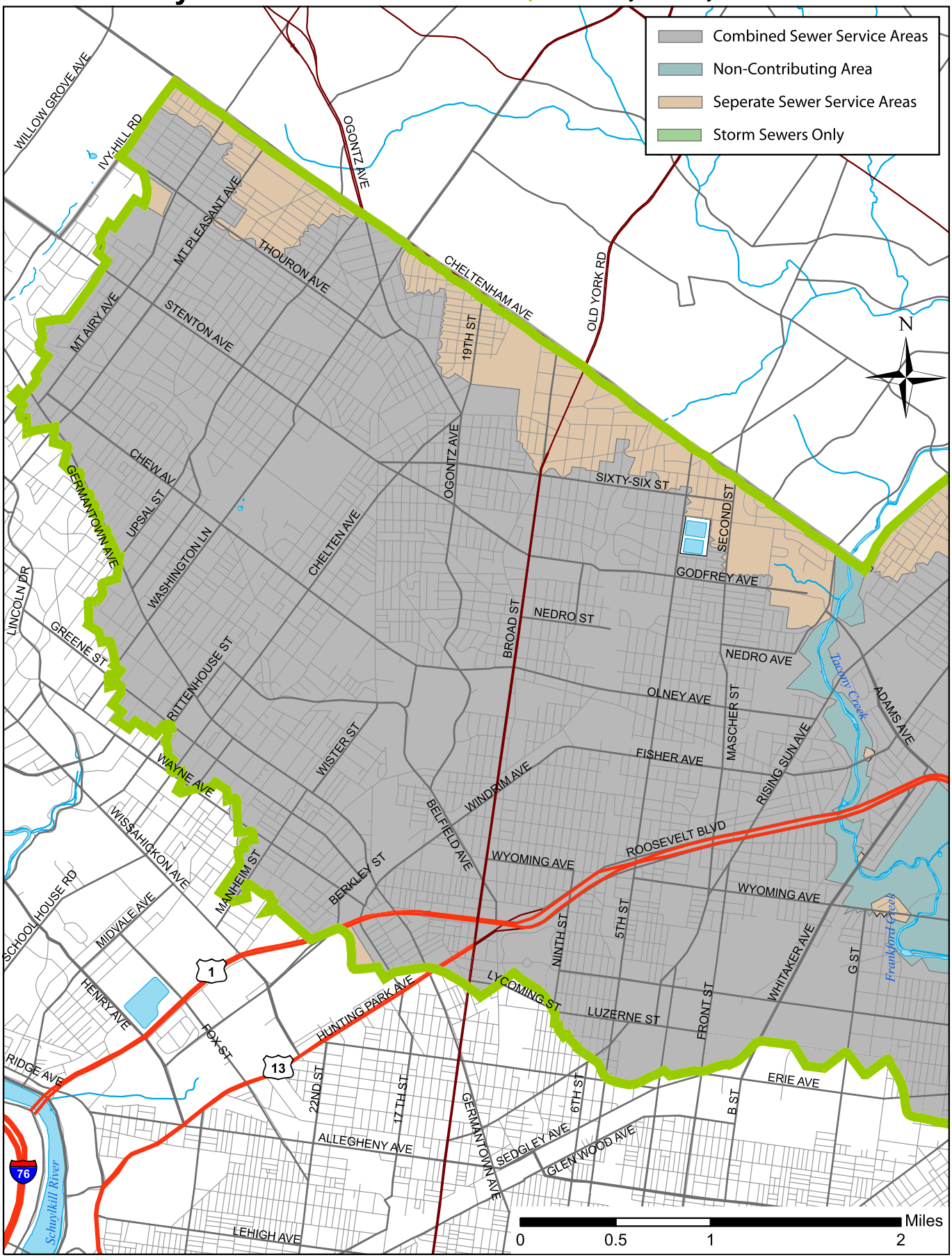
Collection System

Tookany-Tacony Frankford Watershed A



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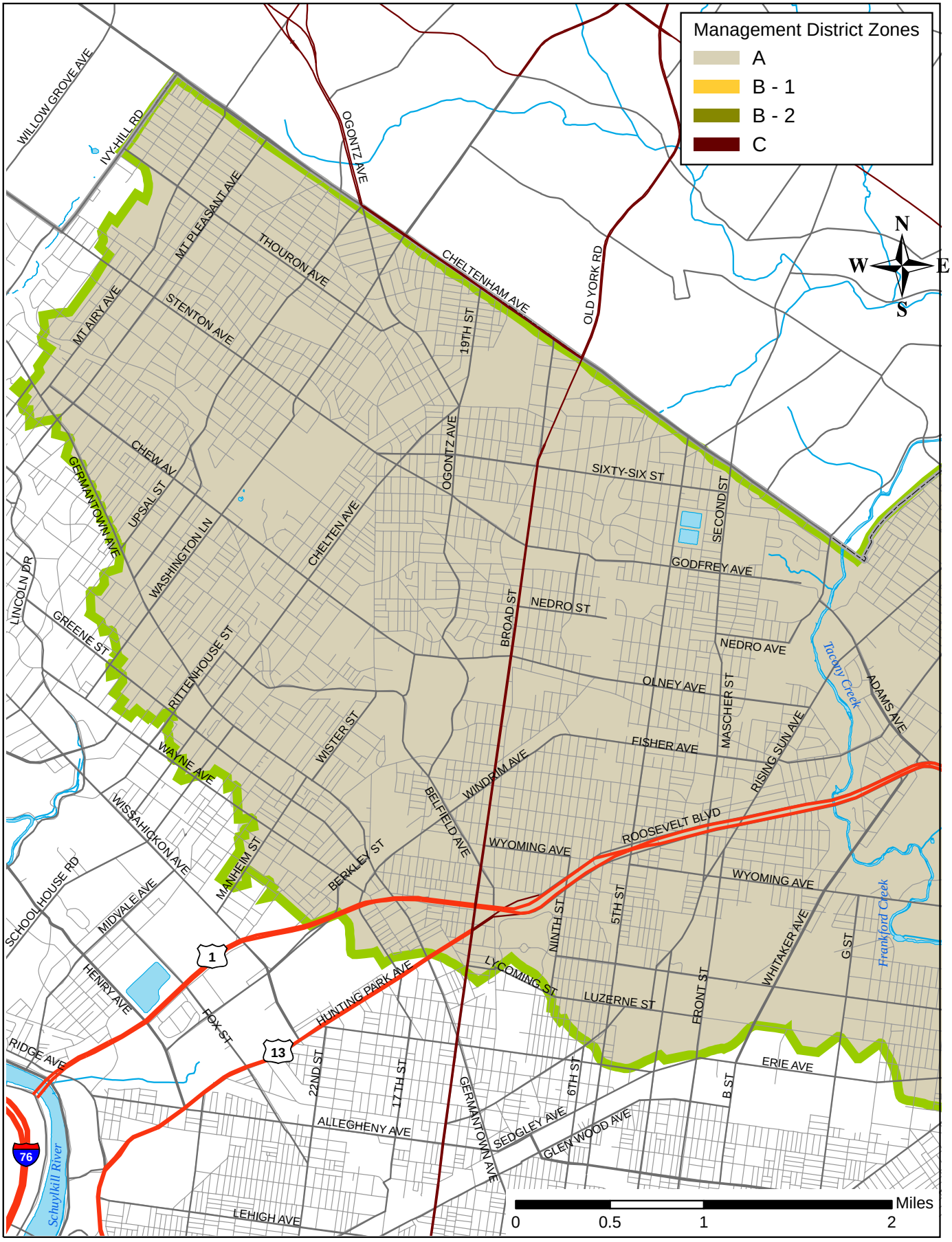
Stormwater Management Districts

Tookany-Tacony Frankford Watershed A



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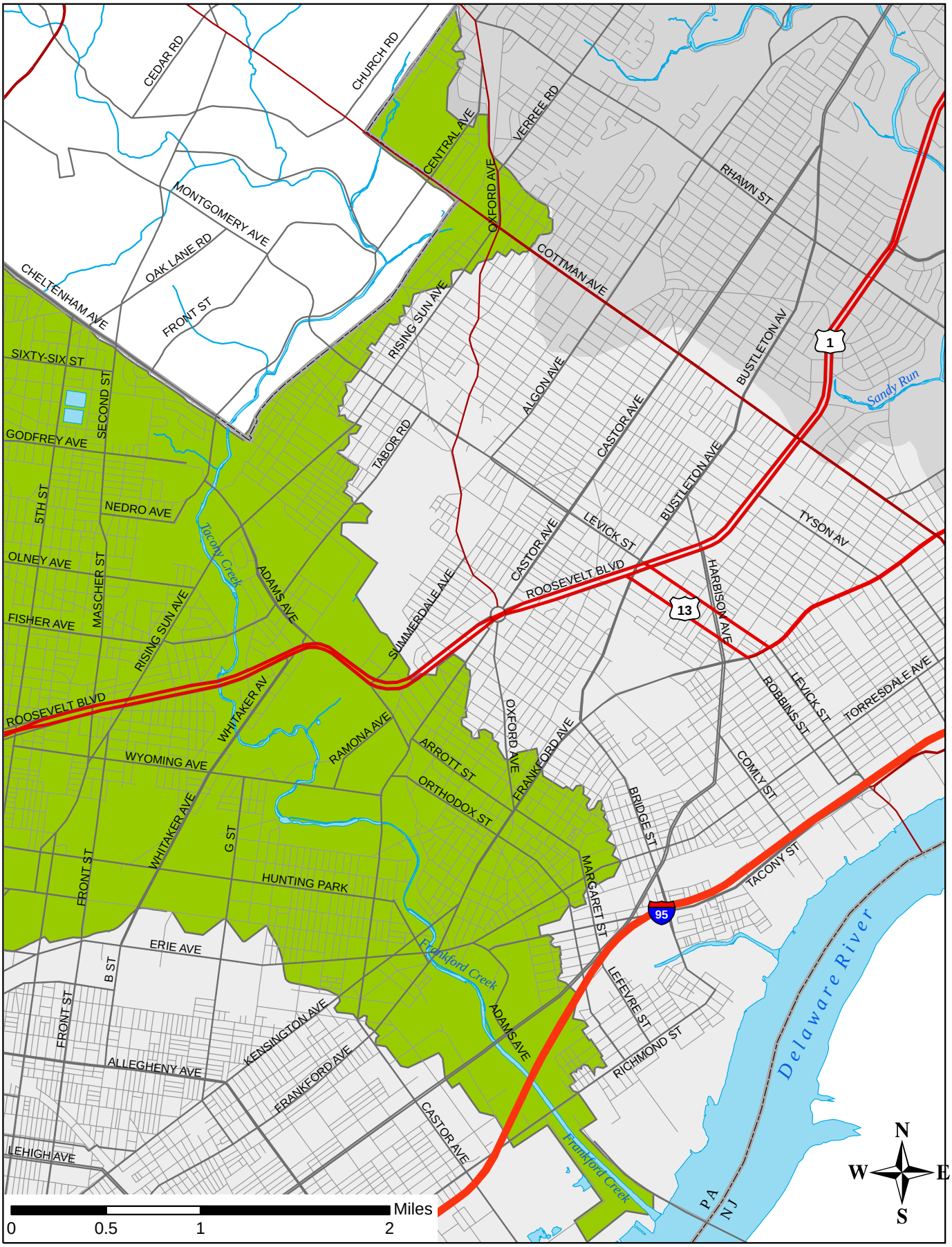
Watershed Locator

Tookany-Tacony Frankford Watershed B



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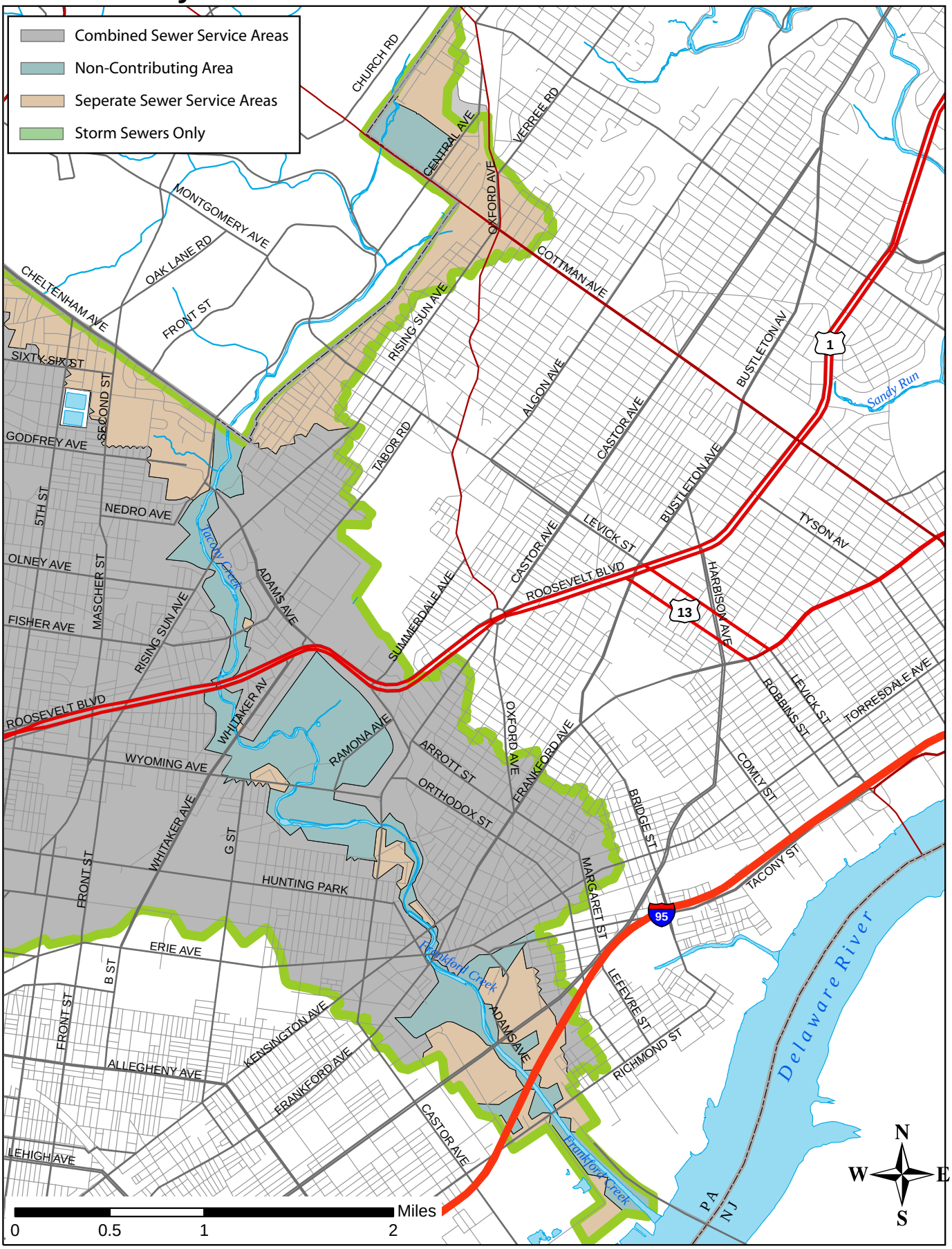
Collection System

Tookany-Tacony Frankford Watershed B



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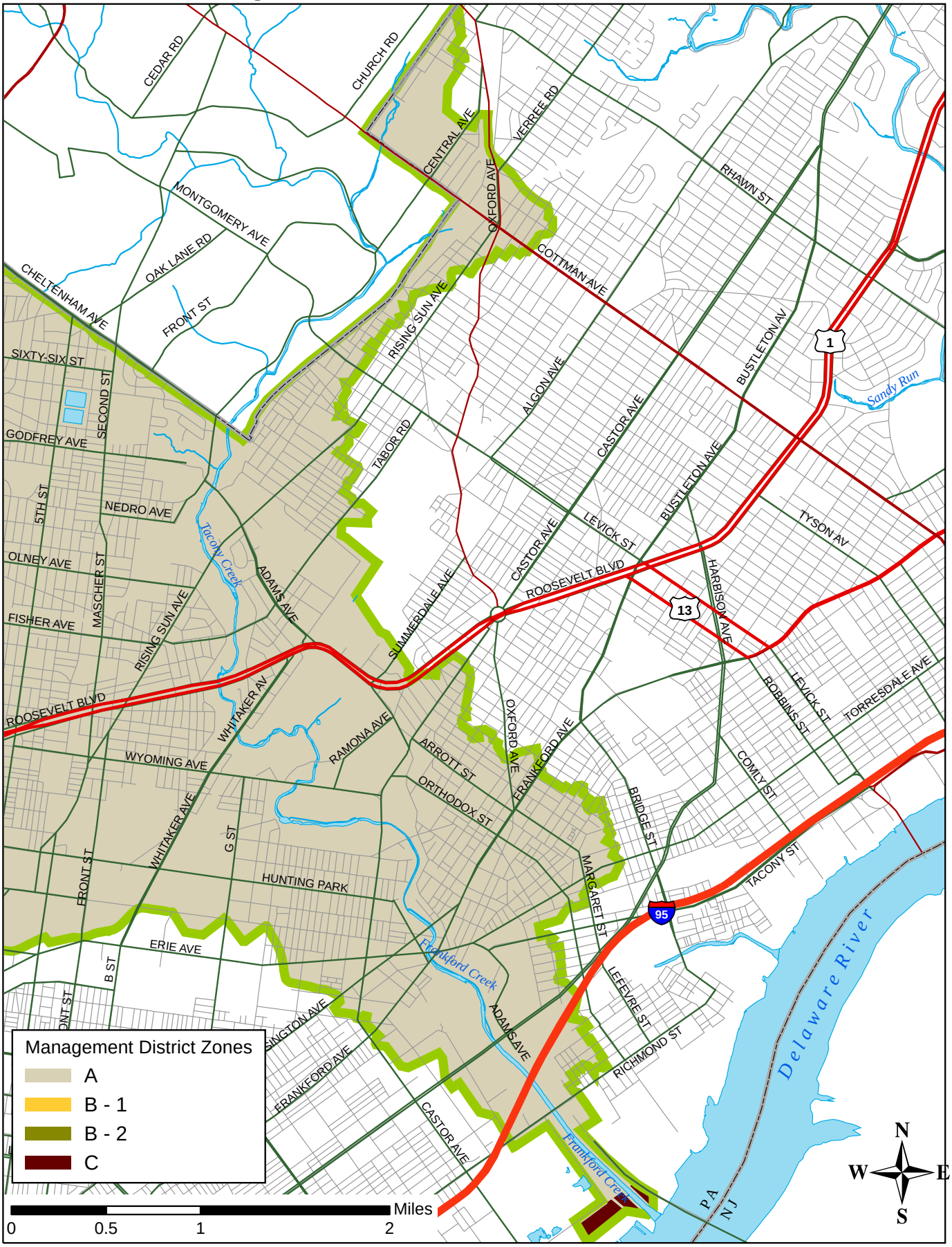
Stormwater Management Districts

Tookany-Tacony Frankford Watershed B



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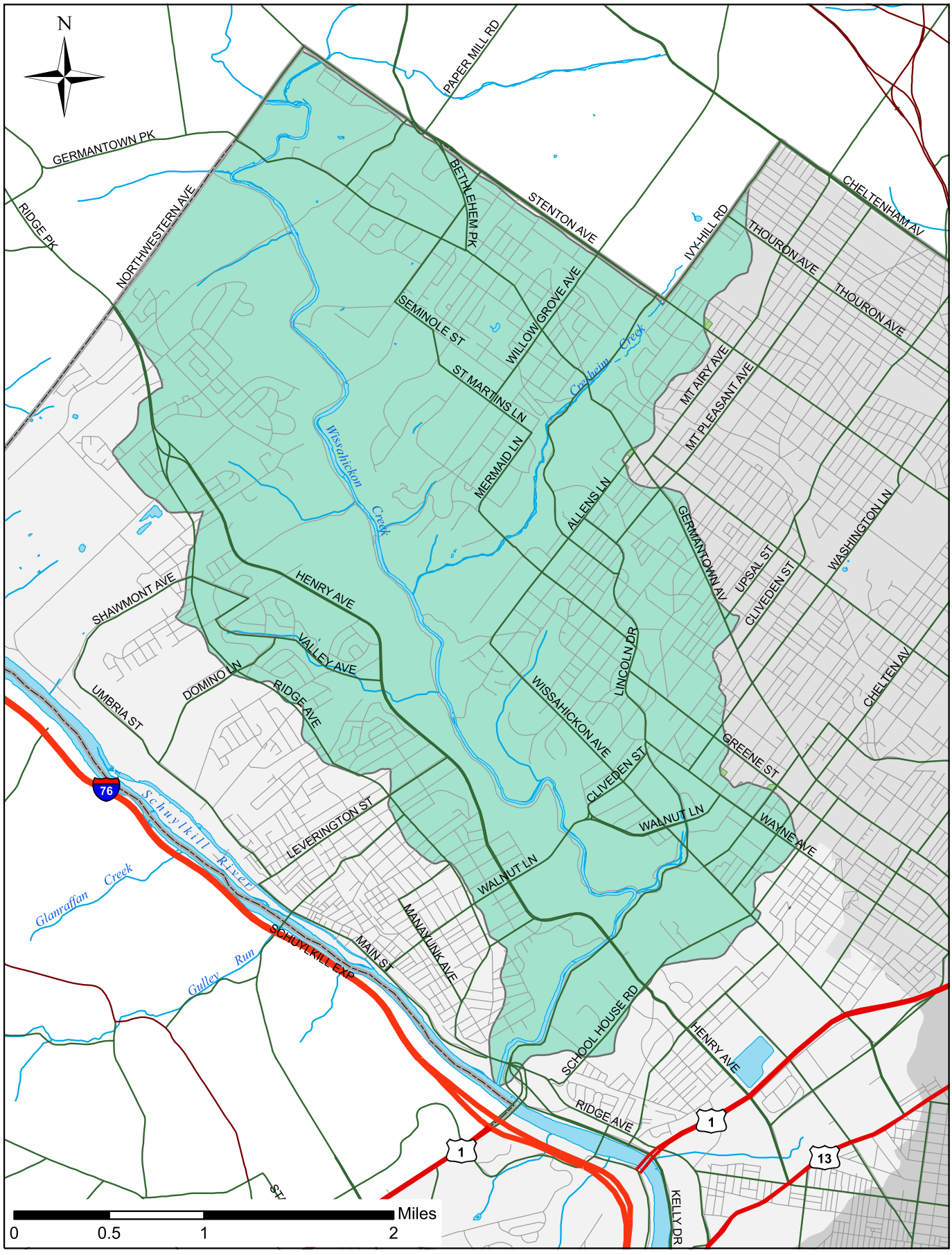
Watershed Locator

Wissahickon Watershed



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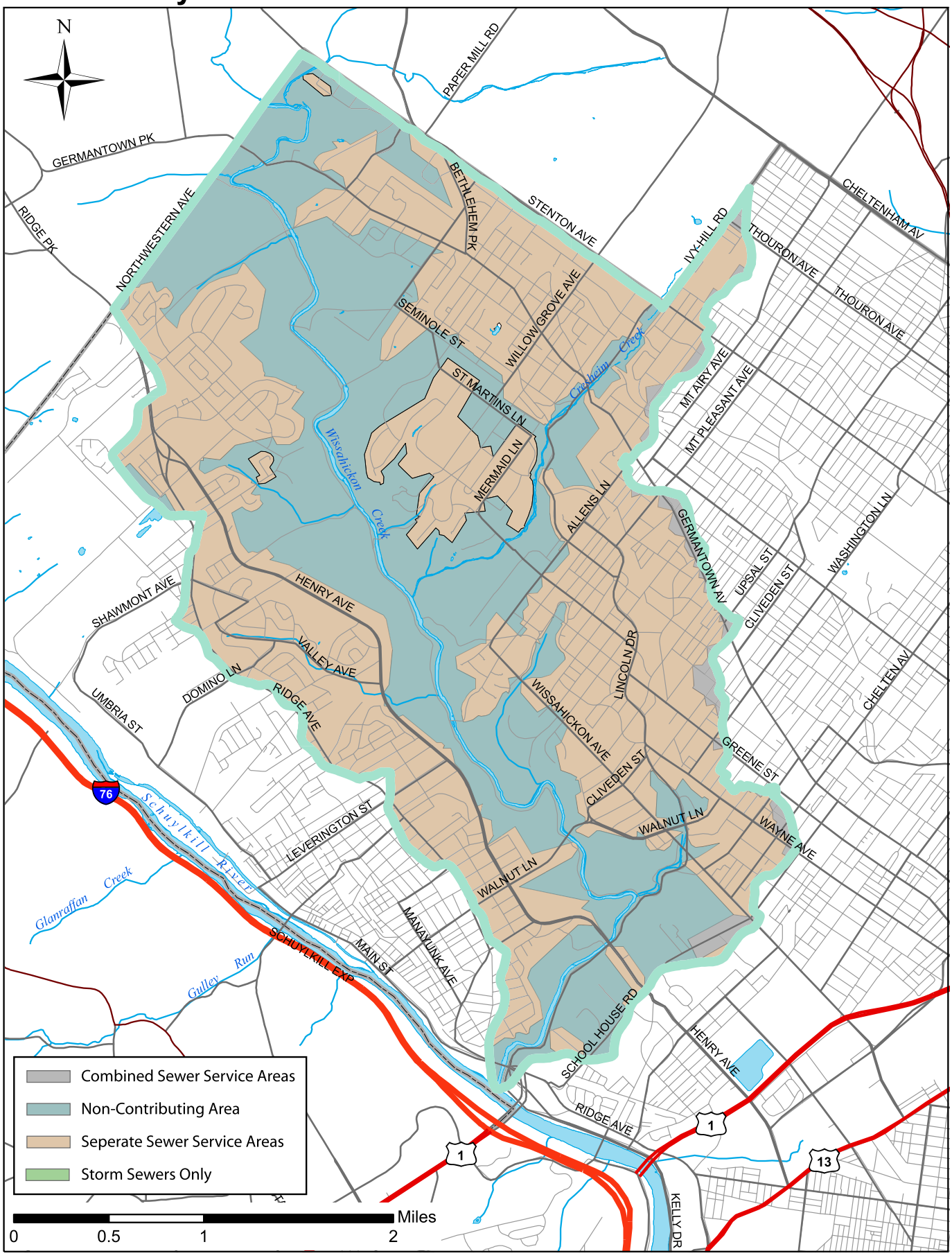

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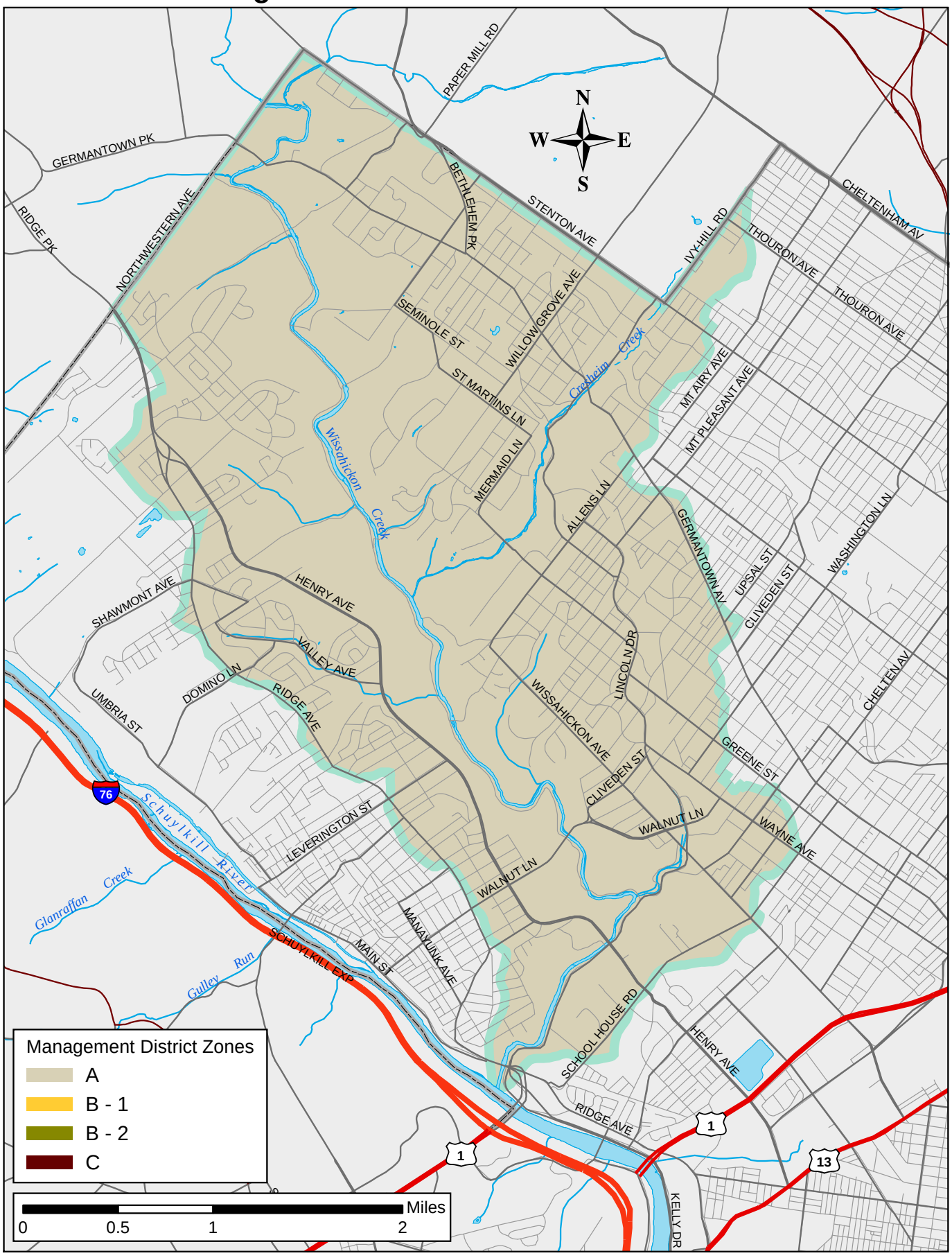
Stormwater Management Districts



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Worksheets and Checklists

Refer to http://www.PhillyRiverInfo.org/PWDDevelopmentReview
for the most recent Checklists and Worksheets

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F

Regulatory Guidance

F.1 The Philadelphia Stormwater Management Regulations
F.2 Local Permitting Requirements
F.3 Federal and State Permitting Requirements
F.4 Special Circumstances and Waiver Requests
F.5 PWD Review Policies

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F.1

The Philadelphia Stormwater Management Regulations

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600.0 STORMWATER MANAGEMENT

The Water Department, as authorized by Section 14-1603.1 of the Philadelphia Code, requires the following specifications for stormwater detention and retention systems as of January 1, 2006.

600.1 Definitions

For the purposes of these Regulations, the following words and phrases shall mean and be interpreted pursuant to the below definitions. Whenever any of these words appear in these Regulations in the singular or plural form, the opposite shall also hold as applicable.

(a) Buffer: The area of land immediately adjacent to any surface water body measured perpendicular to and horizontally from the top-of-bank on both sides of a stream that must remain or be restored to native plants, trees, and shrubs.

(b) Design Professional: A licensed professional engineer registered in the Commonwealth of Pennsylvania.

(c) Design Storm: The magnitude and temporal distribution of precipitation from a storm event defined by probability of occurrence (e.g., five-year storm) and duration (e.g., 24-hours), used in the design and evaluation of stormwater management systems.

(d) Developer: Any landowner, agent of such landowner, or tenant with the permission of such landowner, who makes or causes to be made a subdivision of land or land development project prior to issuance of the Certificate of Occupancy.

(e) Development: Any human-induced change to improved or unimproved real estate, whether public or private, including but not limited to land development, construction, installation, or expansion of a building or other structure, land division, street construction, and site alteration such as embankments, dredging, grubbing, grading, paving, parking or storage facilities, excavation, filling, stockpiling, or clearing. As used in these Regulations, development encompasses both new development and redevelopment. It includes the entire development site, even when the project is performed in stages.

(f) Development Site: The specific tract of land where any Earth Disturbance activities are planned, conducted, or maintained.

(g) Diffused Drainage Discharge: Drainage discharge not confined to a single point location or channel, such as sheet flow or shallow concentrated flow.

(h) Directly Connected Impervious Area (DCIA): An impervious or impermeable surface, which is directly connected to the drainage system as defined in the Manual.

(i) Earth Disturbance: Any human activity which moves or changes the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling, or storing of soil, rock or earth materials.

(j) Erosion and Sediment Control Plan: A plan for a project site that identifies stormwater detention and retention structures that will minimize accelerated erosion and sedimentation during the construction phase.

(k) Groundwater Recharge: The replenishment of existing natural underground water supplies without degrading groundwater quality.

(l) Management District: Sub-area delineations that determine peak rate attenuation requirements, as defined in the Manual. Sites located in more than one management district shall conform to the requirements of the district into which the site discharges.

(m) Manual: The most recent version of the Philadelphia Stormwater Management Guidance Manual.

(n) New Development: Any development project that does not meet the definition of redevelopment as defined in these Regulations or any development project at a site where structures or impervious surfaces were removed before January 1, 1970.

(o) Post Construction Stormwater Management Plan (PCSMP): A complete stormwater management plan as described in these regulations and in the Manual.

(p) Predevelopment Condition: For new development, the predevelopment condition shall be the existing condition of the site, and for redevelopment, predevelopment shall be defined according to the procedures found in the Manual.

(q) Redevelopment: Any development on a site that requires demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970, with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered redevelopment. Interior remodeling projects are also not considered redevelopment.

(r) Stormwater Management Practice (SMP): Any man-made structure that is designed or constructed to convey, store, or otherwise control stormwater runoff quality, rate, or quantity. Typical SMPs include, but are not limited to, detention and retention basins, swales, storm sewers, pipes, and infiltration structures.

(s) Stormwater Pretreatment: Techniques employed to remove pollutants before they enter the SMP, limited to techniques defined and listed as pretreatment in the Manual.

600.2 Regulated Activities

(a) Regulated activities under these Regulations include any development, including new development and redevelopment, that results in an area of earth disturbance greater than or equal to 15,000 square feet. The area of Earth Disturbance during the construction phase determines requirements for both the erosion and sediment controls and the post-construction stormwater management.

(b) The applicability of these Regulations is summarized in the Table of Applicable Stormwater Regulations in Philadelphia.

(c) These Regulations shall apply to the entire development site even if development on that site is to take place in phases.

(d) Existing SMPs may be used on sites where development occurs as long as they meet all of the requirements of these Regulations.

600.3 Exemptions

(a) General Exemptions

The following cases are exempt from the specified requirements of these Regulations.

(1) Development, including new development and redevelopment, that results in an area of Earth Disturbance less than fifteen thousand (15,000) square feet is exempt from all requirements of these Regulations;

(2) Redevelopment that results in an area of Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet, but less than one (1) acre, is exempt from the requirements of Section 600.5(b), Channel Protection Requirement.

(3) Redevelopment that results in an area of Earth Disturbance greater than or equal to one (1) acre and reduces the predevelopment DCIA on the site by at least twenty percent (20%) is exempt from the Channel Protection and Flood Control Requirements of this Regulation.

(b) Exemption Responsibilities

An exemption shall not relieve the Developer from implementing such measures as are necessary to protect public health and safety.

(c) Emergency Exemption

Emergency maintenance work performed for the protection of public health and safety is exempt from the requirements of these Regulations. A written description of the scope and extent of any emergency work performed shall be submitted to the Water Department within two (2) calendar days of the commencement of the activity. If the Water Department finds that the work is not an emergency, then the work shall cease immediately and the requirements of these Regulations shall be addressed as applicable.

(d) Special Circumstances

If conditions exist that prevent the reasonable implementation of water quality and /or quantity control practices on site, upon written request by the owner, the Philadelphia Water Department may at its sole discretion accept off-site stormwater management practices, retrofitting, stream restorations, or other practices that provide water quality and /or quantity control equal or greater than onsite practices for the volume which the owner has demonstrated to be infeasible to manage and treat on site.

Table of Applicable Stormwater Regulations in Philadelphia				
		Earth Disturbance Associated with Development		
		0-15,000 sq. ft.	15,000 sq. ft.-1 acre	> 1 acre
Section 600.5(a) Water Quality Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes
Section 600.5(b) Channel Protection Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Exempt	Yes (Alternate Criteria)
Section 600.5(c) Flood Control Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes (Alternate Criteria)	Yes (Alternate Criteria)
Section 600.6 Nonstructural Project Design Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes
Section 600.8 Post-Construction Stormwater Management Plan Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes

Yes (Alternate Criteria) – requirements of section may be waived depending on post-development site conditions (See Sections 600.3(a)(3), 600.5(b) and 600.5(c) for further details).

N/A - Not Applicable, development project is not subject to requirements of indicated Regulations section. Voluntary controls are encouraged.

Exempt – Development project is not subject to requirements of indicated Regulations section.

**– If the proposed development results in stormwater discharge that exceeds stormwater system capacity, causes a combined sewer overflow, or degrades receiving waters, the design specifications presented in these Regulations may be applied to proposed development activities as warranted to protect public health, safety, or property.

600.4 Erosion and Sediment Control during Earth Disturbance

(a) All Earth Disturbance must comply with the Erosion and Sediment Control requirements of the Pennsylvania Department of Environmental Protection (PADEP) as specified in 25 Pa. Code § 102.4(b).

(b) No Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet and less than 1 acre shall commence until the Water Department approves an Erosion and Sediment Control Plan conforming to the regulations of the PADEP.

600.5 Post-Construction Stormwater Management Criteria

(a) Water Quality Requirement: The Water Quality Requirement is designed to recharge the groundwater table and to provide water quality treatment for stormwater runoff.

(1) The following formula shall be used to determine the water quality volume, (WQv), in cubic feet of storage for the development site.

$$WQ_v = \left(\frac{P}{12}\right) * (I) \qquad \text{Eqn: 600.1}$$

Where:

WQv = Water Quality Volume (cubic feet)

P = 1.0 inch

I = DCIA within the limits of earth disturbance (square feet)

(2) Groundwater Recharge Requirement: In order to preserve or restore a more natural water balance on new development and redevelopment sites, the water quality volume shall be infiltrated on site. A list of acceptable practices for infiltration is provided in the Manual.

(A) The infiltration volume shall be equal to one (1.0) inch of rainfall over all DCIA within the limits of Earth Disturbance.

(B) The Design Professional is required to follow the Hotspot Investigation, Subsurface Stability, and Suitability of Infiltration procedures in the Manual to determine whether the proposed infiltration on the Development Site is appropriate.

(C) If soil investigation reports demonstrate that the soil is unsuitable for infiltration, the Design Professional shall be responsible for providing written documentation to the Water Department showing that the required volume cannot physically be infiltrated within the required time period.

(3) Water Quality Treatment Requirement.

(A) Where it has been demonstrated, in accordance with section 600.5(a)(2) of these Regulations, that a portion or all of the water quality volume cannot be infiltrated on site, the water quality volume which cannot be infiltrated on site must be treated for water quality.

(B) Water quality treatment is attained differently in separate sewer areas than in combined sewer areas. Separate sewer areas achieve water quality treatment through approved stormwater management practices. Combined sewer areas achieve water

quality treatment by detaining and releasing stormwater at a specified maximum rate as stated in the Manual.

(b) Channel Protection Requirement: The Channel Protection Requirement is designed to minimize accelerated channel erosion resulting from stormwater runoff from Development Sites.

(1) To meet the Channel Protection Requirement, SMPs shall retain or detain the runoff from all DCIA within the limits of Earth Disturbance from a one-year, 24-hour Natural Resources Conservation Service (NRCS) Type II design storm in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours to drain from the facility.

(2) Redevelopment sites with less than one (1) acre of Earth Disturbance or redevelopment sites that demonstrate a twenty percent (20%) reduction in DCIA from predevelopment conditions as described in the Manual are exempt from this requirement.

(3) The infiltration and water quality volumes may be incorporated into the channel protection portion of the design provided the design meets all requirements concurrently.

(4) Design criteria and a list of SMPs for channel protection are included in the Manual.

(c) Flood Control Requirement

(1) To prevent flooding caused by extreme events, the City of Philadelphia is divided into Management Districts that require different levels of stormwater attenuation depending on their location. Design Professionals shall determine the appropriate Management District for the development site using the maps provided in the Manual.

(A) The Table of Peak Runoff Rates for Management Districts lists the attenuation requirements for each Management District.

(B) Sites located in more than one Management District shall conform to the requirements of the district where the discharge point is located.

(2) Redevelopment sites that can demonstrate a twenty percent (20%) reduction in DCIA from predevelopment conditions as described in the Manual are exempt from this requirement.

(3) Predevelopment Conditions for Redevelopment are specified in the Manual.

Table of Peak Runoff Rates for Management Districts

District	Column A NRCS Type II 24-hour Design Storm applied to Proposed Condition	Column B NRCS Type II 24 –hour Design Storm applied to Predevelopment Condition
A	2 – year	1 - year
A	5 – year	5 - year
A	10 – year	10 - year
A	25 – year	25 - year
A	100-year	100-year
B-1	2 – year	1- year
B-1	10 – year	5 - year
B-1	25 – year	10 - year
B-1	50- year	25- year
B-1	100-year	100-year
B-2	2 – year	1- year
B-2	5 – year	2 - year
B-2	25 – year	5 - year
B-2	50- year	10- year
B-2	100 – year	100 - year
C*	Conditional Direct Discharge District	

SMPs shall be designed such that peak rates from Column B are less than or equal to Peak Rates from Column A.

* In District C, development sites that can discharge directly to the Delaware River main channel or Tidal Schuylkill River major tributary without use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms.

The Predevelopment Condition for new development is the existing condition. For redevelopment purposes, the Predevelopment Condition is determined according to the procedures found in the Manual.

600.6 Nonstructural Project Design and Sequencing to Minimize Stormwater Impacts

(a) A Developer is required to find practicable alternatives to the surface discharge of stormwater, the creation of impervious surfaces, and the degradation of Waters of the Commonwealth.

(b) All development shall include the following steps in sequence to comply with water quality requirements of §14.1603.1 of the Philadelphia Code. The goal of the sequence is to minimize the increases in stormwater runoff and impacts to water quality resulting from the proposed regulated activity.

(1) Prepare an Existing Resource and Site Analysis (ERSA) map and worksheet, showing environmentally sensitive areas including, but not limited to: steep slopes, ponds, lakes, streams, suspected wetlands, hydric soils, vernal pools, land development, any existing recharge areas, and any other requirements of the worksheet available in the Manual;

(2) establish a Buffer by preserving or restoring native plants, trees, and shrubs to the area of land immediately adjacent to any surface water body.

(A) The Buffer shall be a minimum of ten (10) feet on both sides of the stream, measured perpendicular to and horizontally from the top-of-bank.

(B) In the Wissahickon Watershed, there shall be no new impervious ground cover constructed or erected within 200 feet of the bank of a surface water body or within 50 feet of the centerline of a swale.

(3) prepare a draft project layout avoiding the sensitive areas identified in ERSA;

(4) evaluate nonstructural stormwater management alternatives as described in the Manual;

(5) minimize Earth Disturbance during the construction phase;

(6) use site design techniques described in the Manual to minimize the impervious surfaces within the limits of Earth Disturbance;

(7) use techniques in the Manual to minimize DCIA within the limits of Earth Disturbance;

(8) design appropriate detention and retention structures according to the Manual;

(A) meet Water Quality Requirement and provide for Stormwater Pretreatment prior to infiltration or water quality treatment in accordance with the Manual

(B) meet Channel Protection Requirement in accordance with Section 600.5(b) of these Regulations;

(C) meet Flood Control Requirement for the appropriate Management District in accordance with Section 600.5(c) of these Regulations; and

(9) adjust the site design as needed to meet all requirements of the Regulations concurrently.

600.7 Requirements for the Design of SMPs

(a) General Requirements

(1) In order to provide for the protection of public health and safety and to more effectively manage stormwater in Philadelphia, all SMPs shall meet the requirements of these Regulations.

(2) The existing points of concentrated drainage that discharge onto adjacent land shall not be altered in any manner that could cause property damage without written permission of the owner of the adjacent land.

(3) The design of all SMPs shall incorporate sound engineering principles and practices as detailed in the Manual. The Water Department reserves the right to disapprove any design that would result in the creation or continuation of a stormwater problem area.

(4) All stormwater runoff in excess of any volume infiltrated on site must be routed through a dedicated stormwater pipe and conveyed up to the approved connection or point of discharge.

(5) When the Development Site is located within a combined sewer area and adjacent to a receiving water body, stormwater shall be discharged directly to receiving waters after requirements of these Regulations and any applicable state or federal requirements are met.

(6) Areas of existing diffused drainage discharge shall be subject to any applicable discharge criteria in the general direction of existing discharge, whether proposed to be concentrated or maintained as diffused drainage areas, except as otherwise provided by these Regulations. If diffused drainage discharge is proposed to be concentrated and discharged onto adjacent land, the Developer must document that adequate downstream conveyance facilities exist to safely transport the concentrated discharge, or otherwise prove that no erosion, sedimentation, flooding or other impacts will result from the concentrated discharge.

(7) All SMPs shall incorporate maximum ponding and/or draw down requirements consistent with the Manual.

(8) Calculation Methodology: Acceptable calculation methods for the design of SMPs are provided in the Manual.

600.8. PCSMP Requirements

(a) General Requirements

For any activities regulated by these Regulations and the Philadelphia Code Section §14.1603.1:

(1) No zoning permit may be applied for until the Water Department has approved a conceptual site plan.

(2) No Earth Disturbance may commence or Zoning Permit be issued until the Water Department has approved a PCSMP.

(b) Preliminary Approval

In order to obtain preliminary approval from the Water Department, the owner must complete the ERSA worksheet and map and Site Plan Review Meeting with the City as described in the Manual.

(c) PCSMP Approval

(1) The PCSMP shall include a general description of the project, project sequence, calculations, maps and plans as described in Section 600.6(b) of these Regulations. A list of required contents of the PCSMP is located in the Manual.

(2) For any activities that require one or more state or federal permits, proof of application for said permit(s) or approvals shall be part of the plan.

(3) All PCSMP materials shall be submitted to the Water Department in a format that is clear, concise, legible, neat, and well organized; otherwise, the PCSMP shall not be accepted for review and shall be returned to the Developer for revision.

600.9 Permit Requirements by Other Government Entities

(a) Other government entities may require permits for certain regulated Earth Disturbance activities.

(b) Requirements for these permits must be met prior to commencement of Earth Disturbance.

600.10 Inspections

(a) The Water Department or its designee may inspect any phase of the installation of the SMPs.

(b) During any stage of the work, if the Water Department or its designee determines that the SMPs are not being installed in accordance with the approved PCSMP, the Water Department shall issue a "Stop Work Order" until a revised PCSMP is submitted and approved and the deficiencies are corrected.

(c) As-built drawings for all SMPs must be submitted to the Water Department prior to final inspection.

(d) A final inspection of all SMPs shall be conducted by the Water Department or its designee to confirm compliance with the approved PCSMP prior to the issuance of any Certificate of Occupancy.

600.11 Responsibilities for Operations and Maintenance of SMPs

(a) No regulated Earth Disturbance activities shall commence until the Water Department has approved a PCSMP and SMP Operations and Maintenance Plan (O & M Plan), prepared in accordance with the requirements set forth in the Manual, which describes how the post-construction SMPs will be properly operated and maintained.

(b) The O & M Plan must include a signed agreement between the owner and the City to maintain the SMPs in accordance with the O & M Plan.

(c) There shall be no alteration or removal of any SMP required by an approved PCSMP and O & M Plan, and the owner must not allow the property to remain in a condition which does not conform to an approved PCSMP and O & M Plan.

(d) The Water Department reserves the right to accept or reject the operations and maintenance responsibility for any or all of the stormwater controls and SMPs.

600.12 Stormwater Management Easements

(a) Stormwater management easements or right-of-ways are required for all areas used for off-site SMPs or stormwater conveyance, unless a waiver is granted by the Water Department.

(b) Stormwater management easements shall be provided by the owner if necessary for access for inspections and maintenance, or for the preservation of stormwater runoff conveyance, infiltration, detention areas and/or other stormwater controls and SMPs, by persons other than the property owner.

(c) The stormwater management easement and its purpose shall be specified when recorded in accordance with section 600.13 of these Regulations.

600.13 Recording of O& M Plans

(a) The owner of any land upon which SMPs will be placed, constructed or implemented as described in the PCSMP and Operation and Maintenance Plan (O & M Plan), shall record the following documents with the Philadelphia Department of Records, within fifteen (15) calendar days of approval of the PCSMP by the Water Department:

(1) The O & M Plan, or a summary thereof, and

(2) Operations and Maintenance Agreements as included as part of the PCSMP submitted under Section 600.8 and Easements under Section 600.12 of these Regulations.

(b) The Water Department may suspend or revoke any approvals granted for the project site upon discovery of the failure of the owner to comply with these Regulations.

600.14. Prohibited Discharges

(a) No person shall allow, or cause to allow, stormwater discharges into the City's separate storm sewer system which are not composed entirely of stormwater.

(b) In the event that the Water Department determines that any discharge to a storm sewer is not composed entirely of stormwater, the Water Department will notify the responsible person to immediately cease the discharge.

(c) Nothing in this Section shall affect a discharger's responsibilities under state law.

600.15 Prohibited Connections

(a) The following connections are prohibited, except as provided in Section 600.14(a)(1) of these Regulations.

(1) Any drain or conveyance, whether on the surface or subsurface, which allows any non-stormwater discharge including sewage, groundwater, process wastewater, and wash water, to enter the separate storm sewer system.

(2) Any connections to the storm drain system from indoor drains and sinks.

(3) Any drain or conveyance connected from a commercial or industrial land use to the separate storm sewer system that has not been documented in plans, maps, or equivalent records, and approved by the City.

_____
Bernard Brunwasser
Water Commissioner

Approved as to Form,
Romulo L. Diaz, Jr., City Solicitor

Per:_____
Keith J. Jones
Deputy City Solicitor

F.2

Local Permitting Requirements

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F. 2. Local Permitting Requirements

In order to disturb earth in the City of Philadelphia, developers may be required to obtain permits and/or approvals from various City agencies and departments. The list below is provided for convenience, however, this list is only current as of June 2007. and it is subject to change. Developers should consult with the Department of Licenses and Inspections for the most up to date guidance on permit requirements in the City of Philadelphia.

* Licenses and Inspections (http://www.phila.gov/LI)
    * Zoning Permit
    * Building Permit
* City Planning Commission (http://www.philaplanning.org/)
    * Plat Approval
* Philadelphia Water Department (http://www.phila.gov/water)
    * Act 537
    * Sewer
    * Water
    * Stormwater
    * Groundwater Discharge Permit
    * Industrial Waste
* Fairmount Park (http://www.phila.gov/fairpark/)
* Streets Department (http://www.phila.gov/streets)
* Fire Commissioner (http://www.phila.gov/fire/)
* Historical Commission (http://www.phila.gov/historical/)

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F.3

Federal and State Permitting Requirements

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F. 3 State and Federal Permitting Requirements

In addition to City Permits and approvals as described in F3, land development may be subject to state and federal regulations. Each project is likely to have slightly different requirements. This Manual contains information that was valid as of June 2007 which is subject to change. Developers should consult with the appropriate regulatory agency to determine applicable plan and/or permitting requirements for development or earth disturbance activities. Some common requirements include:

- Pennsylvania Department of Transportation (PENN DOT): Highway Occupancy Permit
- Pennsylvania Department of Environmental Protection (PADEP): Construction Erosion and Sedimentation Control Plan
- Pennsylvania Department of Environmental Protection (PADEP): West Nile Virus Control Plan and Guidance Documents
- National Pollutant Discharge Elimination System (NPDES): General PAG-2 or Individual Permit for Stormwater Discharges Associated with Construction Activities
- PADEP and US Army Corps of Engineers (USACE) Joint Permit: Pennsylvania Water Obstruction and Encroachment Permit and a USACE Section 404 Permit
- PADEP Bureau of Waterways Engineering, Division of Dam Safety: Dam Permit
- PADEP Bureau of Watershed Management: General Permit BDWM-GP-4 Intake and Outfall Structures

For information on Pennsylvania Department of Environmental Protection (PADEP) requirements see the PADEP Guide to Permits for Land Development and/or contact the:

PADEP
Southeast Regional Office
2 East Main Street,
Norristown, PA 19401.
http://www.dep.state.pa.us/

For further information on Federal Regulations:

- Clean Water Act (http://www.epa.gov/region5/water/cwa.htm)
- United States Environmental Protection Agency (USEPA) Region 3

  USEPA Region 3
  1650 Arch Street (3PM52)
  Philadelphia, PA 19103-2029
  (http://www.epa.gov/reg3wapd/programs.htm)
- National Pollutant Discharges Elimination System (NPDES) (http://cfpub.epa.gov/npdes/)
- Pennsylvania Department of Environmental Protection

  PADEP
  Bureau of Water Supply and Wastewater Management
  Permits Section
  PO Box 2063
  Rachel Carson State Office Building
  Harrisburg, PA 17105-2063
- Army Corps of Engineers

  USACE
  Wanamaker Building, Rm 600
  100 Penn Square East
  Philadelphia, PA 19107-3390

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F.4

Special Circumstances and Waiver Requests

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F.4. Special Circumstances and Waiver Requests

F.4.1 Special Circumstances

The Philadelphia Stormwater Management Regulations state:

> *600.3 (d) If conditions exist that prevent the reasonable implementation of water quality and quantity control practices on site, upon written request by the Owner, the Office of Watersheds of the Philadelphia Water Department, may at its sole discretion accept off-site SMPs, retrofitting, stream restorations, or other practices that provide water quality and quantity control equal or greater than onsite practices for the volume that the Owner has demonstrated to be infeasible to treat on site.*

The Philadelphia Water Department (PWD) recognizes that there may be circumstances on a proposed site that make it impractical to implement on-site stormwater management practices to the standards specified in this manual. Applicants who ask to have their projects considered for special circumstances must demonstrate the extent to which onsite Stormwater Management Practices (SMPs) are infeasible.

PWD will review a complete Post Construction Stormwater Management Plan (PCSMP) to determine if special circumstances warrant treatment of a portion or all of the stormwater from a site. The PWD may at its sole discretion accept:

- off-site SMPs,
- retrofitting,
- stream restorations, or
- other practices

that provide water quality control equal or greater than onsite practices for the volume that the Owner has demonstrated to be infeasible to treat on site. The developer shall account for the management of all stormwater runoff from the site unless they can demonstrate that it is infeasible to do so. The developer shall provide stormwater management to the maximum extent practicable, as approved by PWD, in all cases before any off-site facilities or practices as noted above will be allowed. Date

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F.4.2 Waiver Request Process

Infiltration Waiver Requests

A waiver from the infiltration requirement **must** be requested at any site where infiltrilration is infeasible. To request a waiver form the infiltration requirement send the following form letter, a complete infiltration waiver request worksheet and stamed and signed geotechnical report for the project area to:

Projects Control
Philadelphia Water Department
1101 Market Street, 2nd Floor
Philadelphia, PA 19107

It is strongly recommended that all waiver requests be submitted before the PCSMP is submitted as the site design may be significantly affected. A copy of the waiver request approval should be submitted with the PCSMP. Please note that all waivers may be revoked should information become available which contradicts the original request. Electronic versions of all waiver request form letters and worksheets can be downloaded from www.PhillyRiverInfo.org/PWDDevelopmentReview.

Small Orifice Waiver Request

A waiver from the 3-inch minimum orifice design **must** be requested when use of a smaller orifice is being proposed. To request a waiver form the 3-inch minimum, send the following form letter and a complete small orifice request worksheet to:

Projects Control
Philadelphia Water Department
1101 Market Street, 2nd Floor
Philadelphia, PA 19107

It is strongly recommended that all waiver requests be submitted before the PCSMP is submitted as the site design may be significantly affected. A copy of the waiver request approval should be submitted with the PCSMP. Please note that all waivers may be revoked should information become available which contradicts the original request. Electronic versions of all waiver request form letters and worksheets can be downloaded from www.PhillyRiverInfo.org/PWDDevelopmentReview.

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F.5

PWD Review Policies

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Case Studies

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Abbreviations & Acronyms

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Abbreviations & Acronyms

CERM	Civil Engineering Reference Manual
CSO	Combined Sewer Overflow
DCIA	Directly Connected Impervious Area
DIC	**Disconnected Impervious Cover**
PADEP	Pennsylvania Department of Environmental Protection
E & S	Erosion and Sediment
ERSA	Existing Resource and Site Analysis
HSG	Hydrologic Soil Group
L & I	Department of Licenses & Inspections
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
O & M	Operations and Maintenance
PASMM	Pennsylvania Stormwater Management Manual
PA SBMPM	Pennsylvania Stormwater BMP Manual
PCPC	Philadelphia City Planning Commission
PCSMP	Post-Construction Stormwater Management Plan
PWD	Philadelphia Water Department
SMP	Stormwater Management Practice
SWTR	Surface Water Treatment Rule
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
ZBA	Zoning Board of Adjustments

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Glossary

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Glossary Terms

Buffer: The area of land immediately adjacent to any surface water body measured perpendicular to and horizontally from the top-of-bank on both sides of a stream that must remain or be restored to native plants, trees, and shrubs.

Design Professional: A licensed professional engineer registered in the Commonwealth of Pennsylvania.

Design Storm: The magnitude and temporal distribution of precipitation from a storm event measured in probability of occurrence (e.g., five-year storm) and duration (e.g., 24 hours), used in the design and evaluation of stormwater management systems.

Developer: Any landowner, agent of such landowner, or tenant with the permission of such landowner, who makes or causes to be made a subdivision of land or land development project prior to issuance of the Certificate of Occupancy.

Development: Any human-induced change to improved or unimproved real estate, whether public or private, including but not limited to land development, construction, installation, or expansion of a building or other structure, land division, street construction, and site alteration such as embankments, dredging, grubbing, grading, paving, parking or storage facilities, excavation, filling, stockpiling, or clearing. As used in these Regulations, development encompasses both new development and redevelopment. It includes the entire development site, even when the project is performed in stages.

Development Site: The specific tract of land where any earth disturbance activities are planned, conducted, or maintained.

Diffused Drainage Discharge: Drainage discharge not confined to a single point location or channel, such as sheet flow or shallow concentrated flow.

Directly Connected Impervious Area (DCIA): An impervious or impermeable surface, which is directly connected to the drainage system as defined in the Philadelphia Stormwater Management Guidance Manual.

Earth Disturbance: Any human activity which moves or changes the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling, or storing of soil, rock or earth materials.

Existing Conditions: Physical conditions on the site including land use, impervious surface, topography, vegetation, soils, and hydrology that exist on the site on the date the owner starts the development process.

Erosion and Sediment Control Plan: A plan for a project site that identifies stormwater detention and retention structures that will minimize accelerated erosion and sedimentation during the construction phase.

Groundwater Recharge: The replenishment of existing natural underground water supplies without degrading groundwater quality.

Hotspots: Areas where land use or activities have contaminated the soil underlying the site such that infiltration of stormwater would likely cause groundwater contamination through leaching of the soil.

Impervious Surface: A surface that prevents the infiltration of water into the ground. Examples of impervious surface include roofs, streets, sidewalks, and parking or driveway areas that are covered with impervious paving materials such as asphalt or concrete.

Management District: Sub-area delineations that determine peak rate attenuation requirements, as defined in the Manual. Sites located in more than one management district shall conform to the requirements of the district into which the site discharges

Manual: The 2005 or most recent edition of the Philadelphia Stormwater Management Guidance Manual. A comprehensive technical stormwater management reference for use in the City of Philadelphia.

New Development: Any development project that does not meet the definition of redevelopment as defined in these Regulations or any development project at a site where structures or impervious surfaces were removed before January 1, 1970.

Owner: Any person, landowner, developer, or tenant with the permission of such landowner who holds legal title to a property subsequent to issuance of the Certificate of Occupancy.

Post Construction Stormwater Management Plan (PCSMP): A complete stormwater management plan as described in these regulations and in the Manual.

Predevelopment Condition: for the purpose of new development, the predevelopment condition shall be the existing condition of the site. For redevelopment, predevelopment shall be defined according to the procedures found in the Manual.

Redevelopment: Any development on a site that requires demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970 with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered redevelopment. Interior remodeling projects are also not considered redevelopment.

Stormwater Management Practice (SMP): Any man-made structure that is designed or constructed to convey, store, or otherwise control stormwater runoff quality, rate, or quantity. Typical SMPs include, but are not limited to, detention and retention basins, swales, storm sewers, pipes, and infiltration structures.

Stormwater Pretreatment: Techniques employed in SMPs to remove pollutants before they enter the structure, limited to techniques defined and listed as pretreatment in the Manual.

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Voluntary Small Sites Checklist

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Voluntary Small Sites Checklist

Note: Sites smaller than 15,000 sq. ft are not subject to the Philadelphia Water Department Stormwater Management Regulations. However voluntary adherence to these regulations is strongly encouraged, since these regulations were adopted to promote a cleaner, healthier, and a more aesthetically pleasing environment for all to enjoy.

Systems Approach to Stormwater Management

Step 1: Protect and Utilize Existing Site Features (refer to Section 4.1 Protect and Utilize Existing Site Features)

Y	N	
☐	☐	Has an inventory of existing site vegetation been performed?
		☐ If yes, was this inventory a factor in the site layout and design?
☐	☐	Have inventories of existing site soils and slopes been performed?
		☐ If yes, were these inventories factors in the sites layout and design?
☐	☐	Does the site design utilize any of the following nonstructural SMPs?
		☐ Preservation of stormwater sensitive and natural features (i.e. Riparian zone, flood plains, wetlands, steep slopes, etc.).
		☐ Preservation of native ground cover.
		☐ Installation of vegetative buffers.
☐	☐	Was minimization of earth disturbance part of the design process?
☐	☐	Was soil compaction minimized during the design process?
☐	☐	Did the design include a soil erosion and sedimentation plan?
☐	☐	In the design process was impervious areas clustered and concentrated in specific areas?
☐	☐	In the areas of earth disturbance was vegetation reestablished?

Step 2: Reduce Impervious Cover to be Managed (refer to Section 4.2 Reduce Impervious Cover to be Managed)

Y	N	
☐	☐	Were the roof leaders disconnected?
		If yes please specify which of the following SMPs were used.
		☐ Green Roofs.
		☐ Dry wells.
		☐ Rain Barrels.
		☐ Cistern.
		☐ Vegetative Filter.
		☐ Rain Garden.
		☐ Bioretention Islands.
		☐ Planters.
		☐ Other (Please Specify):_____
☐	☐	Were ground level impervious surfaces disconnected?
		If yes please specify which of the following SMPs were used.
		☐ Grading Techniques.
		☐ Porous Pavement.
		☐ Vegetative Filters.

- ☐ Subsurface Storage and Infiltration Techniques.
- ☐ Swales.
- ☐ Bioretention,
- ☐ Other (Please Specify):_____

☐☐ Were trees used as a stormwater management practices?

Note: trees must be within 20 ft of directly connected impervious area inside the earth disturbance boundary in order to be counted toward Stormwater

If yes and the tree are inside the specified area, Please answer the following questions

- ☐ Were new tree planted?
- ☐ Was the canopy from existing tree coverage used to determine stormwater benefit?

Step 3: Management of Remaining Stormwater (refer to Section 4.3 Management of Remaining Stormwater)

Y	N	
☐	☐	Were structural SMPs used to capture and treat stormwater runoff? If yes please list below.

☐	☐	Were pretreatment systems installed for each structural SMP?
☐	☐	Was operation and maintenance taken into account during the structural SMP design process?

Note: Refer to Section 6 Detailed Stormwater Control Design Guideline of the Philadelphia Stormwater Management Manual for specific guidance on each SMP Described above.

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Homeowner’s Guide to Stormwater Management

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A Homeowner's Guide to Stormwater Management

You can make a difference!

Learn what you can do on your property and in your community to improve the health of your watershed.

Prepared by: **Office of Watersheds**
Philadelphia Water Department
Volume 1 • January 2006

SARB_015557

The Office of Watersheds would like to thank the following organizations and partners for their assistance and for the use of their materials in this guide:

Center for Watershed Protection

Fairmount Park Commission

Montgomery County Conservation District

NAM Planning & Design, LLC

National Oceanic & Atmospheric Administration (NOAA)

Pennsylvania Department of Environmental Protection (DEP)

Pennsylvania Horticultural Society

Philadelphia Department of Streets

South River Federation

TreeVitalize

University of Wisconsin — Extension

Washington State Puget Sound Action Team

Wisconsin Department of Natural Resources

Wissahickon Valley Watershed Association

Disclaimer

The information contained in this guide is being offered by the City of Philadelphia (City) through its Water Department (PWD) for the use of residents of the City. Please note that the stormwater management projects or Best Management Practices (BMPs) in this guide are voluntary projects recommended strictly for homeowners. They are not designed for professionals required to comply with the City's Stormwater Regulations.

If you plan to install any of the following structural projects on your property in the City, please notify PWD via its e-mail address (WaterShedsPWD@phila.gov): Rain Barrels, Rain Gardens, or Dry Wells. PWD would like to register your project with the City's Department of Licenses & Inspections (L&I). Also, PWD encourages you to take photographs of your project and to send them to PWD via the above e-mail address

If you experience problems with any water or sewer piping on your property, you should contact a registered plumber.

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A Homeowner's Guide to Stormwater Management

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Introduction



The Office of Watersheds of the Philadelphia Water Department has a vision for Philadelphia—"Clean Water—Green City." We want to unite the City with its water environment, creating a green legacy for future generations while incorporating a balance between ecology, economics and equity.

In order to achieve the goal of "Clean Water-Green City," we must work together with our partners, local residents, homeowner associations and municipalities on managing stormwater in a manner that will restore our watersheds. We can all play a part in taking an active role in converting our streams, creeks and surrounding green spaces into healthy systems that local residents, along with native fish and wildlife, can use as amenities, sanctuaries and habitats. As a homeowner, your part can be as simple as maintaining your car properly or building a rain garden on your lawn. This guide provides you with the steps and actions you can take to improve stormwater management on your property or in your community. These stormwater management projects will not only help protect our invaluable drinking water sources, but they will help green the city, restore our waterways and improve quality of life for all residents.

For more information, please visit www.PhillyRiverInfo.org or e-mail WaterShedsPWD@phila.gov.

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Vehicle Maintenance



By maintaining your car properly you can prevent oil leaks, heavy metals and toxic materials from traveling from your car onto the street. Rain washes oil and other hazardous chemicals from the street into the nearest storm drain, ultimately draining into the Delaware and Schuylkill Rivers, the source of drinking water for many. Just imagine the number of cars in our region and the amount of oil that finds its way into our local waterways! It has been estimated that each year over 180 million gallons of used oil is disposed of improperly (Alameda CCWP, 1992), and that a single quart of oil can pollute 250,000 gallons of drinking water (NDRC, 1994). Please follow proper automotive maintenance.

Maintaining your Vehicle

- Maintain your car and always recycle used motor oil.
- Check your car or truck for drips and oil leaks regularly and fix them promptly. Keep your vehicle tuned to reduce oil use.
- Use ground cloths or drip pans under your vehicle if you have leaks or if you are doing engine work. Clean up spills immediately and properly dispose of clean up materials.
- Collect all used oil in containers with tight-fitting lids. Old plastic jugs are excellent for this purpose.
- Recycle used motor oil. Many auto supply stores, car care centers, and gas stations will accept used oil. Do not pour liquid waste down floor drains, sinks or storm drains.
- Do not mix waste oil with gasoline, solvents, or other engine fluids. This contaminates the oil which may be reused, increases the volume of the waste, and may form a more hazardous chemical.
- Never dump motor oil, antifreeze, transmission fluid or other engine fluids into road gutters, down the storm drain or catch basin, onto the ground, or into a ditch.
- Many communities have hazardous waste collection days where used oil can be brought in for proper disposal. Find out about your program. Recycling just one gallon of used oil can generate enough electricity to run the average household for almost 24 hours.
- Try to use drain mats to cover drains in case of a spill.
- Store cracked batteries in leak proof secondary containers.

Lawn & Garden Care



When fertilizing lawns and using other common chemicals, such as pesticides and herbicides, remember you're not just spraying the lawn. When it rains, the rain washes the fertilizers, pesticides and herbicides along the curb and into storm drains, which ultimately carry runoff into the Schuylkill and Delaware Rivers, our drinking water source. In addition to degrading the water quality of our streams and rivers, pesticides can kill critters in the stream and fertilizers can cause algal blooms, which rob our waterways of oxygen that fish need to survive. If you have to use fertilizers, pesticides, and herbicides, carefully read all labels and apply these products sparingly.

Many homeowners are unaware of the actual nutrient needs of their lawns. According to surveys conducted by the Center for Watershed Protection, over 50% of lawn owners fertilize their lawns, yet only 10 to 20% of lawn owners take the trouble to perform soil tests to determine whether fertilization is even needed (CWP, 1999). *Organic lawn care practices (no chemical pesticides and fertilizers) can also be a wise environmental choice and will save you money.* Conduct a soil test on your lawn and follow the below practices to reduce the need to fertilize on your lawn and garden.

Caring for your Lawn and Garden

- Use fertilizers sparingly. Lawns and many plants do not need as much fertilizer or need it as often as you might think. Test your soil to be sure!
- Consider using organic fertilizers; they release nutrients more slowly.
- Never fertilize before a rain storm (the pollutants are picked up by stormwater during rain events).
- Keep fertilizer off of paved surfaces—off of sidewalks, driveways, etc. If granular fertilizer gets onto paved surfaces, collect it for later use or sweep it onto the lawn.
- Use commercially available compost or make your own using garden waste. Mixing compost with your soil means your plants will need less chemical fertilizer and puts your waste to good use. Another alternative is to use commercial compost, called Earthmate, which is available for free through PWD. Call 215-685-4065 or visit the website to learn more about Earthmate: www.phila.gov/water/brc/brchow2get.html
- Let your grass clippings lay! Don't bag the grass. Use a mulching lawn mower to cut one-third of the blade length each week and naturally fertilize your lawn in the process.

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Lawn & Garden Care

- Wash your spreader equipment on a pervious (penetrable) vegetated area, like the lawn, to allow for the natural absorption of excess fertilizer.
- Never apply fertilizer to frozen ground or dormant lawns.
- Maintain a buffer strip of unmowed natural vegetation bordering waterways and ponds to trap excess fertilizers and sediment from lawns/gardens.
- Grow an organic garden (no pesticides or fertilizers). Call the Organic Landscape Alliance at 1-866-820-0279 or visit www.organiclandscape.org.

Pet Waste



When animal waste is left on the ground, rainwater or melting snow washes the pet waste into our storm drains or directly into our local creeks. The disease-causing bacteria found in pet waste eventually flows from our local waterways into the Delaware and Schuylkill Rivers, our drinking water source. In addition to contaminating waterways with disease-carrying bacteria, animal waste acts like a fertilizer in the water, just as it does on land. This promotes excessive aquatic plant growth that can choke waterways and promote algae blooms, robbing the water of vital oxygen.

Scooping Up the Poop

- Bag it! When going for dog walks, take a shopping bag or sandwich bag. When doggy makes a deposit, turn the baggie inside out over your hand and use it as a glove to pick up the waste.
- Flush the pet waste down the toilet because then it is treated at a sewage treatment plant.
- If flushing down the toilet is not a viable option, put the pet waste in the trash, but never put waste into storm drains.
- Encourage your neighbors to provide pet waste stations for collection and disposal of waste. Check to see if the parks in your neighborhood have them.
- Dig a small trench in your yard where your pets tend to defecate and toss the waste in the trench, cover with a layer of leaves, grass clippings, and dirt.
- Dispose waste in disposal units called Doggy Loos where they are installed into the ground. Decomposition occurs within the unit.
- At the park, set up a pooch patch which has a pole surrounded by a light scattering of sand around it. Dog owners can introduce their dog to the pole upon entry to the park. Dogs will then return to the patch to defecate and then you can place the pet waste in special bins for disposal.

Vehicle Washing



Car washing is a common routine for residents and a popular way for organizations, such as scout troops, schools, and sports teams to raise funds. However, most of the time, cars are washed in driveways and parking lots which allow wash water (dirty water) to finds its way to the nearest storm drain, ultimately draining into our drinking water sources, the Delaware and Schuylkill Rivers. The wash water often contains pollutants, such as oils and grease, phosphates (from the soap), and heavy metals—all of which are unhealthy for people and fish.

Washing Your Car Properly

- The best action is to take your vehicle to a commercial car wash, especially if you plan to clean the engine or the bottom of the car. Most car washes reuse water several times before sending it for treatment at a sewage treatment plant.

If you still want to wash your car at home...

- Wash your car on gravel, grass or another permeable surface, so the ground can filter the water naturally.
- Use soap sparingly. Try to use non-phosphate detergents. Phosphates are nutrients that can cause problems for nearby waterways.
- Use a hose that is high pressure, low volume. Use a hose with a nozzle that automatically turns off when left unattended or one that has a pistol grip or trigger nozzle to save water. Wash one section of the car at a time and rinse it quickly.
- When you're done, empty your bucket of soapy water down the sink, not the street.
- Block off the storm drain during charity car wash events or use an insert with a vacuum pump to catch wash water and empty it into the sink, not the street.

Tree Planting



If you have any tree planting questions and need to ask an expert, go to www.pennsylvaniahorticulturalsociety.org/garden/ask_gardener

Trees are not only a beautiful addition to the landscape, but they also provide invaluable benefits to cities. They reduce heat by cooling and shading homes during the hot summer months, decreasing the amount of energy required to cool a home and its related electric bills. Mature trees can actually cut summer cooling costs by 40% and tree-lined blocks can even decrease local temperatures. Trees naturally clean the air of pollutants and create a neighborhood noise buffer. Trees also improve stormwater management, reducing the amount of polluted stormwater that normally would go directly into storm drains. Tree roots also allow rainwater to filter back into the soil, recharging the often thirsty water table. A 2005 study by the University of Pennsylvania found that trees can increase property values. Planting a tree within 50 feet of a house can increase its sale price by 10 to 15%. Some studies even indicate that the mere presence of trees can create stronger neighborhood ties and reduce crime.

Planting a Tree

Before getting started, you may be interested in participating in the TreeVitalize rebate program where you may be eligible to receive up to a $25 rebate on the purchase of a tree. Whether you are planting a tree in your yard or hiring a contractor to plant a street tree, you may qualify. For more information, visit www.treevitalize.net and www.pennsylvaniahorticulturalsociety.org/phlgreen/tree-pledge.html.

Also, the Pennsylvania Horticultural Society's Tree Tenders Program offers a basic training course designed to teach general tree-care skills to organized community groups and individuals in Philadelphia. If you are interested in the course or a free copy of the *Tree Tenders Handbook* or *Mini-Guide to Tree Planting,* visit www.pennsylvaniahorticulturalsociety.org/phlgreen/treetenders.

1. Now, if you are ready to get started with your tree planting, select a site appropriate for your tree.
2. Dig the hole at least 1½ to 2 times the width of the root ball (container) to be installed, and no deeper than the height of the root ball so that the root flare (the top of the root mass) is flush with the existing ground. The planting pit should be dug so the walls of the pit are angled like a bowl or sloping outward in heavy soils.
3. Break up the walls of the pit after digging, so that fine roots can penetrate the soil. The soil that you dig out of the hole is what you will use to backfill around the root ball. Soil amendments are not recommended when planting a tree; therefore, no compost, moss, or shredded pine bark should be added to the backfill.

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Tree Planting

You can also volunteer to plant trees elsewhere in the city—along creeks and streams in Fairmount Park and at local schools. The more trees in Philadelphia, the healthier we will be! Contact Fairmount Park, Greater Philadelphia Cares and UC Green to learn how you can volunteer to plant trees.

4. Remove all debris from the pit and gently tightly pack the loose soil in the bottom of the pit by hand.
5. Cut and remove the rope and burlap from around the trunk and check for root flare. Remove all nails. Drop the burlap down to the bottom of the hole.
6. Do not handle the plant by the branches, leaves or stem. Place the plant straight in the center of the planting pit, carrying the plant by the root ball. Never carry a plant by the trunk or branches.
7. After the tree is in the pit, carefully cut and remove the top third of the wire basket and as much burlap as possible using the least amount of disturbance.
8. Backfill planting pit with existing soil and pack it in there tightly to fill all voids and air pockets. Do not over compact soil. Make sure plant remains straight during backfilling/ packing procedure.
9. The top of the root mass (root flare) of the tree should be flush with the final grade. Do not cover stem with soil. If your tree has soil over the trunk flare (where the trunk cures outward into the root system), it is essential to plant the trunk flare above soil. Remove the soil from the root ball if the flare is buried by it.
10. Water plant thoroughly and slowly, immediately after planting to saturate backfill. For the first year after planting, water the tree with 15 gallons per week. Use your index finger to check the soil moisture under the mulch. If the soil is cool to the touch, do not water. If it is warm and dry, then water. A layer of mulch (i.e. shredded bark, compost) should be placed around the tree, at a depth between 3 to 4 inches and with a radius of approximately 2 to 4 inches from the tree stem. Do not rest the mulch directly against the tree stem. The mulch makes it easier to water the tree and reduces weed competition.
11. Remove all tags, labels, strings and wire form the plant material.

Many homeowners ask how a newly planted tree can affect the sewer, water lines, sidewalk and/or building's foundation? If you choose the correct tree, site, and planting conditions, your tree shouldn't interfere with your sewer, waterline, etc. Most tree roots grow in the soil's top 12 inches and spread well beyond the tree's canopy in search of water and nutrients. They don't "attack" underground mains, unless these are already damaged, providing entrances for developing roots. An adequate and generous tree pit, or long, narrow continuous "tree lawn" will provide the best conditions for establishing and maintaining a "well behaved" tree with the environment needed to survive in the city.

Tree Planting

Street Trees

If you do not have a yard, but you would like to have a tree in front of your property —on your sidewalk—you have several options in Philadelphia.

You can get a tree for free and installed at no cost by **Fairmount Park**, however, this may involve being placed on a waiting list

You or a group from your neighborhood can sign up for a **Tree Tenders program** through the Pennsylvania Horticultural Society, where you can get trained to care for your tree, learn how to organize a tree planting project and receive free tree care tools in exchange for your participation.

Lastly, you can **hire a contractor** approved by Fairmount Park to plant a tree in front of your house. However, the contractor you hire must apply for a Street Tree Permit from Fairmount Park before any work can be done. The private planting could cost you up to $500 (not including the price of the tree).

Talk to your neighbors and find out if there is a neighborhood organization or Tree Tenders group organizing a street tree planting project. Some local groups that do tree plantings, include The South of South Neighborhood Organization, UC Green and Citizens Alliance.

Recommended Street Tree List for Philadelphia

The Fairmount Park Commission recommends the below list of approved trees which will thrive in an urban setting, have a good track record, and won't interfere with overhead wires in Philadelphia.

Small Trees—Under 30 feet

Acer buergeranum—Trident Maple

Acer campestre—Hedge Maple

Acer ginnala—Amur Maple

Acer tataricum—Tartarian Maple

Crataegus crus-galli 'Inermis'—Thornless Hawthorn, tree form

Crataegus laevigata 'Superba'—Crimson Cloud Hawthorn tree form

Crataegus phaenopyrum—Washington Hawthorn, tree form

Crataegus viridis—Winter King Hawthorne

Prunus triloba—Flowering Plum

Malus (selected varieties)—Crabapple

Syringa reticulata—Japanese Tree Lilac

Medium Trees 30–46 feet

Aesculus x carnea 'Briotii'—Ruby Red Horsechestnut

Cercidiphyllum japonica—Katsura tree

Cladrastis lutea—Yellowwood

Crataegus lavallei—Lavalle Hawthorn

Koelreuteria paniculata—Golden Rain Tree

Malus (selected varieties)—Crabapple

Ostrya virginiana—Hop Hornbeam

Phellodendron amurense—Amur Cork Tree

Prunus x yedoensis—Yoshino Cherry

Ulmus parvifolia—Chinese Elm

Quercus acutissima—Sawtooth Oak

Large Trees Over 47 feet

Acer rubrum (selected cultivars)—Red Maple

Celtis occidentalis—Hackberry

Corylus colurna—Turkish Filbert

Fraxinus pennsylvanica 'Patmore'—Patmore Green Ash

Gleditsia triacanthos (selected cultivars)—Honey Locust, a) Halka, b) Moraine, c) Shademaster

Ginkgo biloba (male selections only)—Ginkgo

Liquidambar styraciflua—Sweetgum

Quercus rubra—Red Oak

Quercus macrocarpa—Bur Oak

Quercus palustris—Pin Oak

Sophora japonica—Japanese Pagoda Tree

Tilia cordata—Little Leaf Linden

Zelkova serrata (selected cultivars)—Japanese Zelkova—a) Green Vase, b) Village Green

Columnar Trees for Narrow Streets

Acer rubrum 'Armstrong'—Armstrong Columnar Red Maple

Carpinus betulus fastigiata—Pyramidal European Hornbeam

Ginkgo biloba 'Princeton Sentry'—Princeton Sentry Ginkgo Grafted Male Variety

Prunus sargentii 'Columnaris'—Columnar Sargent Cherry

Quercus robur 'Rose Hill'—Rose Hill English Oak

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Backyard Stream



Establish a streamside (riparian) buffer—a vegetated area along the edge of the stream that protects it from pollution and erosion. This buffer zone absorbs pollutants and nutrients that would otherwise end up running directly into the stream. Plant material slows runoff and filters out pollutants and sediments. Well-planted streamside buffers are also a great low-cost way to control erosion. While plants slow runoff, filter pollutants, and help control erosion, trees cast shade on the stream, cooling the water, reducing algae growth and improving fish habitat. A buffer with trees and shrubs also becomes a home to birds, butterflies and other creatures. Trees and plants that grow in the buffer play a critical role in keeping streams healthy.

Caring for Your Stream

- Begin with a "no mow" or "no graze" zone along your stream banks. Make your buffer as wide as possible.
- Plant trees and shrubs in your buffer zone. They provide many long-lasting benefits and can be quite inexpensive to establish and maintain.
- Using shrubs will give your buffer a quick start; many reach full size in just a few years.
- Set your mower blades at least three inches high. Taller grass slows runoff, resists drought and needs less fertilizer
- Use hay bales or a special silt fence to prevent soil from washing off your site and into the stream while establishing your stream buffer.
- Cover piles of soil with tarps to protect them from rain.
- Use good farm practices by not cultivating the soil and planting winter cover crops to conserve soil.
- Contact your local DEP office or county conservation district if you see soil runoff in the stream from a nearby construction site.
- Limit your overall use of pesticides and herbicides, and use extreme caution when using them near streams.
- Keep grazing and other farm animals out of and away from the stream. Contact your county conservation district or the U.S. Fish and Wildlife Service to find out about farm fencing programs.
- Compost yard waste. Don't bag lawn trimmings or throw them into the stream; leave them in place for effective recycling of nutrients.
- Store firewood, trash and other materials well away from streams.

Winter De-icing



As snow piles up in the winter, we oftentimes turn to salt to melt snow and ice. Salt, however, causes adverse environmental impacts, especially on our streams and rivers, our drinking water source in Philadelphia. Excess salt can saturate and destroy a soil's natural structure and result in more erosion to our waterways. High concentrations of salt can damage and kill vegetation. Salt poses the greatest danger to fresh water ecosystems and fish. Studies in New York have shown that as salt concentrations increase in a stream, bio-diversity decreases. Excess salt can seep into groundwater and stormwater runoff. Effective ice control can help prevent excess salt runoff to our waterways.

De-icing in the Winter

There are many alternatives to salt including potassium chloride, calcium chloride and magnesium chloride, corn processing byproducts, and calcium magnesium acetate (CMA). Most can be found in your local hardware stores under various trade names, so check the labels for chemical content. While these alternatives can be spread in a dry form or sprayed as a liquid, their best use occurs when they are used with salt. They tend to increase the efficiency of salt thereby reducing the amount that needs to be applied. When over-applied, all chloride compounds can be harmful to the environment. Non-chloride corn byproducts recycled from mills and breweries have been shown to be effective de-icers as well. While they are often advertised as organic or natural, they can have extremely high phosphorus content, a major water pollutant. Numerous studies have shown calcium magnesium acetate (CMA) to be the most environmentally benign de-icer. Many northern states use CMA on roads in sensitive areas (wetlands, endangered species' habitat, drinking water supply, etc.). A couple of disadvantages with CMA however, is that it does not work well below 25° Fahrenheit and it is the most expensive de-icer. Because all de-icers can be harmful to the environment when applied in excess, the best strategy is to reduce the use of these chemicals as much as possible.

- The first line of defense should simply be to shovel sidewalks and pathways to keep them clear and to prevent ice from forming. Also, consider that salt and de-icers are not effective when more than 3 inches of snow have accumulated.
- Consider the temperature. Salt and calcium magnesium acetate (CMA) have a much slower effect on melting snow and ice at temperatures below 25° Fahrenheit.

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Winter De-icing

- Track winter weather and only use salt and de-icers when a storm is about to come through. If a winter storm does not occur, sweep up any unused material, store, and reuse for the next big storm.
- Apply de-icing products discriminately, focusing on high-use areas and slopes where traction is critical. Apply the least amount necessary to get the job done. This will save money in product costs and will also help minimize property damage to paved surfaces, vehicles, and vegetation.
- Reduce salt and other chemicals by adding sand for traction.
- Become familiar with various de-icing products and wetting agents such as magnesium chloride and calcium chloride, which can improve the effectiveness of salt and reduce the amount needed.
- If you observe ongoing issues of ineffective ice management or examples of poor application, such as excess piles of road salt left to disperse, share your concerns with the property manager of your residence or business, or with the City of Philadelphia Streets Department. The Streets Department Hotline is 215-686-5560 and their website is www.phila.gov/streets.
- Plant native vegetation that is salt tolerant in stormwater drainage swales and ponds that may receive salt-laden runoff. Not only will these native species have a greater chance for survival, but they will continue to act as an effective buffer for our local waterways.
- Store salt and other products on an impervious (impenetrable) surface, such as a basement floor, to prevent ground contamination. Also store products in a dry, covered area to prevent stormwater runoff.

Planters (Container Gardens)







*These are just a few of the websites PWD came across during our research. These particular companies are not endorsed by PWD, nor can PWD verify any information on these companies.

Planters reduce impervious cover (impenetrable surfaces, such as concrete sidewalks, parking lots, etc.) by retaining stormwater runoff rather than allowing it to directly drain into nearby sewers and creeks. Planters offer "green space" in tightly confined urban areas by providing a soil/plant mixture suitable for stormwater capture and treatment. They can be used on sidewalks, parking areas, back yards, rooftops and other impervious areas.

Contained Planters

Contained planters are used for planting trees, shrubs, and ground cover. The planter is either prefabricated or permanently constructed and has a variety of shapes and sizes. Planters may range from large concrete planters to potted plants arranged on an impervious surface like the roof garden shown in the bottom photos to left. Planters can be placed on impervious surfaces like sidewalks, back yards, rooftops, or along the perimeter of a building in order to catch stormwater runoff from the roof. Contained planters may drain onto impervious surfaces through holes in their base or by an overflow structure so the plants do not drown during larger rain events.

Plants should be hardy and self-sustaining native species with little need for fertilizers or pesticides. Planters can be made of stone, concrete, brick, wood, or any other suitable material. However, treated wood should be avoided if it leaches any toxic chemicals.

Planters can be permanently fixed in place or easily moved around to enable you to change the look of the planter garden that you have created. Numerous manufactured pots and planters are available at your local hardware or landscaping store. You can create a "do-it-yourself" planter or use recycled items to create planters. Homemade planters may be constructed by stacking and fastening wood beams or laying and mortaring stones. There are many websites with detailed instructions to help with this type of project, such as www.taunton.com, www.hgtv.com, www.diynetwork.com.*

Creating a Contained Planter

- Purchase planters at the local hardware or landscaping store, if you are not building your own planter box.
- Drill holes in the bottom of the planter if they are not already there.
- Fill the planter with soil and leave a 12 inch area from the soil to the top of the planter.
- Choose native drought and saturation tolerant plants and trees to plant in the planter.
- Occasionally turn or till the soil to improve infiltration.

SARB_015572

Rain Barrels



Please read the Disclaimer on the inside cover, if you are interested in installing this project.

A rain barrel collects and stores stormwater runoff from rooftops. By detaining (temporarily holding) the stormwater runoff during a rain event, you can help add capacity to the city's sewer system and reduce sewer overflows to our creeks and rivers, our drinking water source. Also, the collected rain water can be reused for irrigation to water lawns, gardens, window boxes or street trees.

Rain barrels can be purchased on-line or they can be built. If you would like to purchase a rain barrel on-line, view the list of retailers we came across in our research.*

Whether you buy or build a rain barrel, the most important thing to remember is that they are only effective at stormwater management when the stored water is emptied in between storms, making room in the barrel for the next storm.

Building a Rain Barrel

- Rain barrels help lower water costs when the stored water is recycled for lawn irrigation, for example.
- Rain barrels help reduce water pollution by reducing stormwater runoff, which oftentimes picks up pollutants in its path, such as oil, grease and animal waste, and transports these pollutants to the nearest creek, river or stormdrain.
- Storing rainwater for garden and lawn use helps recharge groundwater naturally.

Materials Needed for Building a Rain Barrel

- One 55 gallon drum
- One 5 foot section vinyl garden hose
- One 4 foot diameter atrium grate (basket used in garden ponds and pool skimmers)
- One ½ inch PVC male adapter
- One ¾ inch x ½ inch PVC male adapter
- One 5 foot section of drain hose, drain line, or sump pump line (1¼ inch)
- One 1¼ inch female barbed fitting and
- One 1¼ inch male threaded coupling
- One vinyl gutter elbow
- Drill (or a hole saw)
- Router, jig saw or coping saw
- Measuring tape

Optional:

- Waterproof sealant (silicone caulk, PVC glue)
- Teflon tape
- Fiberglass window screen material or mosquito netting
- Cinder blocks or wooden crate

Rain Barrels



*Rain Barrel Distributors

Clean Air Gardening
Composters.com
Day's Garden
ENVIRO ENERGY International Inc.
Gardener's Supply Company
GARDENWARe
Green Culture
Green Venture
Jerry Baker
Lee Valley Tools
Midwest Internet Sales
New England Rain Barrel and Composter Company
RainCatcher 4000
Plow&Hearth
Rain King
Rainsaver USA
Real Goods
Riversides
The Rain King
Spruce Creek Rainsaver
The Rain Pail
Urban Garden Center

This is not a comprehensive list of rain barrel distributors or suppliers. This is a list of rain barrel distributors that PWD came across during our rain barrel research. The particular companies are not endorsed by PWD, nor can PWD verify any information on these companies.

Instructions for Building a Rain Barrel

Step 1. Cut Holes in Rain Barrel:

- Cut lower drain hole: Measure about 1 inch above the bottom of the barrel (55 gallon drum) where the barrel side begins to rise toward the top. Using a ¾ inch bit (or hole saw), drill a hole through the barrel.
- Cut upper drain hole: Mark the upper drain hole according to where you want the overflow to be in the upper region of the barrel and in relationship to the lower drain. Use a 1⅝ inch hole saw to cut out the overflow hole.
- Cut top hole for atrium grate (filter): Using the atrium grate as a template for size, mark a circle at the center of the top of the drum (locating the rainwater inlet in the center of the barrel lets you pivot the barrel without moving the downspout). Drill a ½ inch hole inside of the marked circle. Use a router, jigsaw or coping saw to cut until the hole is large enough to accommodate the atrium grate, which filters out large debris. Don't make the hole too big—you want the rim of the atrium grate to fit securely on the top of the barrel without falling in.
- Cut notch to hold hose: Using a ½ inch bit or hole saw, cut out a notch at the top of the barrel rim (aligned so that it is above the lower drain hole). The notch should be large enough so that the end of the hose with the adapter will firmly snap into place.

Step 2. Set Up Barrel and Modify Downspout:

- Set up barrel: Since water will only flow from the garden hose when the hose is below the barrel, place the barrel on high ground or up on cinder blocks or a sturdy wooden crate underneath your downspout, making sure the barrel is level.
- Modify your downspout: Cut your existing downspout using a saw so that the downspout's end can be placed over the top of your rain barrel. Use a vinyl downspout elbow that fits the size of your downspout (usually 3 inch or 4 inch) to aim the stormwater into the rain barrel or just simply place the barrel right under the downspout.

Step 3. Assemble Parts:

- Attach garden hose to lower drain hole: Screw in the ½ inch PVC male adapter to the lower drain hole. The hard PVC threads cut matching grooves into the soft plastic of the barrel. Unscrew the ½ inch PVC male adapter from the hole. Wrap threads tightly with teflon tape (optional). Coat the threads of the coupler with waterproof sealant (optional). Screw the coated adapter back into the hole and let it sit and dry for 24 hours (optional). Attach 5 foot garden hose to the PVC male adapter. Attach the ¾ inch x ½ inch PVC

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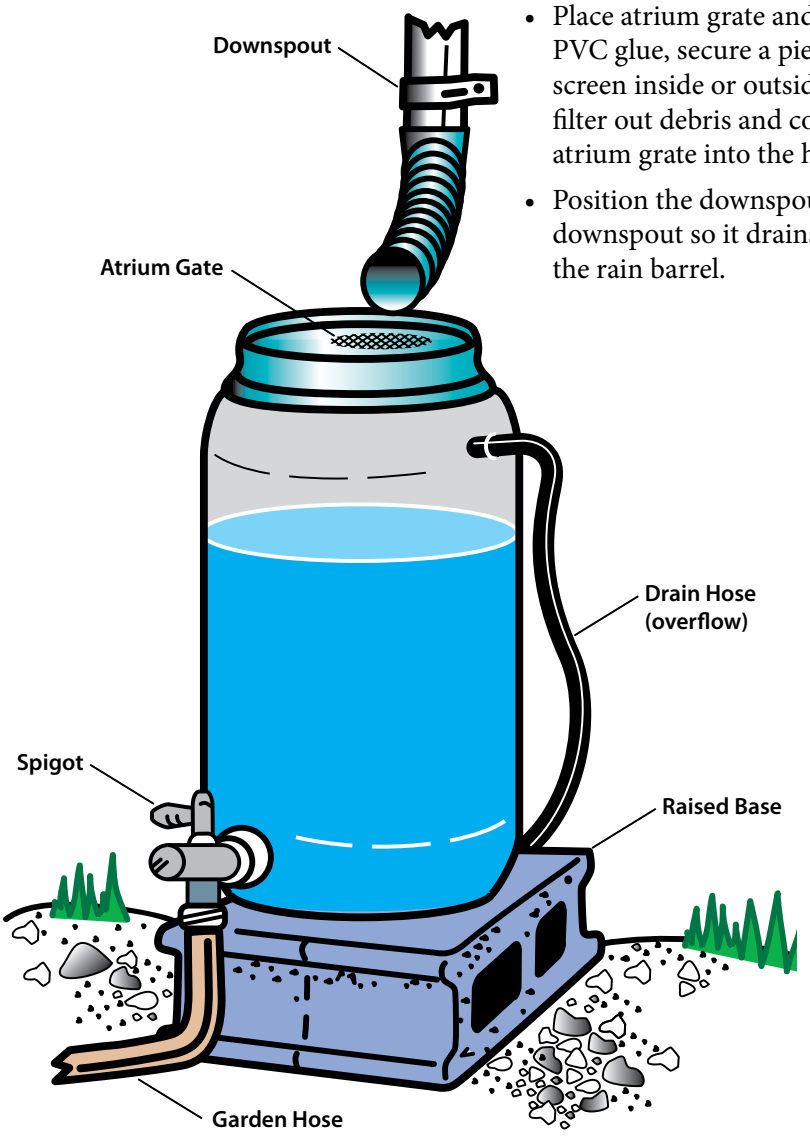
Don't forget to empty your rain barrel after the storm!

male adapter to the other end of the hose (this can be readily adapted to fit a standard garden hose).

- Attach drain hose (overflow hose) to upper drain hole: Put the 1¼ inch male threaded coupling inside the barrel with the threads through the hole. From the outside, screw the 1¼ inch female barbed fitting onto the threaded coupling. Use silicone on the threads (optional). Attach 5 foot section of drain hose to upper fitting and connect it to where the original downspout was connected (sewer riser) in order to transport the overflow into the sewer.

  The overflow must be conveyed safely away from your property and your neighbor's property. If your downspout was not originally connected to the sewer, place a splash pad on the ground under the overflow hose to direct the flow away from the foundation of your home.

- Place atrium grate and screen in top hole: Using PVC glue, secure a piece of fine mesh window screen inside or outside of the atrium grate to filter out debris and control mosquitoes. Place the atrium grate into the hole (basket down).
- Position the downspout: Position the end of your downspout so it drains onto the atrium grate on the rain barrel.



Rain Gardens



Please read the Disclaimer on the inside cover, if you are interested in installing this project.

A rain garden uses native plants and landscaping to soak up rain water (stormwater) that flows from downspouts or simply flows over land during a rain event. The center of the rain garden holds several inches of water, allowing the stormwater to slowly seep into the ground instead of flow directly from your roof, yard or driveway into the nearest storm drain, creek or river.

Creating a Rain Garden

- A rain garden allows 30% more water to seep into the ground than a conventional lawn (South River Federation & Center for Watershed Protection, 2002). This increase helps replenish the groundwater supply (important during a drought!), and also helps hold back stormwater from contributing to the storm-water and sewage overflows into nearby creeks and rivers.
- A rain garden reduces the amount of water pollution that would otherwise eventually reach the streams and rivers through stormwater runoff. Scientific studies have demonstrated that the first inch of rainfall is responsible for the bulk of the pollutants in stormwater runoff. A rain garden is designed to temporarily hold this one-inch of rainfall and slowly filter out many of the common pollutants in the water, such as oil, grease, and animal waste, that would otherwise flow into the waterways via the nearest stormdrain or stormwater runoff.
- The native plants used in rain gardens require less water and less fertilizer than conventional lawns. They also require less maintenance and provide habitat for birds and other wildlife.

Materials

- Plants for the garden (see plant list)
- Hose, rope or string
- Level
- Shovel or spade
- Measuring tape
- Humus or other soil amendments (optional)
- Downspout extension (also optional).

Instructions

Before starting this project, please conduct an Infiltration Test (pages 26–27) to determine if your soil conditions are adequate for a rain garden.

Step 1. Size and Locate your Rain Garden:

- First, measure the footprint of your house by getting the area (length x width) of your house and then determine how much of your rooftop area drains to the downspout you are disconnecting to your garden (for gutters with a downspout at

Sizing Example

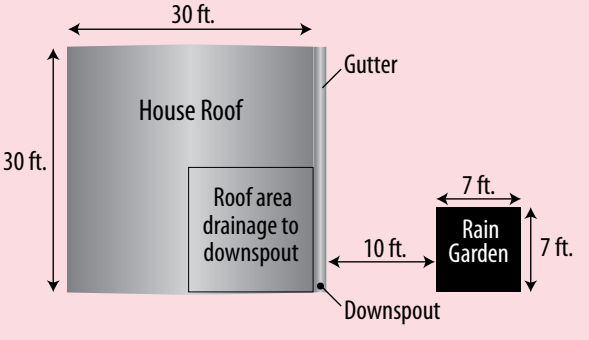
If the area of the house is 30 ft. x 30 ft. and ¼ of this area drains to one downspout:

15 ft. x 15 ft. = 225 ft.^{2}

20% of 225 ft.^{2} = 45 ft.^{2}

30% of 225 ft.^{2} = 67.5 ft.^{2}

The rain garden area should be between 45 and 67.5 square feet, depending on soil type (use 20% for sandier soils).



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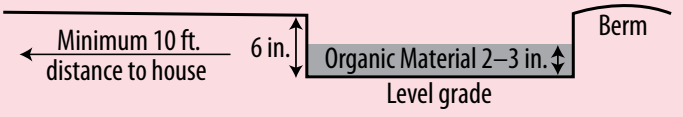
each end, assume that half the water goes to each downspout). Refer to the sizing example for guidance. Be sure you measure the house footprint only, but include the area of any driveway or patio areas that will drain to the rain garden (do not take the roof slope into account). The surface area of your rain garden should be between 20% and 30% of the roof area that will drain into the rain garden.

- Locate the garden at least 10 feet away from your house and your neighbor's house (to prevent water leakage), and create the garden in the lowest point of this section of your lawn, maintaining a minimum 1% slope from the house down to the rain garden. If your yard drain is also located in this section of the lawn, you can build the rain garden around the drain. The bottom of the rain garden would be a few inches lower than the drain and the overflow would actually be in the middle of the rain garden.
- If you build the rain garden around your yard drain, when it fills up with water, the water that overflows from the garden will be conveyed safely to the yard drain. If you are not building around the yard drain, it is imperative that the overflow is safely conveyed to a drain nearby to prevent it from flowing into your neighbor's property.
  Make sure the drain is in a suitable location in relation to the rain garden in order to effectively manage the garden's overflow.

Garden Cross Section



- When finding the right spot for your rain garden, keep in mind that you will want to create a shallow ditch or swale that carries the stormwater runoff from the disconnected downspout to the rain garden. The swale will help slow the runoff before it reaches the rain garden.
- Finally, lay out the boundary of the garden with a rope.

Step 2. Dig the Rain Garden:

- To enable the rain garden to hold several inches of water during a storm, you'll have to dig a hole 3 to 4 inches deep across the entire surface of the rain garden. If the soil lacks organic material, you can improve it by digging the hole 5 to 6 inches deep, and adding 2 to 3 inches of humus or other organic material. Make sure the bottom is level, but gently slopes from the bottom to the ground level around the edges. If the drop at the edge is too steep, you might get some erosion around the edges.



- Next, test how the garden will hold water during a storm by letting water flow into the rain garden from a hose placed at the downspout. Based on this test, make any necessary adjustments (e.g., create a berm on the lower side of the garden using the diggings—the soil that was excavated).

Step 3. Add Plants to the Rain Garden:

- Choose native plants that won't require much watering, but make sure they can withstand wet soils for up to 24 hours. (Refer to the list of native plants below.)
- Also, take into account how much sun your garden receives. It's often helpful to draw out a planting plan before you start, and mark planting areas within the garden with string. After planting, weeding may be required until the plants become established. You may also need to periodically prune some of the plants to let others grow. In the winter, leave dead or dormant plants standing and cut back in the spring.
- Your garden may need a bit more maintenance than a lawn in the beginning, but in the long run it will be easier to care for and provide many added benefits!

Native Plants Recommended by Fairmount Park for Rain Gardens

Perennials

Bee-balm—*Monarda didyma*
Black-eyed Susan—*Rudbeckia hirta*
Blazing star—*Liatris spicata*
Blue flag iris—*Iris versicolor*
Boneset—*Eupatorium perfoliatum*
Butterfly weed—*Asclepias tuberosa*
Cardinal flower—*Lobelia cardinalis*
Early goldenrod—*Solidago bicolor*
Golden alexander—*Zizia aurea*
Joe-pye weed—*Eupatorium purpureum*
New England aster—*Aster novae-angliae*
New York ironweed—*Veronia novaborescensis*
Obedient plant—*Physostegia virginiana*
Ox-eye—Heliopsis helianthoides
Solomon's seal—*Polygonatum biflorum*
White snakeroot—*Eupatorium rugosum*

Grasses and Grass-like plants

Big bluestem—*Andropogon gerardii*
Bottle brush grass—*Elymus hystrix*
Canada wild rye—*Elymus canadensis*
Path rush—*Juncus tenuis*
Purple-top—*Tridens flavus*
Soft rush—*Juncus effusus*
Switch-grass—*Panicum virgatum*
Virginia wild rye—*Elymus virginicus*

Ferns

Christmas fern—*Polystichum acrostichoides*
Hay-scented fern—*Dennstaedtia punctilobula*
Rattlesnake fern—*Botrychium virginianum*
Sensitive fern—*Onoclea sensibilis*

Shrubs

Gray dogwood—*Cornus racemosa*
Highbush blueberry—*Vaccinium corymbosm*
Mountain laurel—*Kalmia latifolia**
Ninebark—*Physocarpus opulifolius*
Pasture rose—*Rosa carolina*
Red osier dogwood—*Cornus sericea*
Spicebush—*Lindera benzoin*
Sweet pepperbush—*Clethra alnifolia*

*Pennsylvania's state flower

When purchasing plants, pay close attention to the scientific names to ensure the correct species are selected.

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Wildflower Meadow



Wildflower meadows present excellent opportunities for stormwater management, promoting groundwater infiltration, water quality treatment, and even flood control. Also, when using native plants in a meadow you are not only providing an aesthetically pleasing landscape, but preserving native species and biodiversity, and creating habitat for wildlife. Meadows allow you to spend less time mowing, less time applying fertilizers and lawn chemicals, and less time watering in the summer months. This low maintenance structure helps protect our nearby local streams from pollutants and other chemicals, in addition to flooding conditions, thereby helping to protect the Delaware and Schuylkill Rivers, the source of our drinking water in Philadelphia.

Creating a Wildflower Meadow

Step 1. Site Selection: First, you need to choose a suitable location, preferably an open sunny site that gets at least six hours of sun every day. It should have good air movement. This helps keep diseases down, and the movement caused by wind will make plants sturdier, and stems stronger. The site should have few weeds. An already cultivated site such as a field or garden plot is ideal. A lawn can work too. The hardest is an overgrown garden bed, or old field full of aggressive weeds and grasses. A site next to such an area to transform is also difficult, due to weed seeds blowing in. A site next to a formal landscape may also be a hard sell. In such formal areas, an informal transition area may be necessary.

Step 2. Plant Selection: Plant selection is important for long bloom, as noted already, but more importantly for species that will last under your conditions. Soil type is not as important as whether the site is dry or moist. A dry site is best. The key is to have a diversity of species, as found in nature, with a mix of graminoides (grasses and grass-like plants) and forbs (flowering meadow wildflowers). If you don't create your own mixture, buy a good quality seed mix from a reputable supplier. When it comes to these seeds, you truly get what you pay for. Inexpensive mixes often contain mainly annuals which are gone after the first year, contain non-native species, seeds that have poor germination, potential weedy species, or just a lot of seed debris. Another consideration under species selection, whether you buy a mix or make your own mixture, is whether you want a short term (1 to 5 years) or longer term meadow. In the former you may have more annuals for color up front, but keep in mind that they may be out competed with weeds after a few years. A long term meadow may have mainly perennials which may take several years to begin a good display, but will last and out compete many weeds.

Wildflower Meadow



The number of plants of any one type will depend on how you will be viewing the meadow. If seeing it from a distance, you'll want to use larger numbers of each plant type, and place them in sweeping masses. If creating a small area, or one viewed at close range, you may have few of any one type plant, and have them all mixed.

Step 3. Site Preparation: This is the step often overlooked, yet the key to success or failure. Since these wildflowers are usually less competitive than weeds, the site should contain no weeds or weed seeds. Unless the site has been cultivated already, with few to no weeds, there are several methods you may use.

You may smother vegetation with black plastic for a whole growing season. You may also smother existing growth with thick layers of leaves, grass clippings, or newspapers. Another method is to plant a summer buckwheat crop, cut and tilled in before going to seed, followed by fall planting of winter wheat, cut and tilled in late winter. You may need to repeat this a second season. Or you may repeat deep soil tillage every three weeks for a full growing season. If it's a lawn with no weeds, remove the sod using a sod-cutter that can be rented from equipment rental firms. Many use a systemic herbicide, but avoid those that are residual (last in the soil).

Step 4. Sowing or Planting: You may sow in spring or early summer, which favors grasses over the forbs. Keep the spring-sown meadow watered as you would a newly seeded lawn, often for a month or two. Sowing in early fall favors the forbs, as some grass seeds rot then. Since many seeds will either not germinate until the following spring, or germinate and not grow until then, you should also use annual rye as a winter cover crop with fall sowings. Avoid sowing in mid to late summer when there may be droughts or seeds drying out before germinating. For sowing, aim for about 80 seeds per square foot. In several years this will result in one or two plants in this space. Of this number per square foot, for spring sowing use about 60 forb and 20 grass seeds. This is about 9 lbs. and 3 lbs. per acre. For fall sowing, use a higher proportion of grass seeds.

For small areas (for instance under 1000 square feet), consider using already-germinated small plants you can buy in trays as "plugs." These are more costly than seeds, but will establish more quickly. You can find these at specialty suppliers, either local, mail-order, or online.

Step 5. Post-planting management: In the first two years, seeds of annual and biennial weeds still in the soil or blown in will grow faster than your perennial wildflowers. Don't allow such weeds the first year to get above one foot tall before cutting back to four to six inches high. The wildflowers will, for the most part, remain short and below this height. The second year, cut back to about one foot high since plants will be larger. A weed or string trimmer works well for this. Don't pull weeds, as this may also disturb wildflower seedlings. Don't use herbicides as these may drift, killing large patches of both weeds and wildflowers!

In the third and future years, mow it close to the ground. This should be done in late fall or early spring, removing the debris from mowing. This exposes the soil to the rapid warmth from the sun in spring, encouraging your wildflowers over cool-season weeds. Learn your wildflowers, and over the years you can selectively weed out any weeds or woody plant seedlings.

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Dry Well



Please read the Disclaimer on the inside cover, if you are interested in installing this project.

Materials

- Measuring tape
- Shovel
- Saw
- Wheelbarrow
- Vinyl downspout elbow to fit your downspout (typically 3 in. or 4 in.)
- Landscape non-woven geotextile fabric
  - Make sure the fabric is porous enough to allow water to pass through it.
- Crushed stone
  - Use stone that is approximately 1–1½ in. diameter.
  - Wash the stone to make sure that it is clean. You can use a sieve to remove fine material if the stone seems to have a lot of small particles.
  - It is important that the stone is washed (no dust or particles) and that the stone is uniformly the same size.
  - The stone does not have to be very large; it just has to be roughly of a similar size to get the maximum amount of void space in the stone while maintaining the structure of the well.

Dry wells are small, excavated pits, filled with stone or gravel that temporarily stores stormwater runoff until it infiltrates (soaks) into the surrounding soil. The stormwater can come straight off of the roof of your house via a downspout that either indirectly or directly connects to the dry well. It can travel indirectly to the dry well through a grassy swale or it can travel directly into the well through a pipe. This design guide describes how you can disconnect your downspout to a swale and dry well that is sized based on the included sizing table (noted below). Dry wells help protect our rivers and streams in combined and separate sewered areas. They help add capacity to Philadelphia's sewer system during heavy rainfalls by helping prevent the stormwater runoff from reaching the system and instead allowing the runoff to soak into the surrounding soil. In separate sewered areas, the impact of stormwater runoff on neighborhood streams, is reduced. By infiltrating the stormwater runoff on land, the combined (sewage and stormwater) sewer overflows into the Delaware and Schuylkill Rivers are reduced, thereby decreasing pollution in our streams, lessening flooding impacts and improving water quality in our rivers, our drinking water source. Dry wells also recharge groundwater through infiltration, which leads to more flow in streams during dry weather (when it is not raining) and less streambank erosion during wet weather (when it is raining).

Building a Dry Well

Site Preparation

- Conduct an Infiltration Test (see pages 24–25) to determine if your soil conditions are suitable for a dry well.
- Make sure buried electrical, telephone, and TV cables and gas piping are not going to be a problem in the area that you will be digging your dry well. If you don't know where they are located, call PA One Call at 1-800-242-1776 at least three days before you dig.
- Install leaf guards to prevent leaves and other plant material from entering the downspout and clogging the dry well.
- Determine the size of the well. Read through the Dry Well Sizing section of this fact sheet.
- Determine the volume of crushed stone you will need.
  Volume of Stone = Dry Well Area x 1½ feet
  For example: 33 square feet x 1½ feet = 49.5 cubic feet of stone.

Dry Well

Dry Well Sizing

- Refer to the sizing table. Decide what size storm you would like to store and infiltrate in your dry well. Find the closest number in Column A. About one-third of storms in the Philadelphia area are 0.25 inches or less, 60% are 0.5 inches or less, and 85% are 1.0 inch or less.
- Estimate the roof area draining to the dry well (length [ft.] x width [ft.] = area in square feet). Find the closest value in Column B for the storm depth you have chosen. At this point, you have narrowed your choice down to just one line of the table.
- Find the area required for your dry well in Column D. When you multiply your dry well length and width, the resulting number (area) needs to be at least as great as the number in Column D. Columns E and F show examples of lengths and widths that will work.
- Determine whether your yard and budget will allow you to build a dry well of this size with a safe overflow. If not, choose a smaller storm and repeat the steps. Storing a larger storm provides a greater benefit, but also requires more space and costs more. Storing even the smallest storm in the table will provide benefits.
- **The dry well should have a safe overflow**, such as an overflow to your yard drain. In larger storms, your dry well will fill up, and you need to make sure that the overflow doesn't damage your property or your neighbors' properties. Keep in mind that the yard drain has to be slightly downhill from the dry well.
- **The dry well should be at least 10 feet from your house** and any other buildings that are level with yours. It should be at least 25 feet from buildings that are downhill from the dry well.

Example

Storm Depth =
0.5 inches (Lines 4-6, Column A)

Roof Area =
250 square feet (Line 5, Column B)

Dry Well Area =
19 square feet (Line 5, Column D)

Possible Dimensions:
7 feet long by 3 feet wide =
21 square feet
(Line 5, Columns E and F)

4 feet long by 5 feet wide =
20 square feet

6 feet long by 3.5 feet wide =
21 square feet

	A Storm Depth (in.)	B Roof Area Draining to Dry Well (sq. ft.)	Dry Well Dimensions			
			C Depth (ft.)	D Area (sq. ft.)	E Example Length (ft.)	F Example Width (ft.)
1	0.25	100	1.5	3.8	2	3
2	0.25	250	1.5	9.4	4	3
3	0.25	500	1.5	19	7	3
4	0.5	100	1.5	7.5	3	3
5	0.5	250	1.5	19	7	3
6	0.5	500	1.5	38	13	3
7	1.0	100	1.5	15.1	6	3
8	1.0	250	1.5	38	13	3
9	1.0	500	1.5	75	26	3

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Dry Well

Step 1. Modify your downspout. Cut your existing downspout close to the ground using a saw so that a vinyl downspout elbow can fit over the disconnected downspout (usually 3 or 4 inches). The elbow should aim the stormwater runoff into the swale

Step 2. Dig a swale—a small channel or ditch starting from the point below the disconnected downspout to the dry well location. The swale should be just a few inches deep and wide. The swale should slope downward from the downspout to the dry well. The runoff draining from the disconnected downspout through the swale should drain readily toward the dry well.

Step 3. After preparing the site and determining the size of your well, shape the well, using the Dry Well Sizing Table.

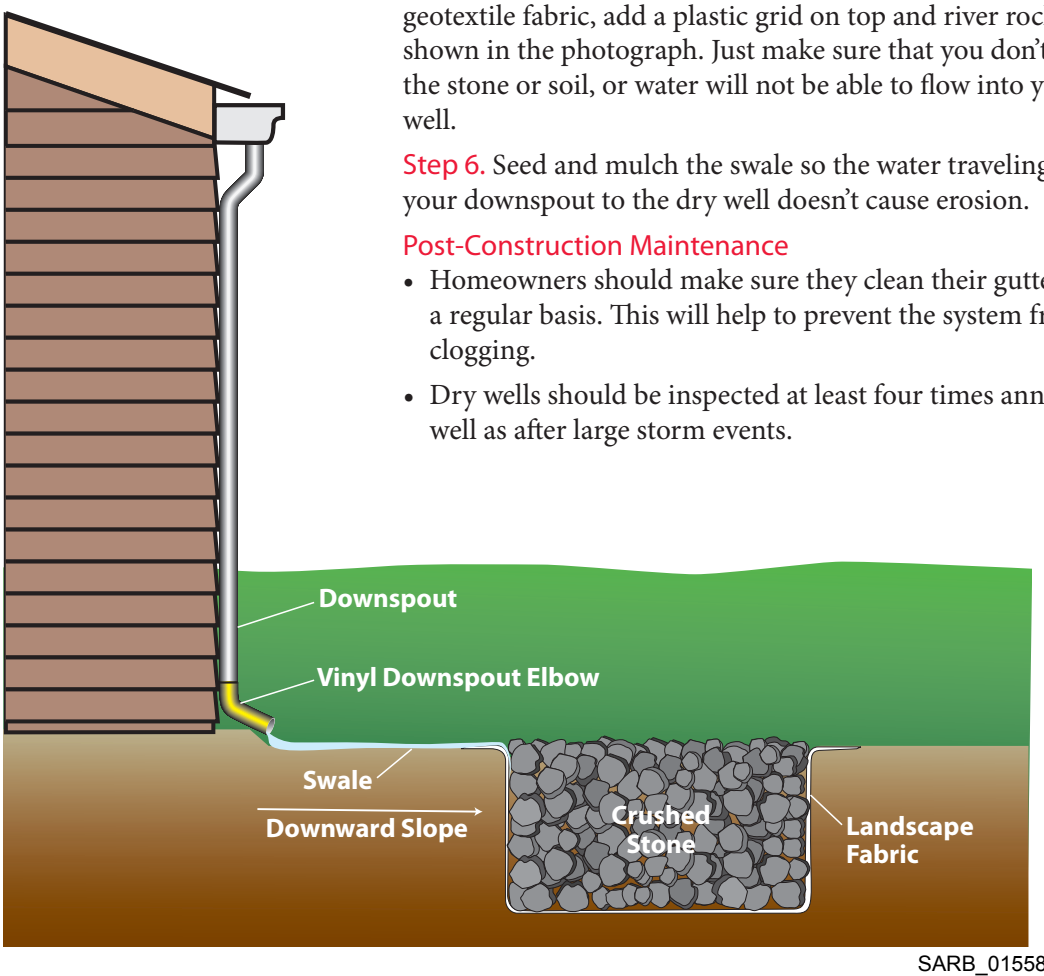
Step 4. Line the well with landscape fabric (non-woven geo-textile fabric or filter cloth). Make sure it is porous enough to allow water to pass through it. Also, excess fabric should be folded over the edges of the well. The fabric prevents surrounding soil from getting into the system and clogging it up.

Step 5. Fill the well with the crushed stone. You can either a) fill the well with stones all of the way to the top until flush with the surrounding soil, b) fill the well with stones just a few inches from the top of the well, add a layer of geotextile fabric and backfill over the well with soil to plant in it (make sure the layer of fabric is between the stone and soil), or c) fill the well with stones just a few inches from the top of the well, add a layer of geotextile fabric, add a plastic grid on top and river rocks, as shown in the photograph. Just make sure that you don't mound the stone or soil, or water will not be able to flow into your dry well.

Step 6. Seed and mulch the swale so the water traveling from your downspout to the dry well doesn't cause erosion.

Post-Construction Maintenance

- Homeowners should make sure they clean their gutters on a regular basis. This will help to prevent the system from clogging.
- Dry wells should be inspected at least four times annually as well as after large storm events.



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Infiltration Test

It is important that water infiltrate well even during saturated conditions. Conduct your infiltration test after a rain storm.

An infiltration test will help you determine if the soil on your property is suitable for certain types of stormwater management measures, such as a dry well or rain garden. An infiltration test measures how quickly water can soak in and flow through the soil. It is important to know how your soil infiltrates water before building a dry well, rain garden or any other stormwater management structure.

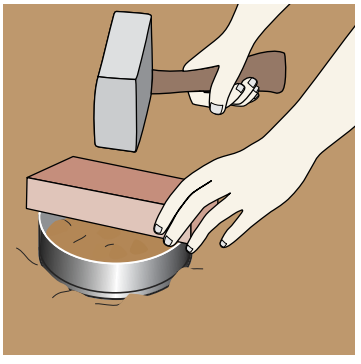
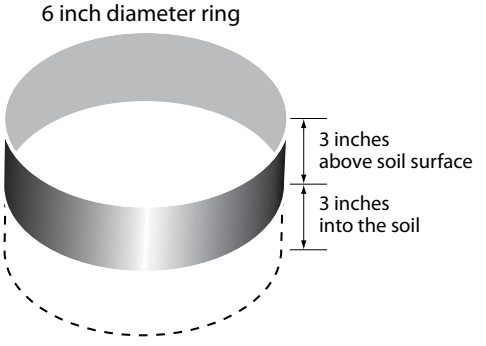


Figure 1
Using the hand sledge and block of wood, drive the 6 inch diameter ring, beveled edge down, to a depth of three inches.

Materials

- 6 inch diameter ring
- Hand sledge and wood block
- Plastic wrap
- 500 mL plastic bottle or graduated cylinder
- Water
- Stopwatch or timer
- Pen and paper



Step 1. Drive Ring into Soil:

- Clear the sampling area of surface residue, etc. If the site is covered with vegetation, trim it as close to the soil surface as possible.
- Using the hand sledge and block of wood, drive the 6 inch diameter ring, beveled edge down, to a depth of three inches (see Figure 1).
- If the soil contains rock fragments, and the ring cannot be inserted to the depth, gently push the ring into the soil until it hits a rock fragment.



Figure 2
Pour the 444 mL of water (1 inch of water) into the ring lined with plastic wrap.

Step 2. Firm Soil:

- With the 6 inch diameter ring in place, use your finger to gently firm the soil surface only around the inside edges of the ring to prevent extra seepage. Minimize disturbance to the rest of the soil surface inside the ring.

Step 3. Line Ring with Plastic Wrap:

- Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring as shown in Figure 2. This procedure prevents disturbance to the soil surface when adding water.

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Infiltration Test

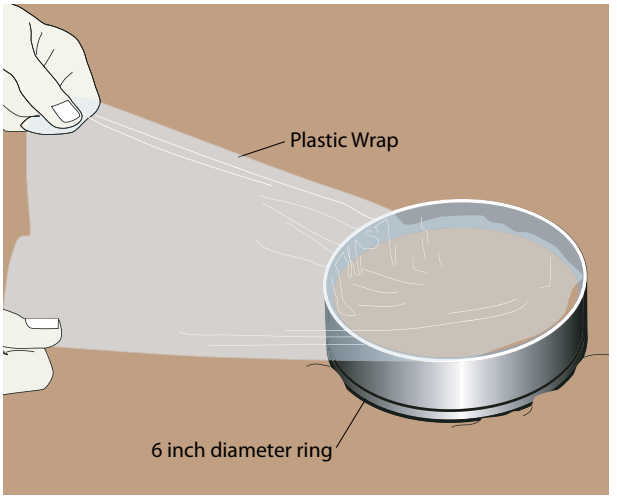

Figure 3
Remove the plastic wrap by gently pulling it out, leaving the water in the ring.

Step 4. Add Water:

- Fill the plastic bottle or graduated cylinder to the 444 mL (1 inch) mark with water. Pour the 444 mL of water (1 inch of water) into the ring lined with plastic wrap as shown in Figure 2.

Step 5. Remove Wrap and Record Time:

- Remove the plastic wrap by gently pulling it out, leaving the water in the ring (Figure 3). Note the time. Record the amount of time (in minutes) it takes for the 1 inch of water to infiltrate the soil. Stop timing when the surface is just glistening. If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening. Record the time.

Step 6. Repeat Infiltration Test:

- In the same ring, perform Steps 3, 4, & 5 with a second inch of water. Record the number of minutes elapsed for the second infiltration measurement. Repeat the test (Steps 3, 4, & 5) a few more times. All of the tests should be conducted consecutively. If the test continues to yield the same results, you will have a good idea of the saturated infiltration rate. If the soil infiltrates the water under 1 hour, your soil is ready for a dry well, rain garden or any of the other structural projects in this manual.

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Tree Planting
page 8 – TreeVitalize

Backyard Stream
NAM Planning & Design

Winter De-Icing
Chuck Leonard

Planter Boxes
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Single planter – Clint Bautz

Rain Barrels
page 15 – Three Rivers Wet Weather Demonstration Program
page 16 – Michael Pickel

Rain Gardens
page 19-20 – Roger Bannerman, Wisconsin Department of Natural Resources

Creating a Wildflower Meadow
Robin Sasek, CDM

Dry Wells
Wissahickon Valley Watershed Association

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To stop your rain from going down the drain, plant more trees. Trees catch rainfall on leaves, branches and trunks. A single London Plane tree will intercept over 130 gallons during a minor (1/4 inch) rainstorm.

Plus, trees help conserve water.

For more info on TreeVitalize planting projects, Tree Tender education classes and homeowner rebates go to **www.treevitalize.net.**

TreeVitalize Partners

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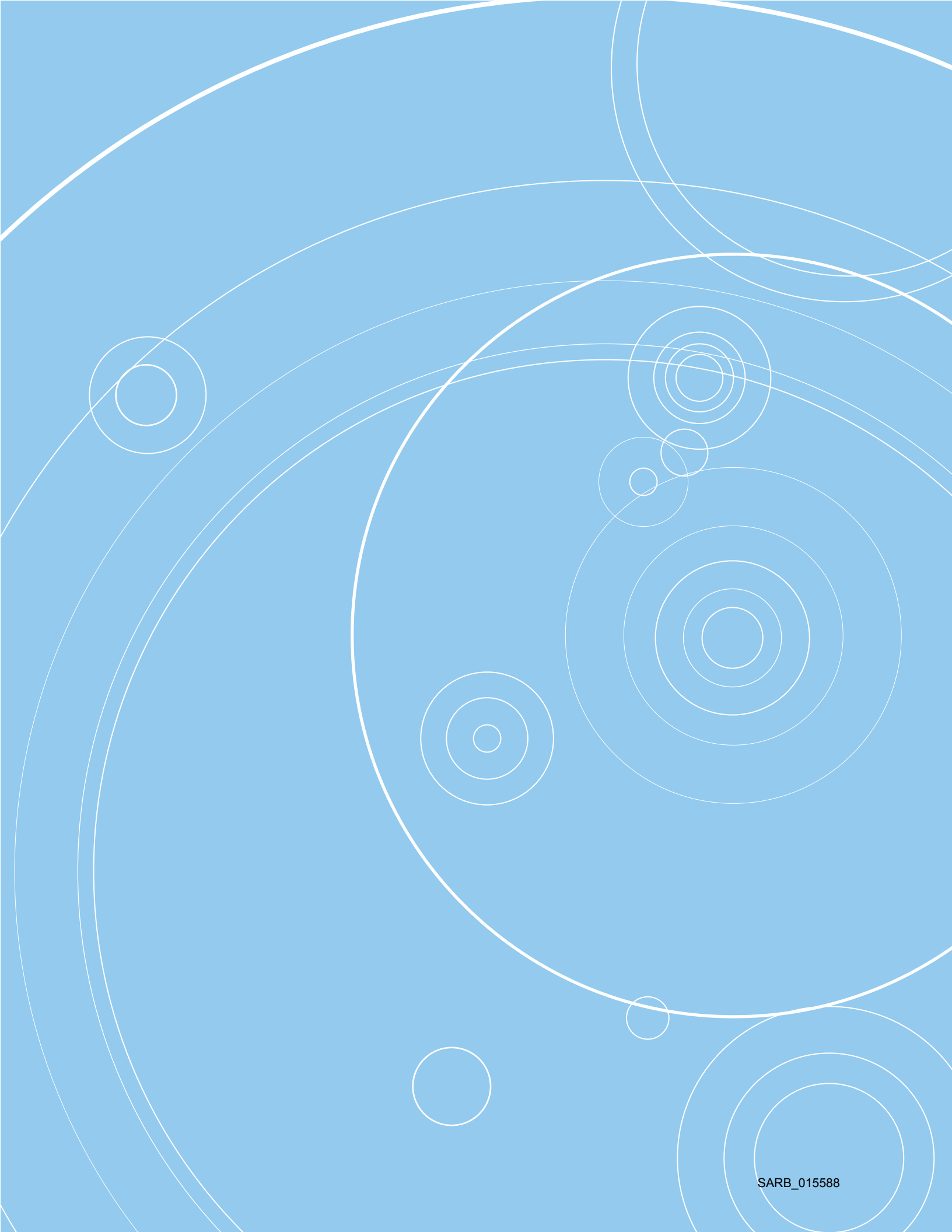

DRAFT

State of West Virginia
Department of Environmental Protection
Division of Water and Waste Management
601 57th Street, SE
Charleston, WV 25304-2345

General
National Pollution Discharge Elimination System
Water Pollution Control Permit

Permit No.: WV0116025

Subject: Stormwater Discharges From small Municipal Separate Storm Sewer Systems

Issue Date:

Effective Date:

Expiration Date:

Supersedes: WV/NPDES General Water Pollution Control Permit No. WV0116025, issued March 7, 2003

To Whom It May Concern:

This is to certify that operators of small municipal separate storm sewer systems (MS4s) located in the State of West Virginia who have satisfied the registration requirements and agreeing to be regulated under the terms and conditions of this general permit are hereby granted coverage under the General WV/NPDES Water Pollution Control Permit to discharge stormwater into waters of the State.

All operators of regulated small municipal separate storm sewer systems are required to apply for and obtain coverage in accordance with this permit, unless waived in accordance with CFR § 122.32(a).

This permit is subject to the following terms and conditions:

The information submitted on and with the site registration application form, once approved, will hereby be known as the stormwater management program (SWMP). The information submitted on and with the site registration application, also known as the SWMP, once approved, will hereby be made terms and conditions of the permit with like effect as if all such information were set forth herein, and other conditions set forth in Parts I, II, III, IV, Appendices A through D and the SWMP approval letter.

The validity of this permit is contingent upon the payment of the applicable annual permit fee, as

required by Chapter 22, Article 11, Section 10 of the Code of West Virginia.

Part I

Coverage under this General Permit

A. Permit Area

1. This permit covers all areas of the State of West Virginia.

B. Eligibility

1. Jurisdictions including, but not limited to; municipalities, counties, transportation facilities, Federal and State owned prison systems, and universities that are located within the boundaries of a Bureau of the Census defined "Urbanized Area" (UA) based on the latest decennial census.

2. Municipalities that are designated by the Division of Water and Waste Management (DWWM) under 40 CFR 122.32(a)(2). Designation criteria are included in Appendix D of this general permit.

C. This permit authorizes the following non-stormwater discharges provided they have been determined not to be substantial contributors of pollutants to a particular small MS4 applying for coverage under this permit. However, the DWWM recommends that your stormwater management program include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to your system.

1. Uncontaminated water line flushing
2. Landscape irrigation,
3. Diverted stream flows,
4. Uncontaminated ground water infiltration (as defined at 40 CFR 35.2005(20)),
5. Uncontaminated pumped groundwater,
6. Discharges from potable water sources,
7. Foundation drains,
8. Air conditioning condensate,
9. Irrigation water,
10. Springs,
11. Water from crawl space pumps,
12. Footing drains,
13. Lawn watering runoff,
14. Water from individual residential car washing,
15. Flows from riparian habitats and wetlands,
16. Residual street wash water,
17. Discharges or flows from fire fighting activities, and
18. A discharge authorized by a separate National Pollutant Discharge Elimination System (NPDES) permit.

D. This permit does not relieve entities that cause illicit discharges, including spills, of oil or hazardous substances, from responsibilities and liabilities under State and Federal law and regulations pertaining to those discharges.

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E. This permit does not authorize a violation of West Virginia State Water Quality Standards (Title 47 CSR Series 2) and West Virginia Ground Water Quality Standards (Title 47 CSR Series 58).

Part II

Notice of Intent (NOI) and Stormwater Management Program (SWMP) Applications

A. Applications

Within thirty (30) days of the effective date of this permit, all operators of small MS4s shall submit a Notice of Intent (NOI) on the form provided in Appendix A of this permit.

Within six months of the effective date of this permit, all operators of regulated small MS4s shall submit a stormwater management program (SWMP) to the DWWM. A SWMP can be submitted on the form provided by DWWM, or in a prescribed manner acceptable to the DWWM that contains all necessary components.

NOIs and SWMPs shall be submitted to:

WVDEP - Division of Water and Waste Management
MS4 / NPDES Stormwater Permitting
601 57th Street, SE
Charleston, WV 25304

B. Requirements of SWMP

1. The permittee must develop a stormwater management program designed to reduce the discharge of pollutants from your small municipal separate storm sewer system to the maximum extent practicable (MEP), to protect water quality, and satisfy the appropriate requirements of the Clean Water Act.

2. The permittee shall, to the maximum extent practicable, use known, available, and reasonable methods of prevention, control and treatment to prevent and control stormwater pollution from entering waters of the State of West Virginia.

3. In order to meet public notice requirements of NPDES permits, the permittee shall make available to the public, in accordance with Code of State Regulations; Title 47, Series 10, Section 12, the opportunity to comment on MS4 stormwater management programs.

4. The SWMP must include the minimum control measures described in Section C of this part along with measurable goals and milestones as appropriate for each measure and justifications for each milestone. Information about developing measureable goals can be found on the USEPAs website: http://cfpub.epa.gov/npdes/stormwater/measurablegoals/part3.cfm

5. Subject to the five-year limitation noted below in this paragraph, extension of milestones will be granted for good cause shown. Failure to implement effective best management practices (BMPs) is not good cause to extend milestones.

6. The SWMP must also provide details on how you will implement and enforce the program. The terms and conditions of this permit and the permittees SWMP must be fully

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implemented, except where noted, within five years of the effective date of this permit.

7. The SWMP shall include an ongoing program for gathering, tracking, maintaining, and using information to evaluate the stormwater management program development, implementation and permit compliance.

8. If the permittees small MS4 discharges into waters listed on the Clean Water Act Section 303(d) list of impaired waters or waters with an approved Total Maximum Daily Load (TMDL), the SWMP must document how the proposed BMP's will control the discharge of the pollutants of concern, as described in Part III.D. Permittees discharging to waters with an approved TMDL shall meet the applicable wasteload allocations of that TMDL.

9. An annual report prescribed in Part IV.D of this permit shall be submitted to DWWM each year on the anniversary of the SWMP approval.

C. Stormwater Management Program for small MS4s

a. Requirements

1. Permittees implementing BMPs specific to their current SWMP shall continue to do so until such time as their SWMP with new and updated BMPs is approved. However, permittees should begin implementation of the terms and conditions of this permit as soon as this permit becomes effective, as full implementation is required within five years.

2. a. Coordination among entities covered under the small MS4 general permit may be necessary to comply with certain conditions of the SWMP. The SWMP shall include, when applicable, coordination mechanisms among entities covered under the small MS4 general permit to encourage coordinated stormwater related policies, programs and projects within adjoining or shared areas. Entities covered under the small MS4 permit include, municipalities, transportation agencies, universities, colleges, hospitals, prisons, and military bases.

   b. Coordination mechanisms shall specify roles and responsibilities for the control of stormwater and its associated pollutants between physically interconnected MS4s covered by the small MS4 general permit.

   c. Coordination mechanisms shall coordinate stormwater management activities for shared water bodies among permittees with the goal of avoiding conflicting plans, policies and regulations.

   d. The SWMP shall include coordination mechanisms among departments within each permittee to address and eliminate barriers to compliance with the terms of this permit.

b. Minimum Control Measures

The SWMP shall include all components described in Part II, Sections B and C. In accordance with 40 CFR 122.35(a), a small MS4 may rely on another entity to implement one or more of the

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components in this section. If the permittee is relying on another entity to implement any component of the SWMP, that entity must be fully disclosed in the SWMP.

1. **Public Education and Outreach**

The SWMP shall include an education program aimed at residents, businesses, industries, elected officials, policy makers, planning staff and other employees of the permittee. The goal of the education program is to reduce or eliminate behaviors and practices that cause or contribute to adverse stormwater impacts. An education program may be developed locally or regionally.

The minimum performance measures are:

a. The permittee shall continue to implement their education and outreach program for the area served by the MS4 that was established during the previous permit cycle. The outreach program shall be designed to achieve measurable improvements in the target audience's understanding of stormwater pollution and steps they can take to reduce their impacts. Newly permitted MS4s shall *begin* implementation of the requirements contained in Part II.C.1. within six months of the approval of their SWMP.

Education and outreach efforts shall be prioritized to target the following audiences and subject areas:

i. General public

- General impacts of stormwater flows into surface waters.
- Impacts from impervious surfaces.
- Source control BMPs and environmental stewardship actions and opportunities in the areas of pet waste, vehicle maintenance, landscaping, and rain water reuse.

ii. General public, businesses, including home-based and mobile businesses

- BMPs for use and storage of automotive chemicals, hazardous cleaning supplies, carwash soaps and other hazardous materials.
- Impacts of illicit discharges and how to report them.

iii. Homeowners, landscapers and property managers

- Yard care techniques that protect water quality.
- BMPs for use and storage of pesticides and fertilizers.
- BMPs for carpet cleaning and auto repair and maintenance.
- Runoff Reduction techniques, including site design, pervious paving, retention of forests and mature trees.
- Stormwater pond maintenance.

iv. Engineers, contractors, developers, review staff and land use planners

- Technical standards for construction site sediment and erosion control.
- Runoff Reduction techniques, including site design, pervious pavement, alternative parking lot design, retention of forests and mature trees.
- Stormwater treatment and flow control BMPs.
- Impacts of increased stormwater flows into receiving water bodies.

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b. Each permittee shall measure the understanding and adoption of the targeted behaviors among the targeted audiences. The resulting measurements shall be used to direct education and outreach resources most effectively, as well as to evaluate changes in adoption of the targeted behaviors.

c. Each permittee shall track and maintain records of public education and outreach activities.

2. **Public Involvement and Participation**

The SWMP shall include ongoing opportunities for public involvement through advisory councils, watershed associations and/or committees, participation in developing rate structures, stewardship programs, environmental activities or other similar activities. The permittee shall facilitate opportunities for direct action, educational, and volunteer programs such as riparian planting, volunteer monitoring programs, storm drain marking or stream clean up programs. Each permittee shall comply with any applicable State and local public notice requirements when developing their SWMP.

The minimum performance measures are:

a. No later than six months from the effective date of this permit, all permittees shall create opportunities for the public to participate in the decision making processes involving the development, implementation and update of the permittees SWMP. Each permittee shall develop and implement a process for consideration of public comments on their SWMP.

b. No later than six months from the effective date of this permit, all permittees shall establish a method of routine communication to groups such as watershed associations and environmental organizations that are located in the same watershed/s as the permittee, or organizations that conduct environmental stewardship projects located in the same watershed/s or in close proximity to the permittee. This is to make these groups aware of opportunities for their direct involvement and assistance in stormwater activities that are in their watershed.

c. Each permittee shall make their SWMP and their annual report required under this permit available to the public when requested. The current SWMP and the latest annual report shall be posted on the permittees website. To comply with the posting requirement, a permittee that does not maintain a website may submit the updated SWMP and annual report in electronic format to the DWWM for electronic distribution when it is requested.

3. **Illicit Discharge Detection and Elimination**

The SWMP shall include an ongoing program to detect and remove illicit connections, discharges as defined in 40 CFR 122.26(b)(2), and improper disposal, including any spills not under the purview of another responding authority, into the municipal separate storm sewers owned or operated by the permittee. Newly permitted MS4s shall *begin* implementation of the requirements contained in Part II.C.3 of this permit within one year of the approval of their SWMP.

The minimum performance measures are:

a. The Permittees existing municipal storm sewer system map/s that were created during the first permit cycle shall be updated on an annual basis and shall include the following information:

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i. The location of all known storm sewer outfalls, receiving waters and structural stormwater BMPs owned, operated or maintained by the permittee. The location and type of all other stormwater conveyances located within the boundaries of the permittees MS4 watershed. The permittee may opt to include land use on the map also. In the process of updating the map, when stormwater outfalls become known, they are to be added to the permittees map.

ii. An update of known connections to the municipal separate storm sewer authorized or allowed by the permittee after the effective date of this permit.

iii. Geographic areas that discharge stormwater into the permittees MS4, which may not be located within the municipal boundary.

iv. Each permittee shall submit this map, or updated map to DWWM with the third year annual report. The map shall be a scale of 1" = 500 ft. and on pages sized 24"x36" or 22"x36" and folded to 8 x 11 inches.

b. Each permittee shall implement a program or system to review and update their Illicit Discharge Detection and Elimination (IDDE) Ordinance or other regulatory mechanism to effectively prohibit and eliminate non-stormwater, illegal discharges, and/or dumping into the permittees municipal separate storm sewer system to the regulatory extent allowable under State and Local law. The ordinance or other regulatory mechanism shall be reviewed on an annual basis and updated when necessary. The IDDE program shall be adequately funded to fulfill the general permit requirements.

i. The regulatory mechanism does not need to prohibit the following categories of non-stormwater discharges, unless they are identified to be significant sources of pollutants to waters of the State:

- Diverted stream flows,
- Rising ground waters,
- Uncontaminated ground water infiltration (as defined at 40 CFR 35.2005(20)),
- Uncontaminated pumped groundwater,
- Foundation drains,
- Air conditioning condensation,
- Irrigation water from agricultural sources
- Springs,
- Water from crawl space sump pumps,
- Footing drains,
- Flows from riparian habitats and wetlands,
- Non-stormwater discharges covered by another NPDES permit,
- Discharges or flows from emergency fire fighting activities,

ii. The regulatory mechanism shall prohibit the following categories of non-stormwater discharges *unless* the stated conditions are met:

- Discharges from potable water sources, including water line flushing, hyperchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water. For planned discharges to the MS4, the discharge shall be dechlorinated to a concentration of 0.1ppm or less, pH adjusted, if necessary, and

volumetrically and velocity controlled to prevent resuspension of sediments in the MS4.

- Discharges from lawn watering and other irrigation runoff. These shall be minimized through; at a minimum, public education activities described in Part II, Section C.1. of this permit.

- Street, parking lot and sidewalk wash water, water used to control dust, and routine external building wash down, that does not use detergents. The permittee shall reduce these discharges through; at a minimum, public education activities described in Part II, Section C.1. of this permit. To avoid washing pollutants into the MS4, permittees must minimize the amount of street wash and dust control water used. At active construction sites, street sweeping must be performed prior to washing the street.

iii. The permittees SWMP shall, at a minimum, address each category in ii above in accordance with the conditions stated therein.

iv. The SWMP shall further address any category of discharges in i or ii above if the discharges are identified as significant sources of pollutants to waters of the State.

v. The ordinance or other regulatory mechanism shall include escalating enforcement procedures and actions.

vi. The permittee shall develop an enforcement strategy and implement the enforcement provisions of the ordinance or other regulatory mechanism.

c. Each permittee shall continue to assess, update and implement their ongoing program to detect and address non-stormwater discharges, spills, illicit connections and illegal dumping into the permittees MS4. New permittees shall develop the aforementioned program. This program shall include:

i. Procedures for locating priority areas likely to have illicit discharges, including at a minimum, evaluating land uses associated with business/industrial activities present; areas where complaints have been registered in the past; and areas with storage of large quantities of materials that could result in spills.

ii. Field assessment activities, including visual inspection of priority outfalls identified in i, above, during dry weather and for the purposes of verifying outfall locations, identifying previously unknown outfalls, and detecting illicit discharges.

- Receiving waters shall be prioritized for visual inspection no later than three years from the effective date of this permit, including a field assessment of at least two water bodies. At a minimum, one field assessment shall be made each year thereafter.

- Screening for illicit connections shall be conducted consistent with: Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments, Center for Watershed Protection, October 2004, or another methodology of comparable effectiveness.

iii. Procedures for characterizing the nature of, and potential public or environmental threat posed by, any illicit discharges found by or reported to the Permittee. Procedures shall include detailed instructions for evaluating whether the discharge must be immediately contained and steps to contain the discharge.

Compliance with this provision shall be achieved by investigating within seven days, any complaints, reports or monitoring information that indicates a potential illicit discharge, spill, or illegal dumping, and immediately investigating problems and violations determined to be emergencies or otherwise judged to be urgent or severe. In some instances, when imminent water quality impairments are deemed severe or urgent, the first step to take is to refer the incident to WVDEP.

iv. Procedures for tracing the source of an illicit discharge; including visual inspections, and when necessary, opening manholes, using mobile cameras, collecting and analyzing water samples, and/or other detailed inspection procedures.

v. Procedures for removing the source of the discharge; including notification of appropriate authorities; notification of the property owner; assistance for eliminating the discharge, if necessary; follow-up inspections; and escalating enforcement and legal actions if the discharge is not eliminated.

Compliance with this provision shall be achieved by initiating an investigation within fifteen (15) days of a report or discovery of a suspected illicit connection to determine the source of the connection, the nature and volume of discharge through the connection, and the party responsible for the connection. Upon confirmation of the illicit nature of a storm drain connection, termination of the connection shall be verified within ninety (90) days, using enforcement authority as needed.

d. Permittees shall inform public employees, businesses, and the general public of hazards associated with illegal discharges and improper disposal of waste.

i. Distribute appropriate information to target audiences pursuant to Part II, Section C.1. of this permit.

ii. Publicly list and publicize a hotline or other local telephone number for public reporting of spills and other illicit discharges. Keep a record of calls received and follow-up actions taken in accordance with Part II, Section C.3. of this permit; include a summary in the annual report.

e. Permittees shall adopt and implement procedures for program evaluation and assessment, including tracking the number and type of spills or illicit discharges identified, inspections made; and any feedback received from public education efforts. A summary of this information shall be included in the Permittees annual report.

f. Each permittee shall provide appropriate training for municipal staff on the identification and reporting of illicit discharges into MS4s.

i. Permittees shall ensure that all municipal field staff who are responsible for identification, investigation, termination, cleanup, and reporting illicit discharges, including spills, improper disposal and illicit connections are trained to conduct

these activities. Follow up training shall be provided on an annual basis to address changes in procedures, techniques or requirements. Permittees shall document and maintain records of the training provided and the staff trained.

ii. Permittees shall develop and implement an ongoing training program shall be for all municipal staff, which, as part of their normal job responsibilities, might come into contact with or otherwise observe an illicit discharge or illicit connection to the storm sewer system. Employees shall be trained on the identification of an illicit discharge/connection, and on the proper procedures for reporting and responding to the illicit discharge/connection. Follow up training shall be provided on an annual basis to strengthen knowledge of illicit discharges/connections and to address changes in procedures, techniques or requirements. Permittees shall document and maintain records of the training provided and the staff trained.

4. Controlling Runoff from Construction Sites

The SWMP shall include an ongoing program to assess, implement, and enforce the existing program to reduce pollutants in stormwater runoff to your small MS4 from construction site activities that result in a land disturbance of one acre or greater. Reduction of stormwater discharges from construction activity disturbing less than one acre must be included in your program if that construction activity is part of a larger common plan of development or sale that will disturb one acre or more. Permittee may opt to include in this program construction sites that are less than one acre. Newly permitted MS4s shall *begin* implementation of the requirements contained in Part II.C.4 of this permit within one year of the approval of their SWMP.

The minimum performance measures are:

a. Permittees shall implement a program or system to review and update their ordinance or other regulatory mechanism that addresses stormwater runoff from construction sites one acre or greater. Newly permitted MS4s that do not yet have an ordinance in place shall begin development an ordinance or other regulatory mechanism within twelve months of the effective date of this permit. The ordinance or other enforceable mechanism shall include, at a minimum:

i. Implementation of erosion and sediment control BMPs at regulated construction sites. Sediment and erosion control BMPs shall be consistent with the BMPs contained in West Virginia's Erosion and Sediment Control Best Management Practices Manual and/or other State manuals, as appropriate, listed in Appendix E.

ii. Requirements for construction site operators to implement appropriate erosion and sediment control BMPs. More stringent requirements may be used, and certain requirements may be tailored to local circumstances through the use of basin or watershed plans or other similar water quality and quantity planning efforts. Such local requirements shall provide equal protection of receiving waters and equal levels of pollutant control to those provided by DWWM WV/NPDES stormwater permits.

iii. Requirements for construction site operators to control waste such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste at the construction site that may cause adverse impacts to water quality.

iv. Requirements for demonstration that registration under the WV/NPDES construction stormwater general permit has been obtained for those sites one acre and greater. Provided that the DWWM has not approved the permittee as a 'Qualifying Local Program' in which coverage under WV/NPDES construction stormwater permit will be issued by the permittee and not by the DWWM.

v. Establishment of authority for site plan review, which incorporate consideration of potential water quality impacts and review of individual pre-construction site plans to ensure consistency with local and State sediment and erosion control requirements.

vi. Establishment of authority for receipt and consideration of comments and information submitted by the public.

vii. Establishment of authority for site inspections and enforcement of control measures including steps to identify priority sites for inspection and enforcement based on the nature of the construction activity, topography, and the characteristics of soils and receiving water quality.

viii. Adequate funding for site inspections and enforcement of control measures.

ix. Measures to provide educational and training measures for construction site operators, including requiring a stormwater pollution prevention plan for construction sites within your jurisdiction.

b. The program shall include a permitting and/or approval process with plan review, inspection and enforcement capability, for both private sector and public sector construction sites. At a minimum, the construction site runoff program shall be applied to all sites that disturb a land area of one acre or greater, including projects less than one acre that are part of a larger common plan of development. For newly permitted MS4s the permitting and/or approval process shall be in place no later than two years from the approval date of their SWMP. In addition to an Ordinance described in Part II, Section C.4.a, the following elements shall be incorporated into this program:

i. Procedures to incorporate plan review of new and redevelopment projects with the planning and approval process of these same projects with other municipal departments within the permittees MS4.

ii. Procedures for routine inspections of permitted construction sites during construction to verify proper installation and maintenance of required erosion and sediment controls. Enforcement shall be conducted as necessary based on the inspection.

iii. Development of an enforcement strategy to respond to issues of non-compliance.

iv. Procedures for providing educational and training measures for construction site operators and the permittees inspectors.

v. Development of an application process whereby the construction site operator will describe the sediment and erosion control measures to be taken on the site. This application process can include submittal of the stormwater pollution prevention plan that was used to obtain registration under DWWM WV/NPDES construction

stormwater permit. The application shall include a listing of all water bodies into which the construction site will discharge and whether or not they are on the 303(d) list for impaired waters.

vi. Development of procedures for keeping records of all regulated construction activities within your MS4, inspection reports, warning letters, and any other enforcement documentation. A summary of inspection and enforcement activities that are conducted shall be included in the annual report.

5. **Controlling Runoff from New Development and Redevelopment**

The SWMP shall include an ongoing program to develop, assess, implement, and enforce their ~~a~~ program to reduce pollutants in stormwater runoff to your small MS4 from new development and redevelopment activities. This program shall be applied to all sites that disturb a land area one acre or greater, including projects less than one acre that are part of a larger common plan of development or sale. The program shall apply to private sector and public sector development, including roads. The program must ensure that controls are in place that will increase groundwater recharge of stormwater runoff where and when possible, and would protect water quality and reduce the discharge of pollutants. Except where otherwise stated, newly permitted MS4s shall *begin* implementation of the requirements contained in Part II.C.4 of this permit within two years after the approval date of their SWMP.

The program shall include the following measures:

a. Long-term Stormwater Controls

The permittee shall protect the physical, chemical and biological integrity of receiving waters, and their designated uses, from the impacts of stormwater discharges through the implementation of watershed protection elements and site and neighborhood design elements. The purpose of *watershed protection* elements is to manage the impacts of stormwater on receiving waters that occur because of regional or watershed-scale management decisions. The primary purpose of *site and neighborhood design* elements is to manage the impacts of stormwater on receiving waters that occur because of site and neighborhood design management decisions. The technical principles of these management practices have many complementary similarities, and must be implemented in tandem.

All elements and standards are required, and must be described in the stormwater management program plan.

i. Watershed Protection

The permittee shall incorporate watershed protection elements into the subdivision ordinance or equivalent document. In addition, the permittee shall incorporate watershed protection elements into all relevant policy and/or planning documents as they come up for regular review. If a relevant planning document is not scheduled for review during the term of this permit, the permittee must identify the elements that cannot be implemented until that document is revised, and provide the DWWM a schedule for incorporation and implementation that cannot exceed seven years from the effective date of this permit. Planning documents include, but are not limited to; comprehensive or master plans, subdivision ordinances, general land use plan, zoning code,

transportation master plan, specific area plans, such as sector plan, site area plans, corridor plans, or unified development ordinances.

A. *Watershed protection elements.* As relevant, policy and/or planning documents must include the following, except where noted:

(1) Minimize the amount of impervious surfaces (roads, parking lots, roofs, etc.) within each watershed, by minimizing the creation, extension and widening of parking lots, roads and associated development.

(2) Preserve, protect, create and restore ecologically sensitive areas that provide water quality benefits and serve critical watershed functions. These areas may include, but are not limited to; riparian corridors, headwaters, floodplains and wetlands.

(3) Implement stormwater management practices that prevent or reduce thermal impacts to streams, including requiring vegetated buffers along waterways, and disconnecting discharges to surface waters from impervious surfaces such as parking lots.

(4) Seek to avoid or prevent hydromodification of streams and other water bodies caused by development, including roads, highways, and bridges.

(5) Implement standards to protect trees, and other vegetation with important evapotranspirative qualities.

(6) Implement policies to protect native soils, prevent topsoil stripping, and prevent compaction of soils.

B. *Measurable Goals.* For each of the six watershed elements in i.A, the permittee shall develop quantifiable objectives that include a time frame for achieving them. Short-term objectives (less than five years) and long-term objectives (greater than five years) are appropriate for many of these elements.

C. *Reporting.* Annual reports must include status of implementation of these elements with respect to incorporation into relevant documents and implementation via relevant policies. Reports should include proposed time frames, changes and measurable goals.

ii. Site and Neighborhood Design

The permittee shall develop a program to protect water resources by requiring all new and redevelopment projects to control stormwater discharge rates, volumes, velocities, durations and temperatures. These standards shall apply at a minimum to all new development and redevelopment disturbing one acre or greater, including projects less than one acre that are part of a larger common plan of development or sale. The permittee shall *begin* implementation of the requirements contained in Part II.C.5.a.ii [other than Part II.C.5.a.ii.A(3) and Part II.C.5.a.ii.A.(4)] within four years after the approval of the SWMP.

A. *Performance Standards.* The permittee must implement and enforce via ordinance and/or other enforceable mechanism(s) the following requirements for new and redevelopment:

1. Site design standards for all new and redevelopment that require, in combination or alone, management measures that keep and manage on site the first one inch of rainfall from a 24-hour storm preceded by 48 hours of no measurable precipitation. Runoff volume reduction can be achieved by canopy interception, soil amendments, evaporation, rainfall harvesting, engineered infiltration, extended filtration and/or evapotranspiration and any combination of the aforementioned practices. This first one inch of rainfall must be 100% managed with no discharge to surface waters, except when the permittee chooses to implement the conditions in paragraph 4 below. This can be achieved through on site utilization of practices to include dry swales, bioretention, rain tanks and cisterns, soil amendments, roof top disconnections, permeable pavement, porous concrete, permeable pavers, reforestation, grass channels, green roofs and other practices that alone or combined will capture the first one inch of rainfall runoff volume. An Underground Injection Control permit may be required when certain conditions are met.

2. The following additional water quality requirements, as applicable:

   i. A project with reasonable potential for pollutant loading(s) must provide water quality treatment for associated pollutants (e.g., petroleum hydrocarbons at a vehicle fueling facility) before infiltration.

   ii. A project with reasonable potential for pollutant loading(s) that cannot implement adequate preventive or water quality treatment measures to ensure compliance with groundwater and/or surface water quality standards, must properly convey stormwater to a NPDES-permitted wastewater treatment facility or via a licensed waste hauler to a permitted treatment and disposal facility.

   iii. A project that discharges or proposes to discharge to any surface water or ground water that is used as a source of drinking water must comply with all applicable requirements relating to source water protection.

3. When considered at the watershed scale, certain types of development can either reduce existing impervious surfaces, or at least create less 'accessory' impervious. Incentive standards may be applied to these types of projects. A reduction of 0.1 inches from the one inch infiltration/evapotranspiration/reuse standard may be applied to any of the following types of development. Reductions are additive such that a maximum reduction of 0.5 inch is possible for a project that meets all five criteria.

   a) Redevelopment
   b) Brownfield redevelopment
   c) High density (>7 units per acre)
   d) Vertical Density, (Floor to Area Ratio (FAR) of 2 or >18 units per acre)
   e) Mixed use and Transit Oriented Development (within ½ mile of transit)

4. For projects that cannot meet 100% of the infiltration/evapotranspiration/reuse requirement on-site, two alternatives are available: off-site mitigation and payment in lieu. If these alternatives are chosen, then the permittee must develop and fairly apply criteria for determining the circumstances under which these alternatives will be available. A determination that standards cannot be met on site may not be based solely on the difficulty or cost of implementing measures, but must include multiple criteria

that would rule out an adequate combination of the practices set forth in section 1, above, such as: too small a lot outside of the building footprint to create the necessary infiltrative capacity even with amended soils; a site use that is inconsistent with capture and reuse of stormwater; too much shade or other physical conditions that preclude adequate use of plants.

These alternatives are only available, in combination or alone, for up to 0.4 inches of the original obligation at a 1:1.5 ratio, i.e., mitigation or payment in lieu must be for 1.5 times the amount of stormwater not managed on site. For either of these options to be available, the permittee must create an inventory of appropriate mitigation projects, and develop appropriate institutional standards and management systems to value, evaluate and track transactions.

i. *Off-site mitigation.* Infiltration/evapotranspiration/reuse measures may be implemented at another location in the same sewershed/watershed as the original project, approved by the permittee. The permittee shall identify priority areas within the sewershed/watershed in which mitigation projects can be completed. Mitigation must be for retrofit or redevelopment projects, and cannot be applied to new development.

ii. *Payment in lieu.* Payment in lieu may be made to the permittee, who will apply the funds to a public stormwater project. MS4s shall maintain a publicly accessible database of approved in lieu projects.

5. When public (local or otherwise) streets or parking lots are repaired, modified or reconstructed opportunities to improve stormwater management using canopy interception, soil amendments, evaporation, rainfall harvesting, engineered infiltration, extended filtration and/or evapotranspiration and/or any combination of the aforementioned practices shall be included in the design work. These requirements apply only to projects begun after the effective date of this permit.

B. *Plan Review, Approval and Enforcement*. To ensure that all new development and redevelopment projects conform to the standards stipulated in Part II, Section C.5.ii, the permittee shall develop project review, approval and enforcement procedures. The review, approval and enforcement procedures shall apply at a minimum to all new development and redevelopment disturbing greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, and shall include:

(1) Requirements to submit for review and approval a pre-application concept plan that describes how the performance standards will be met. A pre-application meeting attended by a project land owner or developer, the project design engineer, and municipal planning staff to discuss conceptual designs may also meet this requirement.

(2) Development of procedures for the site plan review and approval process(es) that include inter-departmental consultations, as needed, and a required re-approval process when changes to an approved plan are desired.

(3) A requirement for submittal of ‘as-built’ certifications within 90 days of completion of a project.

(4) A post-construction verification process to ensure that stormwater standards are being met, that includes enforceable procedures for bringing noncompliant projects into compliance.

(5) A description of a program to educate both internal staff and external project proponents of the requirements of Part II, Section C.5 of this permit.

C. *Maintenance Agreements*. The permittee shall require that all development subject to the requirements of Part II, Section C.5.ii. of this permit develop a maintenance agreement and maintenance plan for approved stormwater management practices. The permittee shall require that property owners or operators provide verification of maintenance for the approved stormwater management practices. These agreements shall allow the permittee, or its designee, to conduct inspections of the stormwater management practices and also account for transfer of responsibility in leases and/or deed transfers. The agreement shall also allow the permittee, or its designee, to perform necessary maintenance or corrective actions neglected by the property owner/operator, and bill or recoup costs from the property owner/operator when the owner/operator has not performed the necessary maintenance within thirty (30) days of notification by the permittee or its designee. Verification shall include one or more of the following as applicable:

(1) The owner/developer's signed statement accepting responsibility for maintenance until the maintenance responsibility is legally transferred to another party; and/or

(2) Written conditions in the sales or lease agreement that require the recipient to assume responsibility for maintenance; and/or

(3) Written conditions in project conditions, covenants and restrictions for residential properties assigning maintenance responsibilities to a home owner’s association, or other appropriate group, for maintenance of structural and treatment control stormwater management practices; and/or

(4) Any other legally enforceable agreement that assigns permanent responsibility for maintenance of structural or treatment control stormwater management practices.

D. *Inventory and Tracking of Management Practices*. The permittee shall develop a system designed to track stormwater management practices deployed at new development and redevelopment projects. Tracking of stormwater management practices shall begin during the plan review and approval process with a database or geographic information system (GIS). The database or tracking system shall include information on both public and private sector projects that are within the jurisdiction of the permittee. In addition to the standard information collected for all projects (such as project name, owner, location, start/end date, etc.), the tracking system shall also include:

1. Source control stormwater management practices (type, number, design or performance specifications)

2. Treatment control stormwater management practices (type, number, design or performance specifications)

3. Latitude and longitude coordinates of stormwater BMP controls using a global positioning system

4. Digital photographs of stormwater management practice controls

5. Maintenance requirements of stormwater management practices (frequency of required maintenance and inspections)

6. Inspection information (date, findings, follow up activities, compliance status)

E. *Stormwater BMP Inspections*. In order to ensure that all stormwater BMPs are operating correctly and are properly maintained, the permittee shall, at a minimum:

1. Develop an inspection calendar for stormwater BMPs. Inspections should be performed so that all stormwater BMP's are inspected at least once during the permit cycle.

2. Complete inspection reports shall include:

i. Facility type,
ii. Inspection date,
iii. Name and signature of inspector,
iv. GIS location and nearest street address,
v. Management practice ownership information (name, address, phone number, fax, and email),
vi. A description of the stormwater BMP condition including the quality of: vegetation and soils; inlet and outlet channels and structures; embankments, slopes, and safety benches; spillways, weirs, and other control structures; and sediment and debris accumulation in storage and forebay areas as well as in and around inlet and outlet structures,
vii. Photographic documentation of all critical stormwater BMP components, and
viii. Specific maintenance items or violations that need to be corrected by the stormwater BMP owner along with deadlines and reinspection dates.

3. Ensure that stormwater BMPs are maintained. The permittee shall promptly notify the stormwater BMP owner or operator of any deficiencies discovered during a maintenance inspection. The owner must correct the deficiency within thirty (30) days of the notice. The permittee must conduct subsequent inspection to ensure completion of all required repairs. If repairs are not made, the permittee shall enforce its correction orders and, if need be, perform the necessary work and assess against the owner the costs incurred for repairs.

F. *Reporting*. The permittee shall demonstrate compliance with the requirements for post-construction controls by summarizing the following in the Annual Report:

(1) A description of how the permittees legal authority addresses the watershed protection elements in Part II, Section C.5.

(2) A summary of the number and types of projects that the permittee reviewed for new and development considerations.

(3) A summary of the number and types of stormwater BMPs approved in new and redevelopment projects, including the number of approved projects that qualified for each of the incentives described in Part II, Section C.5.a.ii.A.3, and that qualified for each of the alternatives described in Part II, Section C.5.a.ii.A.4.

(4) A summary of the number and types of maintenance agreements approved.

(5) A summary of stormwater BMP maintenance inspections conducted by the permittee, including a summary of the number requiring maintenance or repair, the number brought into compliance within stipulated time-frame, and the number of enforcement actions taken.

(6) A summary of any evaluation data collected for long-term stormwater controls, including water quality information, stormwater BMP performance, and model results.

b. Assessments

The permittee shall conduct the following assessment to provide a foundation for program improvements to be implemented during the next permit term.

1. Street/Parking Design Assessment.

Permittee shall submit to DWWM a report assessing current street design guidelines and parking requirements that affect the creation of impervious cover, with the third year annual report. The assessment shall include recommendations and proposed schedules for incorporating policies and standards into relevant documents and procedures to minimize impervious cover attributable to parking and street designs. The local planning commission and the local transportation commission should be involved in the assessment.

6. **<u>Pollution Prevention & Good Housekeeping for Municipal Operations</u>**

Each permittee shall continue to implement their operations and maintenance (O&M) program that includes a training component and has the ultimate goal of preventing or reducing polluted runoff from municipal operations. Newly permitted MS4s shall have one year from the approval date of their SWMP to *begin* implementation of the requirements contained in Part II.C.6 of this permit.

The minimum performance measures are:

a. Develop and implement an operation and maintenance program that incorporates good housekeeping components at all municipal facilities, including but not limited to; municipal waste water treatment facility, potable drinking water facility, municipal fleet operations, maintenance garages, parks and recreation, street and infrastructure maintenance, and grounds maintenance operations.

i. Each permittee shall develop and establish maintenance standards at all municipal facilities that will help protect the physical, chemical and biological integrity of receiving waters.

ii. Each permittee shall establish an inspection schedule in which to perform inspections to determine if maintenance standards are being met. Inspections shall be performed no less than once per calendar year.

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iii. Each permittee shall develop procedures for record keeping and tracking inspections and maintenance at all municipal facilities.

b. Establish and implement policies and procedures to reduce the discharge of pollutants in stormwater runoff from all lands owned or maintained by the permittee and subject to this permit, including but not limited to: parks, open space, road right-of-way, maintenance yards, water/sewer infrastructure and stormwater treatment and flow practices. These policies and procedures shall address, but are not limited to:

i. Application of fertilizer, pesticides, and herbicides including the development of nutrient management and integrated pest management plans.

ii. Sediment and erosion control.

iii. Landscape maintenance and vegetation disposal.

iv. Trash management.

v. Building exterior cleaning and maintenance.

c. Using training materials that are available from WVDEP, USEPA or other organizations, develop and implement an on-going training program for employees of the permittee whose construction, operations or maintenance job functions may impact stormwater quality. The training program shall include, but is not limited to those employees who work in the following areas:

- Street/sewer and right-of-way construction and maintenance,
- Water and sewer departments,
- Parks and recreation department,
- Municipal water treatment and waste water treatment,
- Fleet maintenance,
- Fire departments,
- Building maintenance and janitorial,
- Garage and mechanic crew,
- Contractors and subcontractors who may be contracted to work in the above described areas,
- Personnel responsible for answering questions about the permittees stormwater program, this includes persons who may take phone calls about the program,
- Any other department of the permittee that may impact stormwater runoff

i. The training program shall address the importance of protecting water quality, the requirements of this permit, operation and maintenance standards, inspection procedures, selecting appropriate BMPs, ways to perform their job activities to prevent or minimize impacts to water quality, and procedures for reporting water quality concerns, including potential illicit discharges. Follow-up and refresher training shall be provided at a minimum of once every twelve months, and shall include any changes in procedures, techniques or requirements. Permittees shall document and maintain records of training provided.

d. **Industrial Stormwater coverage for Municipal Operations**

Each permittee that owns or operates a publicly owned treatment works, including sanitary boards, maintenance garages and/or any other industrial activity must obtain coverage for their stormwater

discharges, unless coverage is already granted under DWWM WV/NPDES General Permit for Storm Water Discharges associated with Industrial activity, or an individual WV/NPDES permit.

The following monitoring requirements apply:

Pollutants of Concern	Cut-off Concentration	Measurement Frequency
BOD-5	30 mg/l	Once/Six months
COD	120 mg/l	Once/Six months
TSS	100 mg/l	Once/Six months
Ammonia Nitrogen	4 mg/l	Once/Six months
Oil & Grease	15 mg/l	Once/Six months
pH	6.0 – 9.00 s.u.	Once/Six months

Permittees that receive discharges into their small MS4 from their sewage treatment works must, in addition to the above listed monitoring requirements, also meet the following monitoring requirements for those discharges:

Pollutants of Concern	Cut-off Concentration	Measurement Frequency
Fecal Coliform, General	400 counts/100 ml	Once/Six months

Samples shall be collected once every six months, during the spring and fall seasons. Monitoring results shall be submitted to the DWWM with the annual report.

Stormwater samples shall be collected during the "first flush" of rainfall runoff, at least twenty minutes, but not more than fifty minutes after rainfall of at least 0.5 inches has begun, preceded by a period of dry weather of at least 48 hours.

Part III. Special Conditions

A. Sharing Responsibility

If you are relying on another MS4 regulated under the stormwater regulations to satisfy one or more of your permit obligations, you must note that fact in your stormwater management program. This other entity must, in fact, implement the control measure(s); the measure of component thereof, must be at least as stringent as the corresponding WV/NPDES permit requirement; and the other entity must agree to implement the control measure on your behalf. This agreement between the two or more parties must be documented in writing in the stormwater management plan and be retained by the permittee for the duration of this permit, including any automatic extensions of the permit term.

B. Discharge Compliance with Water Quality Standards

This general permit requires, at a minimum, that permittees develop, implement and enforce a stormwater management program designed to reduce the discharge of pollutants to the maximum extent practicable, to protect water quality, and satisfy the appropriate requirements of the Clean Water Act. If stormwater discharges have a reasonable potential to cause or contribute to violations

of water quality standards in the receiving water, additional controls are required. Full implementation of selected BMPs, using known, available, and reasonable methods of prevention, control and treatment to prevent and control stormwater pollution from entering waters of the State of West Virginia is considered an acceptable effort to reduce pollutants from the municipal storm drain system to the maximum extent practicable.

C. Requiring an Individual Permit

The DWWM may require any person authorized by this permit to apply for and/or obtain an individual WV/NPDES permit. Where the DWWM requires application for an individual WV/NPDES permit, the DWWM will notify the permittee in writing that a permit application is required. This notification shall include a brief statement of the reasons for this decision, an application form and a statement setting a deadline for the permittee to file the application.

D. Discharge to Impaired Waters

1. **303(d) Listed Waters**:

This permit does not authorize new sources or new discharges of pollutants of concern to impaired waters unless consistent an approved Total Maximum Daily Load (TMDL) and applicable state law. Impaired waters are those that do not meet applicable water quality standards. Impaired waters are identified on the West Virginia, Section 303(d) list until a TMDL is developed and approved by USEPA. Pollutants of concern are those pollutants for which the water body is listed as impaired. A list of impaired water bodies in West Virginia can be found at: http://www.wvdep.org/item.cfm?ssid=11&ss1id=720

a. MS4s that discharge into a receiving water which has been listed on the West Virginia Section 303(d) list of impaired waters, and with discharges that contain the pollutant(s) for which the water body is impaired, must document in the SWMP how the BMPs will control the discharge of the pollutant(s) of concern, and must ensure that there will be no increase of the pollutants of concern.

b. If a TMDL is approved during this permit cycle by USEPA for any waterbody into which an MS4 discharges, the MS4 must review the applicable TMDL to see if it includes requirements for control of stormwater discharges. Within six (6) months of the TMDL approval, the MS4 must modify its stormwater management program to include best management practices specifically targeted to achieve the wasteload allocations prescribed by the TMDL. The MS4 must include a monitoring component in the SWMP to assess the effectiveness of the BMPs in achieving the wasteload allocations. Monitoring shall be specifically for the pollutants of concern and be of sufficient frequency to determine if the stormwater BMPs are adequate to meet wasteload allocations. Monitoring can entail a number of activities from outfall monitoring to in-stream monitoring to modeling. For more information see the USEPA/State guidance titled: *Evaluating the effectiveness of municipal stormwater programs* and *Understanding Impaired Waters and Total Maximum Daily Load (TMDL) Requirements for Municipal Stormwater Programs.* Both of these guidance documents can be found on WVDEP's website: http://www2.wvdep.org/dwwm/stormwater/MS4_docs.htm

After monitoring results are carefully considered, the permittee shall ascertain if the SWMP and the mix of BMPs need to be modified to comply with wasteload allocations.

2. **Discharging into Waters with Approved TMDLs**

If a MS4 discharges into a water body with an approved TMDL, and the TMDL contains requirements for control of pollutants from the MS4 stormwater discharges, then the SWMP must include BMPs specifically targeted to achieve the wasteload allocations prescribed by the TMDL. A monitoring component to assess the effectiveness of the BMPs in achieving the wasteload allocations must also be included in the SWMP. Monitoring shall be specifically for the pollutants of concern and be of sufficient frequency to determine if the stormwater BMPs are sufficient to meet wasteload allocations. Monitoring shall be specifically for the pollutants of concern and be of sufficient frequency to determine if the stormwater BMPs are adequate to meet wasteload allocations. Monitoring can entail a number of activities from outfall monitoring to in-stream monitoring to modeling. For more information see the USEPA/State guidance titled: *Evaluating the effectiveness of municipal stormwater programs* and *Understanding Impaired Waters and Total Maximum Daily Load (TMDL) Requirements for Municipal Stormwater Programs.* Both of these guidance documents can be found on WVDEP's website: http://www2.wvdep.org/dwwm/stormwater/MS4_docs.htm

After monitoring results are carefully considered, the permittee shall ascertain if the SWMP and the mix of BMPs need to be modified to comply with wasteload allocations.

E. Endangered and Threatened Species

If a MS4 discharges to a stream where federally endangered or threatened species or its habitat are present, the applicant shall contact the US Fish and Wildlife Service to insure that requirements of the Federal Endangered Species Act are met.

Part IV. Monitoring, Recordkeeping, Reporting and Program Review

A. Evaluating the Stormwater Management Program

MS4s shall evaluate the effectiveness of their stormwater management programs and BMPs implemented to comply with this general permit. The permittee shall use a sufficient number of known, available, and reasonable methods necessary to evaluate the effectiveness of the SWMP. This information shall be submitted in the annual report in accordance with Part IV, Section D. For more information about evaluating your stormwater management program see the USEPA/States guidance titled: *Evaluating the effectiveness of municipal stormwater programs.* This guidance document can be found on WVDEP's website: http://www2.wvdep.org/dwwm/stormwater/MS4_docs.htm

B. Stormwater Monitoring

The permittee shall monitor stormwater from a minimum of one outfall that is representative of the stormwater discharge from the MS4. A representative outfall is one located in the most densely populated section of the MS4. The permittee shall, at a minimum, monitor one outfall for the following parameters:

Parameter	EPA Method No.	Method Detection Limit (mg/l)
Total Kjeldahl Nitrogen	351.4	0.03
Nitrate Nitrogen	300.0	0.002
Nitrite Nitrogen	300.0	0.004
Total Phosphorous	365.4	0.01

The DWWM recognizes there is not an EPA approved method to directly test for Total Nitrogen. The Total Nitrogen value to be reported on the permittees Discharge Monitoring Reports' (DMRs) shall be the sum of the following parameters; Total Kjeldahl Nitrogen, Nitrate, and Nitrite.

If all three constituents of total nitrogen are not detected at its method detection limit (MDL), the permittee shall sum the actual MDLs for each constituent and report the result as less than the calculation.

When calculating the sum of the constituents for total nitrogen, the permittee shall use actual analytical results when these results are greater than or equal to the MDL for a particular constituent and should use zero (0) for a constituent if one or two of the constituents are less than the MDL.

Effluent monitoring for the above pollutants shall be conducted using the most sensitive methods and detection levels commercially available and economically feasible. The methods and detection levels in the table above are recommended to be used unless the permittee desires to use an EPA Approved Method with a lower detection level.

Stormwater samples shall be collected once every six months, during the spring and fall seasons.

Stormwater samples shall be collected during the "first flush" of rainfall runoff, at least twenty minutes, but not more than fifty minutes after rainfall of at least 0.5 inches has begun, preceded by a period of dry weather of at least 48 hours.

C. Recordkeeping and Public Availability of SWMP and Annual Report

The permittee shall keep records under this general permit for at least three years after termination of this general permit. Records shall be submitted to the DWWM only when permittees are specifically asked to do so.

The permittee shall make their SWMP and their annual report available to the public at reasonable times during regular business hours. In addition, the SWMP and the annual report shall be posted on the permittees website. If the permittee does not maintain or utilize a website, an electronic copy of the SWMP and annual report shall be submitted to DWWM for distribution when it is requested.

D. Reporting

Annually, the permittee shall submit a report to the DWWM. The report shall include:

1. A description of the activities undertaken and implemented for each of the minimum control measures;

2. An explanation of how the permittee measured the effectiveness of each of the activities

implemented;

3. The status of compliance with each of the BMPs that were specified in the permittees stormwater management program;

4. An assessment of the progress toward achieving the identified measurable goals for each of the minimum control measures;

5. Results of information collected and analyzed, including monitoring data, during the annual reporting period;

6. A summary of the stormwater activities the permittee plans to undertake during the next annual reporting period;

7. A change in any identified measurable goals that apply to the minimum control measures;

8. A description of the status of the street and parking design assessment;

9. A description of the coordination efforts with other MS4's, County Governments, colleges, universities, correctional facilities, prisons, and any other entity regarding the implementation of the minimum control measures including the status of any memorandum of understanding (MOU) or other agreement executed between the permittee/s and any other entity;

10. A summary of construction site inspections and enforcement activities as described in Part II, Section C.4.b.vi.;

11. A summary of post construction controls as described in Part II, Section C.5.a.ii.F., and Part II, Section C.5.a.i.C.,

12. A description of specific BMPs *that were implemented* in order to reduce pollutants of concern in impaired receiving waters and waters in which a TMDL has been developed, and

13. A fiscal analysis of capital and operating expenditures to implement the minimum control measures. The fiscal analysis shall include only those expenditures by the locality seeking coverage under this general permit and not those for minimum control measures implemented by other entities.

E. Program Review

In order to assess the effectiveness of the permittees NPDES program for eliminating non-storm water discharges and reducing the discharge of pollutants to the maximum extent possible, the DWWM will review program implementation and annual reports. Additional periodic evaluations may be conducted to determine compliance with permit conditions.

The permittee must comply with all terms and conditions of this permit. Permit noncompliance constitutes a violation of the federal Clean Water Act (CWA) and State Act, Chapter 22, Article 11 &

Article 12 and is grounds for enforcement action; for permit modification, suspension or revocation.

Failure to comply with the terms and conditions of this permit, with the plans and specifications submitted with the site registration application, the most currently approved SWMP, and the appropriate appendices shall constitute grounds for the revocation or suspension of this permit and for the invocation of all the enforcement procedures set forth in Chapter 22, Article 11 of the Code of West Virginia.

This permit is issued in accordance with the provisions of Chapter 22, Article 11 of the Code of West Virginia

BY: _____
Director

Appendix A

WV/NPDES GENERAL PERMIT NUMBER WV0116025

SMALL MUNICIPAL SEPARATE STORM SEWER SYSTEMS

NOTICE OF INTENT (NOI)

1. MS4 Operator Information:

Name of city, county, storm water utility district or other jurisdiction that operates a Phase II MS4:

_____

Contact Person: _____ Telephone: _____

E-mail address of contact person: _____

Address: _____

City: _____ State:_____ Zip Code: _____

2. Receiving stream(s): _____

3. Fee - $17.50 per acre of area served by the MS4. Maximum fee is $1750.00

Amount enclosed: _____

NOTE:

The Notice of Intent provides MS4 entities initial coverage under the WV/NPDES MS4 General Permit. This permit requires the permittee to submit their Stormwater Management Program within six months of the issuance date of the General Permit.

I CERTIFY UNDER PENALTY OF LAW THAT I HAVE PERSONALLY EXAMINED AND AM FAMILIAR WITH THE INFORMATION SUBMITTED ON THIS FORM. I AM ALSO AWARE THAT THE STORMWATER MANAGEMENT PROGRAM/SITE REGISTRATION APPLICATION MUST BE SUBMITTED WITHIN SIX MONTHS OF THE ISSUANCE DATE OF THE GENERAL PERMIT NO. WV0116025.

I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT.

OFFICIAL SIGNATURE _____ DATE _____

PRINT NAME _____

Return To: WVDEP - DWWM
MS4/NPDES
601 57th Street, SE
Charleston, WV 25304

Appendix B

Definitions

Accessory Impervious Surfaces means those additional impervious surfaces that are created to service new development; including roads, shopping centers, office parks and parking lots.

Best Management Practices (BMP's) means schedules of activities, prohibitions of practices, maintenance procedures, policies, and other management practices to prevent or reduce the pollution of waters of the State of West Virginia. BMP's also include treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, waste disposal or drainage from material storage. BMP's can include structural as well as non-structural practices.

Bioretention is the water quality and water quantity stormwater management practice using the chemical, biological and physical properties of plants, microbes and soils for the removal of pollution from stormwater runoff.

Canopy Interception is the interception of precipitation, by leaves and branches of trees and vegetation that does not reach the soil.

Clean Water Act (CWA) means Public Law 92-500, as amended by Public Law 95-217, Public Law 97-117 and Public Law 95-576; U.S.C. 1251 et seq.

Common Plan of Development is a contiguous construction project where multiple separate and distinct construction activities may be taking place at different times on different schedules but under one plan. The "plan" is broadly defined as any announcement or piece of documentation or physical demarcation indicating construction activities may occur on a specific plot; included in this definition are most subdivisions and industrial parks.

Cut off concentration is a concentration at which stormwater could potentially impair, or contribute to impairing water quality.

Director means the Director of the Division of Water and Waste Management, West Virginia Department of Environmental Protection, or his/her designated representative.

Engineered Infiltration is an underground device or system designed to accept stormwater and slowly exfiltrates it into the underlying soil. This device or system is designed based on soil tests that define the infiltration rate.

Evaporation means rainfall that is changed or converted into a vapor.

Evapotranspiration means the sum of evaporation and transpiration of water from the earth's surface to the atmosphere. It includes evaporation of liquid or solid water plus the transpiration from plants.

Extended Filtration is a structural stormwater device which filters stormwater runoff through a soil media and collects it an underdrain which slowly releases it after the storm is over.

Hydromodification means the alteration of the natural flow of water through a landscape, and often takes the form of channel straightening, widening, deepening, or relocating existing, natural stream channels. It can also involve excavation of borrow pits or canals, building of levees, streambank

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erosion, or other conditions or practices that change the depth, width or location of waterways. Hydromodification usually results in water quality and habitat impacts.

Illicit Discharge means any non-permitted discharge to a regulated small MS4 or to waters of the State of West Virginia that does not consist entirely of stormwater or authorized non-stormwater discharges covered under a NPDES permit.

Infiltration is the process by which stormwater penetrates into soil.

Land Use means the way in which land is used, especially in farming and municipal planning.

Maintenance Agreement means a formal agreement or contract between a local government and a property owner designed to guarantee that specific maintenance functions are performed.

Municipal Field Staff means employees of the municipality and its departments that spend a portion of their employment in the marketplace, outside of the company office.

Municipal Separate Storm Sewer System (MS4) means conveyances for stormwater, including, but not limited to, roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, human made channels or storm drains owned or operated by any municipality, sewer or sewage board, State agency or Federal agency or other public entity that discharges directly to surface waters of the State of West Virginia.

Municipal Staff means employees of the municipality and its departments.

Notice of Intent (NOI) means a notification of intent to seek coverage under this general permit, to discharge stormwater into waters of the State of West Virginia.

NPDES means National Pollutant Discharge Elimination System, a provision of the Clean Water Act which prohibits the discharge of pollutants into waters of the United States. This federally mandated permit program is used for regulating point source discharges.

Outfall means the point source where the MS4 discharges from a pipe, ditch or other discreet conveyance directly or indirectly to water of the State of West Virginia, or to another MS4.

Planning documents are documents a municipality or jurisdiction uses for planning. They include, but are not limited to; comprehensive or master plans, subdivision ordinances, general land use plan, zoning code, transportation master plan, specific area plans, such as sector plan, site area plans, corridor plans, or unified development ordinances.

Pollutants of Concern are those pollutants which cause a water body to be placed on the Section 303(d) list of impaired waters.

Qualifying Local Program means a WVDEP formally recognized state, municipal or county program that meets or exceeds the provisions of WV DEP stormwater construction program in accordance with 40 CFR 122.44(s).

Rainfall and Rainwater Harvesting is the collection, conveyance, and storage of rainwater. The scope, method, technologies, system complexity, purpose, and end uses vary from rain barrels for garden irrigation in urban areas, to large-scale collection of rainwater for all domestic uses.

Runoff Reduction Techniques means the collective assortment of stormwater practices that reduce the volume of stormwater from discharging off site.

Secretary means the Secretary of the West Virginia Department of Environmental Protection, or his/her designated representative.

Site Registration Application means the forms designed by the Director for the purpose of obtaining coverage under the small MS4 general permit. The information contained on the site registration application once approved becomes the "stormwater management program" for the permittee.

Soil amendments are components added to in situ or native soils to increase the spacing between soil particles so that the soil can absorb and hold more moisture. The amendment of soils changes various other physical, chemical and biological characteristics so that the soils become more effective in maintaining water quality.

Source control stormwater management means practices that control stormwater *before* pollutants have been introduced into stormwater.

Stormwater Pollution Prevention Plan (SWPPP) means the erosion and sediment control plan for a construction site.

Stormwater Management Practice means practices that manage stormwater, including structural and vegetative components of a stormwater system.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL is the sum of individual wasteload allocations for point sources (WLA), load allocations for nonpoint sources and natural background (LA), and must consider seasonal variation and include a margin of safety. The TMDL comes in the form of a technical document or plan. (40 CFR 130.2 and 130.7)

Treatment control stormwater management means practices that 'treat' stormwater after pollutants have been incorporated into the stormwater.

Wasteload allocation (WLA): The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).

Water Quality Treatment means any passive or active process that removes pollutants from stormwater, and/or prevents pollutants from encountering stormwater.

Water Resources, 'Water' or 'Waters' means any and all water on or beneath the surface of the ground, whether percolating, standing, diffused or flowing, wholly or partially within this state, or bordering this state and within its jurisdiction, and includes, without limiting the generality of the foregoing, natural or artificial lakes, rivers, streams, creeks, branches, brooks, ponds (except farm ponds, industrial settling basins and ponds and water treatment facilities), impounding reservoirs, springs, wells, watercourses and wetlands.

Appendix C

I. MANAGEMENT CONDITIONS:

1. Duty to Comply
a) The permittee must comply with all conditions of this permit. Permit noncompliance constitutes a violation of the CWA and State Act and is grounds for enforcement action; for permit modification, revocation and reissuance, suspension or revocation; or for denial of a permit renewal application.
b) The permittee shall comply with all effluent standards or prohibitions established under Section 307(a) of the CWA for toxic pollutants within the time provided in the regulations that establish these standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

2. Duty to Reapply
If the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee must apply for a new permit at least 180 days prior to expiration of the permit.

3. Duty to Mitigate
The permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit, which has a reasonable likelihood of adversely affecting human health or the environment.

4. Permit Actions
This permit may be modified, revoked and reissued, suspended, or revoked for cause. The filing of a request by the permittee for permit modification, revocation and reissuance, or revocation, or a notification of planned changes or anticipated noncompliance, does not stay any permit condition.

5. Property Rights
This permit does not convey any property rights of any sort or any exclusive privilege.

6. Signatory Requirements
All applications, reports, or information submitted to the Chief shall be signed and certified as required in Title 47, Series 10 , Section 4.6 of the West Virginia Legislative Rules.

7. Transfers
This permit is not transferable to any person except after notice to the Chief. The Chief may require modification or revocation and reissuance of the permit to change the name of the permittee and incorporate such other requirements as may be necessary. .

8. Duty to Provide Information
The permittee shall furnish to the Chief, within a reasonable specified time, any information which the Chief may request to determine whether cause exists for modifying, revoking and reissuing, suspending, or revoking this permit, or to determine compliance with this permit. The permittee shall also furnish to the Chief, upon request, copies of records required to be kept by this permit.

9. Other Information
Where the permittee becomes aware that it failed to submit any relevant facts in a permit application, or submitted incorrect information in a permit application or in any report to the Chief, it shall promptly submit such facts or information.

10. Inspection and Entry
The permittee shall allow the Chief, or an authorized representative, upon the presentation of credentials and other documents as may be required by law, to:
a) Enter upon the permittee's premises in which an effluent source or activity is located, or where records must be kept under the conditions of this permit;
b) Have access to and copy at reasonable times, any records that must be kept under the conditions of this permit;
c) Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and
d) Sample or monitor at reasonable times, for the purposes of assuring permit compliance or as otherwise authorized by the State Act, any substances or parameters at any location.

11. Permit Modification
This permit may be modified, suspended, or revoked in whole or in part during its term in accordance with the provisions of Chapter 22-11-12 of the Code of West Virginia.

12. Water Quality
The effluent or effluents covered by this permit are to be of such quality so as not to cause violation of applicable water quality standards adopted by the Environmental Quality Board.

13. Outlet Markers
A permanent marker at the establishment shall be posted in accordance with Title 47, Series 11, Section 9 of the West Virginia Legislative Rules.

14. Liabilities
a) Any person who violates a permit condition implementing sections 301, 302, 306, 307, 308, 318, or 405 of the Clean Water Act is subject to a civil penalty not to exceed $10,000 per day of such violation. Any person who willfully or negligently violates permit conditions implementing sections 301, 302, 306, 307, or 308 of the Clean Water Act is subject to a fine of not less than $2,500 nor more than $25,000 per day of violation, or by imprisonment for not more than 1 year, or both.
b) Any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.
c) Any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.
d) Nothing in I.14 a), b), and c) shall be construed to limit or prohibit any other authority the Chief may have under the State Water Pollution Control Act, Chapter 22, Article 11.

II. OPERATION AND MAINTENANCE:

1. Proper Operation and Maintenance
The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls, and appropriate quality assurance procedures. Unless otherwise required by Federal or State law, this provision requires the operation of back-up auxiliary facilities or similar systems which are installed by the permittee only when the operation is necessary to achieve compliance with the conditions of the permit. For domestic waste treatment facilities, waste treatment operators as classified by the WV Bureau of Public Health Laws, W. Va. Code Chapter 16-1, will be required except that in circumstances where the domestic waste treatment facility is receiving any type of industrial waste, the Chief may require a more highly skilled operator.

2. Need to Halt or Reduce Activity Not a Defense
It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of the permit.

3. Bypass
a) Definitions
(1) "Bypass" means the intentional diversion of waste streams from any portion of a treatment facility; and
(2) "Severe property damage" means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.
b) Bypass not exceeding limitations. The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provision of II.3.c) and II.3.d) of this permit.
c) (1) If the permittee knows in advance of the need for a bypass, it shall submit prior notice, if possible at least ten (10) days before the date of the bypass;
(2) If the permittee does not know in advance of the need for bypass, notice shall be submitted as required in IV.2.b) of this permit.
d) Prohibition of bypass
(1) Bypass is permitted only under the following conditions, and the Chief may take enforcement action against a permittee for a bypass, unless;
(A) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
(B) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate backup equipment should have been installed in the exercise of reasonable engineering judgement to prevent a bypass which occurred during normal periods of equipment downtime or preventative maintenance; and
(C) The permittee submitted notices as required under II.3.c) of this permit.
(2) The Chief may approve an anticipated bypass, after considering its adverse effects, if the Chief determines that it will meet the three conditions listed in II.3.d.(1) of this permit.

4. Upset
a) Definition. "Upset" means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventative maintenance, or careless or improper operation.

b) Effect of an upset. An upset constitutes an affirmative defense to an action brought for noncompliance with such technology-based permit effluent limitation if the requirements of II.4.c) are met. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review.

c) Conditions necessary for a demonstration of upset. A permittee who wishes to establish the affirmative defense of upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:
(1) An upset occurred and that the permittee can identify the cause(s) of the upset;
(2) The permitted facility was at the time being properly operated;
(3) The permittee submitted notice of the upset as required in IV.2.b) of this permit.
(4) The permittee complied with any remedial measures required under I.3. of this permit.

d) Burden of proof. In any enforcement proceeding the permittee seeking to establish the occurrence of an upset has the burden of proof.

5. Removed Substances
Where removed substances are not otherwise covered by the terms and conditions of this permit or other existing permit by the Chief, any solids, sludges, filter backwash or other pollutants (removed in the course of treatment or control of wastewaters) and which are intended for disposal within the State, shall be disposed of only in a manner and at a site subject to the approval by the Chief. If such substances are intended for disposal outside the State or for reuse, i.e., as a material used for making another product, which in turn has another use, the permittee shall notify the Chief in writing of the proposed disposal or use of such substances, the identity of the prospective disposer or users, and the intended place of disposal or use, as appropriate.

III. MONITORING AND REPORTING

1. Representative Sampling
Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

2. Reporting
a) Permittee shall submit, according to the enclosed format, a Discharge Monitoring Report (DMR) indicating in terms of concentration, and/or quantities, the values of the constituents listed in Part A analytically determined to be in the plant effluent(s). DMR submissions shall be made in accordance with the terms contained in Section C of this permit.
b) Enter reported average and maximum values under "Quantity" and "Concentration" in the units specified for each parameter, as appropriate.
c) Specify the number of analyzed samples that exceed the allowable permit conditions in the columns labeled "N.E." (i.e., number exceeding).
d) Specify frequency of analysis for each parameter as number of analyses/specified period (e.g.,3/month is equivalent to 3 analyses performed every calendar month). If continuous, enter "Cont.". The frequency listed on format is the minimum required.

3. Test Procedures
Samples shall be taken, preserved and analyzed in accordance with the latest edition of 40 CFR Part 136, unless other test procedures have been specified elsewhere in this permit.

4. Recording of Results
For each measurement or sample taken pursuant to the permit, the permittee shall record the following information.
a) The date, exact place, and time of sampling or measurement;
b) The date(s) analyses were performed;
c) The individual(s) who performed the sampling or measurement;
d) The individual(s) who performed the analyses; if a commercial laboratory is used, the name and address of the laboratory;
e) The analytical techniques or methods used, and
f) The results of such analyses. Information not required by the DMR form is not to be submitted to this agency, but is to be retained as required in III.6.

5. Additional Monitoring by Permittee
If the permittee monitors any pollutant at any monitoring point specified in this permit more frequently than required by this permit, using approved test procedures or others as specified in this permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the Discharge Monitoring Report Form. Such increased frequency shall also be indicated. Calculations for all limitations which require averaging of measurements shall utilize an arithmetic mean unless otherwise specified in the permit.

6. Records Retention
The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for the permit, for a period of at least three (3) years from the date of the sample, measurement, report or application. This period may be extended by request of the Chief at any time.

7. Definitions
a) "Daily discharge" means the discharge of a pollutant measured during a calendar day or within any specified period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the daily discharge is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the daily discharge is calculated as the average measurement of the pollutant over the day.
b) "Average monthly discharge limitation" means the highest allowable average of daily discharges over a calendar month, calculated as the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during that month.
c) "Maximum daily discharge limitation" means the highest allowable daily discharge.
d) "Composite Sample" is a combination of individual samples obtained at regular intervals over a time period. Either the volume of each individual sample is proportional to discharge flow rates or the sampling interval (for constant volume samples) is proportional to the flow rates over the time period used to produce the composite. The maximum time period between individual samples shall be two hours.
e) "Grab Sample" is an individual sample collected in less than 15 minutes.
f) "is" = immersion stabilization - a calibrated device is immersed in the effluent stream until the reading is stabilized.
g) The "daily average temperature" means the arithmetic average of temperature measurements made on an hourly basis, or the mean value plot of the record of a continuous automated temperature recording instrument, either during a calendar month, or during the operating month if flows are of shorter duration.
h) The "daily maximum temperature" means the highest arithmetic average of the temperatures observed for any two (2) consecutive hours during a 24 hour day, or during the operating day if flows are of shorter duration.
i) The "daily average fecal coliform" bacteria is the geometric average of all samples collected during the month.
j) "Measured Flow" means any method of liquid volume measurement, the accuracy of which has been previously demonstrated in engineering practice, or which a relationship to absolute volume has been obtained.
k) "Estimate" means to be based on a technical evaluation of the sources contributing to the discharge including, but not limited to pump capabilities, water meters and batch discharge volumes.
l) "Non-contact cooling water" means the water that is contained in a leak-free system, i.e., no contact with any gas, liquid, or solid other than the container for transport; the water shall have no net poundage addition of any pollutant over intake water levels, exclusive of approved anti-fouling agents.

IV. OTHER REPORTING

1. Reporting Spills and Accidental Discharges
Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities or penalties established pursuant to Title 47, Series 11, Section 2 of the West Virginia Legislative Rules promulgated pursuant to Chapter 22, Article 11.

Attached is a copy of the West Virginia Spill Alert System for use in complying with Title 47, Series 11, Section 2 of the Legislative rules as they pertain to the reporting of spills and accidental discharges.

2. Immediate Reporting
a) The permittee shall report any noncompliance which may endanger health or the environment immediately after becoming aware of the circumstances by using the Agency's designated spill alert telephone number. A written submission shall be provided within five (5) days of the time the permittee becomes aware of the circumstances. The written submission shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times, and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent recurrence of the noncompliance.
b) The following shall also be reported immediately:
(1) Any unanticipated bypass which exceeds any effluent limitation in the permit;
(2) Any upset which exceeds any effluent limitation in the permit; and
(3) Violation of a maximum daily discharge limitation for any of the pollutants listed by the Chief in the permit to be reported immediately. This list shall include any toxic pollutant or hazardous substance, or any pollutant specifically identified as the method to control a toxic pollutant or hazardous substance.
c) The Chief may waive the written report on a case-by-case basis if the oral report has been received in accordance with the above.
d) Compliance with the requirements of IV.2 of this section shall not relieve a person of compliance with Title 47, Series 11, Section 2.

3. Reporting Requirements
a) Planned changes. The permittee shall give notice to the Chief of any planned physical alterations or additions to the permitted facility which may affect the nature or quantity of the discharge. Notice is required when:
(1) The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source in Section 13.7.b of Series 10, Title 47; or
(2) The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged. This notification applies to pollutants which are subject neither to effluent limitations in the permit, nor to notification requirements under IV.2 of this section.
b) Anticipated noncompliance. The permittee shall give advance notice to the Chief of any planned changes in the permitted facility or activity which many result in noncompliance with permit requirements.
c) In addition to the above reporting requirements, all existing manufacturing, commercial, and silvicultural discharges must notify the Chief in writing as soon as they know or have reason to believe:
(1) That any activity has occurred or will occur which would result in the discharge, on a routine or frequent basis, or any toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels":
(A) One hundred micrograms per liter (100 ug/l);
(B) Two hundred micrograms per liter (200 ug/l) for acrolein and acrylonitrile; five hundred micrograms per liter (500 ug/l) for 2,4-dinitro phenol; and for 2-methyl 4,6-dinitrophenol; and one milligram per liter (1 mg/l) for antimony;
(C) Five (5) times the maximum concentration value reported for that pollutant in the permit application in accordance with Section 4.4.b.9 of Series10, Title 47.
(D) The level established by the Chief in accordance with Section 6.3.g of Series 10, Title 47;
(2) That any activity has occurred or will occur which would result in any discharge (on a non-routine or infrequent basis) of a toxic which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels":
(A) Five hundred micrograms per liter (500 ug/l);
(B) One milligram per liter (1 mg/l) for antimony;
(C) Ten (10) times the maximum concentration value reported for that pollutant in the permit application in accordance with Section 4.4.b.7 of Series 10, Title 47;
(D) The level established by the Chief in accordance with Section 6.3.g of Series 10, Title 47.
(3) That they have begun or expect to begin to use or manufacture as an intermediate or final product or by-product of any toxic pollutant which was not reported in the permit application under Section 4.4.b.9 of Series 10, Title 47 and which will result in the discharge on a routine or frequent basis of that toxic pollutant at levels which exceed five times the detection limit for that pollutant under approved analytical procedure.
(4) That they have begun or expect to begin to use or manufacture as an intermediate or final product or by-product of any toxic pollutant which was not reported in the permit application under Section 4.4.b.9 of Series 10, Title 47 and which will result in the discharge on a non-routine or infrequent basis of that toxic pollutant at levels which exceed ten times the detection limit for that pollutant under approved analytical procedure.

4. Other Noncompliance
The permittee shall report all instances of noncompliance not reported under the above paragraphs at the time monitoring reports are submitted. The reports shall contain the information listed in IV.2.a). Should other applicable noncompliance reporting be required, these terms and conditions will be found in Section C of this permit.

Appendix D

Designation Criteria for small MS4s with a population greater than 1,000.

The DWWM will use the following designation criteria to evaluate and determine if the subject MS4s require permit coverage:

1. Discharge to sensitive waters

2. High growth or growth potential

3. High population density

4. Contiguity to an urbanized area

5. Significant contributor of pollutants to waters of the State

6. Ineffective protection of water quality by other programs

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Appendix E

Sediment and Erosion Control BMP manuals:

1. West Virginia BMP manual; http://www.wvdep.org/dwwm/stormwater/BMP/index.html

2. Maryland Soil Erosion and Sediment Control BMP manual; http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/erosionsedimentcontrol/standards.asp

3. Virginia Erosion and Sediment Control Handbook; http://www.dcr.virginia.gov/soil_&_water/e&s-ftp.shtml

4. USEPA has a listing of available state stormwater manuals here; http://yosemite.epa.gov/R10/WATER.NSF/0/17090627a929f2a488256bdc007d8dee?OpenDocument

5. West Virginia Department of Transportation, Division of Highways, Erosion and Sediment Control Manual, March 1, 2003. http://www.wvdot.com/engineering/TOC_engineering.htm

SARB_015623

State of West Virginia
Department of Environmental Protection
Division of Water and Waste Management
601 57th Street SE
Charleston, WV 25304-2345

Fact sheet, rationale and information for General WV/NPDES Permit for small Municipal Separate Storm Sewer Systems (MS4s)

WV/NPDES Permit No. WV0116025

General

1. **Name and address of applicant**

   An applicant is an entity that owns or operates a separate storm sewer system with stormwater discharges and agreeing to be regulated under the terms and conditions of this general permit.

2. **General WV/NPDES Permit No.WV0116025**

3. **County**: Any WV county

4. **Receiving stream**: Any WV stream

5. **Public comment period** from December 13, 2008 to January 12, 2008

6. **Background**

   Stormwater is the surface runoff that results from rain and snow melt. Urban development alters natural infiltration capability of the land and generates a host of pollutants that are associated with the activities of urban populations, thus causing an increase in stormwater runoff volumes and pollutant loadings in stormwater discharged to receiving waterbodies. Urban development increases the amount of impervious surface in a watershed as farmland, forests, and meadowlands with natural infiltration characteristics are converted into buildings with rooftops, driveways, sidewalks, roads, and parking lots with virtually no ability to absorb stormwater.

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Polluted stormwater runoff is often transported to municipal separate storm sewer systems (MS4s) and ultimately discharged into local rivers and streams without treatment.

The National Pollutant Discharge Elimination System (NPDES) stormwater regulations establish permit requirements for discharges from MS4s. The USEPA's Stormwater Phase II Rule establishes an MS4 stormwater management program that is intended to improve the Nation's waterways by reducing the quantity of pollutants that stormwater picks up and carries into storm sewer systems during storm events.

Common pollutants include oil and grease from roadways, pesticides from lawns, sediment from construction sites, and carelessly discarded trash, such as cigarette butts, paper wrappers, and plastic bottles. When deposited into nearby waterways through MS4 discharges, these pollutants can impair the waterways, thereby discouraging recreational use of the resource, contaminating drinking water supplies, and interfering with the habitat for fish, other aquatic organisms, and wildlife.

In 1999, USEPA promulgated rules establishing requirements for small MS4s. The federal regulations require West Virginia to permit stormwater discharges from small MS4s in the State. A regulated small MS4 is defined as any small MS4 located in an "urbanized area" as defined by the U.S. Bureau of Census, as well as those MS4s located outside of an urbanized area that are designated a regulated small MS4 by the NPDES permitting authority. [40 CFR § 122.32(a)] A regulated small MS4 includes storm drain conveyance systems owned or operated by a state, city or federal entity, a town, or other public entity where stormwater discharges into waters of the United States.

The Federal regulations establish six categories of minimum control measures that must be implemented by permittees. Best Management Practices (BMPs) are put into practice in order to implement the six minimum control measures. Rather than numeric 'end of pipe' limits, these are 'narrative' best management practices that will ultimately reduce the amount of pollutants discharged in stormwater runoff. By implementing and executing the BMPs to the Maximum Extent Practicable (MEP) specified in the permittees stormwater management program, the requirements for antidegradation, up to and including, Tier 2 protection are met.

7. General Permits

The Division of Water and Waste Management is utilizing a general WV/NPDES permit to permit MS4 discharges.

Under 47CSR10-13.6 of the Legislative Rules, a general permit can be used to regulate either separate storm sewers or a category of point sources other than separate storm sewers if the sources all:

a. Involve the same or substantially similar types of operations;
b. Discharge the same types of wastes;

c. Require the same effluent limitations or operating conditions;
d. Require the same or similar monitoring; and
e. In the opinion of the Director, are more appropriately controlled under a general permit than under individual permits.

A general permit is issued for facilities that are similar in nature. This saves the Division time in issuing individual permits for similar discharges.

The Division of Water and Waste Management assumed primacy for the NPDES Program from the USEPA in 1982.

8. **Types of Discharges Covered**

This permit covers stormwater discharges from small MS4s.

SECTION-BY-SECTION RATIONALE

Part I

A. This General Permit covers all areas in the State of West Virginia.

B. According to 40 CFR 122.26(b)(8), "***municipal separate storm sewer*** means a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):

> (i) Owned or operated by a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law)...including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into waters of the United States.
>
> (ii) Designed or used for collecting or conveying stormwater;
>
> (iii) Which is not a combined sewer; and
>
> (iv) Which is not part of a Publicly Owned Treatment Works (POTW) as defined at 40 CFR 122.2."

The Stormwater Phase II Final Rule requires nationwide coverage of all operators of small MS4s that are located within the boundaries of a Bureau of the Census-defined "urbanized area" (UA) based on the latest decennial Census. Once a small MS4 is designated into the program based on the UA boundaries, it cannot be waived from the program if in a subsequent UA calculation the small MS4 is no longer within the UA boundaries.

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C. Registration under this permit to discharge stormwater is appropriately issued to the municipality or governing body of an MS4. It is the municipality that owns the municipal separate storm sewer system. In most cases in West Virginia, the permittee is the City or the County. This permit is not, nor was ever intended to be issued to a 'sub' department of a municipality. All departments of a municipality fall under the 'governing umbrella' of its City Council. And, this permit covers the entire municipal separate storm sewer *system*, not just select portions.

Public Works and Utility Boards are created, appointed and function on behalf of the City Council, which represent the citizens that live in that municipality. City Councils enact Ordinances that its departments implement and enforce. This permit cannot be adequately implemented without all the appropriate departments of the regulated MS4 working together. Doing so would make would make it impossible to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP), protect water quality, and satisfy the appropriate requirements of the Clean Water Act.

The successful implementation of the MS4 general permit, probably more than any other NPDES permit is hinged upon municipal departments communicating and working together. Especially, those departments that affect stormwater management. Therefore, this permit contains certain terms and conditions that require communication between departments of the MS4.

D. Development and implementation of certain components of the minimum control measures was required under the prior MS4 permit. MS4s are to already have these programs in place, per the requirements of the prior permit.

According to 40 CFR § 122.44(l), to avoid backsliding, the standards and conditions in reissued permits must be at least as stringent as the standards and conditions in the previous permit. All currently regulated MS4s in the State have had more than five years to establish their stormwater programs. The prior permit is very clear in the language stating that; "You must fully implement your program within five years of the effective date of this permit", (Part II.A). MS4s that have not developed and implemented these requirements will be in violation of the new permit once it becomes effective.

The language in the second draft MS4 general permit has been modified to reflect the provision in 40 CFR § 122.44(l)

E. 40 CFR § 122.34(g) states that small regulated MS4's "must evaluate program compliance, the appropriateness of your identified best management practices, and progress towards achieving your identified measurable goals." Therefore, there are several stated evaluation goals in this small MS4 general permit. DWWM believes that the stormwater management program components must be assessed and evaluated to know if measureable goals are being met.

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USEPA has several guidance documents available to help the MS4 permittee to understand and meet this requirement. The recently completed "Evaluating the effectiveness of Municipal Stormwater Programs" is available at; http://www.epa.gov/npdes/pubs/region3_factsheet_swmp.pdf USEPA's "MS4 Program Evaluation Guidance" is available at www.epa.gov/npdes/pubs/ms4guide_withappendixa.pdf.

Part II

A. An application is required of the small MS4 operator. Applications can be sent to DWWM on the form provided by DWWM, or an appropriate substitute, with all the required information can be used.

B. Requirements of the SWMP

Maximum Extent Practicable (MEP) Discussion

Section 402(p)(3)(B) of the Clean Water Act establishes NPDES permit standards for discharges from municipal separate storm sewer systems, or MS4s. NPDES permits for discharges from MS4s (1) may be issued on a system or jurisdiction-wide basis, (2) must include a requirement to effectively prohibit non-storm water discharges into the storm sewers, and (3) must require controls to reduce pollutant discharges to the maximum extent practicable, including best management practices, and other provisions as the Administrator or the States ***determine*** to be appropriate for the control of such pollutants.

Therefore, this General Permit requires the permittee to develop a stormwater management program that is designed to reduce the discharge of pollutants to the **maximum extent practicable** (MEP). The MEP standard involves applying best management practices that are effective in reducing the discharge of pollutants in stormwater runoff. This requires that the permittee use all known, available and reasonable methods of prevention, control and treatment of stormwater discharges. Such stormwater BMP controls include management practices, control techniques and systems, design and engineering methods, and such other provisions the Director deems necessary for the control of pollutants in stormwater discharges.

There must be a serious attempt to comply, and although permittees may not have knowledge of *all* stormwater BMPs, ignorance of BMPs is ***not*** a reason for non compliance.

MEP requires that permittees to choose effective BMPs and to reject applicable BMPs only where other effective BMPs will serve the same purpose, the BMPs would not be technically feasible, or the cost would be prohibitive.

And, because MEP is an iterative standard, the BMPs used *and* the MS4 stormwater management program will evolve over time as technology and urban runoff management knowledge increases. As such, the permittees MS4 program must continually be assessed and modified to incorporate improved programs, control measures, BMPs, etc., to attain compliance with water quality standards.

The decision of a permittee to not adopt a stormwater utility is not a reason for an ineffective stormwater management program. In 2003, the West Virginia legislature enabled municipalities to form stormwater utilities in order to pay for and effectively manage stormwater. The 2008 Legislature further strengthened State Law so that municipalities can effectively enforce their stormwater ordinances.

Numerous stormwater BMP's are described in varying degrees of detail on the World Wide Web (internet). It is recommended that the permittee spend time researching BMPs to ascertain if and how they can be implemented in their particular MS4. In most instances, other regulated MS4 entities across the United States may have already implemented certain stormwater BMPs that the permittee is considering. Communities that have implemented stormwater BMPs are usually happy to discuss their successes and failures with other MS4 communities, and therefore, there is no reason to "reinvent the wheel".

By implementing and executing the BMPs to the Maximum Extent Practicable (MEP) specified in the permittees stormwater management program, the requirements for antidegradation, up to and including, Tier 2 protection are met.

Public Education and Outreach

The permittee must implement a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of stormwater discharges on water bodies and steps the public can take to reduce pollutants in stormwater runoff.

Since there is greater support for the stormwater management program as the public gains a better understanding of the reasons why the SWMP is necessary and important, an informed and knowledgeable community is crucial to the success of a SWMP. Public support is particularly beneficial when operators of small MS4s attempt to institute new funding initiatives for the program or seek volunteers to help implement aspects of the program. Education can lead to greater compliance with the local programs, as the public becomes aware of the personal responsibilities expected of them and others in the community, including individual actions they can take to protect or improve the quality of local waters.

West Virginia's small MS4 permit specifies audiences to target with a message to reduce or eliminate practices and behaviors that contribute to polluted stormwater runoff.

Public Involvement and Participation

The small MS4 general permit contains three minimum performance measures for public participation and involvement. By making sure that the public will have opportunities to get involved in the stormwater program, there is greater chance of success of the SWMP. The public can provide valuable input and assistance in the development of a successful SWMP. The public must be given opportunities to play an active role in both the development and the

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implementation of the SWMP. Broad public support is critical to the success of a SWMP because citizens who participate in the development and decision making process may be less likely to raise legal challenges to the SWMP and are more likely to take an active role in its implementation. In addition, the community is a valuable intellectual resource that can provide a broader base of expertise and economic benefit. Citizens involved in the SWMP development process provide important networking avenues and relationships with other community and government programs that can be particularly valuable when trying to implement a SWMP on a watershed basis.

There are many ways to provide opportunities for the public to participate in the SWMP, a few of which are listed here;

- Conduct annual forums or open house to obtain input from the public.
- Create and maintain a telephone hot line for citizen suggestions and complaints.
- Sponsor or co-sponsor community cleanup activities or workshops
- Conduct storm drain stenciling with scouts or students from a local school.
- Provide a booth at a festival or other family event where citizens can interact with municipal stormwater officials.
- Give prizes or credits to innovation stormwater BMP's or slogan creation.

The general permit requires that the SWMP and annual report be posted on the permittees website. This is to ensure reasonable public access to information and documents relevant to the stormwater program.

Illicit Discharge Detection and Elimination

Dry weather discharges into the MS4 system can contribute significant pollutants to receiving water bodies. Detecting and eliminating these illicit discharge involves complex detective work, which makes it hard to establish a specific prescription to "hunt down" and correct all illicit connections. Frequently, there is no single approach to take, but rather a variety of ways to get from detection to elimination. This process is ongoing and the effectiveness of a program should improve with time.

This minimum measure requires the permittee to detect and eliminate illicit discharges from their storm sewer system. An illicit discharge is any discharge to a MS4 that is not composed entirely of stormwater. There are some exceptions to this definition, such as fire fighting activities and discharges already authorized by another NPDES permit.

Discharges into MS4s often include wastes and wastewater from non-stormwater sources. Illicit discharges enter the system through either direct connections (e.g., wastewater either mistakenly or deliberately connected to storm sewers) or indirect connections (e.g., infiltration into the MS4 from leaking sanitary sewer systems, spills collected by inlets, or paints/oils dumped directly into a drain). Examples of other sources include, but are not limited to: sanitary waste water effluent from septic tanks; car wash waste water; radiator flushing disposal; laundry waste water; and improper disposal of auto and household hazardous waste. The result can be untreated

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discharges that contribute high levels of pollutants, including heavy metals, toxics, oil and grease, solvents, nutrients, and bacteria to receiving water bodies.

The regulations at 40 CFR § 122.34(b)(3) contain four required components to this control measure. The MS4 operator must:

- Develop a map of the MS4 that shows the location of all outfalls and names of receiving waters;
- Effectively prohibit discharges of non-stormwater to the MS4 through the use of an ordinance or other regulatory mechanism, and provide for enforcement procedures and actions;
- Develop and implement a plan to detect and address non-stormwater discharges; and
- Inform public employees, businesses, and the general public of the hazards associated with illegal discharges and improper disposal of waste.

For comprehensive guidance on building an IDDE program, see "Illicit Discharge Detection and Elimination; A Guidance Manual for Program Development and Technical Assessments". Published in 2004 by the U.S. Environmental Protection Agency, this manual provides excellent guidance to MS4 communities for their IDDE program.
This manual is available free of charge from the USEPA at:
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=3 It is also available on WVDEPs stormwater webpage:
http://www2.wvdep.org/dwwm/stormwater/MS4_BMP.htm

Controlling Runoff from Construction Sites

Polluted stormwater runoff from construction sites often flows to MS4s and ultimately is discharged into receiving water bodies. Sediment is usually the main pollutant of concern. According to the 2000 National Water Quality Inventory, States report that sedimentation is one of the most widespread pollutants affecting assessed rivers and streams. Sediment runoff rates from construction sites are typically much higher than runoff from forested lands. During a short period of time, construction sites can contribute more sediment to streams than can be deposited naturally during several decades. The resulting siltation, and the contribution of other pollutants form construction sites, can cause physical, chemical, and biological harm to receiving waters. Excess sediment can quickly fill rivers and lakes, requiring dredging and destroying aquatic habitats.

This control measure requires permittees to develop, implement and enforce a program to reduce pollutants in stormwater runoff from construction activities that result in a land disturbance of one acre or greater. The program must include control of runoff from construction activity disturbing less than one acre if the construction is part of a larger common plan of development that would disturb one acre or more.

Although discharges from construction sites disturbing one or more acres in West Virginia are subject to the NPDES General Permit for Stormwater Discharges from Construction Activity,

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#WV0115924, this control measure is necessary to enable local MS4 operators to effectively and directly control construction site discharges into their MS4s.

The regulations at 40 CFR § 122.34(b)(4) contain four required program components. All regulated permittees must incorporate the following elements into their local programs:

- An ordinance or other regulatory mechanism requiring proper sediment and erosion control, and proper waste management controls, at construction sites;
- Procedures for site plan review that considers potential water quality impacts;
- Procedures for site inspection and enforcement; and
- Procedures for the receipt and consideration of information submitted by the public.

More information about this minimum control measure can be found on USEPAs website: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=4

Controlling Runoff from New and Redevelopment

The way we develop and use land has great impact on the quality of our State's water bodies. It is revealing that West Virginia's most pristine waters are found in undisturbed areas where there is limited or no development. Yet, nearly 100% of West Virginia's water bodies located in Urban Areas are impaired.

An urbanized area is a land area comprising one or more places and the adjacent densely settled surrounding area that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile. It is a calculation used by the U.S. Bureau of Census to determine the geographic boundaries of the most heavily developed and dense urban areas.

For more information about how Urban Areas are defined by the U.S. Census Bureau see: http://www.census.gov/geo/www/ua/uafedreg031502.pdf

Land development directly affects watershed functions, and water quality in receiving waters. When development occurs in previously undeveloped areas, the resulting alterations to the land can dramatically change how water is transported and stored. Development created impervious surfaces and compacted soils increase surface runoff and decreases ground water infiltration. These changes can increase the volume and velocity of runoff, the frequency and severity of flooding, peak storm flows as well as the type, concentration, and quantity of pollutants in discharges. The effects of this process include stream bank scouring and downstream flooding, which often lead to a loss of aquatic life and damage to property.

This control measure applies in areas undergoing new development or redevelopment and that disturb one acre or more of land, including projects that are less than one acre that are part of a larger common plan of development that disturbs one or more acres.

The best way to mitigate stormwater impacts from new developments is to use practices to treat, store, and infiltrate runoff *on-site* before it can affect water bodies downstream. Innovative site designs that reduce imperviousness and smaller-scale low impact development practices

dispersed throughout a site are excellent ways to achieve the goals of reducing flows and improving water quality.

In contrast with the traditional approaches, the guiding principle behind capturing the first one inch of rainfall is to control stormwater at the source. It is much easier and cost efficient to prevent polluted stormwater from entering water than trying to remove pollution once it's in the waterbody. Capturing stormwater and managing it onsite by runoff reduction techniques seek to maximize the area available for infiltration so that runoff volume and pollutant concentrations are reduced. This is achieved through a variety of site design and engineered infiltration techniques. In addition to the environmental benefits, many community value benefits are realized including increased aesthetics and land value.

Section by section rationale for Controlling Runoff from New Development and Redevelopment minimum control measure

Long-term Stormwater Controls

Phase II MS4 regulations found at 40 CFR 122.23(b)(5) state that a Phase II MS4 must "Develop, implement, and enforce a program to address storm water runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale that discharge into [the] small MS4. [The] program must ensure that controls are in place that would *prevent or minimize water quality impacts*." To that end, the regulations require that a MS4 develop and implement a program to address post-construction runoff from newly developed and redeveloped areas, and ensure the long-term operation and maintenance of these management practices.

Because the creation of impervious surfaces and the generation of runoff pollutants are created by activities and decisions at the site scale, neighborhood scale, and watershed or regional scale, this permit sets up a framework to consider pivotal activities at multiple scales. A program to implement site level controls for new and redevelopment are an evolution of activities required under the prior MS4 permit, and implementation of the necessary components of this programs are achievable within the time frame of this five year permit term. Implementation of some pivotal controls for activities at the watershed or regional scale may be, in some cases, longer-term propositions. Therefore, this permit sets up the framework for initial steps, with the understanding that some institutional controls may not be fully implemented until the next permit term. However, even though all of these activities may be on different schedules, the permittee should consider all of them in the context of an integrated stormwater management program to ensure that they complement each other.

Watershed Protection provisions require that the permittee incorporate six (6) watershed protection elements into the subdivision ordinance or equivalent document within the permit term. Within seven years the permittee must incorporate watershed protection elements into other applicable local policy documents. The extended time period for the remaining documents is done in recognition that these documents periodically come up for review, but that schedule may not coincide with the effective period of this permit. Additional documents include

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comprehensive or master plans, general land use plan, zoning code, transportation master plan, specific area plans, and unified development ordinance. Inclusion of the elements into these legal authority and planning documents will act as the impetus to direct appropriate land use decisions to support the watershed elements.

This permit does not stipulate specific baselines or standards for these elements in order that permittees may develop criteria that meet the characteristics of their watershed(s). However, consideration for environmental outcomes is of critical importance in implementation of this provision.

The permittees legal authority and planning documents shall address the following watershed elements:

(1) ***Minimize the amount of impervious surfaces (roads, parking lots, roofs) within each watershed, by minimizing the creation, extension and widening of roads and associated development.***

Stormwater research shows a high correlation between the level of imperviousness in a watershed and the degree of overall degradation of water quality and habitat[1]. In order to minimize this type of degradation, the permittee should incorporate a number of planning principles to manage the creation of impervious surfaces at the watershed level, such as reducing the footprint of streets and parking lots. These principles apply to urban and suburban development.[2] [3]

(2) ***Preserve, protect, create and restore ecologically sensitive areas that provide water quality benefits and serve critical watershed functions. These areas may include, but are not limited to; riparian corridors, headwaters, floodplains and wetlands.***

Certain ecologically sensitive lands and undeveloped areas naturally provide extraordinary protection of water quality. For example, wetlands act as natural filters of pollutants, and as sponges to maintain existing hydrology. Intact riparian corridors provide the shading necessary to minimize water temperature, the organic matter to feed aquatic organisms, slow the velocity of flood waters and allow the flood waters to be absorbed into the ground of the floodplain instead of causing damage downstream. Vegetated buffer zones provide a filter to remove sediment and other particles in stormwater as well as the pollutants which adhere to the particulates. In addition to being critical for stormwater management functions, headwaters, floodplains and wetlands all serve a wide variety of ecological functions such as flood control, nursery habitat, and production of food to maintain fisheries.

Protection of ecologically sensitive areas should be based on an inventory and prioritization of such areas through a process such as watershed planning. Restoration of these areas *after*

[1] See the Center for Watershed Protection for more information. www.cwp.org and www.stormwatercenter.net
[2] See Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks, Randalll Arendt, Island Press, 1996.
[3] See NEMO publications at http://nemo.uconn.edu/tools/publications.htm#technical

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they are already degraded will be more difficult because of the significant expense involved. Therefore, it is important to protect high quality areas with important ecological functions before development occurs.

(3) ***Implement management practices that prevent or reduce thermal impacts to streams, including requiring vegetated buffers along waterways, and disconnecting discharges to surface waters from impervious surfaces such as parking lots.***

Temperature changes result from increased flows, removal of vegetative cover, and increases in impervious surfaces as well. Impervious surfaces, such as pavement or asphalt, increase storm water runoff temperature by absorbing heat from the sun and transferring that heat to the stormwater runoff. Water sitting in stormwater basins is also subject to solar radiation, and contributes to increased temperature of stormwater discharges. Increased temperature in runoff subject aquatic organisms in the receiving waters to thermal stress, and can drive out fish and other organisms that require cool water. Removal of shade trees along water bodies can also affect in-stream temperatures.

(4) ***Seek to avoid or prevent hydromodification of streams and other water bodies caused by development, including roads, highways, and bridges.***

Disturbance (e.g. piping and moving streams, installing bridges) of natural water bodies and drainage systems reduces the ability of the systems to convey flood waters and natural sediment loads as well as impacts the overall health of the riparian and aquatic ecosystems through scouring of stream banks and sediment overloading. The careful selection and design of stream crossings, highways, and development projects in order to minimize this type of hydrologic disturbance will prevent sediment pollution and protect existing systems.

(5) ***Implement standards to protect trees, and other vegetation with important evapotranspirative qualities.***

Trees, even in relatively unnatural settings such as street trees in tree boxes, still have a remarkable capacity to take up water and return it to the atmosphere. One tree can reduce stormwater runoff by 13,000 gallons per year.[4] Coupled with their cooling ability, aesthetic qualities and carbon sequestering capacity this can make trees a very important component of a watershed protection program.

(6) ***Implement policies to protect native soils, prevent topsoil stripping, and prevent compaction of soils***

Native soils, especially topsoil, contain important organic materials generally not present in underlying soil layers. In areas with thin soil layers, like many parts of West Virginia, those soil layers are especially critical. Unfortunately topsoil layers are often stripped off prior to or during construction operations. Also, heavy traffic both during and after construction can

[4] Riverkeeper Report: "Sustainable Raindrops, Cleaning New York Harbor by Greening the Urban Landscape", Mike Plumb, http://riverkeeper.org/special/Sustainable_Raindrops_FINAL_2008-01-08.pdf

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compact soils so that they lose most of their ability to infiltrate stormwater, and become effectively impervious. An effective stormwater program will incorporate measures to protect the integrity of soils.

Measurable goals must be developed for each of the six watershed protection elements, including quantifiable objectives and time frames achieving those objectives. It is appropriate to establish both long-term and short-term objectives for each of these watershed elements, as some may take longer than five years to fully implement. The status of implementation of the watershed elements should be summarized in each annual report.

Site and Neighborhood Design provisions require the permittee to adopt and implement stormwater performance standards for new and redevelopment projects, and a program to implement those standards.

A variety of water quality standards continue to be exceeded in most urban and urbanizing streams, and stormwater discharges are commonly identified as the causes. There are thousands of waters nation-wide with impairment attributed to stormwater. [5] Clearly, we need a better approach.

As urbanization occurs, a corresponding increase in impervious surface area also occurs. These changes to the landscape cause the volumes, rates and duration of runoff-related discharges to increase, along with a corresponding increase in pollutant loadings. In addition, stream channels are destabilized due to the increase energy of the runoff that results in bank cutting, stream channel widening, channel incision and detrimental sediment transport and deposition. Because of these changes in runoff volumes and rates, the stream systems and water bodies within and downstream of urban areas are commonly impaired due to sediment and nutrient loads, increased total suspended solids, poor biotic communities, and increased stream temperatures.

Stormwater management standards are most commonly written with provisions that promote or require extended detention controls, such as extended detention wet ponds, dry detention basins or constructed wetlands. There are multiple problems with the extended detention approach. The primary reason is - that receiving stream dynamics are based on balances of more than just discharge rates.[6]

Extended detention practices are first and foremost designed to prevent downstream flooding and not to protect downstream channel stability and water quality. For decades, water quality protection has been a secondary goal, or one omitted entirely during the design of these facilities. Over time it has become apparent through research and monitoring that these practices do not effectively protect the physical, chemical or biological integrity of our receiving waters[7].

[5] Riverkeeper Report: "Sustainable Raindrops, Cleaning New York Harbor by Greening the Urban Landscape", Mike Plumb, http://riverkeeper.org/special/Sustainable_Raindrops_FINAL_2008-01-08.pdf

[6] A Review of Low Impact Development Policies: Removing Institutional Barriers to Adoption. Low Impact Development Center, December 2007.

[7] U.S. EPA, *Protecting Water Quality from Urban Runoff*, Nonpoint Source Control Branch, EPA-841-F-03-003, February 2003.

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Furthermore, operation and maintenance of these systems to ensure they perform as designed requires a level of managerial and financial commitment that is often not provided. A number of researchers have documented that detention ponds fail to meet their design goals in terms of maintaining water quality, downstream habitat and biotic integrity of the receiving waters.[8,9,10,11] There is now a large body of research demonstrating that practices that mimic the natural water cycle – processes that result in the infiltration, evapotranspiration and capture and use of stormwater (runoff reduction techniques) – are simultaneously advantageous for protecting the physical, chemical and biological characteristics of receiving waters. Why? Because these practices are designed to mimic the way natural vegetated landscapes respond to precipitation events. When it rains or when snow melts, vegetated areas such as forests, prairies and grasslands, gardens and trees, intercept, evaporate and absorb much of the rainfall. Some of the precipitation is also absorbed or infiltrated into the soil. Ideally, site designs and plans should make use of these natural systems and processes as much as possible to mimic or preserve the site hydrology, i.e., the balance of plant uptake of water, infiltration of runoff into the soil and groundwater table, and the natural runoff patterns into natural drainage ways and streams.

Most bioinfiltration measures are designed to not discharge at all during small storm events, which means that pollutants do not reach the receiving water. There are good performance data for practices that infiltrate and/or evapotranspire stormwater. Research studies on bioretention practices and permeable pavements can be found at the following links:

Dr. Allen Davis, University of Maryland
http://www.ence.umd.edu/~apdavis/LID-Publications.htm

Dr. William Hunt, North Caroline State University
http://www.bae.ncsu.edu/topic/bioretention/publications.html,

Dr. Michael E. Dietz, Utah State University
"Low Impact Development Practices: A Review of Current Research and Recommendations for Future Directions"
http://www.springerlink.com/content/nq44j610685n4112/

Dr. Jack Clausen, University of Connecticut
http://www.bae.ncsu.edu/programs/extension/wqg/319/319index_files/Ct-98.1.pdf

Under natural conditions approximately 10% of the volume of precipitation falling to earth runs off to surface waters via surface/overland flow.[12] Nearly all of the remaining amount of stormwater infiltrates, or is intercepted or taken up by plants. Nature's elegant system can be

[8] MaCrae, C.R. Experience from Morphological Research on Canadian Streams: Is Control of the Two Year Frequency Runoff Event the Best Basis for Stream Channel Protection? Kingston, Ontario, Canada.
[9] May, C, Livingston, E. Blaha, D, Scoggins, M. & Tims, J. Structural and Nonstructural BMPs for Protecting Streams. Watershed Management Institute, Crawfordville, Florida.
[10] Booth, D.B. & Jackson, C.R. 1997. Urbanization of Aquatic Systems – Degradation Thresholds, Stormwater Detention and the Limits of Mitigation. Journal of the American Water Resources Association 22(5).
[11] Fundamentals of Urban Runoff Management, Chapter 10, North American Lake Management Society. http://www.nalms/org/Resources/PDF/Fundamentals/Fundamentals_Chapter_10.pdf
[12] Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices. PB98-158348LUW.

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successfully adapted in developed and developing watersheds to protect receiving waters from both pollutants and altered hydrology.

This permit proposes a simple performance standard to approximate 10% discharge, with most of the remainder handled on-site. Analysis of precipitation data for West Virginia indicates that 90% of the 24 hour (or less) rainfall events are one inch or less. Therefore stormwater systems designed to manage one inch of rain will reasonably mimic the natural hydrologic process. All new and redevelopment projects must design, implement and maintain a system of controls that will infiltrate, evapotranspire and/or capture and use the first inch of rain from a 24-hour storm preceded by 48 hours of no measurable precipitation.

Because implementing this performance standard will require changes to local codes and ordinances, as well as development of a municipal review and approval process, the permit allows four years from the date of SWMP approval to begin implementation of this standard. This performance standard must be implemented and enforced via an ordinance and/or other enforceable mechanism(s).

The permit also includes several additional water quality requirements, as applicable, that the permittee should implement via enforceable requirements within their jurisdiction. For activities/operations with demonstrable potential for pollutant loadings, water quality treatment for pollutants of concern must be provided if infiltration measures are to be used. Activities such as automobile service stations, lawn care operations/greenhouses/nurseries that handle fertilizers and pesticides and operations that handle chemicals are all activities with demonstrable potential for pollutant loading.

If an activity/operation cannot implement adequate preventive or treatment measures to ensure compliance with groundwater and/or surface water quality standards, then stormwater must be properly treated via an NPDES-permitted facility or licensed waste hauler.

There are cases where stormwater infiltration practices are regulated as Class V wells under the Underground Injection Control (UIC) program, and some stormwater managers report that some developers are hesitant to incorporate stormwater infiltration practices because they fear regulatory approvals will slow the process and increase costs. The DWWM encourages the use of infiltration and notes that most of these practices do not meet the Class V definition and can be installed with requiring UIC permits.

To provide clarification on which stormwater infiltration techniques meet UIC Class V well definitions, USEPA's Office of Water has developed a "Class V Well Identification Guide." MS4 permittees are requested to refer to this guide when considering stormwater infiltration practices. The guide can be found at this website:
http://www.wvdep.org/dwwm/stormwater/MS4_docs.htm

When considered at the watershed scale, certain types of development can either reduce existing impervious surfaces, or at least create less associated imperviousness. At this scale, development strategies can be used as one approach to improving water resources.

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Recognizing that certain development strategies can be part of the process of reducing stormwater runoff and improving water quality, five specific development types can receive a reduction of 10% of the volume of relevant runoff reduction (infiltration/evapotranspire/reuse) standard described in section C.5.a.ii.A(1). Reductions are additive such that a maximum reduction of 50% of the standard in section C.5.a.ii.A(1) is possible for a project that meets all five criteria.

Incentive standards may be applied to these types of projects. A reduction of 10% of the volume of the relevant runoff reduction (infiltration/evapotranspiration/reuse) standard described in section C.5.a.ii.A(1) may be applied to any of the following types of development.

Reductions are additive such that a maximum reduction of 50% of the standard in section C.5.a.ii.A(1) is possible for a project that meets all five criteria.

i Redevelopment
ii Brownfield redevelopment
iii High density (>7 units per acre)
iv Vertical Density, (Floor to Area Ratio (FAR) of 2 or >18 units per acre)
v Mixed use and Transit Oriented Development (within ½ mile of transit)

1. REDEVELOPMENT

Definition
Redevelopment is defined as the act of improving by renewing or restoring any developed property that results in the land disturbance of one acre or greater, and that has one of the following characteristics:

- Land that currently has an existing structure, such as buildings or houses, or
- Land that is currently covered with an impervious surface, such as a parking lot or roof, or
- Land that is currently degraded and is covered with sand, gravel, stones, or other non-vegetative covering.

Redevelopment activities shall not apply to development that occurs on farmland, whether active or fallow fields, or on land that is covered with vegetation.

To receive the credit:

- A developer will receive a 10% reduction to the amount of stormwater required to be managed for only the part of the development could be considered redevelopment. For example, if 100% of the project site is redevelopment, the 10% credit is applied to the whole site. If 50% of the project site is redevelopment, the 10% reduction is applied only to the land mass that is redevelopment.

Rationale

Redeveloping already degraded sites can reduce regional land consumption and minimize new

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land disturbance. Minimizing land disturbance and impervious cover is critical to maintaining watershed health. The amount of land that is converted, or "disturbed," from undeveloped uses, such as forests and meadows, to developed uses, such as lawns, buildings, parking lots, and playing fields, significantly affects watershed health. Research clearly indicates that the volume of runoff from highly compacted lawns is almost as high as that from paved surfaces.[13,14] This research indicates that lawns and other residential landscape features do not function, with regard to water, in the same way as non-degraded natural areas. In part, the difference arises because developing land in undeveloped 'green' areas involves wholesale grading of the site and removal of topsoil, which can lead to severe erosion during construction and soil compaction by heavy equipment.

Typically, there is little or no increase in net runoff when redeveloping underused properties such as vacant properties, brownfield sites, or greyfield sites, since new impervious cover replaces existing impervious cover. For example, an abandoned shopping center (a greyfield property) is often almost completely impervious cover and is already producing high volumes of runoff.[15] If this property were redeveloped, the net runoff increase would likely be zero since the property was already predominately impervious cover. In many cases, redevelopment of these properties breaks up or removes some portion of the impervious cover, converting it to pervious cover and allowing for some stormwater infiltration. In this instance, redevelopment of these properties can produce a net improvement in regional water quality by decreasing total impervious area and its associated runoff. Redevelopment activities can also reduce regional land consumption. By building on underused, already degraded land, the pressure to convert previously undeveloped land is reduced. Numerous studies support the environmental benefits of redevelopment:

- A 1982 study of three urban areas found that vacant land within developed areas could accommodate from two-thirds to 100 percent of the projected 10-year housing need.[16]

- A 1996 study found that brownfields in Detroit, Chicago, Milwaukee, and Cleveland could absorb one to five years of residential development, ten to 20 years of industrial development, or 200-400 years of office space.[17]

- A George Washington University study found that for every brownfield acre that is redeveloped, 4.5 acres of open space are preserved.[18]

[13] Schueler, Tom. 1995. "The Peculiarities of Perviousness." *Watershed Protection Techniques*. 2.1.
[14] Schueler, Tom. 2000. "The Compaction of Urban Soil." *Techniques for Watershed Protection*. Ellicottt City, MD: Center for Watershed Protection.
[15] Sobel, Lee and Steven Bozdin. 2002. Greyfields into Goldfields: Dead Malls Become Living Neighborhoods. San Fransico, CA: Congress for New Urbanism.
[16] Real Estate Research Corporation. 1982. Infill Development Strategies. Washington, D.C.: the Urban Land Institute and American Planning Association.
[17] Simons, Robert. 1996. Brownfields Supply and Demand Analysis for Selected Great Lakes States. Cleveland State University: Planning and Development.
[18] Deason, Jonathan, et al. 2001. Public Policies and Private Decisions Affecting the Redevelopment of Brownfields: An Analysis of Critical Factors, Relative Weights and Area Differentials. Prepared for U.S. EPA, Office of Solid Waste and Emergency Response. Washington, D.C.: The George Washington University.

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- An analysis by King County, Washington, demonstrated that property that is vacant and eligible for redevelopment in the county's growth areas can accommodate 263,000 new houses—enough for 500,000 people.[19,20]

2. BROWNFIELDS

Definition

A 'brownfield site' is "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant." [21]

The Government Accounting Office estimates that the United States has approximately 450,000 brownfield sites.[22]

To receive the stormwater credit, the project shall remediate all site contamination.

Rationale

A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Cleaning up and reinvesting in these properties increases local tax bases, facilitates job growth, utilizes existing infrastructure, takes development pressures off of undeveloped, open land, and both improves and protects the environment.

A contaminated site often impacts surface water, ground water, drinking water, sediments, soil and air. Brownfields typically possess the following contaminants: Petroleum/Petroleum Products, Controlled Substances, Asbestos, PCBs, VOCs, lead, PAHs. Moreover, over 800 redeveloped brownfield properties have removed or ameliorated groundwater contamination. Atlantic Station in Atlanta, Georgia is a good example. Formerly a 139-acre brownfield site, the redevelopment of this property included installing a "cap" just under the top soil that prevents the underlying soil contamination from entering groundwater resources.[23]

Given the importance of removing these harmful contaminants from the wide range of water supplies, a project that remediate a brownfield is eligible for one stormwater incentive worth ten percent reduction of the standard in section C.b.5.a.ii.A(1).

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[19] Pryne, Eric. 2002. "20 Years' Worth of County Land?" Seattle Times. May 20.

[20] Real Estate Research Corporation. 1982. Infill Development Strategies. Washington, D.C.: the Urban Land Institute and American Planning Association.

[21] The Brownfields Site definition is found in Public Law 107-118 (H.R. 2869) - "Small Business Liability Relief and Brownfields Revitalization Act" signed into law January 11, 2002.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. 1996. Brownfields Initiative. Quick Reference Fact Sheet.

[22] U.S. General Accounting Office. 1995. Community Development: Reuse of Urban Industrial Sites. GAO/RCED-95-172.

[23] There are several EPA documents that detail site conditions and remediation strategies. For general information on the Atlantic Steel redevelop, see http://www.epa.gov/projectxl/atlantic/page1.htm and for specific technical information on site conditions, see http://www.epa.gov/ProjectXL/atlantic/fonsi.pdf.

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3. HIGH DENSITY AND VERTICAL DENSITY DEVELOPMENT

Definition

High density is defined as seven or more housing units per *gross* developable acre.[24]

- To receive this credit, the developer shall build any residential components of the project at an average density of seven or more dwelling units per acre of buildable land available for residential uses.

Vertical density is defined as development that has:

(1) a floor to area ratio (FAR) of at least 2.0; and/or
(2) 18 or more housing units per gross acre.

- To receive this credit, the developer shall build any residential components of the project at an average density of 18 or more dwelling units per acre of buildable land available for residential uses or build any non-residential components of the project at an average density of 2.0 FAR or greater per acre of buildable land available for non-residential uses.

- In some cases, the developer may wish to combine residential units and commercial space. Often referred to as a mixed use, the density of a mixed use building is calculated by:

    a. Determining the total square footage of all residential and non-residential uses;
    b. Calculating the percentages of the total square footage that the residential and non-residential components each represent;
    c. Applying those percentages to the building parcel to determine the proportionate share of land area for each component; and
    d. Calculating residential density as the number of dwelling units per acre using the residential share of the building parcel, and calculating non-residential density as FAR using the non-residential share of the land area divided by total non-residential square footage.

- A housing unit can include a single-family detached home, town home, condominium, apartment, accessory dwelling unit, mobile home, or any other housing type that allows year-round occupancy.

- The Floor Area Ratio (FAR) is the ratio of the total floor area of buildings on a certain location to the size of the land of that location.

[24] As this section discusses, there is considerable research confirming that higher density development can reduce overall stormater runoff and is better for watershed water quality. The determination that the developer could receive an incentive for higher density at seven units or more an acre is based on the U.S. Green Building Council's Leadership in Energy and Environmental Design- Neighborhood Development criteria. For more information on LEED-ND, see http://www.usgbc.org/DisplayPage.aspx?CMSPageID=148.

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For example, a FAR of 2.0 indicates the total floor area of a building is two times the gross area of the plot on which it is constructed. By raising the Floor Area Ratio, the permittee can reduce overall impervious cover across the MS4 jurisdiction. A builder can plan for either a single-story building consuming the entire allowable area in one floor, or a multi-story building that rises higher above the plane of the land, but which must consequently result in a smaller footprint than would a single-story building of the same total floor area. By combining the horizontal and vertical limits into a single figure, some flexibility is permitted in building design, while achieving a hard limit on at least one measure of overall size.

To receive the credit:

- The specified density must be achieved by the point in the project's construction at which 50% of dwelling units are built, or within five years of the date that the first building is occupied, whichever is longer.

Rationale

The effect of low-density urbanization on watersheds and the hydrologic cycle is substantial. Several studies have found that covering just ten percent of the watershed's land area with impervious surface can impair hydrological function and water quality within the watershed. The USEPA, the Center for Watershed Protection, and other environmental agencies and organizations have conducted research that indicates that higher density projects may provide more water quality benefits than low-density development. In particular:

1. Higher density does not necessarily mean more impervious surface overall. In fact, multiple units in a compact arrangement may reduce the building footprint and result in less impervious coverage on a per unit or per capita basis than stand alone units dispersed across the landscape. In addition, more compact development requires fewer miles of roads and parking lots than low-density development, thereby reducing a substantial contributor to total impervious cover.

2. Not all pervious surfaces are equal. Many disturbed surfaces that appear pervious, such as lawns, golf courses, or other maintained lands, may be compacted, which greatly reduces their ability to infiltrate runoff. Therefore developing less total land, including for lawns or other developed "green space," and maintaining more land in its natural, undisturbed condition, is better for water quality.

High-density development, including vertical density, slows land consumption rates and accommodates more land uses on a smaller footprint. Numerous studies support these conclusions:

- A 2006 USEPA study[25] found that higher density development can be more protective of regional water quality than lower density scenarios because less stormwater and associated pollutants are produced on a per unit basis. Many communities assume that low-density development automatically protects water resources. The USEPA study

[25] U.S. EPA. 2006. Protecting Water Resources with Higher-Density Development. EPA 231-R-06-001.

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demonstrated that this assumption is flawed and that pursuit of low-density development can be counterproductive, contributing to high rates of land conversion and stormwater runoff, and missing opportunities to preserve valuable undeveloped land within watersheds.

- Queensland University of Technology, Gold Coast City Council, and the Department of Public Works in Brisbane, Australia, examined the relationship between water quality and six different land uses to offer practical guidance in planning future developments. When comparing monitored runoff and associated pollutants from six areas, they found the most protective strategy for water quality was high-density residential development.[26]

- The Belle Hall study, by the South Carolina Coastal Conservation League, examined the water quality impacts of two development alternatives for a 583-acre site in Mount Pleasant, South Carolina. The town planners used modeling to examine the potential water quality impacts of each site design. In the "Sprawl Scenario," the property was analyzed as if it developed along a conventional suburban pattern. The "Town Scenario" incorporated traditional neighborhood patterns. In each scenario, the overall density and intensity (the number of homes and the square feet of commercial and retail space) were held constant. The results found that the "Sprawl Scenario" consumed eight times more open space and generated 43 percent more runoff, four times more sediment, almost four times more nitrogen, and three times more phosphorous than the "Town Scenario" development.[27]

- New Jersey's State Plan calls for increasing densities in the state by directing development to existing communities and existing infrastructure. Researchers at Rutgers University analyzed the water quality impacts from current proposed compact development. The study found that compact development would generate significantly less water pollution for all categories of pollutants than current development patterns, which are mostly characterized by low-density development.[28] The reductions ranged from over 40 percent for phosphorus and nitrogen to 30 percent for runoff. These conclusions supported a similar statewide study completed in 1992 that concluded that compact development would result in 30 percent less runoff and 40 percent less water pollution than would a lower-density scenario.[29]

- Studies in the United States, United Kingdom, and Canada agree that vehicle miles

[26] Goonetilleke, A., E. Thomas., S. Ginn, D. Gilbert. 2005. "Understanding the Role of Land Use in Urban Stormwater Quality Management." Journal of Environmental Management, 74: 31-42.
[27] South Carolina Coastal Conservation League, Environmental Protection Agency, National Oceanic and Atmospheric Administration, South Carolina Department of Health and Environment; Town of Mount Pleasant. 1995. The Belle Hall Study: Sprawl vs. Traditional Town: Environmental Implications. South Miami, FL: Dover, Kohl, and Partners.
[28] Rutgers University. 2000. The Costs and Benefits of Alternative Growth Patterns: The Impact Assessment of the New Jersey State Plan. New Brunswick, NJ: Center for Urban Policy and Research.
[29] Burchell, R.W. and D. Listokin. 1995. "Land, Infrastructure, Housing Costs and Fiscal Impacts Associated with Growth: The Literature on the Impacts of Sprawl Versus Managed Growth." New Brunswick, NJ: Rutgers University, Center for Urban Policy Research. As summarized in The Technological Reshaping of Metropolitan America, Office of Technology Assessment, OTA-ETI-643, Washington, DC.

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traveled (VMT) are reduced 20-30% every time density doubles.[30,31,32] By increasing density, VMT and associated auto-related water and air pollution can be effectively reduced.

4. MIXED-USE DEVELOPMENT AND TRANSIT ORIENTED DEVELOPMENT

Definition

A mixed-use development has complementary functions that are located close together in an integrated fashion, e.g., apartments and condos above stores and businesses. It has three or more revenue producing uses and has significant functional and physical integration of uses. The multiple uses are either inside a single structure or placed within a neighborhood, where a variety of different living activities (live, work, shop, and play) are in close proximity, and accessible via safe walking routes.

A **Transit Oriented Development** (TOD) is a mixed-use development that is walkable by distance and design, to a transit stop. The development mixes residential, retail, office, open space, and public uses in a way that makes it convenient to travel on foot or by public transportation instead of by car. Successful transit-oriented developments reduce driving if they are both close to transit and well designed. Characteristics include:

- Higher density development, appropriate to the regional context (urban core, suburban center, neighborhood center).
- Well designed, pedestrian friendly street networks allowing for safe and attractive walking routes.
- Street design that follows a Context Sensitive Design approach with more narrow streets, smaller block sizes, wide-sidewalks, and well defined pedestrian cross walks.[33]
- Parcels adjacent to transit containing a mix of land use activities and a range of housing types.
- Walking distance to transit is generally ½ mile for rail/ferry, and ¼ mile for bus.

30 Holtzclaw, John. "Explaining Urban Density and Transit Impacts on Auto Use." Presented to State of California Energy Resources Conservation and Development Commission, January, 1991. As cited in The Growth Management Institute paper, "The Influence of Regional Land Use and Transportation Patterns on Air Quality: A Framework for Discussion" by Douglas R. Porter, May 23,2001 http://www.gmionline.org/InfluenceRegionalLandUse.htm

31 Newman, P.; Kenworthy. J. *Cities and Automobile Dependence: An International Sourcebook*, Gower Publishing: Aldershot, England, 1989.

32 University of Toronto/York University. *The Transportation Tomorrow Survey: Travel Survey Summary for the Greater Toronto Area*, June 1989.

33 For Design Guidelines See – *Context Sensitive Solutions for in Designing Major Urban Thoroughfares for Walkable Communities*, Institute of Transportation Engineers, Draft Recommended Practice. http://www.ite.org/css/

The following table describes categories of TOD and the minimum densities that support effective transit.

Typology of Transit-Oriented Development, Reconnecting America

TOD Type	Land Use Mix	Minimum Housing Density	Regional Connectivity	Frequencies
Urban Downtown	Office Center Urban Entertainment Multifamily Housing Retail	>60 units/acre	High Hub of Radial System	<10 minutes
Urban Neighborhood	Residential Retail Class B Commercial	>20 units/acre	Medium Access to Downtown Subregional Circulation	10 minutes peak 20 minutes off-peak
Suburban Center	Primary Office Center Urban Entertainment Multifamily Housing Retail	>50 units/acre	High Access to Downtown Subregional Hub	10 minutes peak 10-15 minutes off-peak
Suburban Neighborhood	Residential Neighborhood Retail Local Office	>12 units/acre	Medium Access to Suburban Center and Access to Downtown	20 minutes peak 30 minutes off-peak
Commuter Town Center	Retail Center Residential	>12 units/acre	Low Access to Downtown	Peak Service Demand Responsive

To receive this credit, the project site shall include a minimum of three land uses, excluding open space and parking, and shall meet all the characteristics of TOD:

- Higher density development, appropriate to the regional context (urban core, suburban center, neighborhood center).
- Well designed, pedestrian friendly street networks allowing for safe and attractive walking routes.
- Street design that follows a Context Sensitive Design approach with more narrow streets, smaller block sizes, wide-sidewalks, and well defined pedestrian cross walks.[34]
- Parcels adjacent to transit containing a mix of land use activities and a range of housing types.
- Walking distance to transit is generally ½ mile for rail/ferry, and ¼ mile for bus.

Rationale

Mixing uses supports a range of transportation options and facilitates shared parking, thereby reducing the amount of surface needed for roads and parking lots. By bringing a mix of jobs,

[34] For Design Guidelines See – *Context Sensitive Solutions for in Designing Major Urban Thoroughfares for Walkable Communities,* Institute of Transportation Engineers, Draft Recommended Practice. http://www.ite.org/css/

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housing, and commercial activities closer together, total requirements for land, roads, and parking decrease.

Mixing land uses can have direct effects on reducing runoff since mixed-use developments have the potential to use surface parking lots and transportation infrastructure more efficiently, requiring less pavement. When office buildings also contain retail shops and restaurants, the infrastructure that supports the building, such as roads and parking lots, is in use for more of the day. Office traffic uses parking lots mainly during weekday days; so the same parking space can be used for restaurant and theater traffic on evenings and weekends. This shared set-up eliminates the need for two sets of roads and parking lots, one serving office buildings and the other serving retail and entertainment areas.

By encouraging people to walk, bike, and use transit rather than drive, mixed-use development patterns reduce vehicle miles traveled (VMT). Reductions in VMT lead to decreases in automobile emissions, which translate into less automobile pollution in runoff and less air pollution being deposited into water - thereby improving water quality.

Research supports these conclusions. Researchers at Purdue University examined two possible project sites in the Chicago area.[35] The first site was in the city; the second was on the urban fringe. The study found that placing a hypothetical low-density development on the urban fringe would produce ***ten*** times more runoff than a mixed-use development in the urban core.

A study by the Center for Watershed Protection[36] measured the percent of impervious cover in developed areas that was devoted to building footprints (people habitat) versus to streets, driveways, and parking lots (car habitat). The study found that car habitat accounted for 55-75% of the total impervious surface area among the sites measured. Compact, mixed- use designs that ***reduce*** the need for vehicle travel and parking space therefore have great potential to reduce impervious cover and associated water impacts in developed areas.

Moreover, transit oriented development produces water quality benefits by reducing: (1) land consumption due to smaller site footprints; (2) parking spaces and the impervious cover associated with them; and (3) average vehicle miles traveled, which, in turn, reduces deposition of air pollution into water bodies.

Land Consumption. TOD can spur neighborhood revitalization, increase ridership on a region's existing public transportation system, and help protect natural resources.[37] As higher density development is clustered around transit stops, the need for developing land elsewhere in a region is minimized. A number of studies have evaluated TOD projects relative to comparable development on suburban sites. Not only are most of these projects built on previously

[35] Harbor, J., B. Engel, et al. 2000. A Comparison of the Long-Term Hydrological Impacts of Urban Renewal Versus Urban Sprawl. West Lafayette, IN: Purdue University.
[36] Cappiella, Karen, and Brown, Kenneth. 2001. "Impervious Cover and Land Use in the Chesapeake Bay Watershed." Center for Watershed Protection. January. http://www.cwp.org/Downloads/elc_imperv.pdf
[37] Building a Regional Framework: TOD, NIPC

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developed land, but they accommodate the same amount of residential and commercial space on one-half to one-tenth of the land area.[38]

Reduced Parking Needs. Parking management strategies for TOD also lead to less impervious surface on the site, therefore, creating ***less*** stormwater runoff. The reduced parking is a result of the greater share of trips made by transit or on foot, lower auto ownership rates, and shared parking arrangements. These three outcomes are a direct result of well-designed TOD projects that place residents and office workers in close proximity to daily activities such as shops, offices, grocery stores, playgrounds, and dry cleaning. This convenience makes it easy for residents to accomplish tasks from their homes or offices by transit, biking, or walking, instead of by car, thus reducing the amount of parking required. Recognizing this effect, several communities across the United States have reduced parking requirements for businesses located in TOD districts. For example:

- Seattle, Washington's existing parking code allows commercial uses a 20 percent reduction in parking based on frequency of adjacent transit service.
- Portland, Oregon has no minimum parking requirements for sites well served by transit.
- Oakland, California reduces their Parking requirements to 0.5 parking spaces per housing unit within a TOD zone.
- Arlington, Virginia regularly decreases required parking in their TOD areas.

Reduced Air Deposition. The range and quality of transportation choices available to people not only have a direct impact on where and what type of development is likely to occur, they also have an indirect effect on water quality. Air emissions from vehicles, through air-to-water deposition of pollutants, are a major contributor to poor water quality and can undermine other efforts to improve regional water quality. For example, in the Washington, D.C. region, mobile sources (e.g., cars, buses, trucks) are a primary cause of not only air quality problems, but also of water pollution through deposition or stormwater runoff.[39] Specifically, the USEPA estimates that 35 percent of the nitrogen entering the Chesapeake Bay originates from mobile sources.[40] Therefore, reducing vehicle travel through transit oriented development can produce significant benefits to water quality.

Over a dozen studies have been conducted that compare the travel and emissions of transit oriented infill development projects to conventional suburban development. These site level analyses conducted by regional transportation planning agencies have demonstrated that TOD produces 30 to 70% less vehicle miles traveled (VMT) due to increased transit use, increased walking, and shorter car trips.[41] This can translate into reduced pollutants from cars entering sewer systems and water bodies.

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[38] Ewing et al 2007, *Growing Cooler*, Ch. 3.5, Urban Land Institute, Washington D.C.

[39] Metropolitan Washington Council of Governments, Metropolitan Washington Air Quality Committee. August 13, 2003. *Plan to Improve Air Quality in the Washington, DC-MD-VA Region.* <www.mwcog.org/ environment/air>.

[40] Alliance for the Chesapeake Bay. 1997. "Air Pollution in the Chesapeake Bay." Baltimore, MD.

[41] Eliot A. and F. K. Benfield, "Environmental Characteristics of Smart Growth Neighborhoods, Phase II: Two Nashville Neighborhoods," Natural Resources Defense Council, February 2003. "Environmental Benefits of Brownfield Redevelopment: Empirical Results of Previous Studies," Environmental Mgmt Support Inc, working

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Off-site mitigation and payment in-lieu. With the wide array of management practices that can infiltrate, evapotranspire, and capture and use stormwater there should be very few situations where management of one inch of stormwater using combinations of those mechanisms is not possible. However, it is certainly reasonable to expect that a series of physical constraints may exist, particularly in redevelopment situations, making it infeasible to manage an entire inch of stormwater. Therefore this permit provides the permittee the option of creating off-site mitigation and/or payment in lieu programs.

If the permittee chooses to implement one or both of these options, several requirements must be met:

1. The permittee must establish clear and stringent criteria for the conditions under which these options are available that must be related to real physical constraints such as a combination of thin soils limiting infiltration opportunities, space or light limited situations restricting the amount of vegetation that can be used, and a land use that is not conducive to capture and use of stormwater. While one or two of these characteristics should not be adequate to qualify for the alternative, the combination of multiple constraints could;

2. A minimal requirement for at least 0.4 inch of stormwater managed on-site;

3. A 1:1.5 ratio of the amount of requisite stormwater not managed on site to the amount of stormwater required to be mitigated at another site, or for which in-lieu payments must be made;

4. The necessary tracking systems for both types of programs, including the necessary inventory of public and retrofit projects for off-site mitigation; and,

5. The establishment of a credible valuation structure for payment in lieu, i.e., what is the actual cost for the permittee to provide retrofits for the necessary amount of stormwater, not just a token payment. The purpose of these provisions is to disincentivize the use of alternatives unless really needed, but also to provide a financial foundation for implementation of public stormwater management projects, including retrofits where those needs have been identified.

Road and parking lot repairs, modifications and reconstruction. Although most roads and parking lots are not repaired, modified or reconstructed with great frequency, most municipalities engage in these types of activities on a fairly regular basis. Since roads and parking lots are often a significant percentage of urban impervious areas these are land uses with significant opportunity for implementation of better stormwater controls. Because road and parking lot work is a major investment of resources, it makes sense to incorporate controls when work is ongoing for another purpose.

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paper for US EPA, July 2006. Hagler Bailly Inc. and Criterion Planners/Engineers, The Transportation and Environmental Impacts of Infill versus Greenfield Development: A Comparative Case Study Analysis, EPA 231-R-99-005, U.S. Environmental Protection Agency, Washington, D.C., October 1999.

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This permit term provides the permittee with an opportunity to experiment with different management practices and designs, in conjunction with the assessment in section C.5.b. There are numerous stormwater management practices for streets, street rights-of-way, and parking lots including Portland, OR style Green Streets planters and bump-outs[42], porous pavements[43], Seattle, WA style **Street Edge Alternatives** (SEA) bioretention cells[44], parking lot bioretention islands[45], and a variety of other stormwater management practices[46].

Plan Review, Approval and Enforcement provisions require that the permittee incorporate the standards outlined in section C.5.a.ii into site plan review, approval and enforcement procedures to ensure accountability for their implementation. Plan review procedures include pre-application procedures, site plan review and approval procedures, submittal of as-built certification within 90 days of project completion, post-construction verification procedures, and an education program for municipal staff and those subject to these requirements.

Maintenance Agreements provisions require that the permittee obligate the owner of long-term management practices to properly operate and maintain them for their accepted life span. This obligation can take the form of a maintenance agreement between the land owner and/or the developer, which would be transferred to subsequent owners, between the permittee and a homeowner's association, covenants and restrictions on the property deed itself, or other type of contract requiring all owners of the property to properly maintain and operate management practices. The maintenance agreement shall allow the permittee or its designee to perform maintenance or corrective actions neglected by the property owner/operator, and bill or recoup costs from that owner/operator.

Inventory and Tracking of Management Practices provisions require the permittee to create a tracking system for stormwater management practices implemented on development and redevelopment projects. The information contained in the inventory database will allow the permittee to locate facilities for inspection, track necessary maintenance, and accurately report the level of implementation in each annual report. [47]

Stormwater Management Practices Inspections provisions require that the permittee perform regular inspections of post-construction management practices in order to ensure that they are operating correctly and that the owners are maintaining them for maximum performance.[48] It is

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[42] http://www.portlandonline.com/bes/index.cfm?c=44407& and http://www.portlandonline.com/bes/index.cfm?c=44213&

[43] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=71

[44] http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/Street_Edge_Alternatives/index.asp

[45] http://www.lid-stormwater.net/biocomind_home.htm and http://www.civil.umd.edu/~apdavis/Bioinstallations.htm

[46] http://cfpub.epa.gov/npdes/home.cfm?program_id=298

[47] For more information on management practices tracking systems go to www.stormwatercenter.net [Program Resources, STP Maintenance Resources].

[48] For example checklists go to http://www.epa.gov/npdes/pubs/sw_maintenance_inspection_checklists.pdf

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recommended that the permittee develop an inspection schedule for stormwater management BMPs so that all BMPs are inspected at least once during the term of this permit.

With this inspection frequency, the permittee could manage to inspect most management practices in its jurisdiction in this five year permit term. The inspections are to be followed by any necessary compliance or enforcement action, and follow up inspections are to be conducted to ensure corrective maintenance has occurred. The DWWM anticipates that eventually, perhaps as soon as the next permit term, it may not be feasible to inspect all management practices on a five year cycle. At that time it may be reasonable to implement a 3rd party inspection program paid for by land-owners, or a municipal inspection program that identifies high priority management practices for inspection. The DWWM welcomes suggestions on workable frameworks for future permit terms.

Reporting provisions require that the permittee submit information in each annual report detailing the level of implementation of the long-term stormwater management program during the previous year, including summaries of numbers of site plan reviews and approvals, types of management practices approved, number of maintenance agreements approved, and number of management practices inspections conducted and follow-up actions. In addition, the permittee must provide a summary of any evaluation data collected, and must also provide a comparison of new development trends using implementation data from the current and past years during the permit term.

The goal of the trend analysis is to apply the iterative management process to identify strengths and weaknesses, new development program areas, management practices, and activities that may need to be modified in order to meet the goals of this permit.

Assessments provisions require the permittee to conduct assessments to provide a foundation for program improvements to be implemented during the next permit term.

Street/Parking Design Assessment provisions require the permittee to assess current street design guidelines and parking requirements that affect the creation of impervious cover. This assessment shall be conducted within two years of the effective date of this permit.

Pollution Prevention & Good Housekeeping for Municipal Operations

This control measure requires permittees to implement an operation and maintenance program to prevent or reduce polluted runoff from ***activities conducted by the municipality***. The permittee must examine and subsequently alter their own actions to reduce the amount and type of pollution that: (1) collects on streets, parking lots, open spaces, storage and vehicle maintenance areas, that may be discharged into local waterways; and (2) results from actions such as environmentally damaging land development and flood management practices or poor maintenance of storm sewer systems.

Activities associated with maintenance of parks and open spaces, as well as fleet and building maintenance, must also be considered for possible water quality impacts.

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While this measure is meant primarily to improve or protect receiving water quality by altering municipal or facility operations, it also can result in a cost savings for the permittee, since proper and timely maintenance of storm sewer systems can help avoid repair costs from damage caused by age and neglect.

The regulations at 40 CFR § 122.34(b)(4) require the permittee to:

- Develop and implement an operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations into the storm sewer system;

- Include employee training on methods to incorporate pollution prevention and good housekeeping techniques into municipal operations such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, and stormwater system maintenance.

The permittee can use training materials that are available from the USEPA, WVDEP or any other organization with suitable training material that will meet the needs of the MS4.

In September 2008, the Center for Watershed Protection released a guidance manual for Municipal Pollution Prevention & Good Housekeeping in the summer of 2008. It is available on WVDEPs website: http://www2.wvdep.org/dwwm/stormwater/MS4_BMP.htm

The West Virginia small MS4 general permit also requires that monitoring be conducted at municipal sites that discharge "industrial" stormwater. This includes, but is not limited to maintenance yards, vehicle fueling, storage and maintenance areas, salt storage areas, parks and recreation maintenance areas, public works buildings and storage, and sewage treatment facilities.

Samples are to be collected once every six months, during spring and fall seasons.

PART III

Special Conditions

A. Sharing Responsibility.

The DWWM supports and encourages permittees partnering with other MS4s to meet the requirements of the small MS4 permit. Especially, if two or more permittees are in close or adjacent proximity to each other. Sharing resources can be more cost effective, save time and gain knowledge from a greater intellectual pool of people. It just makes sense to pool resources and knowledge to implement a stormwater management program.

Many Phase I municipalities across the United States have already developed and implemented stormwater management programs. Duplication of efforts is unnecessary. Most of these municipalities are usually very open to sharing their stormwater program successes and failures.

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B. Discharge compliance with Water Quality Standards

Full compliance with all the terms and conditions of this permit is considered an acceptable effort to reduce stormwater pollutants from the small MS4 to the maximum extent practicable.

The Clean Water Act 301(b)(1)(C) provides that all NPDES permittees achieve water quality standards. If a discharge has the reasonable potential to cause or contribute to violations of water quality standards the receiving water, additional controls are required.

In 1987 Congress added the following provision in § 402(p)(3)(B) requiring State permitting authorities to require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and ***such other provisions*** as the Administrator or State determines appropriate for the control of such pollutants.

The Phase II Final Rule, published in the Federal Register on December 8, 1999, 64 F.R. 68722, required NPDES permit coverage for stormwater discharges from both small MS4s and smaller construction sites. The promulgation of those Phase II requirements also includes language in which EPA officially clarified the relationship between sections 301(b)(1)(C) and 402(p) of the Act for all municipal dischargers (small, medium and large):

> Today's rule specifies that the 'compliance target' for the design and implementation of municipal storm water control programs is 'to reduce pollutants to the maximum extent practicable (MEP), *to protect water quality, and to satisfy the appropriate water quality requirements of the CWA*.' The first component, reductions to the MEP, would be realized through implementation of the six minimum measures. The second component, to protect water quality, reflects the overall design objective for municipal programs based on CWA section 402(p)(6). The third component, to implement other applicable water quality requirements of the CWA, recognizes *the Agency's specific determination under CWA section 402(p)(3)(B)(iii) of the need to achieve reasonable further progress toward attainment of water quality standards according to the iterative [Best Management Practices] process*, as well as the determination that State or EPA officials who establish TMDLs could allocate waste loads to MS4s, as they would to other point sources.

As a result, it is clear that USEPA intends all municipal dischargers to achieve both technology-based and water quality-based limits.

Also, see the discussion on MEP on page five of this fact sheet.

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C. Individual Permit

There may be special instances where DWWM will require an individual permit. The DWWM will notify the permittee in writing and include a statement of the reasons.

D. Discharge to impaired waters

Impaired waters are those that do not meet applicable water quality standards. Impaired waters are identified on the West Virginia Section 303(d) list until a Total Maximum Daily Load (TMDL) is developed and subsequently approved by the USEPA.

A MS4 that discharges into a receiving waterbody that has been listed on the WV Section 303(d) list must provide details in their stormwater management program how the selected BMPs will control the discharge of the pollutants of concern.

TMDL Development Schedule:

From 1997 until 2003, USEPA Region III developed West Virginia TMDLs under the settlement of a 1995 lawsuit, Ohio Valley Environmental Coalition, Inc., West Virginia Highlands Conservancy, et. al. v. Browner, et. al. The lawsuit resulted in a consent decree between the plaintiffs and the USEPA that specifies TMDL development requirements and compliance dates.

While the USEPA was working on developing TMDLs, the DEP concentrated on building its own TMDL program. With the help of the TMDL stakeholder committee, the agency secured funding from the state legislature and created the TMDL section within the Division of Water and Waste Management.

The TMDL section is committed to implementing a TMDL process that reflects the requirements of TMDL regulations, provides for the achievement of water quality standards, and ensures that ample stakeholder participation is achieved in the development and implementation of TMDLs. The DWWM's approach to TMDL development allows 48 months to develop a TMDL from start to finish. This approach enables the agency to carry out an extensive data generation and gathering effort to produce scientifically defensible TMDLs, and allows ample time for modeling, report drafting and frequent public participation opportunities.

Barring unforeseen circumstances, all DEP TMDLs will be developed according to the Watershed Management Framework cycle. The framework divides the state into 32 major watersheds and operates on a five year, five-step process. The watersheds are divided into five hydrologic groups (A - E). Each group of watersheds is assessed once every five years.

The TMDL process begins in the first year of the cycle with pre-TMDL sampling and public meetings in the affected watersheds. The data is compiled and TMDL

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development begins in year two of the cycle. In the third year, TMDL development continues and the TMDL is drafted.

The TMDL is finalized in the fourth year. In the fifth year of the cycle, TMDL implementation is initiated through the NPDES permitting process and efforts toward limiting nonpoint source loading. Throughout the TMDL development process, there are numerous opportunities for public participation and input.

A schedule of TMDL implementation can be found in several of the documents on WVDEP's TMDL webpage: http://www.wvdep.org/item.cfm?ssid=11&ss1id=720

It is strongly advised that the permittee become familiar with the schedule of TMDL development and implementation. If a TMDL is scheduled to be developed during the permit term, any specific practices or changes that need to take place in the SWMP in order to meet the wasteload allocations can be planned and anticipated. If your MS4 discharges into waters in which a TMDL has been developed, the SWMP must be modified within six months. The MS4 operator must modify the SWMP to include BMPs that are appropriate and specifically targeted to achieve wasteload allocations prescribed by the TMDL. The MEP standard does not apply to water bodies with approved TMDL. The NPDES permitted entity must meet their wasteload allocations.

The SWMP must be modified within six months. The MS4 operator must modify the SWMP to include BMPs that are appropriate and specifically targeted to achieve wasteload allocations prescribed by the TMDL.

The MS4 General Permit requires that a description of the BMPs that the permittee implemented be included in the annual report.

Part IV

Monitoring, Recordkeeping, Reporting and Program Review

A. Evaluating the SWMP

Permittees shall evaluate the effectiveness of their stormwater management programs and chosen BMPs. The process of developing a stormwater management program, implementing the program, and evaluating the program is a dynamic, iterative process that helps move MS4 communities toward achievement of their stormwater goals.

There are several reasons to evaluate the effectiveness of the SWMP;

1. 40 CFR 122.26(d)(2)(v) and 122.34(g) requires MS4 operators to assess BMPs and the effectiveness of their SWMP.
2. Evaluation of SWMP effectiveness is essential to document progress toward meeting water quality goals.

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3. Knowledge of program effectiveness can help to justify SWMP expenditures to decision makers and the public, and will help to improve cost effective implementation and management of the SWMP.
4. Stormwater management is an iterative process and knowledge of program effectiveness is essential for mid-course corrections to improve the program.
5. If a receiving water body is impaired, it is very helpful to assess the effectiveness of the SWMP in reducing the pollutants of concern.

The three approaches to evaluating effectiveness are:

- Assessing program operations;
- Evaluating social indicators; and
- Monitoring water quality.

Stormwater program evaluation must be more than an exercise in collecting and tabulating data. Evaluation data must be analyzed, interpreted, and reported so that results can be used to modify and/or strengthen the SWMP when necessary.

Water quality monitoring is the most direct, and usually the best, approach to evaluating the effectiveness of a SWMP. Program evaluation through water quality monitoring can apply to several of the SWMP components, including illicit discharge detection, construction site runoff control and post-construction runoff control. However, if the permittee discharges to a waterbody with an approved TMDL, the collection of water quality data (along with BMP performance data) is very important. (For more information about the TMDL program, visit **www.epa.gov/owow/tmdl**). Detailed guidance on design and operation of monitoring is available elsewhere, e.g., *USDA-NRCS National Handbook of Water Quality Monitoring* **(ftp://ftp.wcc.nrcs.usda.gov/downloads/wqam/wqm1.pdf)** and *EPA Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (Sept. 1997, EPA 841-B-96-004).

Water quality monitoring approaches range from qualitative observations to highly quantitative measurements, covering areas as small as individual BMPs to large receiving waters such as lakes or estuaries. A good monitoring program for evaluation of SWMP effectiveness will probably contain several elements at various levels of detail and scale. Before embarking on new monitoring, however, it is important to collect and evaluate historic and current data from existing monitoring activities. Data from state 305(b) assessments, 303(d) lists, and published TMDLs, ongoing state and federal agency monitoring programs, water supply intake testing, and watershed volunteer groups, for example, can be useful both in designing a monitoring program and in supplementing program results.

For more information see the USEPA/State guidance titled: *Evaluating the effectiveness of municipal stormwater programs* and *Understanding Impaired Waters and Total Maximum Daily Load (TMDL) Requirements for Municipal Stormwater Programs.* Both

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of these guidance documents can be found on WVDEP's website: http://www2.wvdep.org/dwwm/stormwater/MS4_docs.htm

B. Stormwater Monitoring

There are no numerical effluent limits established in this general permit. Effluent limits are established in the small MS4 general permit in the form of stormwater BMPs, which, when implemented, are designed to prevent the discharge of polluted stormwater runoff to surface waters of the state.

Part IV of this general permit requires two stormwater samples per year to ascertain certain pollutants found in stormwater runoff, and to measure the effectiveness of the stormwater management program.

When a representative outfall for stormwater sampling is chosen, that sample location must remain the same throughout the permit period. A representative outfall is one located in the most densely populated area. The latitude and longitude of the outfall must be determined also.

Upon approval of the SWMP a Discharge Monitoring Report will be issued to the permittee.

C. Recordkeeping & Public Availability of SWMP and Annual Report

Records are documentation of the activities and policies that are implemented under the small MS4 general permit. Records must be maintained for at least three years after the termination of this permit.

It is strongly advised that the permittee record and maintain documentation of all components of the stormwater management program, including all six minimum control measures and any monitoring activities. Records do not need to be submitted to the DWWM unless requested.

The SWMP and the annual report shall be made available to the public during regular business hours. This permit requires that the SWMP and subsequent annual reports be made available on the permittees website. However, if the permittee does not maintain or operate a website, the SWMP and annual report can be submitted to the DWWM in either Microsoft Word or Adobe PDF format for distribution to the public.

D. Annual Report

To aid in assessing achievement of improved water quality from the development and implementation of stormwater BMPs, the permittee is required to submit an annual report to the DWWM. Annual reports may be used to assess the effectiveness of the permittees stormwater management program.

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Appendix D

Management Conditions

This section is boilerplate language essentially extracted from Title 47, Series 10 of the West Virginia Legislative Rules. These rules establish that every NPDES permit contains certain standard conditions. A reference to Title 47, Series 11, Section 9 of the West Virginia Legislative Rules was included that requires that outlet markers be posted.

The State of West Virginia, Department of Environmental Protection, Division of Water and Waste Management, has made a tentative decision for a state NPDES permit as listed on this fact sheet. In order to provide public participation on the proposed issuance of the required permit, the following information is being supplied in accordance with Title 47, Series10, Section 11.3.e.2 and 3, of the West Virginia Legislative Rules.

During the public comment period, any interested person may submit written comments on the draft permit and may request a public hearing. A request for a public hearing shall be made in writing and addressed to:

Director, Division of Water and Waste Management, DEP
601 57th Street SE
Charleston, WV 25304-2345
Attention: William Timmermeyer
E-mail: William.F.Timmermeyer@wv.gov

The request shall state the nature of the issues proposed to be raised in the hearing and must be received within the comment period. The Director shall hold a public hearing whenever he or she finds, on the basis of requests, a significant degree of public interest on issues relevant to the draft permit. Any person may submit oral or written statements and data concerning the draft permit; however, reasonable limits may be set upon the time allowed for oral statements, and the submission of statements in writing may be required. A tape recording or written transcript of the hearing shall be made available to the public upon request.

If information received during the public comment period appears to raise substantial new questions, the Director may reopen the public comment period.

All applicable information concerning any permit application and the tentative decisions is on file and may be inspected by appointment, or copies obtained at a nominal cost, at the offices of the Division of Water and Waste Management, 601 57th Street SE, Charleston, West Virginia 25304, Monday through Friday (except State holidays) between 8:00 a.m. to 4:00 p.m.

Requests for additional information should be directed to William Timmermeyer at (304) 926-0499, Extension 1336.

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State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

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plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

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[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

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facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of beneficial use impairment. Urban area runoff may contain[9] elevated levels of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

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pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

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[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

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a) A summary of status of current Storm Water Management Program;

b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

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19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

    Inland Surface Streams

    Santa Ana River, Reaches 1 and 2

    Aliso Creek (tributary to Santa Ana River)

    Carbon Canyon Creek (tributary to Santa Ana River)

    Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

    Silverado Creek (tributary to Santiago Creek)

    Black Star Creek (tributary to Santiago Creek)

    Ladd Creek (tributary to Santiago Creek)

    San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

    San Joaquin Freshwater Marsh (tributary to San Diego Creek)

    Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

    Santa Ana Delhi Channel (tributary to Newport Bay)

    Big Canyon Wash (tributary to Newport Bay)

    Buck Gully

    Los Trancos Creek

    Coyote Creek (tributary to San Gabriel River)

    Other tributaries to the above listed rivers, creeks and channels

    Bays, Estuaries, and Tidal Prisms

    Anaheim Bay and Seal Beach National Wildlife Refuge

    Sunset Bay

    Bolsa Bay and Bolsa Chica Ecological Reserve

    Upper and Lower Newport Bay

    Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

    Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

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Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin)

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includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

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27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants. The Regional Board recognizes that a watershed management program should integrate all related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary. The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and

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efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB 411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

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32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12.] The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13.]

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, "Management Guidelines for Use of Fertilizers and Pesticides". The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

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leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

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38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

    Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

    Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

    Seal Beach (listed for enteroccocus, PCBs);

    Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

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Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be

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conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation

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of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.46(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This

[15] Attachment 2 to Resolution No. R8-2007-0024

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

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order requires the permittees to comply with the urban runoff/storm water wasteload allocations for both EPA-promulgated and Regional Board adopted/EPA approved TMDLs. Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

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57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

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are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mititgative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. To the extent practicable, these LID BMPs must be implemented at the project site.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25]and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009)

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009)

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

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concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be a better metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to 10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently , new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues.

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However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of groundwater pollution and could become a nuisance and/or cause the spreading of surface water pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

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of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

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problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.46(d)(vii)(B)) require the Permittees to comply with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of

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increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

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78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide

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24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic

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framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicitl discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the

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California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

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PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.
7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.

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3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.
2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.

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3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.

   i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.

      a) Discharges composed entirely of storm water;

      b) Air conditioning condensate;

      c) Irrigation water;

      d) Passive foundation drains;

      e) Passive footing drains;

      f) Water from crawl space pumps;

      g) Non-commercial vehicle washing;

      h) Diverted stream flows;

      i) Rising ground waters and natural springs;

      j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

      k) Flows from riparian habitats and wetlands;

      l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5);

      m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

      n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

   ii. The permittees shall prohibit the following categories of non-storm water discharges unless the stated conditions are met:

      a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001, except that separate coverage under the General De Minimus Permit is not required.

      b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and

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pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

c) Discharges from lawn watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be minimized through public education and water conservation efforts, as prescribed under Section XI, Residential Program.

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.

5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

[33] See previous footnote.

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6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.
8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.
2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.
3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:
   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;
   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;
   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

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d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial. construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.

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3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.

4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a) Sewage (also prohibited under the Statewide SSO order[34]);

   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

[34] State Board WQO No. 2006-0003.

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d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;

e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[35];

g) Discharges of runoff from the washing of toxic materials[36] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.

2. The permittees shall control, to the maximum extent practicable, the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks,

[35] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

[36] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

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and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.

3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.
4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.
6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.
7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.
2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location

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(latitude/longitude [in decimals] or NAD83/WGS84[37] compatible formatting), inspection data, etc.

3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.
4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:
   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;
   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);
   c) Visual observation for non-storm water discharges and potential pollutant sources;
   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,
   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.
5. At a minimum, the inspection frequency shall include the following:
   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

[37] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

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b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.
7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitutde/longitude (in decimals) or NAD83/WGS84[38] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of

[38] See Footnote 38.

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Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.

3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.

4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.

5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.

6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.

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8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period.

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction. As required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

   Commercial facilities may include, but may not be limited to[40]:

   a) Transport, storage or transfer of pre-production plastic pellets.
   b) Automobile mechanical repair, maintenance, fueling or cleaning;
   c) Airplane maintenance, fueling or cleaning;
   d) Marinas and boat maintenance, fueling or cleaning;
   e) Equipment repair, maintenance, fueling or cleaning;
   f) Automobile impound and storage facilities;
   g) Pest control service facilities;
   h) Eating or drinking establishments, including food markets and restaurants;
   i) Automobile and other vehicle body repair or painting;
   j) Building materials retail and storage facilities;
   k) Portable sanitary service facilities;
   l) Painting and coating;
   m) Animal facilities such as petting zoos and boarding and training facilities;
   n) Nurseries and greenhouses;
   o) Landscape and hardscape installation;
   p) Pool, lake and fountain cleaning;
   q) Golf courses;
   r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
   s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the

[39] See Footnote 38.

[40] Mobile cleaning services are addressed in X.8, below.

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permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. The following minimum criteria must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[41]; 40% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.
4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or

[41] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

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steam cleaning. The pilot program shall include at least two notifications of the individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.

9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:

   a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;

   d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

   All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period.

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s to the maximum extent practicable so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should

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include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[42] and USDA's Backyard Conservation Program[43].

3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[44] to encourage efficient water use and to minimize runoff[45].
5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[46].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

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[42] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[43] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

[44] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[45] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[46] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.

2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.

3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.

4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24 months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings

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of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

a) Potential impact of project construction on storm water runoff;

b) Potential impact of project's post-construction activity on storm water runoff;

c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance with the approved Model WQMP and shall incorporate LID principles in the WQMP.

   a. All significant redevelopment projects, where significant redevelopment is defined as priority development projects, which include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance

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activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b. Subdivisions creating 10 lots or units and more, and subdivisions creating less than 10 lots or units, where the combined impervious surface area of the lots or units is equal to or greater than 10,000 square feet. This includes single family residences, multi-family residences, condominiums, apartments, etc.

c. Commercial and industrial developments, which are not subdivisions, of 10,000 square feet or more. This includes non-residential developments.

d. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

e. Restaurants where the land area of development is 5,000 square feet or more.

f. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

g. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[47] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

h. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

i. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" to the maximum extent practicable. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

[47] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

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j. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

k. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[48] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

A. Volume

Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

[48] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

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1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[49]; or,

2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

   b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

   c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

[49] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

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d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[50].

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for approval to the Executive Officer.

2. The permittees shall incorporate LID site design principles to reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design strategy shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration and treatment systems as close as

[50] This restriction applies only to sites that are known to have soil and groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

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possible to the source of runoff. Site design considerations shall include, but not be limited to:

a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable concrete and porous asphalt; minimize pipes, culverts and engineered systems for storm water conveyance; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales to replace curbs gutters and conventional storm water conveyance systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

3. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-

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structural measures, e.g., preservation of natural features to the maximum extent practicable; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

4. LID structural site design BMPs shall ensure capture of the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above.

5. The LID goal shall be to infiltrate, evapotranspire, harvest and beneficially reuse the design capture volume at the project site. Any volume that is not captured by the LID BMPs shall be treated using conventional treatment control BMPs in accordance with Section XII.B.4, above.

6. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[51], New Urbanism[52] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

7. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality. If site conditions do not permit infiltration and/or harvesting and re-use of the design capture volume at the project site as close to the source as possible, the alternatives discussed below and the credits and in-lieu programs discussed under Section E, below, may be considered:

3.

a) Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains

[51] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[52] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

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to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

b) Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume.

c) Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

d) Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate and/or harvest and re-use at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[53])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

[53] Hydromodification is the alteration of natural flow characteristics.

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c) Changes in time of concentration;

d) Potential for increases in post development downstream erosion; and,

e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected. These conveyance channels should not include any waters of the U.S.

   c) The site infiltrates at least the runoff from a two-year storm event.

   The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees have the option to address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan that integrates

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water quality, hydromodification, water supply, and habitat. The Watershed Master Plan may be prepared for the whole watershed or for sub-watersheds. The Plan should include a map to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and specify hydromodification management standards for each sub-watershed. In the preparation of this Plan or plans, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; and (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board. The Watershed Master Plan or the sub-watershed plans shall be submitted to the Executive Officer for approval.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs. This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing. Waivers shall only be granted with prior approval from the Executive Officer.

2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

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3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.
4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:
   a) Redevelopment projects that reduce the overall impervious footprint
   b) Brownfield redevelopment
   c) High density developments (>7 units per acre)
   d) Mixed use and transit-oriented development (within ½ mile of transit)
   e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses
   f) Regional treatment systems with a capacity to treat flows from all upstream developments
   g) Contribution to an urban runoff fund (see 1, above)
   h) Offsite mitigation or dedications within the same watershed
   i) City Center area
   j) Historic Districts and Historic Preservation areas
   k) Live-work developments
   l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.

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2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.
3. The permittees shall develop a database with information regarding each structural treatment control BMP. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance

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verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.

4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.
5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 50% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within a two year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented to the maximum extent practicable for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.
2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.
3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes

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to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.

4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of

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the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.
2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.
3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:
   a) Parking facilities;
   b) Flood management and storm water conveyance systems (open channels);
   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and
   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.
4. All applicable public agency staff shall be trained as specified under Section XVI.
5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:
   a) Conduct annual integrated pest management self-audits;
   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;
   c) Provide proper training to municipal and contract staff involved in the above activities;

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d) Within six months of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within six months of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.

13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance

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contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.

14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.

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2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training (Certificate of Completion).
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.

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8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections.
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

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1. Implementation plans are being developed for the following TMDLs:
   a) Metals (San Diego Creek and Newport Bay)
   b) Metals (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay, also see Paragraph 2, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)

   As required under a consent decree, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay that included TMDLs for metals, organochlorine compounds, selenium and organophosphate pesticides. As noted in the Findings, the Regional Board adopted TMDLs, including an implementation plan, for the organophosphate pesticides diazinon and chlorpyrifos. The diazinon and chlorpyrifos TMDLs have been fully approved and are now being implemented. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. The Regional Board adopted organochlorine TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. It has not been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. However, until Regional Board adopted TMDLs for the organochlorine compounds, metals and selenium are approved by the State Board, the Office of Administrative Law (OAL), and the EPA, the EPA promulgated TMDLs (see a-f, above) are the applicable TMDLs for these waterbodies. The permittees in the Newport Bay Watershed shall comply with the EPA-promulgated wasteload allocations in Tables 1 A/B/C, 2 A/B/C/D and 3.

Tables 1 A/B/C – Urban Runoff Waste Load Allocations for Metals

(TMDLs promulgated by U.S. EPA)[54]

A- San Diego Creek and Tributaries – Concentration based TMDL

[54] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

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	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

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Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[55]

A- San Diego Creek and Tributaries

Total DDT	**Chlordane**	**Dieldrin**	**PCBs**	**Toxaphene**
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	**Chlordane**	**PCBs**
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	**Chlordane**	**Dieldrin**	**PCBs**
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	**Chlordane**	**Dieldrin**	**PCBs**
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

[55] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[56]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

2. For the organochlorine compounds TMDLs, the Regional Board has adopted an implementation plan. That plan requires approvals from the State Board, OAL and the EPA. Once approved by the State Board, OAL, and EPA, the Regional Board TMDL will replace the TMDLs promulgated by EPA. The urban runoff wasteload allocations in those TMDLs are presented in Table 4. The permittees in the Newport Bay Watershed shall comply with the WLAs in Table 4 and the water column targets in Tables 5 A/B. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated a Toxicity Reduction and Investigation Program (TRIP) consistent with the implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations. Tables 6 A/B have EPA-promulgated WLAs for toxic pollutants for San Diego Creek and Newport Bay. The permittees in the Newport Bay Watershed shall comply with the WLAs specified in Tables 6 A/B.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Pesticides (TMDLs approved by Santa Ana Regional Water Quality Control Board)[57]

[56] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[57] From Resolution No. R8-2007-0024, Table NB-OCs-10

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	Total DDT	**Chlordane**	**Total PCBs**	**Toxaphene**
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.7 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[58]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l
Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

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Table 6 – Allocations for San Diego Creek and Newport Bay Watershed from the EPA-Promulgated TMDLs for Toxic Pollutants[59]

A- Sand Diego Creek

	Chlordane	DDT (including dicofol)	PCBs	Dieldrin	Toxaphene
Urban Runoff WLA		302.8 g/yr	177.7 g/yr	183.4 g/yr	6.2 g/yr
B- Upper Newport Bay					

[58] From Resolution No. R8-2007-0024, Table NB-OCs-4

[59] U.S. EPA Region 9, Total Daily Loads for Toxic Pollutants, San Diego Creek and Newport Bay, California, June 14, 2002.

Urban Runoff WLA	120.5 g/yr	207.4 g/yr	609.7 g/yr		

3. In conjunction with watershed stakeholders, Regional Board staff is in the process of developing recommendations for revisions to the nutrient TMDLs and to the EPA promulgated TMDLs for selenium, and is formulating a selenium TMDL implementation plan. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive nitrogen and selenium management plans, which are expected to form the basis, at least in part, for a revised nutrient TMDL implementation plan and the selenium implementation plan. A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one month after approval of the TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

4. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall ensure compliance with the following wasteload allocations:

Table 7 – Municipal Storm Water Wasteload Allocations

Coyote Creek

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	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

5. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 8 – Numeric Targets - Coyote Creek (total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[60]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

Dry Weather limit for copper is based on CTR saltwater criterion in San Gabriel River estuary

C. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 9A – Fecal Coliform TMDL and Allocations for Newport Bay To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL

[60] Based on saltwater CTR criterion.

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Fecal Coliform	As soon as possible, but no later than December 30, 2013	for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 9B – Fecal Coliform TMDL and Allocations for Newport Bay Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables 9a and 9b in accordance with the deadlines in Tables 9a and 9b. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and

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Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.
3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 10A and 10B are extracted from the Implementation Plan[61]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 10 A and B.

Table 10A

Diazinon and Chlorpyrifos Allocations for San Diego Creek

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Actue	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6
Load Allocation	72	45	18	12.6
MOS	8	5	2	1.4
TMDL	**80**	**50**	**20**	**14**

MOS=Margin of safety; Chronic means 4-consecutive day average

[61] Attachment to Resolution No. R8-2003-0039

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Table 10B

Chlorpyrifos Allocations for Upper Newport Bay

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1
Load Allocation	18	8.1
MOS	2	0.9
TMDL	**20**	**9**

MOS=Margin of safety; Chronic means 4-consecutive day average

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall comply with the waste load allocations for urban runoff in Tables 9A and 9B. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 11 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[62]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[63]	2007 Summer Allocation (Apr-Sept)[64]	2012 Winter Allocation (Oct-Mar)[65]

[62] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

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Newport Bay Watershed	lbs/year TN[66,67]	lbs/season TN	lbs/season TN	lbs/season TN
Wasteload Allocation				
Urban runoff	277,131[68]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 12 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[69]

	2012 Allocation lbs/day TN[70]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table 13 - Annual Total Phosphorous Load Allocations

[63] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[64] See previous footnote.

[65] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[66] TIN = (NO3+NH3).

[67] TN = (TIN + Organic N).

[68] Estimated annual average (summer and winter loading).

[69] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[70] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

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For The Newport Bay Watershed[71]

	2002 Allocation lbs/year TP[72]	2007 Allocation lbs/year TP[73]
TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 11, 12 and 13 in accordance with the schedules in Tables 11, 12 and 13. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

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[71] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[72] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[73] See previous footnote

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1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determination is based on monitoring within the receiving waters. For sediment TMDLs, compliance determination is based on monitoring in the Creek.
2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
    a) Review of the formal training needs of municipal employees
    b) Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.
3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
    a) Each permittee's expenditures for the previous fiscal year,
    b) Each permittee's budget for the current fiscal year,

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c) A description of the source of funds, and

d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.
5. Within six months of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.

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7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:
   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for

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additional source control and/or structural BMPs, any proposed pilot studies, etc.;

b) Changes in land use and/or population including land use map updates;

c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).

3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on April 24, 2009.

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Gerard J. Thibeault
Executive Officer

To be provided at a later date.

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Order No. R8-2008-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities
Area wide Urban Storm Water Runoff

Attachment "B"

To be provided at a later date.

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Order No. R8-2008-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

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Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

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State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2008-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

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I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

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determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

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f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

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c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

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V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual

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		Report

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Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

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Ordered by_____
Gerard J. Thibeault
Executive Officer

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

ORDER: WQ 2000 - 11

In the Matter of the Petitions of
THE CITIES OF BELLFLOWER, ET AL., THE CITY OF ARCADIA, AND WESTERN STATES PETROLEUM ASSOCIATION
Review of January 26, 2000 Action of the Regional Board
and
Actions and Failures to Act
by both the
California Regional Water Quality Control Board,
Los Angeles Region and Its Executive Officer
Pursuant to Order No. 96-054,
Permit for Municipal Storm Water and Urban Run-Off Discharges Within
Los Angeles County
[NPDES NO. CAS614001]

SWRCB/OCC FILES A-1280, A-1280(a) and A-1280(b)

BY THE BOARD:

On July 15, 1996, the Los Angeles Regional Water Quality Control Board (Regional Water Board) issued a revised national pollutant discharge elimination system (NPDES) permit in Order No. 96-054 (permit) to the 85 incorporated cities and the county within Los Angeles County (the County).[1] The permit covers storm water discharges from municipal separate storm sewer systems throughout the County.[2]

[1] This was the second storm water permit adopted for Los Angeles County and its cities. The first permit was the subject of an earlier Order. (In the Matter of Natural Resources Defense Council, Inc., Order WQ 91-04). In this permit, the County is designated as the Principal Permittee, and each city is designated as a permittee. The County is required to submit various documents on behalf of all of the permittees.
[2] The Regional Water Board has since issued a separate permit for one city, Long Beach. The relevant provisions of the Long Beach permit are similar to those in Order No. 96-054.

The permit contains provisions for the regulation of storm water discharges from development planning and construction.[3] Pursuant to these provisions, the County was required to submit Standard Urban Storm Water Mitigation Plans (SUSMPs).[4] The SUSMPs are plans that designate best management practices (BMPs) that must be used in specified categories of development projects. The County submitted SUSMPs, but the Regional Water Board approved the SUSMPs only after making revisions. The Executive Officer issued the revised SUSMPs on March 8, 2000.[5]

On February 25, 2000, the State Water Resources Control Board (State Water Board or Board) received a petition for review of the actions and failures to act regarding the SUSMPs from a number of cities, the Building Industry Association of Southern California and the Building Industry Legal Defense Foundation (jointly referred to as Cities). A second petition was received from the City of Arcadia. And a third petition was received from the Western States Petroleum Association (WSPA). On April 7, 2000, the petitioners filed amendments to their petitions, concerning the March 8, 2000 issuance of the SUSMPs. The Cities' amendment also revised the list of cities included in the petition. The Cities' petition now includes 32 cities. The petitions are legally and factually related, and have therefore been consolidated for purposes of review.[6] The petitioners also requested a stay of the SUSMPs. This request was denied by letter, dated May 11, 2000.

[3] Permit, Part 2.III. These provisions focus more on post-construction impacts of development than on discharges from construction activities.
[4] Permit, Part 2.III.A.1.c.
[5] These are referred to herein as the Final SUSMPs. The Final SUSMPs also apply to Long Beach, even though it is subject to a separate permit.
[6] Cal. Code of Regs., tit. 23, section 2054.

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On June 7 and 8, 2000, the Board held a hearing in Torrance. Several entities, including the petitioners, the Regional Water Board, and several environmental groups[7], were designated parties. The evidence from that hearing has been included in the record before the Board. The record for comments on the petition was kept open until the end of the hearing. The parties were allowed to submit post-hearing briefs.[8]

I. BACKGROUND

In prior Orders[9] this Board has explained the need for the municipal storm water programs and the emphasis on BMPs in lieu of numeric effluent limitations. The emphasis for preventing pollution from storm water discharges is still on the development and implementation of effective BMPs, but with the expectation that the level of effort will increase over time. In its Interim Permitting Approach[10], the United States Environmental Protection Agency (U.S. EPA) stated that first-round permits should include BMPs, and expanded or better-tailored BMPs in subsequent permits where necessary to attain water quality standards. Dischargers, consultants, and academic institutions in California and nationwide have conducted numerous studies on the effectiveness of BMPs and appropriate design standards. While many questions are still

[7] The environmental groups are Natural Resources Defense Council, Inc., Santa Monica BayKeeper, and Heal the Bay.

[8] There are several documents that were not timely received and, therefore, are not made a part of the record before the Board. The hearing notice specified that all evidence from parties must be received by May 31, 2000. The Regional Water Board submitted documents on June 6, 2000. The hearing notice specified that policy statements were due by the close of the hearing. Several comment letters were received June 12, 13, and 19, 2000. None of these submittals are a part of the record. The post-hearing briefs were subject to a 10-page limit. The environmental groups submitted objections to the post-hearing brief submitted by the Cities. First, the environmental groups challenge the length of the brief. All briefs were subject to a 10-page limit. The Cities submitted a 10-page brief, with a 22-page attachment showing extensive proposed revisions to the SUSMPs. This submittal violates the page limit, and only the brief is considered part of the record. Second, the environmental groups claim that an e-mail message referred to by the petitioners is subject to attorney-client privilege and should not have been used in this hearing. This e-mail message, from the Regional Water Board's counsel to one of its engineers, was placed in the Regional Water Board's administrative record and submitted to the State Water Board. Any privilege that may have attached to the message has been waived and no longer exists. Finally, the post-hearing brief from the City of Arcadia was received late and will not be considered. Documents submitted late for interim deadlines (such as the deadline for submitting responses to the petitions), have been included in the record.

[9] See, especially Orders WQ 91-03 (In the Matter of Citizens for a Better Environment et al.) and WQ 91-04.

[10] Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits. (61 Federal Register 57425.)

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outstanding, more is expected of municipal dischargers, and many are implementing more effective programs.

While storm water management plans are improving, our knowledge of the impacts is also growing. Urban runoff has been determined to be a significant contributor of impairment to waters throughout the state. In Los Angeles specifically, beach closures are sometimes associated with urban runoff. In adopting the SUSMPs, the Regional Water Board took note of the urgent need for preventing further pollution from urban runoff and storm water discharges.

It is important to emphasize the role of the SUSMPs within the totality of regulating storm water discharges, and the purpose of these particular control measures. The requirement to prepare SUSMPS was part of the development controls in the permit. In addition to development controls, the permit requires education, public outreach, programs to restrict illicit connections and discharges, and controls on public facilities. In the context of the entire effort required by the permit, the development controls can be seen as preventing the existing situation from becoming worse.

The Final SUSMPs include a list of mandatory BMPs for nine categories of development. There are provisions that are applicable to all categories and lists of BMPs for individual categories. Requirements applicable to all categories include provisions to limit erosion from new development and redevelopment, requirements to conserve natural areas, protection of slopes and channels, and storm drain stenciling. Examples of BMPs specific to categories of discharge include design of loading docks for commercial projects and design of fueling areas for retail gasoline outlets. In most respects, the Final SUSMPs were similar to those proposed by the County. The significant departures were the inclusion of a numeric design standard for structural or treatment control BMPs, and the inclusion of certain types of projects that were not

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covered in the County's proposal. The design standard creates objective and measurable criteria for the amount of runoff that must be treated or infiltrated by BMPs.

The record indicates that the purpose of the development controls, including the SUSMPs, is not simply to prevent pollution associated with construction runoff. As the petitioners point out, construction discharges are already subject to this Board's Statewide Construction Permit. The development controls in the SUSMPs, on the other hand, focus on post-construction runoff. They are aimed at limiting not just the pollutants in runoff from the new development, but also the volume of runoff that enters the municipal storm sewer system. By limiting runoff from new development, the SUSMPs prevent increased impacts from urban runoff generally. There is adequate technical information in the record to show that by controlling the volume of runoff from new development, BMPs can be effective in reducing the discharge of pollutants in storm water runoff.

The Procedure for Adopting the SUSMPs

The permit requires a program for controls on Development Planning and Construction. It involved a number of submissions by the County in consultation with the Cities. The first step was submission of a checklist for determining priority projects and exempt projects. The checklist was due on January 30, 1998. A list of recommended BMPs for development projects was also due on that date. The SUSMPs were due within six months of approval of the BMP list, and were to incorporate BMPs for certain categories of development. Following approval of the SUSMPs, the cities and County were to implement development programs for priority projects, consistent with the BMP list and the SUSMPs.

The BMP list was not approved until April 22, 1999. Thereafter, the County submitted proposed SUSMPs on July 22, 1999. The Regional Water Board held a public workshop on

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August 10, 1999. Following the workshop, the County submitted revisions to the SUSMPs on August 12, 1999. On August 16, 1999, the Regional water Board gave notice that it would discuss the SUSMPs in a public meeting on September 16, 1999. There was significant discussion at that meeting regarding the intent of the Executive Officer to approve the SUSMPs, but with revisions including a numeric design standard. At the conclusion of the meeting, the Regional Water Board members asked the Executive Officer to revise the SUSMPs and bring them back to another meeting. On December 7, 1999, the Executive Officer circulated revised SUSMPs for public review. This document incorporated a numeric design standard and made other revisions to the permittees' proposal. The Regional Water Board held a hearing on the SUSMPs on January 26, 2000. At that meeting, the Regional Water Board endorsed the SUSMPs revised by the Executive Officer, but directed him to make further changes. The Executive Officer issued the Final SUSMPs on March 8, 2000.

The Contents of the Final SUSMPs

The permit provides that the SUSMPs must incorporate the appropriate elements of the BMP list and, at a minimum, apply to seven development categories: 100-plus home subdivisions; 10-plus home subdivisions; 100,000-plus square foot commercial developments; automotive repair shops; retail gasoline outlets; restaurants; and hillside single-family dwellings.

The SUSMPs proposed by the County applied to these seven categories. Various BMPs applied to the different categories, and the SUSMPs contained narrative mitigation requirements for source control and treatment. The July proposals stated:

> "The development must be designed so as to mitigate (infiltrate and/or treat) the site runoff generated from impervious directly connected areas that may contribute pollutants of concern to the storm water conveyance system."

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There were no numeric design criteria for mitigation. According to various participants, earlier County drafts had included design standards to mitigate flows from 0.6-inch storm events. But any numeric criteria had been removed from the version that was submitted.

In its revised SUSMPs, submitted on August 12, the County explained in its cover letter that the mitigation language did not mean that all runoff must be mitigated. Rather, the County's intent was to omit a numerical standard from the SUSMPs. The revised SUSMPs no longer referred to mitigation at all. Instead, the following language replaced the mitigation requirement:

> "The development must be designed so as to minimize, to the maximum extent practicable (MEP), the introduction of pollutants of concern that may result in significant impacts, generated from site runoff of directly connected impervious areas (DCIA), to the storm water conveyance system as approved by the building official."

The Final SUSMPs, as approved by the Executive Officer and the Regional Water Board, included several revisions from the County's submittal. The revision that is of greatest concern to the petitioners is the addition of Design Standards for Structural or Treatment Control BMPs.[11] The design standards require that developments subject to the SUSMPs shall be designed to mitigate storm water runoff (by treatment or infiltration) from one of the following:

> "1. The 85th percentile 24-hour runoff event determined as the maximized capture storm water volume for the area…, or
> 2. The volume of annual runoff based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment…, or
> 3. The volume of runoff produced from a 0.75 inch storm event, prior to its discharge to a storm water conveyance system, or
> 4. The volume of runoff produced from a historical-record based reference 24-hour rainfall criterion for "treatment" (0.75 inch average for the Los Angeles County area) that achieves approximately the same reduction in pollutant loads achieved by the 85th percentile 24-hour runoff event."

[11] The Final SUSMPs also include the narrative language quoted from the County's August 22, 1999 proposal.

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The Final SUSMPs also applied to two additional categories of development: parking lots over 5,000 square feet or with 25 or more spaces and exposed to storm water, and to developments in environmentally-sensitive areas. Other revisions included application to all projects in the categories instead of discretionary projects only and the definition of redevelopment.

II. CONTENTIONS AND FINDINGS[12]

Contention: The petitioners contend that the Regional Water Board erred in not complying with the Administrative Review Process within the permit, and acted arbitrarily and capriciously and in violation of the Clean Water Act and state law.

Finding: The permit required the County, in consultation with the cities subject to the permit, to submit SUSMPs. The permit includes some general minimum requirements for the SUSMPs.[13] The Executive Officer is granted authority to approve the SUSMPs.[14]

The permit also contains an administrative review process.[15] The permit states that the administrative review process "formalizes the procedure for review and acceptance of reports and documents" and "provides a method to resolve any differences in compliance expectations between the Regional Board and Permittees, prior to initiating enforcement action."[16] Following this introductory statement, the permit includes two procedures. The first is for review and approval or disapproval of reports and documents. The second is the dispute resolution section that must be followed prior to enforcement action.

[12] This Order does not address all of the issues raised by the petitioners. The Board finds that the issues that are not addressed are insubstantial and not appropriate for State Water Board review. (See *People v. Barry* (1987) 194 Cal.App.3d 158, [239 Cal.Rptr. 349], Cal. Code Regs., tit. 3, § 052.)
[13] Permit, Part 2, III.A.1.c.
[14] Permit, Part 2, III.A.2.
[15] Permit, Part 2, I.G.
[16] *Id*.

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The process for review of documents that are subject to the Executive Officer's approval is that the Executive Officer will notify the permittees of the results of the review and approval or disapproval within 120 days. If the Executive Officer does not do so, the permittees must notify the Regional Water Board of their intent to implement the documents without approval. The Executive Officer then has 10 days to respond, or the permittees may implement the program and the Executive Officer may not make modifications.

The dispute resolution procedure is to be used when the Executive Officer determines that a permittee's storm water program is insufficient to meet the permit's provisions. The Executive Officer must send a "Notice of Intent to Meet and Confer" with the permittee. A meet and confer period then ensues, resulting in a written "Storm Water Program Compliance Amendment (SWPCA)." The permittee is provided time to comply with the SWPCA. The Executive Officer is not allowed to take enforcement action against a permittee until the Executive Officer notifies the permittee in writing that the administrative review process has been exhausted and that a violation exists warranting enforcement.

The petitioners contend that the Executive Officer failed to notify the permittees that their SUSMPs were inadequate within 120 days of its submittal. The petitioners also argue that, by revising the SUSMPs without pursuing the dispute resolution process, the Regional Water Board "violated" the terms of the permit.

The provision for review of documents, which clearly includes the SUSMPs, requires that the Executive Officer notify the permittees of the results of the review and approval or disapproval within 120 days. The County submitted the revised SUSMPs on August 12, 1999. Within 120 days, the Regional Water Board held a workshop where staff expressed their concerns with the SUSMPs. Also within 120 days the Regional Water Board itself held a public

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meeting where there was extensive discussion and concern by board members that the SUSMPs did not include a numeric standard. And, prior to any notification by the permittees that they would proceed with implementing their SUSMPs, the Regional Water Board held a hearing January 26, 2000, where it directed the Executive Officer to issue the SUSMPs with revisions. The Executive Officer did so on March 8, 2000.

It is clear from the record that the Executive Officer, and the Regional Water Board itself, did inform the permittees that the SUSMPs were inadequate. There was no requirement for a specific form for expressing disapproval of documents. The extensive discussion and meetings on the need for revisions to the SUSMPs, and the Executive Officer's approval of revised SUSMPs, plainly refutes the allegation that the Regional Water Board never notified the permittees of its disapproval of the County's proposed SUSMPs.

The permittees also claim that the Regional Water Board "violated" the permit by failing to institute the meet and confer process.[17] The dispute resolution process, which includes meet and confer, did not apply to the decision to disapprove the proposed SUSMPs. That process is only required when the Regional Water Board ultimately takes an enforcement action against a permittee. It is separate from the process for review and approval or disapproval of documents, and does not even appear to relate to possible enforcement actions for submission of inadequate documents. This is illustrated by the fact that the provision regarding documents refers to submittals from both the Principal Permittee and the individual permittees, while the dispute resolution provision refers only to the permittees. This distinction is relevant because the County is charged with submitting the documents, while the individual permittees are responsible for compliance. A fair reading of the entire section on the administrative review process is that the

[17] We note that permits are issued to permittees to allow discharges to waters of the state. It is only permittees, and not Regional Water Boards, who can be charged with violating permits.

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review and approval or disapproval of documents applies to submission of documents by the County on behalf of the cities, while the dispute resolution process applies to enforcement actions against any permittees for failing to implement adequate programs.

Contention: The petitioners contend that the Regional Water Board was not authorized to revise the SUSMPs to add more stringent requirements.

Finding: The petitioners contend that the mitigation standards in the SUSMPs are more stringent than the requirement in the permit to reduce pollutants in storm water runoff to the maximum extent practicable (MEP)[18]. The issue of what level of protection constitutes MEP will be discussed *Infra*, in the discussion of the reasonableness of the numeric standards. But the petitioners also make certain procedural claims on this point. They argue that in approving the BMP list, the Regional Water Board determined that those BMPs constituted MEP and that the Board could not add additional BMPs in the SUSMPs. They also contend the Regional Water Board itself had no authority to "usurp" the Executive Officer's role in reviewing the SUSMPs.[19] Finally, the petitioners contend that the Regional Water Board was not authorized to mandate a program for the permittees without amending the permit.

The permit requires the County to submit a list of BMPs for approval. The Regional Water Board approved this list. Following approval of the list, the County was required to submit the SUSMPs, which must "incorporate the appropriate elements of the recommended BMPs list."[20] The petitioners contend that by approving the list, the Regional Water Board determined that those BMPs constituted MEP, and that under the terms of the permit the Regional Water Board could not require additional BMPs.

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[18] The technology-based standard for controls under municipal storm water permits is MEP. For a fuller discussion of this standard, see Order WQ 91-03.

[19] It is undisputed that, at its January 26, 2000 meeting, the Board directed the Executive Officer to make additional revisions to the SUSMPs.

[20] Permit, Part 2, III.A.1.c.

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In addressing this contention, we face what appears to be a fundamental misunderstanding of the numeric design standards on the part of the petitioners. The design standards are objective criteria that developers must achieve in designing their BMPs. The design standards are not separate BMPs. The standards tell what magnitude of storm event the BMPs must be designed to treat or infiltrate. They do not specify the BMPs that must be employed.

The SUSMPs as submitted by the County specify BMPs for various categories of development. Many of these BMPs are designed to minimize the pollutants in storm water runoff, by reducing flow through infiltration or by treatment. Examples of BMPs proposed by the County include infiltration basins and trenches, oil/water separators, and media filtration. The County's proposed SUSMPs also included language requiring minimizing the introduction of pollutants to the storm water conveyance system. That language remains unchanged in the Final SUSMPs. The only significant difference between the two versions of the SUSMPs was that the Regional Water Board established numeric criteria for designing the BMPs.

In adopting the Final SUSMPs, the Regional Water Board based its decision on the MEP standard.[21] The Regional Water Board did not significantly revise the BMP list or specify further the actions that developers must take to comply with the SUSMPs. Thus, we find that the Regional Water Board did not inappropriately revise its determination of what constituted MEP.

The Regional Water Board is the political body responsible for water quality control in the Los Angeles region.[22] While the Regional Water Board may delegate specified powers and duties to its Executive Officer,[23] it can at any time act on its own behalf. The fact that the Board authorized its Executive Officer to approve the SUSMPs in the permit did not mean that the Board thereby denied itself the opportunity to provide direction to the Executive Officer in his

[21] Resolution R-00-02.
[22] Water Code sections 13200 and 13225.
[23] Water Code section 13223.

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approval. Such an interpretation of its delegation authority would result in an improper failure of the Board to assume responsibility for water quality in the region.

We also find that the Regional Water Board was authorized to revise the SUSMPs to achieve compliance with the permit's requirements. The SUSMPs are a part of implementation of the permit. Because the permit regulates storm water discharges throughout the entire Los Angeles region and it is implemented by 85 cities and the County, it is obvious that the permit could not spell out every detail of the program for the five-year term of the permit. Instead, the implementation is through the submission, review and approval, and implementation of various programs, including the SUSMPs.[24] Where it receives a submission that it finds is not consistent with the requirements of the permit, it is reasonable for the Regional Water Board to be able to require revisions. The Regional Water Board is not required to amend the permit each time it approves a submittal or approves a submittal with revisions. On the other hand, if the Regional Water Board's action in requiring revisions is inconsistent with the terms of the permit, then the Board should not act without first amending the permit. While the Regional Water Board could have required the County to make the revisions rather than making them itself, we see no harm in the Regional Water Board's approach.

As will be discussed below, in most respects the Final SUSMPs are consistent with the permit. But there are some portions of the SUSMPs that are not consistent, and in those cases the SUSMPs provisions are further revised in this Order.

Contention: The petitioners make various procedural claims, including that they were denied due process, and that the Regional Water Board violated the Administrative Procedure

[24] A fuller discussion of the use of storm water management plans to incorporate a developing program is found in Order No. WQ 91-03.

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Act, the California Environmental Quality Act (CEQA), and the California Constitution, Article XIII B, section 6 (regarding state mandates).

Finding: The petitioners point out that at the January 26, 2000 Regional Water Board hearing, there was some confusion over late changes to the SUSMPs and they contend they were not provided adequate opportunity to comment. There was significant discussion of the SUSMPs over several months. We do not agree with the petitioners that a program of this magnitude must necessarily take years to develop. But we are concerned that at the January 26, 2000 hearing, interested persons and permittees were not given adequate time to review late revisions or to comment on them. Given the intense interest in this issue, the Regional Water Board should have diverged from its strict rule limiting individual speakers to three minutes and conducted a more formal process. Such a process should provide adequate time for comment, including continuances where appropriate.[25] But to the extent the Regional Water Board's process caused any harm, this Board cured those harms. We held a two-day hearing in Los Angeles County, where all parties were allowed significant time to present their positions and testimony. In addition, we allowed the introduction of new evidence that had not been presented to the Regional Water Board. At this point, all parties have been afforded a full opportunity to review the Final SUSMPs, to present their positions and evidence, and to engage in cross-examination. The petitioners' due process rights have been protected.

The Board has already addressed the contentions regarding compliance with other laws in prior decisions. The Administrative Procedure Act exempts the adoption of permits from its requirements.[26] While the SUSMPs are not a permit, they are implementing documents for a

[25] For future adjudicative proceedings that are highly controversial or involve complex factual or legal issues, we encourage regional water boards to follow the procedures for formal hearings set forth in Cal. Code of Regs., tit. 23, section 648 et seq.

[26] Government Code section 11352; See, Order No. 95-4 (In the Matter of the City and County of San Francisco).

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permit, and are therefore subject to the exemption. Moreover, they are relevant only to this permit, and are not a general rule of application. The constitutional provisions regarding state mandates also do not apply to NPDES permits.[27] As will be explained below, the SUSMPs as revised herein, are consistent with MEP and therefore are federally mandated. The provisions of CEQA requiring adoption of environmental documents also do not apply to NPDES permits.[28] Again, as an implementing document for the permit, there is no requirement for a separate CEQA analysis.[29]

Contention: The petitioners contend that the SUSMPs do not properly apply the maximum extent practicable standard.

Finding: The permit, consistent with Clean Water Act section 402(p)(3)(B)(iii), requires controls to reduce the discharge of pollutants to the maximum extent practicable, or MEP.[30] In approving the Final SUSMPs, the Regional Water Board acknowledged that one of the primary objectives of the municipal storm water program is the requirement to reduce the discharge of pollutants from storm water conveyance systems to the MEP.[31] While all parties appear to agree that the standard for the SUSMPs is MEP, they disagree about what level of effort is necessary to comply with that standard.

The petitioners approach this issue from two angles. First, they contend that the SUSMPs will not provide water quality benefits that reflect MEP. Second, they contend that there could be adverse impacts on groundwater quality that have not been adequately evaluated.

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[27] See, Order No. WQ 90-3 (In the Matter of San Diego Unified Port District).
[28] Water Code section 13389.
[29] We do note with interest the environmental groups' comment that if the permittees believed it was necessary to comply with the APA and CEQA prior to adoption of the SUSMPs, then they themselves would have violated those acts in their submissions of the proposed SUSMPs.
[30] Permit, Finding 13.
[31] Final SUSMPs, at page 2; Resolution No. R-00-02, at page 3.

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Storm Water Design Standards as MEP

In adopting the Final SUSMPs, the Regional Water Board found that many rivers and streams in Los Angeles County are impaired for pollutants found in storm water and urban runoff, and that storm water runoff carries pollutants from nearly all types of developed properties.[32] Pollutant loading from the aggregate of development in the basin results in impairments from sediments, metals, complex organic compounds, oil and grease, nutrients, and pesticides.[33] The Final SUSMPs reflect two goals: to reduce the amounts of these pollutants in runoff and to reduce the ability of runoff to act as a conveyance system to deliver more pollutants to receiving waters. The Final SUSMPs, which include lists of BMPs and design standards requiring treatment or infiltration, address these two goals.

Clean Water Act section 402(p)(3)(B)(iii), which sets forth the requirements for establishing MEP in municipal storm water permits, provides that such permits "shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." The United States Environmental Protection Agency (U.S. EPA), in a guidance document, explains that BMPs should be used in first-round storm water permits, and "expanded or better-tailored BMPs in subsequent permits, where necessary, to provide for the attainment of water quality standards."[34] The Clean Water Act, as interpreted by U.S. EPA, does require that, in a second-round permit,[35] expanded BMPs may be appropriate. In light of the number of water

[32] Resolution No. R-00-02.
[33] *Id*.
[34] Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits, 61 Federal Register 57425 (1996).
[35] The original permit was issued in 1990. The 1996 permit is a second-round permit.

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bodies impaired by runoff in Los Angeles County, it was appropriate to expand the scope of BMPs during the permit term.

The regulations implementing section 402(p) specifically require municipalities to have controls to reduce the discharge of pollutants from their storm sewer systems that "receive discharges from areas of new development and significant redevelopment," including post-construction discharges.[36] Clearly, it was appropriate for the Regional Water Board to require BMPs for new development and significant redevelopment. The permittees, who submitted their own version of SUSMPs with listed BMPs for categories of development, appear to have no real quarrel with this general mandate.

This Board has already endorsed requirements to limit the flow of the "first flush" of storm water, which may contain more significant pollutants.[37] The permittees' own version of the SUSMPs required mitigation of storm water runoff by treatment or infiltration, thus conceding the propriety of these two approaches to lessening the impact of storm water discharges. The crux of the disagreement is that the Regional Water Board added numeric design standards to establish the amount of runoff that must be treated or infiltrated, and required the mandatory application of these standards to categories of development.

The addition of measurable standards for designing the BMPs provides additional guidance to developers and establishes a clear target for the development of the BMPs. The U.S. EPA guidance manual suggests the use of design criteria and performance standards for post-construction BMPs.[38] The numeric criteria the Regional Water Board adopted essentially

[36] 40 CFR section 122.26(d)(2)(iv)(A)(2).
[37] In the Matter of National Steel and Shipbuilding Company, et al., Order WQ 98-07, at slip opinion 7.
[38] Guidance Manual for the Preparation of Part 2 of the NPDES Permit Applications for Discharges from Municipal Separate Strom Sewer Systems, at page 6-4 (November 1992).

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requires that 85 percent of the runoff from the development be infiltrated or treated.[39] In adopting these standards, the Regional Water Board based its decision on a research review of standards in other states and a statistical analysis of the rainfall in the area. The standard was set to gain the maximum benefit in mitigation while imposing the least burden on developers.[40] In light of the evidence of the use of this or more stringent standards in other states, the expert testimony supporting this standard, the endorsement by U.S. EPA in its comments, and the cost-effectiveness of its implementation (discussed below), the Regional Water Board acted appropriately in determining that the standards reflect MEP.[41]

We also find that the Regional Water Board appropriately applied these standards to seven of the categories listed in the SUSMPs: single-family hillside residences, 100,000 square foot commercial developments, automotive repair shops, restaurants, home subdivisions with 10 to 99 housing units, home subdivisions with 100 or more housing units, and parking lots with 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to storm water runoff.[42] These categories, except for parking lots, were already targeted for special treatment in the permit. The evidence shows that each listed category can be a significant source of pollutants and/or runoff following development. It is appropriate that the design standards apply so that BMPs for these categories of development result in the infiltration or treatment of a significant about of the runoff.

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[39] Four different methods of calculation are permitted, so the percentage of capture may vary slightly.

[40] At the hearing in this matter, Regional Water Board staff explained that the standard was set at the bottom of the "knee" of the curve where the benefits of the mitigation requirements decrease and the cost increases. Other states have set the standard higher along this curve, requiring 90 to 95 percent mitigation.

[41] This conclusion in no way departs from our acceptance of BMPs in lieu of numeric effluent limitations in storm water permits. (See, e.g., Order WQ 91-03 and Order WQ 91-04.) The numeric standard is a design standard for BMPs. It does not quantify or limit the pollutants in the effluent. It also does not specify which of the listed BMPs must be employed.

[42] As discussed below, this Board is revising the SUSMPs to delete the application of the design standards to retail gasoline outlets and to locations within or directly adjacent to or discharging directly to environmentally-sensitive areas.

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Potential Impacts on Ground Water

The petitioners contend that infiltration of runoff may lead to ground water pollution, and that the Regional Water Board did not properly consider such potential impacts. The mitigation standards provide for a waiver where there is a risk of ground water contamination because a known unconfined aquifer lies beneath the land surface or an existing or potential underground source of drinking water is less than ten feet from the soil surface.[43] The Final SUSMPs also include a discussion on how to use infiltration so that the risk of contamination of groundwater is reduced, and where infiltration is not appropriate.[44]

The Regional Water Board did consider the potential impacts to groundwater from infiltration, and included appropriate limitations and guidance on its use as a BMP. These provisions will ensure adequate protection of groundwater from any adverse impacts due to infiltration.

Contention: The petitioners contend the Regional Water Board failed to show that the SUSMPs as adopted are cost-effective and that the benefits to be obtained outweigh the costs.

Finding: The petitioners refer to the Preamble to the Phase II storm water regulations[45] as the basis for their economic argument. The quoted language, however, does not wholly support the petitioners' contention. The Preamble states that President Clinton's Clean Water Initiative clarifies "that the maximum extent practicable standard should be applied in a site-specific, flexible manner, taking into account cost considerations as well as water quality effects."[46] It is clear that cost should be considered in determining MEP; this does not mean that

[43] Final SUSMP, page 14.
[44] *Id*., at page 15.
[45] 64 Federal Register 68722 and following. These regulations do not apply to the permit, but the general language on MEP is relevant to EPA's interpretation of the standard.
[46] 64 Federal Register 68722, 68732 (December 8, 1999).

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the Regional Water Board must demonstrate that the water quality benefits outweigh the economic costs.

While the standard of MEP is not defined in the storm water regulations or the Clean Water Act, the term has been defined in other federal rules. Probably the most comparable law that uses the term is the Superfund legislation, or CERCLA, at section 121(b). The legislative history of CERCLA indicates that the relevant factors, to determine whether MEP is met in choosing solutions and treatment technologies, include technical feasibility, cost, and state and public acceptance.[47] Another example of a definition of MEP is found in a regulation adopted by the Department of Transportation for onshore oil pipelines. MEP is defined as to "the limits of available technology and the practical and technical limits on a pipeline operator . . . ."[48]

These definitions focus mostly on technical feasibility, but cost is also a relevant factor. There must be a serious attempt to comply, and practical solutions may not be lightly rejected. If, from the list of BMPs, a permittee chooses only a few of the least expensive methods, it is likely that MEP has not been met. On the other hand, if a permittee employs all applicable BMPs except those where it can show that they are not technically feasible in the locality, or whose cost would exceed any benefit to be derived, it would have met the standard. MEP requires permittees to choose effective BMPs, and to reject applicable BMPs only where other effective BMPs will serve the same purpose, the BMPs would not be technically feasible, or the cost would be prohibitive. Thus while cost is a factor, the Regional Water Board is not required to perform a cost-benefit analysis.

In reviewing the record, it is apparent that the Regional Water Board did evaluate the cost of the SUSMPs. While the petitioners claim there is no evidence in the record to show the

[47] 132 Cong. Rec. H 9561 (Oct. 8, 1986).
[48] 49 CFR section 194.5.

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SUSMPs are necessary and cost effective, the opposite is true. The record is replete with documentation of costs of pilot mitigation projects, studies from similar programs in other states, and research studies. The Regional Water Board complied with the requirement to consider cost.

The Regional Water Board found that the cost to include BMPs that will meet the mitigation criteria will be one to two percent of the total development cost. This amount appears reasonable, especially in light of the amount of impervious surface already in Los Angeles County and the impacts on impaired water bodies. In considering the cost of compliance, it is also important to consider the costs of impairment. The beach closures in the Los Angeles region, well documented in the evidence, have reached critical proportions. These beach closures clearly have a financial impact on the area, and should be positively affected by the SUSMPs.

We do note that there could be further cost savings for developers if the permittees develop a regional solution for the problem. We recommend that the cities and the County, along with other interested agencies, work to develop regional solutions so that individual dischargers are not forced to create numerous small-scale projects. While the SUSMPs are an appropriate means of requiring mitigation of storm water discharges, we also encourage innovative regional approaches.[49]

Contention: The petitioners have raised contentions regarding details of the SUSMPs, including the amount of time allowed for inclusion of SUSMPs in local ordinances, and their application to both "discretionary" and "non-discretionary" projects. In addition, during the hearing certain ambiguities in the wording of the Final SUSMPs became apparent, including the provisions regarding redevelopment and environmentally-sensitive areas. In this portion of the

[49] We note that the SUSMPs as written do not in any way preclude the development of regional solutions approved by the Regional Water Board as a means to comply with the BMP and design standard requirements.

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Order we address these issues and also the application of the design standards to retail gasoline outlets (RGOs) and the waiver funding requirements.

Finding: The testimony at the hearing in this matter revealed that there are specific provisions of the SUSMPs that create confusion as to the types of development projects subject to the mitigation design standards. The petitioners also contend that application of the standards to specific types of development either is unreasonable or is inconsistent with the terms of the permit. The specific requirements are discussed below.

Retail Gasoline Outlets

Petitioner WSPA contends that RGOs should be excluded from the SUSMPs. Its petition raised the same general contentions as the other petitioners, but at the hearing WSPA presented evidence specific to RGOs. In particular, WSPA raised questions about the propriety of applying the design standards for BMPs to RGOs. In considering this issue, we conclude that construction of RGOs is already heavily regulated and that owners may be limited in their ability to construct infiltration facilities. Moreover, in light of the small size of many RGOs and the proximity to underground tanks, treatment may not always be feasible, or safe. The mandatory BMPs that are included in the SUSMPs may be adequate to achieve MEP at RGOs, but the Regional Water Board should add additional mandatory BMPs, such as use of dry cleanup methods (e.g. sweeping) for removal of litter and debris, use of rags and absorbents for leaks and spills, restricting the practice of washing down hard surfaces unless the wash water is collected and disposed of properly, annual training of employees on proper spill cleanup and waste disposal methods, and the inclusion of BMPs to address trash receptacle areas and air/water supply

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areas.[50] We conclude that because RGOs are already heavily regulated and may be limited in their ability to construct infiltration facilities or to perform treatment, they should not be subject to the BMP design standards at this time, and recommend that the Regional Water Board undertake further consideration of a threshold relative to size of the RGO, number of fueling nozzles, or some other relevant factor. This Order should not be construed to preclude inclusion of RGOs in the SUSMP design standards, with proper justification, when the permit is reissued.

.

Redevelopment Projects

The SUSMPs were written to apply to new development and to some types of redevelopment in nine categories of projects. The definition of "redevelopment" reflected the intent of the Regional Water Board to define the scope of redevelopment projects subject to the requirements. That definition[51], however, was somewhat confusing, and it was apparent from testimony at the hearing that the parties had different understandings of the scope of redevelopment subject to the SUSMPs. In their post-hearing briefs, the various parties appeared to agree on the actual intent of the Regional Water Board in including redevelopment in the SUSMPs. This intent was to include redevelopment that adds or creates at least 5,000 square feet of impervious surface to the original development and, where the addition constitutes less than 50 percent of the original development, to limit the application of the BMP design standards to the addition.

[50] These BMPs are from a list of BMPs in a publication of the California Storm Water Quality Task Force. (Best Management Practice Guide – Retail Gasoline Outlets. March 1997.) This publication includes BMPs in addition to those listed in the SUSMPs. All BMPs recommended in this publication should be mandated.

[51] The SUSMPs state: "Redevelopment" means, on an already developed site, the creation or addition of at least 5,000 square feet of impervious surfaces or the creation or addition of fifty percent or more of impervious surfaces or the making of improvements to fifty percent or more of the existing structure. Redevelopment includes, but is not limited to: the expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities related with structural or impervious surfaces.

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While some parties requested further requirements for development, it appears that the Regional Water Board's original intent was relatively simple to apply and results in a fair and appropriate application of the SUSMPs' requirements to redevelopment. Therefore, we will revise the definition in the SUSMPs accordingly.

Environmentally-Sensitive Areas

The permit required that the SUSMPs address at least seven development categories.[52] The final SUSMPs added two more categories: parking lots of 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to storm water runoff; and location within or directly adjacent to an environmentally-sensitive area (ESA). The petitioners contend that the addition of ESAs was inappropriate because the permit refers only to "development categories"[53] and ESA is a location category.

Whether or not the Regional Water Board went beyond the permit's terms in including this category, we find a fundamental problem with the language of the SUSMPs regarding ESAs. All of the other categories are relatively simple to apply because they describe the types of development that fall within the category. For instance, the threshold for a commercial development is 100,000 square feet. If the development is smaller, it is not subject to the SUSMPs. But for developments within ESAs, the SUSMPs contain no threshold. This absence led to speculation by the petitioners that something as small as a new patio on a home in an ESA would make the SUSMPs applicable. The Regional Water Board, at the hearing and in its post-hearing brief, conceded that there should be some threshold. While the Regional Water Board

[52] The categories listed in the permit are: single-family hill residences, 100,000 square-foot commercial developments, automotive repair shops, retail gasoline outlets, restaurants, home subdivisions with 10 to 99 housing units, and home subdivisions with 100 or more housing units. Permit, Part 2, III.A.1.c.
[53] *Id*.

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did recommend a specific threshold, we believe that it is inappropriate for this Board to add a threshold that has not been fully discussed by all interested persons.

While it may be appropriate to include more stringent controls for developments in ESAs, we also note that such developments are already subject to extensive regulation under other regulatory programs. Moreover, in light of the permit language limiting the SUSMPs to development categories, ESAs are not an appropriate category within the SUSMPs. The Regional Water Board may choose to consider the issue further when it reissues the permit.

Discretionary and Non-Discretionary, or Ministerial, Projects

The petitioners contend that the SUSMPs should apply only to projects that are considered "discretionary" within the meaning of California Environmental Quality Act (CEQA).[54] They argue that the inclusion of non-discretionary, or ministerial, projects is inconsistent with the terms of the permit.

The permit provisions on development projects do refer to "discretionary" projects in several places. The permittees are directed to develop a checklist for determining priority and exempt projects.[55] Priority projects are defined as development and redevelopment projects requiring discretionary approval, which may have a potential significant effect on storm water quality.[56] The permittees are also required to develop a BMP list.[57] In developing the SUSMPs, the permittees are required to incorporate appropriate elements of the BMP list.[58] Next, the permittees must develop a program on planning control measures for priority projects (which are limited to projects requiring discretionary approval), consistent with the list of BMPs and the

[54] Public Resources Code section 21000 *et seq*.
[55] Permit, Part 2, III.A.1.a.
[56] *Id*.
[57] Permit, Part 2, III.A.1.b.
[58] Permit, Part 2, III.A.1.c.

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SUSMPs.[59] The permit further states that, in order to assure compliance with these requirements, the permittees must develop guidelines on preparing CEQA documents that link mitigation conditions to "local discretionary project approvals."[60]

Taken as a whole, the provisions of the permit appear to link the development requirements for SUSMPs to developments that receive discretionary approval by local governments, as defined in CEQA. The SUSMPs are an implementation tool for the permit and must be consistent with the permit. While the limitation of the SUSMPs to discretionary projects may not be sufficiently broad for an effective storm water control program, the Regional Water Board acted inappropriately in expanding the SUSMPs to include non-discretionary projects. The Regional Water Board may consider expanding the development controls beyond CEQA discretionary projects when it reissues the permit. But at this time, the SUSMPs must be revised so that they are limited to development projects requiring discretionary approval within the meaning of CEQA.[61]

Waiver Funding Requirement

Where a waiver is granted from the design standard requirements, the Final SUSMPs provide that the permittee must require the project proponent to transfer the cost savings to a storm water mitigation fund. The fund is to be operated by a public agency or a non-profit entity, to promote regional or alternative solutions for storm water pollution in the same storm watershed. The petitioners contend that the funding requirement will create an additional administrative burden.

[59] Permit, Part 2, III.a.2.
[60] Permit, Part 2, III.a.3.b.
[61] We note that the Final SUSMPs already include a definition of "discretionary project" consistent with the definition in the CEQA guidelines. Final SUSMPs at page 4 of 25; Title 14, California Code of Regulations, section 15357. Apparently this definition was inadvertently retained after the Regional Water Board decided to expand the SUSMPs beyond discretionary projects.

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The concept of a mitigation fund or "bank" is a positive idea for obtaining regional solutions to storm water runoff. As a long-term strategy, municipal storm water dischargers should work to establish regional mitigation facilities, which may be more cost-effective and more technically effective than mitigation structures at individual developments. But at this point there are not sufficient resources in place to require all permittees to establish such funds or to find appropriate non-profit organizations. Before mandating funding, preliminary questions should be answered, including who will manage the fund, what types of projects it will be used for, what entities can legally operate such funds, and how permittees will determine the amount of the assessments. It would be appropriate for the County to consider developing a program with the appropriate flood control agency, or as a model for the separate cities to develop. There may be suitable agencies to administer such funds, but the development of programs may take some time. The Regional Water Board should consider adopting such a program when it reissues the permit, after consultation with the appropriate local agencies.

III. CONCLUSIONS

Based on the discussion above, the Board concludes that:

1. The Regional Water Board complied with the procedural requirements of the permit, including the Administrative Review Process, in approving the Final SUSMPs.
2. The Regional Water Board was authorized to revise the SUSMPs by including more stringent requirements than the permittees had proposed.
3. The Regional Water Board complied with did not violate the Administrative Procedure Act, CEQA, or the Constitutional provisions on state mandates. The petitioners' due process rights have been protected
4. The Regional Water Board considered the costs of the SUSMPs, and acted reasonably in requiring these controls in light of the expected benefits to water quality.

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5. The Final SUSMPs reflect a reasonable interpretation of development controls that achieve reduction of pollutants in storm water discharges to the maximum extent practicable.
6. The SUSMPs include adequate protections of groundwater quality from any impacts from infiltration.
7. The SUSMPs will be revised to clarify the intent of the Regional Water Board and to make them consistent with the permit. Specifically, retail gasoline outlets should not be subject to the BMP design standards because they are already heavily regulated and may be limited in their ability to construct infiltration facilities or to perform treatment. Redevelopment projects should be subject to the SUSMPs only if they result in creation or addition of 5,000 square feet of impervious surfaces. Environmentally-sensitive areas should not be listed as a category in the SUSMPs. The SUSMPs should only apply to discretionary projects. The requirement for funding by project proponents who receive waivers should be deleted. The SUSMPs will be amended as shown in the attachment to this Order.
8. In light of the revisions of the SUSMPs made by this Order, and to allow the permittees adequate time to adopt implementing ordinances, the deadline for adopting ordinances will be revised to January 15, 2001, and the effective date of the Final SUSMPs will be revised to February 15, 2001.

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IV. ORDER

IT IS HEREBY ORDERED that the Standard Urban Storm Water Mitigation Plans for Los Angeles County and Cities in Los Angeles County is revised consistent with the amendments attached hereto. In all other respects the petitions are dismissed.

CERTIFICATION

The undersigned, Administrative Assistant to the Board, does hereby certify that the foregoing is a full, true, and correct copy of an order duly and regularly adopted at a meeting of the State Water Resources Control Board held on October 5, 2000.

AYE: Arthur G. Baggett, Jr.
Mary Jane Forster
John W. Brown

NO: None

ABSENT: Peter S. Silva

ABSTAIN: None

/s/
Maureen Marché
Administrative Assistant to the Board

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AMENDMENTS TO SUSMPS

[These amendments are to the Final SUSMP, as published March 8, 2000]

Page 3 of 25

First full paragraph:

All **discretionary development and redevelopment** projects that fall into one of ~~seven~~ **the following** categories are ~~identified in the Los Angeles County MS4 Permit as requiring~~ **subject to these** SUSMPs. These categories are:

- Single-family Hillside Residences
- 100,000 Square Foot Commercial Developments
- Automotive Repair Shops
- Retail Gasoline Outlets
- Restaurants
- Home Subdivisions with 10 to 99 housing units
- Home Subdivisions with 100 or more housing units
- **Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to storm water runoff**

Second full paragraph:

~~The Regional Board Executive Officer has designated two additional categories subject to SUSMP requirements for the Los Angeles County MS4 Permit. These categories are:~~

- ~~Location within or directly adjacent to or discharging directly to an environmentally sensitive area, and~~
- ~~Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to storm water runoff~~

Fourth full paragraph:

Permittees shall amend codes, if necessary, not later than ~~September 8, 2000~~ **January 15, 2001**, to give legal effect to the SUSMP requirements. The SUSMP requirements for projects identified herein shall take effect not later than ~~October 8, 2000~~ **February 15, 2001**.

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Delete definition of "Environmentally Sensitive Area"

Revise Definition of "Redevelopment":

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"Redevelopment" means, on an already developed site, the creation or addition of at least 5,000 square feet of impervious surfaces ~~or the creation or addition of fifty percent or more of impervious surfaces or the making of improvements to fifty percent or more of the existing structure~~. Redevelopment includes, but is not limited to: the expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routing maintenance activity; and land disturbing activities related with structural or impervious surfaces. **Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to these SUSMPs, the Design Standards apply only to the addition, and not to the entire development.**

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Add to "Limited Exclusion": Retail Gasoline Outlets

Page 15 of 25

Delete the first full paragraph (storm water mitigation funding)

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Parking Spaces / Community Places

Finding the Balance through Smart Growth Solutions





Parking Spaces / Community Places

Finding the Balance through Smart Growth Solutions

Development, Community, and Environment Division (1807T)
U.S. Environmental Protection Agency
Washington, DC 20460

EPA 231-K-06-001
January 2006

Acknowledgements

This guidebook was compiled by U.S. EPA's Development, Community, and Environment Division (DCED) and contractors using existing and new case studies, current bibliographical research, and interviews with experts. The work was funded through EPA Contracts 68-W4-0041 and 68-W-99-046. DCED would like to thank representatives of the following organizations for their participation in developing this report: City Carshare; Institute of Transportation Engineers; Lindbergh City Center; McCaffery Interests; Melvin Mark Companies; NASA Ames Research Center; Prendergast & Associates, Inc.; SAFECO; TransManagement; Valley Transit Authority; the Cities of Wilton Manors (Florida), Long Beach (California), Miami Beach, Milwaukee, and Seattle; Arlington County, Virginia; and the developers of the Van Ness and Turk project and the Rich Sorro Commons project described in this report. DCED is grateful for the contributions of these participants.

In addition, DCED would like to thank the following individuals for their comments on drafts of the document. Organizations are provided for identification purposes only.

Robert Dunphy, Urban Land Institute
Kenneth Fritz, Village of Schamburg, Illinois
Christopher Hudson, Congress for New Urbanism
Todd Juhasz, Westchester County Department of Planning
Michael R. Kodama, Michael R. Kodama Planning Consultants
Todd Litman, Victoria Transport Policy Instititute
Thomas Robertson, Montgomery County Department of Park and Planning
Timothy Rood, Calthorpe Associates
Dr. Richard Wilson, California State Polytechnic University
Staff from the U.S. DOT's Federal Highway Administration and Federal Transit Administration

Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

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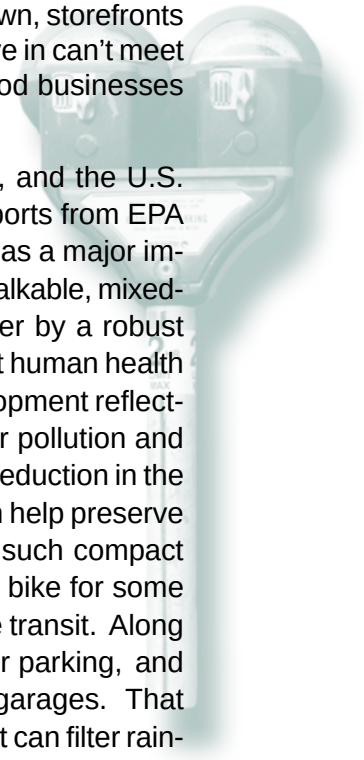
Introduction

When you shop, you may visit a mall, or go to your town's main street. At the mall, you probably cruise past rows and rows of empty parking, the spaces filled only one day a year. Maybe you head downtown, but can only find vacant storefronts. And where things are bustling, you can't find convenient parking near the stores you want to visit. All three of these scenarios represent a "parking problem" that has a negative impact on other community goals. At the mall, overbuilt parking consumes land and wastes money. Downtown, storefronts may sit empty because new businesses that would like to move in can't meet high parking requirements – and too little parking makes good businesses less viable.



But what does parking have to do with the environment, and the U.S. Environmental Protection Agency (EPA)? Research and reports from EPA and others show that the way we develop our communities has a major impact on the quality of the natural environment. Regions with walkable, mixed-use, compact neighborhoods, towns, and cities, knit together by a robust network of transportation and environmental corridors, protect human health and the natural environment. The research shows that development reflecting smart growth principles can lead to reduced growth in air pollution and less polluted runoff into streams and lakes. It also leads to a reduction in the amount of pristine land consumed by development, which can help preserve habitat for many species. Air pollution is reduced because such compact areas make it easier for some people to choose to walk and bike for some trips, and others will be able to drive shorter distances or take transit. Along with fewer and shorter trips by car comes a reduced need for parking, and that means less land needs to be paved for parking lots or garages. That reduces development costs and leaves more open ground that can filter rainwater, and more open space for birds, animals, and people to enjoy. For a thorough discussion of the connections between development patterns and environmental quality, see *Our Built and Natural Environments: A Technical Review of the Interactions Between Land Use, Transportation, and Environmental Quality* (EPA, 2001a).

Many communities are evaluating parking issues as part of a broader process of reevaluating their overall goals for growth. They want and need new residents and jobs – for vitality, economic growth, and other reasons – but they need to decide how and where to accommodate them. In cities, towns, and countryside, new and newly rediscovered development patterns offer solutions. In many places, walkable town centers that offer stores, workplaces, and housing in close proximity are replacing malls and office parks, offering shops and dining along with places to live and work. New neighborhoods offer different housing types and daily conveniences within a pleasant, safe walking distance. Vacant, underused and contaminated sites

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can be reclaimed and benefit their communities with new jobs and housing, improved recreational opportunities, and increased fiscal stability. Many communities are working to offer choices to residents, so they can take a train, ride a bike, or walk instead of driving, if that is what is best for them and their families. Whether the resulting development patterns are called smart growth, quality growth, or balanced growth, they work by creating great places.

Communities and developers recognize that compact, mixed-use, walkable places need parking to thrive. Retail activity in particular requires convenient parking spaces that can handle high turnover. Businesses almost always need some parking for their employees, but the amount needed can vary widely. The need for parking may shift throughout the day as people come to shop, employees head to work, and residents go out for the evening. Residents and employees in more compact areas usually own fewer cars and drive less than is typical in conventional developments. Yet typical parking regulations and codes simply require a set amount of parking for a given square footage or number of units, assuming all trips will be by private automobile and ignoring the neighborhood's particular mix of uses, access to transit and walking, and context within the metropolitan region. Such inflexible parking requirements can force businesses to provide unneeded parking that wastes space and money. The space and money devoted to unnecessary parking could be used to accommodate other homes, businesses, shopping, or recreational opportunities in the community. In some cases, rigid parking standards can discourage or even prevent development, because providing it is just too expensive -- and developers are usually offered no alternative.

In cities and counties across the country, inflexible minimum parking requirements are the norm -- but they represent a barrier to better development, including redevelopment of vacant city land and contaminated sites. EPA developed this guide for local government officials, planners, and developers in order to:

- demonstrate the significance of parking decisions in development patterns;
- illustrate the environmental, financial, and social impact of parking policies;
- describe strategies for balancing parking with other community goals; and
- provide case studies of places that are successfully using these strategies.

The policies described in this report can help communities explore new, flexible parking policies that can encourage growth and balance their parking needs with their other goals. The case study in this report of the SAFECO Corporation (see page 50) illustrates the potential to use parking policies to

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save money, improve the environment, and meet broader community goals. SAFECO has its corporate headquarters in the Seattle region. To accommodate new employees, this insurance company built three new buildings and underground parking garages. In an effort to balance parking needs with their financial, environmental, and design goals, they choose to offer employees transit passes, vanpool and rideshare incentives, or parking. Over 40 percent of SAFECO's employees choose an alternative to driving alone. As a result, each year SAFECO's 1700 employees drive about 1.2 million miles less than average commuters in the Seattle region, saving 28 tons of carbon monoxide, a serious pollutant tracked by the EPA. SAFECO also reduced the amount of ground that needed to be paved by 100,000 square feet, leading to less runoff in this rainy area. The company saves an estimated $230,000 per year, after accounting for the costs of incentives and the savings from reducing the amount of parking built.

Several EPA programs recognize the superior environmental performance of alternatives to driving alone and to conventional low-density, single-use development patterns. For example, EPA and the U.S. Department of Transportation sponsor the successful Best Workplaces for Commuters program (EPA, 2005a), which advocates employer-provided commuter benefits that encourage shifts from long-distance solo driving and parking. On a regional level, EPA offers areas that wish to recognize the emissions benefits of smart growth guidance for "Improving Air Quality Through Land Use Activities" (EPA, 2001b). EPA has also published "Protecting Water Resources with Smart Growth" (EPA, 2004), which includes 75 policies and programs that help meet water quality and other community goals. EPA and its partners in the Smart Growth Network (see box) also offer very successful resources on the policies and actions that create smart growth. "Getting to Smart Growth" (ICMA, 2002) and "Getting to Smart Growth II" (ICMA, 2003), published by the International City/County Management Association and the Smart Growth Network, detail 200 policies that communities have used to create new development to serve the needs of their residents and businesses, local governments, and the environment. For more information on these and other resources, and instructions on how to receive them, visit www.epa.gov/smartgrowth.

This report adds to this collection of resources, pointing communities and developers to proven techniques for balancing parking and other goals to enhance the success of new compact walkable places. The report begins with a discussion of the demand for parking and a review of the costs of parking. The following sections detail innovative techniques and case studies explain how they have been used to solve parking problems in specific places.

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Principles of smart growth

Smart growth is development that serves communities, the economy, public health, and the environment. The original Smart Growth Network partners articulated the following principles describing smart growth, based on their experience in communities nationwide. These principles have since been adopted by many organizations and communities to help describe the development patterns they seek to create.

1. Mix land uses.

2. Take advantage of compact building design.

3. Create a range of housing opportunities and choices.

4. Create walkable neighborhoods.

5. Foster distinctive, attractive communities with a strong sense of place.

6. Preserve open space, farmland, natural beauty, and critical environmental areas.

7. Strengthen and direct development toward existing communities.

8. Provide a variety of transportation choices.

9. Make development decisions predictable, fair, and cost-effective.

10. Encourage community and stakeholder collaboration in development decisions.

For more information, visit www.epa.gov/smartgrowth.

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About the Smart Growth Network

The Smart Growth Network, formed in 1996, is a loose coalition of organizations and individuals that believe that where and how we grow is important to our communities, health, and environment. The network is led by a partnership of over thirty private sector, public sector, and nongovernmental organizations that work to help create better development patterns in neighborhoods, communities, and regions across the United States. It also includes a membership organization of over 900 individuals, community organizations, and other stakeholder groups. These organizations endorse the principles listed on the previous page.

The Smart Growth Network partners range from planners and architects to developers and financiers and funders, from community advocates to traditional environmentalists, from real estate agents to transportation engineers, and include both governmental associations and parts of the federal government. For more information on the Smart Growth Network, its partners and membership program, and the annual New Partners for Smart Growth conference, visit www.smartgrowth.org.

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Beyond Generic Parking Requirements

In calculating parking requirements, planners typically use generic standards that apply to individual land-use categories, such as residences, offices, and shopping. The most commonly used guidelines, issued by the Institute of Transportation Engineers in the Parking Generation Handbook (ITE, 2004), are based on observations of peak demand for parking at single-use developments in relatively low-density settings with little transit (Shoup, 2005). In such places, the destinations are widely separated, parking is typically free, and walking, biking, and transit are not available. As a result, planners assume in effect that every adult has a car, every employee drives to work, and every party visiting a restaurant arrives by car. Under these conditions, parking can take up more than 50 percent of the land used in a development (see figure). For more compact, mixed-use, walkable places, these standards end up calling for far more parking than is needed.

A surplus of parking really can be too much of a good thing. It creates a 'dead zone' of empty parking lots in the middle of what ought to be a bustling commercial district or neighborhood. This dead zone means there is less room for the offices and homes that would supply a steady stream of office workers and residents who might patronize businesses in the area -- and less room to cluster other businesses that will attract more foot traffic. Requiring more parking than the market actually demands adds substantial costs to development and redevelopment, and in some cases the added costs will prevent development altogether. For example, the future site of the D'Orsay Hotel in a prime location in Long Beach, California sat for years as a low-revenue parking lot -- every developer who considered building on it was stopped in part by the high cost of building a garage to fulfill the city's minimum parking requirement. It is under development today as a hotel and retail complex in large part because innovative strategies reduced the parking burden on the developer. See page 52 for the full case study.

Most planners surveyed relied on neighboring cities and national handbooks to determine parking requirements. This practice may result in inappropriate requirements if local conditions or policy approaches differ.

— Michael Kodama, Michael R. Kodama Planning Associates

Parking requirements are often copied from one jurisdiction to another, and so are remarkably consistent across different cities. Generic standards do not take into account the many highly local variables that influence parking, such as density, demographics, availability of public transit, potential for biking and walking, or the availability of other parking nearby. The obvious results of such rigid requirements are big empty parking lots -- and they can also result in empty buildings. Perfectly useable space in older buildings with limited or no on-site parking may prove unrentable, because the businesses that would like to locate there are unable to meet high minimum parking requirements. The buildings remain vacant, thwarting redevelopment plans (Shoup, 2005).

Generic parking standards have simply not kept up the complexity of mod-

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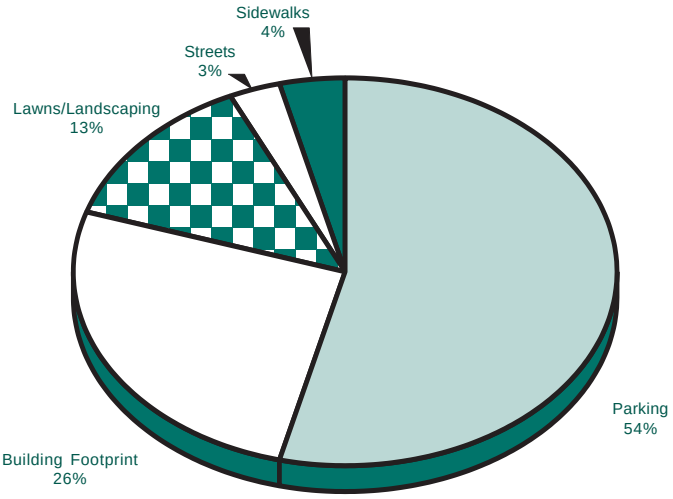
ern mixed-use development and redevelopment. But parking requirements can be altered to allow planners to better measure the true demand for parking and to balance parking with wider community goals. This approach entails careful consideration of land-use and transportation characteristics that relate to parking demand. Successful examples consider the following factors.

■ **Development type and size.** Take into account the specific characteristics of the project: is there a large theatre that requires evening parking, or will small shops attract short-term, daytime patronage? Can the two share parking spaces? Parking demand is of course also influenced by the size of the development, which is typically measured by total building square footage.

■ **Development density and design.** Consider the density of the development. Research shows that each time residential density doubles, auto ownership falls by 32 to 40 percent (Holtzclaw et al. 2002). Higher densities mean that destinations are closer together, and more places can be reached on foot and by bicycle—reducing the need to own a car. Density is also closely associated with other factors that influence car ownership, such as the presence of good transit service, the community's ability to support stores located in neighborhoods, and even the walkability of neighborhood streets.

■ **Demographics.** Consider the characteristics of the people using

Site Coverage
for Typical Commercial Development
(averages for Olympia, Washington)



Source: City of Olympia Public Works Department, and the Washington State Department of Ecology, 1995.

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In the process of establishing parking requirements, local communities are sometimes engaged in a balancing act. They must consider access, mobility, and traffic safety, but they also must encourage appropriate land use and traffic management, environmental protection, and energy and resource conservation.

— Thomas P. Smith
"Flexible Parking Requirements"
Planners Advisory Service Report 377

the development, including employees, customers, residents, and visitors. People of different incomes and ages tend to have different car ownership rates.

- **Availability of transportation choices.** Take into account the modes of transportation available to employees, visitors, and residents. Access to public transportation in a particular development, for example, can reduce parking demand. Walkable neighborhoods and bicycle amenities can also reduce parking demand.

- **Surrounding land-use mix.** Consider the neighboring land uses and density to better understand parking needs. For example, an office building parking lot will be empty when the restaurant next door is packed, so requiring both to provide for 100 percent of their parking needs simply wastes space.

- **Off-site parking.** Consider the parking that is already available nearby: on the street, on nearby properties, or in public garages that may be available for users of a new development. On-street parking can be considered to reduce the amount of on-site parking required for new development, or as a reserve should new uses require more parking than expected. On street parking has the added benefit of acting as a buffer between pedestrians and traffic, increasing the attractiveness of walking.

Land use and demographic information are important tools for establishing context-specific parking requirements that better balance supply and demand for parking.



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The Costs of Parking

This section describes the costs of providing parking, both in terms of financial and environmental health. While parking is necessary, providing too much of it can exert a high cost, so understandings its impact is important. That impact can vary considerably with the amount and type of parking provided, and the types of development being served.

Financial Costs

The financial cost of providing parking is driven by three key factors: the number of parking spaces required, the 'opportunity cost' of the land used for parking, and the cost per parking space[1]. Parking requirements that assume suburban levels of demand in urban locations may necessitate large surface lots or parking garages, unnecessarily increasing the cost of infill and other compact development. The opportunity cost is the cost of using a space for parking instead of for a use with higher value. This varies considerably depending on the development context. In infill locations, the opportunity cost can be quite high, as each on-site parking space can reduce the number of new housing units or other users by 25 percent or more (Transportation and Land Use Coalition, 2002).

The cost per space depends on engineering and design considerations. Cost per parking space includes land, construction, maintenance, utilities, insurance, administrative, and operation costs (Tumlin and Siegman, 1993). The per-space costs tend to be higher in infill locations, providing a strong incentive for avoiding a parking surplus. Towns that are trying to encourage infill development or compact new suburbs can help spur those activities by accurately gauging parking demand. In general, the following factors affect the cost per space of parking:

- **Structured versus surface parking.** Parking garages are more costly to construct, operate, and maintain than surface parking lots, but can be desirable in urban locations seeking to create a more walkable environment. For example, Shoup (1998) reports construction costs of over $29,000 per space for a structured garage in Walnut Creek, California, against perhaps $2,000 per space to construct surface parking. Underground parking structures are more costly to construct than above-ground structures because of the added expense of excavation and required engineering.

Ignoring both the cost of providing parking spaces and the price charged for parking in them, urban planners thus set minimum parking requirements to satisfy maximum parking demand.

— Donald Shoup
Department of Urban Planning, UCLA

[1] All costs are updated to 2004 dollars. Costs include various components as noted. Where amortized, they assume a 7.5% interest rate over a 30-year period, and annual operating costs.

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- **Land cost.** Land costs vary widely across settings (urban/suburban), geographic areas, and location within a particular city. Land costs in urban centers are generally much higher than in suburban areas. For example, in 1997 the cost per square foot of land in downtown Charlotte, North Carolina, was $121, while suburban land cost $21 (ULI, 1997). Higher land costs make the efficient supply and use of parking critical to development and redevelopment in urban areas.

- **Configuration and size of parking facility.** Parking structures and lots are more expensive to build and operate on smaller lots and complex land configurations, due in part to economies of scale. For example, smaller garages have higher costs per parking space because of the fixed capital costs (e.g., stairwells, ramps, and elevators) and fixed operating costs. These characteristics—smaller lots and more complex land configurations—are typical of urban areas, making parking more expensive at these locations.



- **Geologic conditions.** Parking structures on land with more sensitive seismic conditions or land with difficult terrain also cost more per parking space because they require more complex engineering and construction design. While geologic conditions vary across the country, developers have a greater choice of sites when considering development in suburban and rural areas. Sites in urban areas are more limited, and terrain with geologic constraints may be more difficult to avoid.

Land and construction costs, which account for most of the costs of parking, vary considerably across cities and parking designs. Construction costs alone also range widely due to building codes, materials, and labor costs, but per space construction costs for structures (above- or below-grade) are typically much higher than for surface lots. Willson (1995) expresses parking costs in terms of a monthly amount that would pay for the land, construction, and operating costs of providing a parking space. The reported monthly cost calculated for six surface parking sites in Southern California ranged from $50 to $110 per space, with an average of $86. The average cost for two sites in Southern California with above ground structured parking was $175 per space per month. Litman (2004) analyzes cost-recovery thresholds for parking under various scenarios, finding a range from $20 to nearly $200 per month to finance, build, operate, and maintain a parking space. With such wide variability, national averages, especially those including land costs, clearly do not have much meaning. This underlines the

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importance of looking at costs for a specific area when assessing potential savings from reducing oversupply.

Environmental Costs

In addition to tangible financial costs, parking has 'external' costs that affect the natural environment and the surrounding community, and these are typically not factored into development decisions. Parking lots and garages themselves have a direct impact on the environment, and they can affect the environment indirectly by cutting off transportation choices, encouraging driving that pollutes the environment.

Direct environmental impacts include: degraded water quality, stormwater management problems, exacerbated heat island effects, and excessive land consumption. Construction of surface parking often paves ground that once absorbed and filtered rainwater. This increases stormwater runoff, which can result in more flooding. The oil and other pollutants washed off the parking lot exacerbate water pollution. Dark pavement can artificially raise air temperature, resulting in 'heat islands' that raise air-conditioning bills. In undeveloped areas, forests, wetlands and other natural features should be considered part of a region's "green infrastructure" that process stormwater, clean the air, and provide wildlife habitat. Ensuring that parking areas are sized to a development's actual needs instead of to a generic requirement can preserve this infrastructure.

Parking also indirectly affects the environment, primarily because parking influences how and where people choose to travel. In conventional low-density, single-use development, the required large surface parking lots create places that are not friendly to pedestrians or transit. These places also require more and longer trips between homes, workplaces, schools, shops, and parks. As a result, people make the rational choice to drive almost everywhere -- and these areas register more vehicle miles of travel per capita. Increases in travel rates are associated with increased emissions of pollutants, including carbon monoxide and the pollutants that contribute to dangerous ground-level ozone. Air pollution is associated with asthma and many other health problems, driving up health-care costs.

Compact development that mix uses can reduce the need for surface parking, preserving green infrastructure while also reducing the amount of driving necessary for community residents. By creating an environment that supports the efficient use of parking, such development can also lead to better balance between parking needs and other community goals.

For further discussion of the environmental impact of development patterns, see *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation and Environmental Quality* (EPA, 2001a).

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Innovative Parking Alternatives

As local governments respond to public demand for better development patterns, many have created alternatives to inflexible minimum parking requirements. The alternatives are aimed at avoiding an oversupply of parking, minimizing parking demand, or using the power of the marketplace to regulate parking. In areas of existing development, avoiding oversupply encourages better use of existing parking facilities and better evaluation of parking needs. Other policies give people an alternative to driving, and so reduce the demand for parking. And market-based pricing systems can help better match demand and supply, ensuring expensive parking spaces are used efficiently. Some of these strategies have lowered total development costs, further encouraging compact, mixed-use development patterns that moderate parking demand.

This section presents a selection of policies that make parking requirements more flexible. It includes a discussion of how and why these alternatives were developed, their advantages and limitations, and real-world examples. Each application has its own unique characteristics, and this diversity makes it impossible to isolate the costs and benefits of specific policies. The discussion presented here is not intended to portray any specific policy as universally applicable. Rather, community context should always be considered when balancing parking with other goals.

Strategies That Work

Parking Alternative	Example Location
Context-Specific Requirements	Montgomery County, Maryland Milwaukee, Wisconsin Los Angeles, California Eugene, Oregon Seattle, Washington Boston, Massachusetts
Centralized Parking, In-Lieu Fees	Miami, Florida Chattanooga, Tennessee West Palm Beach, Florida
Shared Parking	Long Beach, California Indianapolis, Indiana
Other Supply Strategies	Portland, Oregon Redmond, Washington Iowa City, Iowa
Land Banking and Landscape Reserves	Portland, Oregon Palo Alto, California Carmel, California Cleveland, Ohio Iowa City, Iowa
Car-Sharing	Boston, Massachusetts Washington, DC San Francisco, California Seattle, Washington Boulder, Colorado
Subsidies for Transit	Boulder, Colorado Santa Clara County, California San Bernardino County, California Montgomery County, Maryland
Transit Improvements	Portland, Oregon Chattanooga, Tennessee
Pedestrian and Bicycle Facilities	Schaumburg, Illinois Kendall, Florida
Transportation Demand Management Programs	Cambridge, Massachusetts Seattle, Washington Montgomery County, Maryland
Pricing Strategies	Los Angeles, California Santa Monica, California San Diego, California Pasadena, California

Reduce Oversupply

As discussed earlier, in communities working to create mixed-use, compact, walkable places, inflexible application of conventional minimum parking requirements tends to create an oversupply of parking. This creates unnecessary environmental impacts and fi-

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nancial costs. The strategies discussed below can reduce the supply of parking while still effectively meeting demand.

Context-Specific Standards

Setting parking standards to fit the particular context of a neighborhood or development is a challenge planners are just beginning to tackle. As discussed earlier, parking requirements are often applied for each land use city wide, and so lack the flexibility needed to address different parking needs.

A major challenge for city planners is how to make codes more flexible and sensitive to specific local conditions, but still provide the predictability desired by developers. Codifying reductions in parking requirements provides the greatest certainty for governments, citizens and neighbors, and developers, and enables all to plan for balancing parking with other development goals. When the reductions in parking requirements are clearly stated in the codes, developments are less likely to be held up in the permitting process or challenged by local residents. Planners need to develop an understanding of local parking markets, combine this with experience from other settings, and then create local parking requirements. Some of the mechanisms being used are:

- **Transit zoning overlays.** In areas with frequent transit service, especially those served by rail stations, fewer residents, workers, and shoppers require parking. In addition, the density and mix of uses possible around rail stations can sometimes support market-rate parking, which leads to more efficient use. Many cities find they can reduce minimum parking requirements for certain uses that are within a specified distance of a rail station or frequent bus route. For example, Montgomery County, Maryland reduces parking requirements by as much as 20 percent, depending on distance from a Metrorail station. Parking are only one aspect of transit zoning overlays, which often address issues such as density, design, and allowable uses. Codes may encourage shared parking in transit zones, which accommodates more cars than parking reserved solely for residents and commuters.

- **New zoning districts or**

Location- and Use-Specific Requirements

Milwaukee, Wisconsin

Milwaukee has some of the lowest city wide parking ratios anywhere in the country. Parking ratios for retail are two spaces per 1,000 square feet, compared to the Institute of Transportation Engineers' standard of one to 300 square feet. For business uses, Milwaukee requires eight spaces for the first 2,000 square feet, and one for each subsequent 1,000 square feet. In the downtown zone, there are no minimum parking requirements for any land use except high-density housing, where the ratio is a very low two spaces per three units. The city generally discourages surface lots within the downtown and dictates that at least 50 percent of the ground floor of parking structures be used for retail.

These policies were enacted in 1986 and strengthened in October 2002 with new credits for transit-oriented development, on-street parking, and shared parking. Developments within a defined geographical area near transit (which encompasses over half of the city area) are granted reductions of up to 15 percent in the minimum requirements. Further reductions are allowed for on-street spaces adjacent to the property (up to a 1:1 space credit), and for shared parking (up to 0.75 space credit for each shared space). One to one credits are also allowed for leased parking spaces in existing lots within 750 feet of the site.

Source: Milwaukee Department of City Development, 2002.

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specific plans. In compact, mixed-use, walkable neighborhoods and town centers parking requirements can frequently be lower than typical minimum requirements. Some communities have adopted designated zoning districts or neighborhood specific plans to accomplish this. Most commonly, this applies to the downtown; Milwaukee finds that parking and other goals can be met with lower parking requirements than in outlying locations. Some areas waive the minimums altogether, letting the development market decide where and how to build parking. The same techniques can be applied to neighborhoods outside of downtowns that offer frequent transit, such as Seattle's Pike/Pine district. Specific plans, which detail development requirements at the parcel level, are particularly useful to encourage infill development in older neighborhoods or on brownfield sites.

Location- and Use-Specific Requirements
Seattle, Washington

Seattle's zoning code grants reductions in minimum parking requirements based on several factors, including:

- Affordable housing. Minimum parking requirements are reduced to between 0.5 and 1.0 space per unit, depending on income, location, and size of unit.
- Senior housing and housing for people with disabilities.
- Car-sharing. Only for multi-family developments that allow dedicated on-site parking for the city's recognized car-sharing operator.
- Location. No parking minimums are set for downtown and they are reduced in mixed-use, dense neighborhoods.\

Source: Seattle Department of Transportation, 2001.

- **Parking freezes.** The amount of parking required can be directly reduced through parking freezes that cap the total number of parking spaces in a particular metropolitan district. . Cities with successful parking freezes generally have strong economies and well developed transit systems, and are attractive to tenants, customers, and visitors. Such cities can attract businesses because the benefits of the urban location outweigh the potential drawback of limited parking, and because public transit offers a viable alternative to automobile use. Downtown Boston has had a parking freeze in effect for many years in an effort to control driving and the associated emissions. Downtown San Francisco has applied a cap on commuter parking, as their downtown street network functions at capacity during rush hours, and transit and other travel options are numerous. Jurisdictions using the restrictions generally view each new parking space (commuter spaces in particular) as the generator of one more rush-hour vehicle trip, and want to limit those trips to reduce air pollution and congestion.

- **Reductions for affordable and senior housing.** Successful regions frequently struggle to provide affordable housing, as desirability and supply drive up housing prices. In many of these places, providing housing to lower-income workers and senior citizens can become an important goal. Since people with lower incomes and older people tend to own fewer vehicles parking requirements can

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be reduced for below-market-rate units and senior housing. This reduces the overall cost of providing such housing, and may increase the number of units that can be provided. Los Angeles grants a reduction of 0.5 spaces per unit for deed-restricted affordable housing units, with further reductions if they are within 1,500 feet of mass transit or a major bus line.

- **Case-by-case evaluation.** Where area-wide or systematic code changes are not possible, reductions in parking requirements can be granted on a case-by-case basis, often on the condition that mitigation measures such as car-sharing (see page 23) are provided. Cities such as Eugene, Oregon specify in their zoning codes that such reductions will be granted subject to a parking study showing that the proposed provision will be adequate to meet demand.
- **Abolish requirements.** Another approach is for cities to simply abolish all parking requirements in neighborhoods that are served by a range of travel options and where surrounding residential areas are protected from spillover parking from other users (Millard-Ball, 2002). This leaves it up to developers—who have a financial interest in meeting tenants' needs while not oversupplying parking—to determine how many spaces are needed.

Maximum Limits and Transferable Parking Entitlements

Maximum limits turn conventional parking requirements upside down by restricting the total number of spaces that can be constructed. Planners set maximum limits much as they set minimum requirements. Typically, a maximum number of spaces is based on the square footage of a specific land use. For example, Portland, Oregon, allows buildings in the central business district a maximum of 0.7 parking spaces per 1,000 square feet of office space, and 1.0 space per 1,000 square feet of net building area for retail.

The generous parking capacity required by planners often goes unused. Studying office buildings in ten California cities, Richard Willson (1995) found that the peak parking demand averaged only 56 percent of capacity.

— Donald Shoup, UCLA

Communities can make maximum parking requirements more flexible by introducing transferable parking entitlements, as in Portland Oregon. The allowed number of parking spaces for a particular development are an "entitlement" that can be transferred or sold to another development if they are unused. This policy enables cities to control the parking supply, without restricting developments that would not be feasible without additional parking. Projects that require more parking can proceed, while those that need less parking can benefit by selling their rights, or negotiating shared parking agreements for their employees or customers.

Portland's planners are using parking maximums in an attempt to "improve mobility, promote the use of alternative modes, support existing and new economic development, maintain air quality, and enhance the urban form of the Central City" (City of Portland, 1999). By combining maximums with transferable parking entitlements, Portland's downtown provides ample

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parking for retail and other priority uses, along with market-rate commuter parking, in a compact, walkable area with a mix of uses and transportation choices.

Both planners and developers benefit from restricting the number of parking spaces allowed. From the city's perspective, maximum limits:

- Improve the urban environment by preserving open space and limiting impervious surfaces;
- Reduce congestion;
- Encourage attractive, pedestrian-friendly urban design; and
- Promote transportation choices.

From the developer's perspective, maximum limits:

- Minimize costs for parking construction, operations, and maintenance;
- Reduce traffic and traffic-related costs; and
- Allow development at a greater floor-to-area ratio, increasing leasable space.

There are challenges to setting and maintaining maximum limits. Planners must consider possible spillover parking in surrounding residential neighborhoods if parking in those areas is free.. To avoid such spillover, developers must understand the factors that affect parking demand and ensure that viable transportation choices exist. A common policy for preventing parking spillover into residential areas is to implement residential parking permit programs, but these have drawbacks (see discussion of parking benefit districts on page 33). Changes in frequency or routing of transit, increases or decreases in development densities, or changes in land use can all influence the demand for parking in the neighborhood.

Linking Maximum Limits and Transit Improvements

Portland, Oregon

In Portland, Oregon, maximum parking limits vary according to distance from light rail stations. For example, new office space on the light rail transit mall is allowed 0.8 spaces per 1,000 square feet, while office space in Goose Hollow, located several blocks from the transit mall, is allowed 2.0 spaces per 1,000 square feet.

These maximum limits have not been problematic to developers. In fact, property values and customer volume in the parking-restricted areas near transit stations are higher than in other areas. In a 1987 survey of 54 businesses located near light rail transit, 66 percent of business owners said that their businesses had been helped because they were located near public transit; 54 percent reported increased sales volumes as a result of being located near transit, in spite of reduced parking supply.

Source: Tri-County Metropolitan Transportation District of Oregon, 1999.

With restrictive maximum limits on the number of parking spaces, developers may worry about the long-term marketability of a property. Marketability should not be a concern for competing developments in the same locale if all developments must adhere to the maximum limits. Parking restrictions that may seem to place urban areas at a disadvantage can be offset by amenities other than parking, such as convenient access to services and places of employment, attractive streetscapes, or pedestrian-friendly neighborhoods. City governments and developers should

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incorporate these elements to attract businesses and residents. Maximum requirements are not ideal for all locations. Municipalities that employ maximum requirements must have accompanying accessible and frequent public transportation. It is also important for the area to be sufficiently stable economically to attract tenants without needing to provide a surplus of parking. A number of cities have implemented maximum parking requirements, including San Francisco and Seattle.

Shared Parking

The concept of shared parking is based on the simple idea that different destinations attract customers, workers, and visitors during different times of day. An office that has peak parking demand during the daytime, for example, can share the same pool of parking spaces with a restaurant whose demand peaks in the evening. The first shared parking programs arose when developers, interested in reducing development costs, successfully argued that they could accommodate all demand on site with a reduced number of spaces. The Urban Land Institute (ULI) report *Shared Parking* (2005) presented analytic methods for local governments and developers to use on specific projects, and as mixed-use projects continue to grow in number and sophistication, ULI continues to update this methodology.

By allowing for and encouraging shared parking, planners can decrease the total number of spaces required for mixed-use developments or single-use developments in mixed-use areas. Developers benefit, not only from the decreased cost of development, but also from the "captive markets" stemming from mixed-use development. For example, office employees are a captive market for business lunches at restaurants in mixed-use developments.

Shared parking also allows for more efficient use of land and better urban design, including walkability and traffic flow. Shared parking encourages use of centralized parking lots or garages and discourages the development of many scattered small facilities. A sidewalk with fewer driveway interruptions and more shop fronts is more comfortable and interesting for pedestrians and will encourage walking. Reducing driveways also results in more efficient traffic flow because there are fewer turning opportunities on main thoroughfares. This has the added benefits of reducing accidents and reducing emissions from idling vehicles stuck in traffic.

Establishing shared parking requirements involves

Shared Parking

Circle Centre — Indianapolis, Indiana

Opened in September 1995, Circle Centre in Indianapolis' central business district offers retail and entertainment destinations. This development contains 630,600 square feet of retail space and100,000 square feet of restaurant, speciality, and entertainment space, as well as a 2,700-seat cinema. One of the factors that led to the financial success of this $300 million project was a shared parking arrangement that saved money and allowed a pedestrian-friendly design.

Under generic minimum parking requirements, Circle Centre would have needed about 6,000 parking spaces. By using shared parking, the project was built with just 2,815 spaces. Shared parking for Circle Centre is used for both customers and employees. The mixed-use nature of the development project allows customers to use a single parking space for multiple destinations within the complex. Employees can use nearby off-site parking, particularly in evenings and on weekends when more than 12,000 nearby off-site spaces that normally serve downtown office workers become available. Taking these two shared parking components into account decreases the estimated need for on-site parking by more than 50 percent.

This reduction in parking demand translates into considerable cost savings. At parking costs of about $10,000 per space for aboveground structured parking, development costs were reduced by about $30 million.. In addition, operating costs were reduced by approximately $1 million per year.

Source: Smith, 1996.

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site-specific assessment or use of time-of-day parking utilization curves, which were developed by the ULI in *Shared Parking.* Planners need to consider several factors when developing shared parking requirements, including the physical layout of the development; the number of spaces for each of the individual land uses; the types of parking users (e.g., employees, residents, or hotel guests who park all day, or customers and visitors who park for short periods of time); and hourly accumulation of parking for each land use.

Montgomery County, Maryland, allows for shared parking to meet minimum parking requirements when any land or building under the same ownership or under a joint-use agreement is used for two or more purposes. The county's ordinance also allows parking reductions based on proximity to transit, participation in TDM programs, or location in the central business district. The county uses the following method to determine shared requirements for mixed-use developments:

Calculating Parking for Mixed-Use Developments (Montgomery County, Maryland)

	Weekday		Weekend		Nighttime
	Daytime (9 a.m. - 4 p.m.)	Evening (6 p.m. - 12 a.m.)	Daytime (9 a.m. - 4 p.m.)	Evening (6 p.m. - 12 a.m.)	(12 a.m. - 6 a.m.)
Office	300*	30	30	15	15
Retail	168	252	280*	196	14
Entertainment	40	100*	80	100*	10
TOTAL	**508**	382	390	311	39

* Peak demand by use.
Source: Smith 1983, page 7.

- Determine the minimum amount of parking required for each land use as though it were a separate use, by time period;
- Calculate the total parking required across uses for each time period; then
- Set the requirement at the maximum total across time periods.

The table above illustrates how peak demand occurs at different times of the day and week for different land uses. While maximum parking demand for the office component of the project occurs during the daytime on weekdays, maximum demand for retail occurs during the daytime on weekends, and peak entertainment demand is in the evening. For this example, setting parking requirements using maximum demand would have resulted in requiring 680 spaces (300 spaces for office, 280 spaces for retail, and 100 spaces for entertainment). By recognizing the shared parking potential, the developer cut almost 200 unnecessary parking spaces (about 25 percent), represent-

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ing a considerable cost savings.

An American Planning Association report, *Flexible Parking Requirements*, highlights factors that facilitate shared parking (Smith, 1983). The report suggests that for shared parking to function effectively, parking requirements for individual land uses must reflect peak-demand land use and common parking facilities must be near one another. Parking spaces should not be reserved for individuals or groups.

Centralized Parking
Chattanooga, Tennessee

To encourage urban development in downtown Chattanooga while limiting congestion and air pollution, the Chattanooga Area Regional Transit Authority (CARTA) developed a strategy to provide peripheral parking and a free shuttle service. The system is designed for the city's linear central business district and allows workers and visitors to drive to the city, park in one of the two peripheral garages, and use the shuttles to travel up and down the 15-block business corridor. By constructing parking at either end of the business district, CARTA intercepts commuters and visitors before they drive into and through the city center, reducing traffic congestion.

The two parking garages Shuttle Park South (550 spaces) and Shuttle Park North (650 spaces), are owned by CARTA and operated privately. The free shuttle buses are financed through the garages' parking revenues. They depart from each garage every five minutes all day, every day, and pass within walking distance of most downtown destinations.

The electric-powered shuttles transport approximately one million riders each year, making shuttle-served property attractive to businesses. Since 1992, when the shuttle service began, over $400 million has been spent on development in Chattanooga, including the successful aquarium, over 100 retail shops and over 60 restaurants. CARTA's initiatives won commendation from EPA, receiving a "Way to Go" award in 1996 for innovative transportation solutions that support urban development.

Sources: EPA, 1998; Chattanooga News Bureau, 1999.

Centralized Parking Facilities and Management

A subset of shared parking is the construction of centralized parking lots and garages. Some cities mandate centralized parking facilities and finance them through development impact fees, in lieu parking fees, or negotiated contributions established during the environmental review process. Centralized parking can be built and operated by a public entity or public/private partnership and reduce the costs of parking because large facilities are less expensive on a per space basis to build and maintain than small facilities. The example in the next chapter of Wilton Manors, Florida, is such a case.

Centralized parking facilities can meet urban design goals if they allow the elimination of small surface parking lots and driveways that interrupt the walkable fabric of mixed-use areas. Centralized parking enables travelers to park once to visit several destinations, potentially reducing on-street congestion from short trips within an area. Developers are sometimes concerned that centralized parking will be inconvenient for building occupants, but these concerns can be addressed in part by building several "centralized" facilities throughout a business district or mixed-use area. Centralized management can still ensure coordinated policies for their use, maintaining many of the advantages of centralized parking. In other cases, the operator can provide shuttle services to and from centralized garages. Many downtown areas have successfully instituted centralized parking. Some cities, such as Pittsburgh and Chattanooga (see box) operate such facilities at the periphery of the downtown, reducing traffic and mobile source emissions in the core and freeing up land in the center city for other development.

In-Lieu Parking Fees

In-lieu parking fees are one way to finance such centralized public garages and give developers flexibility in providing parking on-site. Developers

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are able to avoid constructing parking on site by paying the city a fee, and the city in return provides off-site parking that is available for use by the development's tenants and visitors. The city determines the fees, generally based on the cost of providing parking.

Cities set fees in one of two ways, either by calculating a flat fee for parking spaces not provided by a developer on site, or by establishing development-specific fees on a case-by-case basis. Shoup (2005) reports that in-lieu fees in the United States range from $2,000 to $20,000 per parking space and may or may not reflect the true costs of providing parking. These fees can be imposed as a property tax surcharge or at the time of development permitting.

In-lieu parking fees provide a mechanism for providing parking in balance with other community goals, satisfying the public as well as planners and developers. Using in-lieu fees and centralized garages can:

- Reduce overall construction costs;
- Avoid construction of awkward, unattractive on-site parking that could compromise historic buildings;
- Increase public access to convenient parking;
- Ensure that parking facilities will be used more efficiently; and
- Encourage better urban design with streetscapes uninterrupted by parking lots and driveways.

In establishing in-lieu parking fees, planners must be aware of potential developers' concerns that the lack of on-site parking will make developments less attractive to tenants and visitors. This can be an issue if available public parking is insufficient, inconveniently located, or inefficiently operated. Planners must carefully consider the parking demand for each participating property and provide enough parking to meet this demand in order to avoid creating a perceived or real parking shortage. Planners must also work to ensure that public parking facilities are located and operated in ways that support development.

In-Lieu Parking Fees

Coconut Grove — Miami, Florida

Coconut Grove is a pedestrian-oriented, entertainment, dining, and shopping village in southern Miami. To maintain Coconut Grove's continuous street frontage and keep it attractive to pedestrians, city planners established flexible parking requirements. Developers or property owners have three choices for satisfying minimum parking requirements: they can provide off-street parking, contract spaces elsewhere, or pay in-lieu fees. With little space left to develop and high land costs, most property owners choose to pay the $50 per space per month fee to the city and use the land for more productive, revenue-generating purposes. The city uses the in-lieu fees to provide shared, structured parking, improve transit service, and maintain the sidewalks and pedestrian amenities. By investing the in-lieu fees in a combination of parking and other improvements, the city helps to keep Coconut Grove walkable and maintain the attractive aesthetic character of the area.

Source: Coconut Grove Chamber of Commerce.

Accounting for Uncertainty

Estimating parking demand is not an exact science, and a few communities are setting aside land through land banking and landscape reserves that can be converted into parking if shortages arise. Landscaping can often be used to turn this set-aside land into an attractive amenity for the development

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or wider community, but requiring new development to purchase additional land as insurance against uncertain parking demand imposes additional costs, which may work against community redevelopment goals.

Land banking and landscape reserves are particularly useful policies when the expected need for off-street parking for a particular use is uncertain, due to unknown or unusual operating characteristics, or if no data is available to establish need. Cities could respond by requiring the construction of parking spaces that may well sit empty. But these techniques allow supply to be determined by the best estimates, with the security that more parking can be constructed if needed. In some cases, landscape reserves can be required in conjunction with parking reductions granted in return for company plans to reduce private vehicle trips, known as Transportation Demand Management (TDM) plans. If the employer falls out of compliance with the TDM plan, they can be required to go to the expense of constructing additional parking.

Land Banking

Iowa City, Iowa, and Palo Alto, California

Both Iowa City and Palo Alto have enacted land-banking policies in their parking codes. In some neighborhood commercial zones in Iowa City, minimum parking requirements may be waived or relaxed, and land banking used in place of up to 30 percent of the otherwise required parking. If an enforcement official determines in the future that the additional parking spaces are needed, the property owner can be required to construct parking on the land banked area.

Palo Alto's code authorizes the city to defer up to 50 percent of the required spaces as a landscape reserve where the expected need for off-street parking for a particular development is uncertain. The California Park Apartments development, for example, was allowed to defer 22 of the 95 parking spaces required by city code, using the land instead for a family play lot, a barbeque area, and picnic benches. Nearly 15 years after construction, the landscape reserve has not been needed for parking, and the community enjoys the environmental and social benefits of the recreation area.

Source: Iowa City and Palo Alto Zoning and Parking Codes.

Land banking and landscape reserve policies have been implemented in cities throughout Oregon (including Portland), as well as Palo Alto, California; Carmel, California; Cleveland; and Iowa City, Iowa. Palo Alto allows reductions of up to 50 percent in minimum parking requirements, provided that the difference is made up through a landscape reserve. None of the city's landscaped reserves have subsequently been required for parking.

To avoid confusion with terminology, it should be noted that land banking can also refer to the purchase of land by a local government or developer for use or resale at a later date. Banked land is sometimes used as interim parking to generate revenue generation—parking fees from temporary lots are put towards construction of later phases of the development, and at some point built over into buildings or structured parking.

Manage Demand

While reducing excess parking supply is important in eliminating the waste of unused parking spaces, some communities are looking to directly reduce the demand for parking, by providing people with readily available alternatives to driving. Demand reduction programs include car sharing, subsidies for transit, transit improvements, pedestrian and bicycle facilities, and comprehensive vehicle trip reduction programs that may include telecommuting and/or flexible work schedules to reduce commuting. While these programs are typically developed by local governments, their success often depends

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on the commitment of businesses to implement them effectively.

Car-Sharing

Car-sharing is a neighborhood-based, short-term vehicle rental service that makes cars easily available to residents on a pay-per-use basis. Members have access to a common fleet of vehicles, parked throughout neighborhoods so they are within easy walking distance, or at transit stations. In programs with the most advanced technology, members simply reserve the nearest car via telephone or the Internet, walk to its reserved space, open the door using an electronic card, and drive off. They are billed at the end of the month, gaining most of the benefits of a private car without the costs and responsibilities of ownership, and without having to search for parking when their trip is over.

In urban neighborhoods with good transit access, car-sharing can eliminate the need to own a vehicle, particularly a second or third car that is driven less than 10,000 miles per year. In San Francisco, nearly 60 percent of households that owned vehicles before joining the car-sharing program have given up at least one of them within a year, and another 13 percent were considering it (Nelson\Nygaard, 2002). Zipcar, which operates in Boston, New York, and Washington, DC, reports that 15 percent of members sell their private car. In Europe, which has a far longer experience with car-sharing, each shared vehicle takes between four and ten private cars off the road -- and out of city parking spaces (City of Bremen, 2002).

Car-Sharing, Pricing Strategies

Van Ness and Turk Development -- San Francisco, California

This development includes 141 residential units in a dense area of San Francisco, with only 51 parking spaces. The development was granted a substantial reduction in parking requirements—nearly two-thirds—from the city's minimum of 1 space per unit, to 1 space per 2.8 units. The reduction was granted in large part because of the developers' agreement to provide two parking spaces for car-sharing operator City CarShare, accessible to residents and all CarShare members. Strong community and organizational support, as well as proximity to major transit corridors, were also factors.

If the developers had been required to build the additional 90 spaces required by code, they would have been forced to add either subterranean levels or parking lifts, which save space by stacking vehicles on top of each other. These expensive options would have cost between $1.35 million for lift technology (estimated at $15,000 per space) or $8.1 million for additional below-grade parking levels (estimated at $60,000 to $90,000 per space).

The developer also "unbundled," parking costs, so that residents are charged for parking separately from rent. The current market rate for parking is $280 to $300 per space per month. By charging separately for parking and incurring lower construction costs, the developer is able to keep apartment rents lower.

Source: Thieophilos Developers, 2002.

In some cities, developers have been allowed to reduce the number of parking spaces if they incorporate car-sharing. Developers may need to contribute towards set-up costs and/or provide parking spaces reserved for car-sharing vehicles as part of a project. Car-sharing can be provided as part of a mitigation agreement with the local jurisdiction in return for a reduction in minimum parking requirements. Alternatively, the parking reduction can be codified through zoning ordinances, as is being considered in Portland, Oregon, San Francisco, and Seattle.

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Car-sharing can also be a useful tool to reduce parking demand in commercial developments. Employees can use a shared vehicle for meetings and errands during the workday, allowing them to take transit, carpool, walk, or bicycle to work. Car-sharing works best in compact, mixed-use neighborhoods, where firms with corporate memberships tend to use the vehicles during the day and residents can use them in the evenings and on weekends.

Formal car-sharing programs have been established in many cities, including Boston; Washington, DC; San Francisco; Oakland, California; Portland, Oregon; Seattle; and Boulder, Colorado, and are being established in many others. Some programs are run by non-profits with significant government support. Private for-profit companies, notably Flexcar and Zipcar, are operating in a number of cities, but they often work with the city or the local transit agency to secure reserved parking spaces on city streets or in transit park-and-ride lots. Alternatively, developers can provide shared vehicles themselves, or facilitate informal car-sharing among residents. Car-sharing reduces parking demand, but it also brings a broad range of other benefits, including fewer vehicle trips with less associated pollution, and improved mobility for low-income households who may not be able to afford to own a car, if rental rates are low enough..

Incentives for Transit

Financial incentives to ride transit can help reduce parking demand. They can be provided by employers, by cities, or by residential property managers.

Car-Sharing, Parking Maximums

Rich Sorro Commons -- San Francisco, California

Plans for Mission Bay, a 303-acre brownfield redevelopment area in San Francisco, include 6,000 units of housing, office space, university facilities, a hotel, community services, and retail. The city introduced parking maximums in this area to maximize the amount of new housing, make the most of the new Third Street Light Rail line through the neighborhood, and minimize traffic impacts on congested streets and the nearby freeway. Residential parking maximums were set at one space per unit.
One of the first projects completed was Rich Sorro Commons, a mixed-use project with 100 affordable units and approximately 10,000 square feet of ground floor retail. It was constructed with only 85 parking spaces, due to:

- Excellent proximity to light rail, commuter rail, and frequent bus service;
- Provision of two parking spaces for City CarShare; and
- Units below market rate, with tenants who are less likely to own a car.

With fewer parking spaces, Rich Sorro Commons was able to make space available for a childcare center and retail stores at ground level. The 17 would-be parking spaces were converted to retail space that is expected to generate revenues of $132,000 annually for the project (300 square feet per space at $25.80 per square foot in rent), making housing more affordable. The two City CarShare vehicles are available to residents, giving them access to a car without the costs of ownership – a particularly important benefit for low-income households.

Source: Kenneth Jones, Developer, 2002.

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In the case of employer-paid transit pass plans, the employer pays the cost of employees' transit, often instead of providing a free parking space. This fringe benefit for employees reduces the demand for parking at the workplace, which in turn reduces traffic, air pollution, and energy consumption. It can equalize the transportation benefit that traditionally only went to employees who drove to work and received a free parking space. It also reduces costs, as transit benefits are generally less expensive to employers than providing parking. A transit pass in Los Angeles, for example, costs $42 per month, whereas the average cost for a parking space is $91 per month (Shoup, 1997b). To promote transit subsidies, the 1998 Transportation Equity Act for the 21st Century changed federal law so that transit benefits are not counted as payroll or as income (see also the description of cash-out programs on page 31). In some cases, city planners respond to employer-paid transit benefits by lowering minimum parking requirements. For example Montgomery County, Maryland's office zoning requirements allows a 15 percent reduction in minimum parking requirements if businesses offer reimbursed transit passes (Smith, 1983). The reduction in required parking can make urban development opportunities more inviting.

Transit incentives can also be useful for residential developments, or even for neighborhoods.. Property managers in Boulder, Colorado, and Santa Clara County, California, for example, can bulk-purchase transit passes for all their



Courtesy of City Car Share

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residents at deeply discounted rates. The principle is similar to that of insurance—transit agencies can offer lower rates on passes because not all residents will actually use them regularly. Residents can take transit for free, meaning they are less likely to own a vehicle. Another benefit of prepaid transit programs is that they encourage residents to take transit spontaneously, since costs are paid up-front. A person does not have to commit to transit full-time in order to be able to reduce their demand for vehicle travel and parking. Developers who agree to fund transit passes can thus be rewarded with lower parking requirements.

Using Parking Revenue to Support Transit

Boulder, Colorado

Faced with a shortage of parking for customers, Boulder developed a program to encourage downtown employees to commute by other means. In 1993, Boulder's City Council mandated restricted downtown parking and appealed for parking demand management for the city's commuters.

The Central Area General Improvement District (CAGID), made up of many of downtown's 700 businesses, responded to the Boulder City Council's demands by creating a system using revenue from downtown parking meters to pay for free bus passes. The passes are provided for all of the district's 7,500 employees, and cost $500,000 each year The program has changed travel behavior, freeing up valuable customer parking spaces:

- Employee carpooling increased from 35 percent in 1993 to 47 percent in 1997.
- The district's employees require 850 fewer parking spaces.
- The increase in available parking has encouraged more retail customers to shop in downtown Boulder.

Boulder has created a special website with information about parking issues in the region: http://boulderparking.com.

The City of Boulder offers deeply discounted Eco-Passes to businesses outside the CAGID and to residents, and encourages walking and bicyccling. These programs mean Boulder employees avoid 212,500 single-occupancy vehicle trips per year, saving an estimated two million miles of pollution- and congestion-causing automobile trips. use is prevented each year.

Source : Boulder Community Network, 1999.

Transit Improvements

One of the best ways to reduce the demand for parking is to improve transit service so that it is frequent, convenient, and easy to use. Local government officials can improve public transit through major projects, such as adding light rail lines or streetcars, or creating systems that give buses priority at lights and intersections. They can also lengthen transit service hours, increase the frequency of bus and train service, and revitalize transit stations. Small improvements can also help, such as convenient SmartCard payment systems, improved bus stops and shelters, and real-time directional and schedule information systems. Portland, Oregon's MAX light rail system exemplifies the widespread benefits of transit improvements. The light rail system encourages transit-oriented development, decreases automobile commuting, and eases demand for parking. In fact, the light rail improvements eliminated the need for six downtown parking towers (EPA, 1998). These improvements are also partially responsible for $1.3 billion in new development in Portland over the last 10 years.

Pedestrian and Bicycle Facilities

Demand for parking can be reduced by providing pedestrian and bicycle facilities and amenities that make it easier and more pleasant for people to walk or bicycle to work, on errands, or to lunch. These changes can alleviate traffic congestion; for example, the automobile-dependent design of Tyson's Corner, Virginia, has resulted in high volumes of traffic at lunch time because

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people cannot walk to restaurants or to run errands.

Promoting bicycling and walking can be accomplished through both comprehensive policies and simple changes to the street.. Some jurisdictions have adopted 'complete streets' policies that require every road construction or improvement project to provide safe access for everyone using the road, including transit users, bicyclists, and pedestrians (see www.completestreets.org). Other communities have focused on closing gaps in the sidewalk or bikeway network, by adding sections of sidewalks, bike lanes, or multi-use paths where needed to ensure safe travel by those modes.

In addition to paying attention to the street, bicycling and walking can be encouraged through design changes that make walking and bicycling more secure and pleasant. The Downtown Master Plan for Kendall, Florida (Miami-Dade County), discusses several design concepts to improve pedestrian and bicycle access. Some of the key elements promoted, but not required, by this program are listed in the text box to the right.

Developers can also encourage bicycling and walking by providing on-site facilities such as bicycle racks and even lockers and showers. For example, officials in Schaumburg, Illinois, a suburb of Chicago, have incorporated provisions into their zoning ordinance to encourage bicycle use. The ordinance requires all retail centers to have a minimum of 10 bicycle spaces located at each main building entrance. To increase awareness, the ordinance requires that bike racks be highly visible; to protect bicyclists, the ordinance requires bicycle parking areas to be separated from automobile parking. Other jurisdictions require covered, secure bicycle parking for employees who will be leaving their bicycles all day.

Designing for Pedestrians

Kendall, Florida

Close attention to design can dramatically improve the environment for pedestrians. The city of Kendall, Florida, has started to redevelop a conventional mall near a rail station into a new town center. The Downtown Master Plan specifies a number of improvements to create a compact, walkable place with good connections to existing neighborhoods:

- Bicycle/pedestrian access via new sidewalks and pathways.
- Trees and shrubs along edges facing streets and sidewalks.
- Parking hidden in the rear or in parking garages.
- Shade and rain protection for pedestrians, such as colonnades, arcades, marquees, second-floor balconies, wide awnings, or tree canopies.
- Buildings positioned along the sidewalks at a deliberate alignment, giving a designed shape to the public space.
- Doors and windows spaced at close intervals to generate activity, direct views to merchandise, and make walking interesting.
- Minimal number of driveways and parking lot entries that can making walking unsafe and erode urban space.

Source: Downtown Master Plan, Kendall, Florida, 1998.

Travel Demand Management (TDM) Programs

Travel demand management (TDM) programs combine several trip-reduction strategies to meet explicit travel goals. Some TDM programs are put into place by a single employer; others are managed by governments or business improvement districts and focus on a developed area that may include both businesses and homes. These programs typically attempt to decrease the number of trips by single-occupant vehicles, sometimes setting goals such as reduced vehicle trips or reduced miles traveled, while increasing the use of a variety of commuting and travel alternatives, including transit, carpooling, walking, and bicycling. TDM plans can be used by city planners to allow developers to build fewer parking spaces.

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TDM programs may encourage transit incentives, parking cash-out, and other strategies mentioned here. In addition, these programs typically incorporate an assortment of complementary program elements that make it easier for people to give up solo driving. Examples include:

- "Guaranteed ride home" services that allow employees who use public transit to get a free ride home (usually via taxi) if they miss their bus or if they need to stay at work late.
- Company fleet cars that can be used for business meetings or running errands during the workday
- Preferential and/or reserved parking for vanpools/carpools.
- Carpooling and/or vanpooling with ride-matching service. Ride matching through informal "ride boards" or an employee transportation coordinator, helps people find and form carpools with neighbors.
- Cell phones for carpoolers to facilitate timing of pick-ups.

Shared Parking, Transit Improvements, TDM Program
Lindbergh City Center -- Atlanta, Georgia

The Lindbergh City Center is a mixed-use, high-density development in Atlanta on property owned by the transit agency, MARTA. The project was envisioned with a goal of having transit carry 30 percent of all trips to and from the center. The development, which includes a hotel and restaurant as well as office, retail, and residential space, centers on a MARTA light rail station that connects it to downtown Atlanta, the airport, and other areas. Parking reductions were allowed because of shared parking between office and retail uses, because of the ample transit access, and as a result of the Transportation Demand Management programs. Parking requirements for the first phase of the development were reduced by 20 percent overall; for office space the reduction is as high as 70 percent. Condominiums are allowed an 8 percent reduction, from 2 to 1.85 spaces per unit.

Source: Paul Vespermann, Lindbergh City Center, 2002.

Employers have little incentive to implement vehicle trip reduction programs if they are not granted reductions in minimum parking requirements. They would not be able to realize the potential cost savings from providing less parking, but would simply be faced with a large number of empty spaces. Some cities, such as South San Francisco (see box), have acknowledged this through ordinances that reduce parking requirements for projects that include vehicle trip reduction programs.

Pricing Strategies

Although parking is often provided at no charge to the user, it is never free. Each space in a parking structure can cost upwards of $2,500 per year in maintenance, operations, and the amortization of land and construction costs. Even on-street spaces incur maintenance costs and an opportunity cost in forgone land value. These costs end up hidden in rental fees and even in the costs of goods and services. Donald Shoup, Professor of Urban Planning at UCLA, has published extensively on parking policy in the United States. He believes that accurately pricing parking would solve many park-

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ing problems (Shoup, 2005).

The cost of parking is generally subsumed into lease fees or sale prices. However, providing anything for free or at highly subsidized rates encourages overuse and means that more parking spaces have to be provided. Charging users for parking is a market-based approach that passes the true cost of parking to users, and encourages use of other transportation modes. If the fee charged to users of parking facilities is sufficient to cover construction, operation, and maintenance costs, it may encourage some users to seek alternative transport modes. Even where there are few alternatives to driving, parking pricing can encourage employees to seek out carpooling partners. In addition to reducing the cost of parking provision, pricing strategies bring substantial environmental and congestion benefits, particularly since they tend to reduce peak-period vehicle trips the most.

Travel Demand Management Ordinance

South San Francisco, California

South San Francisco is one of the few cities in the U.S. to enact a citywide Transportation Demand Management (TDM) ordinance, which allows reduced parking requirements for projects meeting TDM requirements. The ordinance applies to all nonresidential developments that expect to generate 100 or more average daily trips, or to projects seeking a floor area ratio (FAR) bonus. Parking reductions are not fixed, but are subject to case-by-case review and depend on the number and extent of TDM elements.

For example, the brownfield, mixed-use Bay West Cove development, which is located close to transit and bus service, was able to reduce required parking by 10 percent by implementing the following TDM strategies:

- Free parking for carpools and vanpools.
- Late-night taxi service and feeder shuttle service.
- Transit subsidy of $25 per month for all tenant employees.
- Late-night taxi service and feeder shuttle service.
- Guaranteed ride home program.
- Provision of a transportation coordinator.
- On-site project amenities such as child care, showers and lockers, electric vehicle charging, bicycle storage facilities, and a transit information kiosk.
- Parking charges of at least $20 per month for employee parking spaces.

Developers can use the savings from reduced parking construction and the income from paid parking to offset or cover the costs of implementing such programs.

Source: City of South San Francisco, 2003.

However, free parking is an ingrained American tradition. An estimated 99 percent (Shoup, 2005) of parking in the United States is free. How can paying for parking ever be a good thing for drivers? Drivers are willing to pay for parking that is more convenient and readily available. For example, on-street spaces near shopping destinations are much more likely to be available to customers if priced and regulated to prioritize short stays -- if they are free, they will be used for all-day parking by employees or residents. For residents, separating the cost of parking from the cost of rent or a mortgage provides an economic benefit to those who choose to own fewer cars. In addition, the revenue generating from putting an accurate value on parking can be used to benefit an entire neighborhood.

For commuters, making the cost of parking part of the decision on how to get to work encourages transit use and other alternatives, reducing traffic congestion. Parking charges have been found to reduce employee vehicle trips, and thus daily parking demand, by between 7 percent and 30 percent

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or more, depending on factors such as the level of charges and the availability of alternatives to driving alone. One researcher has calculated that each 1 percent rise in parking fees is accompanied by a 0.3 percent decrease in demand (Pratt, 2000).

Cities and developers are using a variety of pricing strategies to better balance parking demand and supply. They include parking cash-out programs, pricing that prioritizes certain types of trips, residential parking plans, and parking benefit districts.

Cash-Out Programs

Cash-out programs allow employees to choose a transportation benefit, rather than simply accepting the traditional free parking space. Under such programs, employers offer employees the choice of:

- Free or subsidized parking,
- A transit or vanpool subsidy equal to the value of the parking (of which up to $100 per month is tax-free under current federal law), or
- A taxable payment approximately equal to the value of the parking, essentially cash to commuters who bicycle or walk to work.

Employees who opt for the non-parking subsidies are not eligible to receive free parking from the employer and are responsible for their parking charges on days when they drive to work. The cost savings for employers



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associated with cash-out payments depend on the amount of the payments. If the full cash equivalent is provided, this demand reduction program does not reduce the total costs of providing parking. However, employees may accept cash payments lower than the full equivalent of the parking subsidy. If partial cash payments are used, employers face lower overall transportation subsidy costs, and employees still benefit. The programs help end the inequity of providing a free parking space benefit to drivers, while offering nothing to those who choose to arrive via transit, foot, or bicycle.

Cash-out programs are often easier to implement than direct charges, as they are generally more acceptable to employees, particularly when free parking had been the norm. However, their impact on travel behavior is usually lower, due to the administrative burden on employees, inertia in changing travel habits, and the fact that cash-out payments can be a taxable benefit whereas free parking is not.

Cash-out programs provide significant environmental, social, and economic benefits. For example, in response to California's mandatory cash-out requirement, eight firms reported an average 17 percent reduction in the total number of solo drivers (Shoup, 1997a). Thus, another benefit of cash-out programs is a reduction in traffic congestion and associated pollution.

Cash-Out Program

Santa Monica, California

In 1992, California instituted a mandatory cash-out program. The California Health and Safety Code Section 43834 reads, "'Parking cash-out program' means an employer-funded program under which an employer offers to provide a cash allowance to an employee equivalent to the parking subsidy that the employer would otherwise pay to provide the employee with a parking space."

The effects of the cash-out program on transportation use in Santa Monica have been significant. A study conducted by Donald Shoup of the UCLA found that for two Santa Monica employers, the share of solo commuters decreased by between 7 and 8 percent once the cash-out program was in place. This reduction in solo commuters is responsible for a decrease in annual commuting of 858 vehicle miles (Shoup, 1997a).

Prioritizing Trips

Parking pricing can be a tool to prioritize some types of trips over others, according to their purpose and duration. It allows managers to cater to certain users, such as short-term shoppers, while discouraging other users, such as commuters, who add to peak-hour congestion and occupy a parking space for an entire day. These pricing strategies allow the overall supply of parking to be minimized, while ensuring spaces are available for critical users. They can also alleviate pressure to provide more parking from retailers and businesses, who may be concerned that lack of parking discourages shoppers. For example:

- Low prices for short-term parking encourages shopping trips, and limiting the duration of parking can also support these high-turnover trips. For example, charging $0.25 per hour with a two-hour maximum will allow many people to use a single space over the course of a day. The same space priced at $2.50 for up to ten hours will likely serve a single commuter. The parking revenue might be the same, but the sales for businesses and sales tax for the city will likely be much higher with short-term parking.

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- Parking charges that are levied by the hour or day, with no discounts for monthly parking, remove the incentive to drive every day to "get your money's worth" from the monthly parking pass.
- Parking charges at transit stations that only apply before a certain time (such as 9:00 am) encourage users to ride transit when it is less crowded, rather than contributing to crowding in the peak.
- Sophisticated new parking meters can charge visitors a different rate than residents or employees with parking permits, preserving parking for regular users while maximizing revenue from occasional users.

Residential Parking Pricing

Parking charges can also be introduced at residential developments, through separating or "unbundling" the cost of parking from rents or sale prices. Rather than being provided with a set number of spaces whether they need them or not, residents can choose how many spaces they wish to purchase or rent. An alternative to direct charges is to provide "rent rebates" or discounts to residents who own fewer vehicles and do not use their allocated parking spaces.



In many urban areas with limited off-street parking, curb parking is reserved for residents through residential parking permit programs. In most cases these programs give residents free or very inexpensive curb parking permits and prohibit anyone else from parking there. However, this can leave many spaces unused during the day when nearby businesses could use extra parking. A few communities, including Aspen Colorado and Tucson Arizona, are experimenting with allowing businesses to buy permits in these areas at very high rates, or are charging hourly parking fees (Shoup, 2005). The revenue generated can be used to benefit the neighborhood, in one version of a parking benefit district, as described below.

Parking Benefit Districts

The revenue from parking can be used to directly benefit the street or the

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neighborhood where the money is collected. Parking benefit districts receive the revenue from meters and residential permits within the district. Once administrative costs are covered, all money goes to transportation and neighborhood improvements such as undergrounding of utility wires (Shoup, 1995), regular street and sidewalk cleaning, installation of benches, nice lighting, or other amenities. Parking benefit districts can allow new development to use available on-street and other spaces, while addressing potential capacity problems through market pricing of curb and off-street parking. Earmarking revenue to directly benefit the neighborhood or commercial district helps to generate support for charges from local residents and businesses, who might otherwise resist paying for parking that used to be free. Often, local residents or businesses have a say in how the newly available revenue will be spent.

The most common use of Parking Benefit Districts has been in downtown business districts, usually using parking meter revenue. Cities such as San Diego and Pasadena, California, have implemented such districts. The concept also applies to residential areas. Most residential parking permit programs give residents free or very inexpensive curb parking permits and prohibit anyone else from parking there. However, this can leave many spaces unused during the day when nearby businesses could use extra parking, and neighborhoods could certainly use the revenue that could be generated by charging for street parking.. A few communities, including Aspen Colorado and Tucson Arizona, are experimenting with allowing businesses to buy permits in these areas at very high rates, or are charging hourly parking fees (Shoup, 2005). Furthermore, this concept can be refined based on the neighborhood. For example, a neighborhood adjacent to an institution such as a hospital or university might implement a two-tiered residential permit program. Residents could buy permits at one rate, while excess on-street capacity would be sold at market value to non-residents.

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Case Studies

This section presents case studies that illustrate how specific metropolitan areas have benefited from innovative parking alternatives. Little data has been collected comparing the effectivness of various parking strategies, and much cost data is proprietary and not available for analysis. Therefore, these examples are presented to illustrate the ways that parking strategies are being used in real-word settings to help communities balance parking and other goals.

- Portland, Oregon: Parking policies include maximums, location- and use-specific requirements, shared parking entitlements, car-sharing, and vehicle trip reduction or Transportation Demand Management (TDM) measures. The Hilton Hotel and the Buckman Heights and Buckman Terrace apartments have used these policies to alter their parking mix..
- Arlington County, Virginia: Location- and use-specific standards and vehicle trip reduction strategies were used to reduce parking requirements in two developments, the Market Common and the 1801 North Lynn Street commercial development.
- NASA Research Park, Santa Clara County, California: A large mixed-use development illustrates vehicle trip reduction strategies
- The Shoppes of Wilton Manors, Wilton Manors, Florida: This case illustrates how shared parking arrangements can be used to reduce parking requirements for a mixed-use redevelopment in one of the fastest growing areas of the country.
- SAFECO Insurance Company Expansion, Redmond, Washington: SAFECO responded to the state's transportation demand management requirements with an effective vehicle trip reduction program.
- The D'Orsay Hotel, Long Beach, California: This case illustrates how a downtown parking management plan that allows shared parking and in lieu parking fees can reduce development costs and put scarce land to productive use.



These six case studies were chosen to highlight the range and depth of parking alternatives, including those created for a specific development basis and those written into code. The case studies include some description of

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outcomes, including parking costs and development decisions; support for compact, mixed-use, walkable communities; and other goals. As city and county jurisdictions, Portland and Arlington have innovative approaches to managing their transportation systems, including parking, and the case studies illustrate how these policies affect specific developments.. Arlington County is an example of code-based parking reduction strategies—it encourages reduced parking primarily through lowered minimum requirements. Portland, on the other hand, has a varied toolbox of strategies to offer developers to reduce parking. In other cases, specific developments took the initiative to go against development trends in reducing parking.to achieve broader goals, such as the NASA development in California. For the Wilton Manors (Florida) and D'Orsay Hotel (California) cases, the lowered cost associated with parking alternatives was a key element that allowed the projects to be built in a way that satisfied multiple goals of the community and developers. The parking alternatives can also provide directly documentable environmental benefits: SAFECO's use of transportation management measures and development design, limited air emissions associated with automobile commuting and protected water quality. Parking alternatives used for The Shoppes of Wilton Manors and D'Orsay Hotel developments facilitated these infill projects, thus preventing additional sprawl and the associated air and water quality impacts.

Innovative Parking Policies: Portland, Oregon

Portland, Oregon, has introduced several innovative planning policies (listed in the box on this page) to balance transportation needs with environmental protection, community design, affordable housing, and other goals. The two developments profiled below are just a sample of the numerous projects that have taken advantage of the city's parking reduction policies to achieve economic, environmental, and social benefits. Others, in brief, include:

Innovative Parking Policies
Portland, Oregon

Portland has adopted a range of parking policies to promote infill development and balance driving and alternatives to the private car, including:

- No minimum parking requirements in the central city;
- Parking maximums in most neighborhoods, including downtown;
- Transferable parking rights in areas with parking maximums;
- Reductions from typical minimum requirements for car-sharing vehicles;
- Reductions from typical minimum requirements for vehicle trip reduction strategies, such as transit access and bicycle parking;
- Context-specific standards; and
- Provisions for shared parking.

■ Stadium Station Apartments: 115 affordable apartments, with parking at 0.6 spaces per unit. Of the 40 units already leased, only one-third of households own automobiles. Despite already low parking ratios, 50 percent of the parking remains unused at full occupancy.

■ Orenco Station and La Salle Apartments: Both have parking reductions to 1.8 spaces per unit and provide transit pass allowances to residents. This has achieved a large increase in

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transit ridership among occupants.

- Collins Circle, Center Commons, and Russellville Commons Apartments: each is able to serve residents with a combination of transit access, walkability, and fewer than one parking space per unit

Hilton Hotel

The Hilton Executive Tower Hotel and garage, developed by Melvin Mark Companies, is in the heart of the Portland downtown business district, within the Free Transit Zone. Constructed on a block that was the former home to the Greyhound bus terminal, the 20-story, 440,000-square-foot project consists of 312 hotel rooms, conference space, 20,000 square feet of ground-floor retail, and 680 parking spaces. The Hilton Hotel is the owner of the hotel portion of the project, and a Melvin Mark partnership owns the parking structure. Under the Portland zoning code, the maximum allowed parking for the development would have been 380 spaces—312 hotel spaces, plus 68 growth spaces for the retail.

The developers recognized that unmet demand for parking existed in Portland, but not primarily from hotel visitors. They sought to make the new parking available to other users, which would make it more efficiently used (and profitable) than if it were restricted to hotel use. They were able to accommodate needs of the new development and surrounding uses by building 680 spaces — more parking than downtown Portland parking maximums allow. This case study illustrates not only the benefits of shared parking, but that parking maximums combined with transferable parking entitlements can increase the value of real estate and development.

Under the Portland zoning code, the maximum allowed parking for the development would have been 380 spaces—312 hotel spaces, plus 68 growth spaces for the retail. These maximums are lower than both the parking generation rates published by the Institute of Transportation Engineers, and the *minimums* adopted by most cities. The maximums for new office and retail development downtown are one space per 1,000 square feet; for hotels, the maximum is one space per room.

The city views the parking maximum as an “entitlement.” New developments can either build the parking “entitlement” (the maximum parking allowed) or can transfer those spaces to another development, as long as the transfer contract is signed before the foundation is laid. Buildings that choose not to build the parking they are entitled to, or historic buildings constructed before parking became an issue, are granted an entitlement of 0.7 spaces per 1,000 square feet—70 percent of the parking entitled to new construction—which they can transfer to other developments at any time. Transferred rights are generally not sold, but are granted under certain rules that allow the project delivering the parking rights to reserve use of some of the spaces -- but at market rates paid to the development that built the parking.

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In addition to parking limits, the city also has created three different types of parking spaces applicable to the Hilton Hotel development:

- **Hotel spaces**: By code, these spaces may only be sold to hotel users (guests or visitors) between the hours of 7:00 a.m. and 6:00 p.m., weekdays. If the hotel is in a slow season, or if not all hotel visitors want parking, the remaining parking spaces go unused—a potential financial liability.
- **Growth spaces**: These are the spaces entitled to new development. They have no constraints and can be sold however the developer sees fit.
- **Preservation spaces**: These are spaces generally entitled to older and historic buildings that were constructed without parking. They are more restrictive than growth spaces; if they are not used by building occupants, they can only be sold to other cash users on a daily or hourly basis.



Courtesy of Melvin Mark Companies

The Hilton project combined these two policies -- the transferable rights and the categorization of parking spaces -- to build enough spaces to serve both the hotel and surrounding developments. The spaces built include:

- 100 hotel spaces allowed under the zoning code, but restricted to use by hotel visitors (only 30 percent of their entitlement in this category).
- 68 growth spaces allowed for the retail space under the zoning code (100 percent of their entitlement).
- 512 spaces by transferring the parking entitlement from nearby buildings and new projects:
- 200 growth spaces transferred from a concurrent project, the 250,000 -square-foot Pioneer Place mall. The project wanted the parking to attract customers, but did not want to assume development costs or lose retail density on the site to parking.
- 312 preservation spaces transferred from seven buildings in the area. Most of these were office buildings built at a time when parking was not included.

Transferable parking rights made the Hilton/Melvin Mark development financially beneficial to all parties involved. The Hilton project would not have been feasible had its developers not been able to get the additional parking spaces and the flexibility to manage parking. As a major revenue component, the transfer of parking entitlements allowed the developers to secure funding from lenders. Prior to development, they were able to sell 500 monthly parking passes to managers of the buildings from which they had obtained

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preservation space rights. Like pre-leasing an office building, this committed revenue helped in obtaining financing. The additional parking and more flexible preservation and growth parking spaces also reduced risk and seasonal fluctuations that the code's "hotel use" parking constraints present. The garage operates with day-to-day averages of 85 to 90 percent occupancy from being able to sell to many different users—a major source of revenue for the project.

Transferable parking entitlements retains the advantages of maximum parking requirements, such as reduced vehicle trips and reduced land area devoted to parking, while creating flexibility and a potential for profit that attracts major developments to the area. In this way, transferable parking entitlements help to reinforce the economic health of the central city, and important goal in the Portland region. Downtown development ensures that the city of Portland retains its property tax base, promotes an active and pedestrian-friendly downtown with multiple amenities, and produces more foot traffic for surrounding businesses. Pioneer Place mall, for example, attracts more customers by having available parking at an adjacent site, without adding the risk of developing parking or losing retail space on their property.

Portland Hilton Executive Tower

Profile:

- Hotel, conference center, retail, parking garage
- 312 hotel rooms
- 20,000 square feet retail
- 680 shared parking spaces – 45% more than typically allowed under parking maximums

Strategies:

- Transferable parking entitlements
- Parking maximums
- Shared parking

Benefits:

- Increased parking revenue helped attract major downtown development
- New parking benefit provided for older downtown buildings without their own garages
- Shared use reduced impact of extra, empty parking spaces

The preservation buildings that transferred their spaces to Melvin Mark Companies also reap significant financial benefit. Typically older, commercial buildings are at a market disadvantage for leasing space because they cannot provide or commit parking for their tenants in office leases. With parking built at the Hilton/Melvin Mark garage and preferential rights to lease to their tenants, the older buildings compete on a more level playing field with newer buildings for prospective tenants.

Buckman Heights and Buckman Terrace

Located adjacent to Portland's central city Lloyd District and along the edge of a light-industrial area, the site of the Buckman Heights mixed-use development and the Buckman Terrace Apartments was used for decades as a car dealership. Despite a heated real estate market, the 3.7-acre site had been on sale for well over a year, unattractive to most developers. Prendergast & Associates saw an opportunity to build housing on the site, given its prime location—the project is located nine blocks from light rail, within five blocks of four high-frequency bus lines, and surrounded by a growing network of bike lanes and routes. It is also within easy walking distance of jobs in the Lloyd District, the Central Eastside, and downtown. In part because of Portland's parking policies, Prendergast was able to purchase the site in 1997,



Courtesy of Pendergast & Associates, Inc.

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sell the dealership building to a retail user, and convert the remaining 2.5 acres of vacant parking lots into sites for 274 units of housing—an 8-unit townhouse project, a 144-unit mixed-income apartment building, and a 122-unit apartment building with a small retail space. Creative parking strategies helped to keep development costs low.

Buckman Heights Apartments and Buckman Terrace

Profile:

- Mixed market-rate and affordable housing with modest retail
- 144 units and 122 units, respectively
- Parking ratios of 0.4 and 0.57 spaces per unit, respectively

Strategies:

- Parking maximums
- Use of on-street parking
- Shared off-site parking
- Car-sharing and bicycle parking available
- Parking charges separated from rents

Benefits:

- Lowered parking ratios increase affordability: 40% of Buckman Heights units are affordable
- Elminating excess parking saved Buckman Terrace developers at least $875,000
- Eliminating excess parking made room for more affordable units
- Residents benefit from affordable transportation options: bicycle facilities are well used

The city of Portland has very low minimum parking requirements in the area. Zoned for general employment, with housing allowed but not actively encouraged, the minimum parking requirements were just 0.5 spaces per unit—already a significant reduction from the typical urban standards of between one and two spaces per apartment. This neighborhood is close to transit and jobs, providing consumers with a choice of different housing types and mobility options.

Both developments have extremely low parking ratios. Buckman Heights has 58 on-site parking spaces for a ratio of 0.4 spaces per unit. Buckman Terrace has 70 spaces at a ratio of 0.57 spaces per unit, with only on-street parking for the retail. These spaces are a mix of carport, surface, and at-grade structure spaces.

The developmenter was able to both reduce the parking required and keep parking demand lower than supply through the following strategies:

- **Bicycle Facilities:** Buckman Heights Apartments eliminated 14 required on-site parking spaces by providing 56 secure, covered bicycle parking spaces in addition to the 36 spaces required by code. Portland zoning provision allows four covered, secure bike parking spaces to be substituted for one automobile parking space, up to a maximum of 25 percent of the required parking. The developer also provided lockers, floor pumps, and a workstand in the bike rooms. The bicycle parking has been so well used that the developer added even more bike parking to Buckman Terrace.

- **On-street parking:** The Buckman Heights development included restriping a wide street between the two apartment buildings to accommodate angled parking, increasing the supply of on-street spaces as well as creating a more pedestrian-friendly feel through the addition of generous sidewalks, landscaping, and street lamps. Although this did not directly replace the requirement for off-street spaces in this case, it provided a buffer and allowed the development to build as little parking as possible.

- **Shared off-site parking:** The development made use of on-street parking in the adjacent area where a sewing/assembly plant and a high school were located. The adjacent uses had huge on-street

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parking demand during the day (when residents are typically at work) but were empty on evenings and weekends (when residents are typically home and parking their cars). This unique setting allowed the developer and the lenders to feel comfortable with the sharply reduced on-site parking ratios.

- **Unbundled Parking Costs:** Paying for parking separately from rent helps keep residents aware of parking costs and allows them to make informed, economic choices about vehicle ownership and other transportation options. Parking at Buckman Heights costs between $15 and $30 per month, depending on surface or covered spaces. Buckman Terrace parking (structured) costs $50 per month.
- **Car Sharing:** FlexCar (originally CarSharing Portland) now has two vehicles at the complex. Since car-sharing was not available at the time of construction, it did not reduce the amount of parking that had to be built, but it now reduces the need for residents to own cars and, consequently, the demand for parking.

Keeping development costs low was particularly important because the project was not eligible for property tax abatements that are given to low-income and central city market-rate housing, because it lies just outside the central city boundary. By cutting costs, partially from parking, the developers were able to secure the funding needed for development.

Considering per space construction costs in Portland of $5,000 to $7,000 for surface parking, upwards of $15,000 for surface structures, and $25,000 to $30,000 for below-grade structures, parking reductions in the Buckman developments significantly reduced development costs. Buckman Terrace was constructed with no surplus land, so additional parking would have been forced to go underground. By forgoing the construction of 50 additional spaces, the developers were able to reduce the cost of the apartments with the savings of between $875,000 and $1,125,000. For Buckman Heights Apartments, the developers were able to add additional apartments to the project using the money saved from parking, especially helpful for revenue given rent restrictions on the affordable units.

The attention to a walkable environment has given the residents more transportation choices and improved their quality of life, while also making the project marketable. Both developments have been at or near full occupancy (95 to 100 percent leased) since the openings in 1999 and 2000, even outper-



Courtesy of Pendergast & Associates, Inc.

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forming the soft Portland housing market in recent months. The developments have provided more than 80 new affordable homes. In addition, charging for parking separately from rent benefits households who do not have cars—particularly low-income families. Infill housing also increases the city's tax base.

Context-Specific Requirements and TDM: Arlington County, Virginia

Arlington County is an urban area of about 26 square miles directly across the Potomac River from Washington, DC. Arlington County has adopted countywide development standards and guidelines, including lower parking ratios, to support future growth of high-density commercial and residential development around Metrorail stations in their two corridors—the Rosslyn-Ballston Corridor and the Jefferson Davis Corridor. Two specific projects are profiled here—a high-density residential development and a commercial development. Both have used the county's context-specific parking requirements and travel demand management program to better match parking supply with demand, making resources available for other community benefits.

Context-Specific Requirements
Arlington, Virginia

Commercial Uses:
- Commercial Office Zoning area outside of station areas: one space per 530 square feet.
- Commercial Redevelopment Zone (along Metro Corridor): one space per 580 square feet.
- Rosslyn-Ballston Metro Corridor Development and developments within one-quarter mile of a Metro station: one space per 1,000 square feet.

Retail Uses:
- For retail and service-commercial uses within 1,500 feet of a Metro station, no parking is required for the first 5,000 square feet of gross floor area.
- Any square footage above that has the same parking requirements as commercial in the area (either 1:580 square feet or 1:1,000 square feet, depending on its location in the corridor).

Residential Uses:
- High-density residential: 1.08 spaces per unit (1:1 + visitor).
- Townhouses: 2.2 per unit (2:1 + visitor).
- Single family homes: one space per house. This ratio assumes space in a driveway or on the street.

Arlington County dictates minimum parking requirements based primarily on distance from Metro stations. Parking requirements for commercial development are particularly transit-sensitive, with the lowest ratios for properties closest to Metro stations. According to Richard Best from the county Public Works Planning Division, if a development is within one-quarter mile of a Metro station, the county is open to allowing development with no new on-site parking, although this is not specifically written in the code.

Every project that goes through the site plan process for development along Metro corridors is required to have a transportation plan, which varies depending on density and use. Further reductions in minimum parking requirements, beyond the location- and use-specific standards, are granted for projects that include robust transportation choices, such as free or discounted transit passes for employees, other transit subsidies, ridesharing, and information on transit.

While not written into code, Arlington also enforces urban design criteria in parking construction. All parking is encouraged to be below ground, or if at surface level, it must be in a structure that is wrapped with occupiable ground floor space, in order to

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reduce the impact of the parking on the walkability of the street. There are no codes dictating such design, but a site-plan review process strongly encourages it.



Courtesy of McCaffery Interests

The Market Common

The Market Common in Clarendon is a mixed-use development with retail and restaurant space, 300 market-rate apartment units on upper floors, and adjacent office space. Located three blocks from two Metro stations along the Rosslyn-Ballston corridor, and in close proximity to dense employment and retail, the area has a variety of uses and urban form that supports walking, transit, and biking as well as driving and parking. Realizing that patrons of retail establishments would be using the parking during the day while residents would mainly need parking at night, developers of the Market Common devised a shared parking strategy.



Courtesy of McCaffery Interests

Under typical suburban parking requirements, the development would have required over 2,000 parking spaces.Under the Arlington County Code, the project would have required 1,504 spaces for the retail, housing, and office space. But by using a shared parking strategy, the development was able to reduce the requirement by 25 percent—to 1,160 spaces. The Market Common is the first recent development approved in the county with no assigned spaces for residential units—all spaces are equally available for all uses.

Parking demand is mitigated through several strategies:

- Parking costs are unbundled from rent for residents: $25 per month for the first car, $75 to $100 per month for the second;
- Daily parking is variable for other users, with rates of $1 to $4 per hour, with higher rates for longer stays;
- Bicycle parking reduces demand, as does proximity to transit.

Perhaps the parking could have been reduced even more and still met demand. Studies of parking use at Market Common indicate that up to 20 percent of available parking remains unused at peak times. The developer and county agreed to count that surplus parking toward requirements at future phases of this development.

The Market Common

Profile:
- 225,000 square feet of retail and restaurant use
- 300 market-rate apartment units
- Parking: 25 percent reduction from county code

Strategies:
- Shared parking
- Parking costs separated from rents
- Transit and bicycle facilities

Benefits:
- Fewer required spaced reduced development costs by an estimated $16 million
- Parking paid for only by those who use it

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1801 North Lynn Street

The 1801 North Lynn Street development is a new commercial building in the Rosslyn Metrorail station area, zoned for parking requirements of one space per 1,000 square feet, dependent upon the choices available to travelers. The zoning in this area permits increases in density and height when the County Board finds that the development offers important community benefits. The 1801 North Lynn Street development has 347,295 square feet of office space, 6,065 square feet of retail, and 386 parking spaces. At typical suburban parking ratios, that amount of development would have been accompanied by roughly three times as many parking spaces. Transportation Demand Management strategies allowed parking to be reduced to one space per 1,000 square feet ratio. The transportation program included the following elements:

1801 North Lynn Street

Profile:
- Office building with street-level retail
- 348,000 square feet of office space
- 6,000 square feet of retail space
- 386 parking spaces, one-third of typical requirements

Strategies:
- Extensive TDM program including fare subsidies
- Bicycle, pedestrian, and transit facilities

Benefits:
- Employees have a range of commuting choices
- Eliminating unnecessary parking helped make project financially feasible
- Increased tax base from new commercial activity

- Full-time, on-site Employee Transportation Coordinator to manage the program;
- Financial contribution to the Rosslyn Commuter Store;
- Transit fare subsidies for employees;
- Implementation of several ridesharing and parking strategies, including promoting ridesharing, helping commuters find rides, and subsidizing parking for carpools and off-peak commuting; and
- Bike facilities and showers to encourage bicycle commuting.



For workers in this building, the discounted Metro fare, along with walking and biking access to many residential neighborhoods, provides real choices in how to get to work. For shoppers at its retail establishments, newly available on-street parking in front of the stores provides a better option than existed before. The county gets an increased tax base and the vitality of mixed-use development and street-level retail in an area that in the past has not enjoyed off-peak activity.

Financial benefits to the developers of the two Arlington County projects are obvious -- reduced parking requirements sharply reduce construction costs, which in Arlington can mean upwards of $15,000 per space for structured parking, and up to $25,000 or more for below-grade spaces. Building less parking is a major part of making the projects financially feasible, in terms of balancing land costs, construction costs, revenue, and

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lending. The Market Commons project, for example, saved $16 million from the 400 forgone parking spaces, without which it would not have been a feasible project.

Arlington has succeeded in promoting high-density, mixed-use developments with reduced parking in its Metrorail corridors. This kind of design promotes walk and bike trips as people can go from home to work and shopping in very short distances. Urban design in both projects pays close attention to pedestrian comfort, by providing usable public space, circulation paths, attractive landscaping, and engaging street-level architecture.

Transportation Management for Mixed-Use Development: Santa Clara, California NASA Research Park

The NASA Ames Research Center (ARC) is a 1,500-acre site of federally owned land that lies between the southwestern edge of the San Francisco Bay and Silicon Valley, in Santa Clara County, California. Part of the site includes Moffet field, a decommissioned military site. Years of planning and community input led to an award-winning plan for a mixed-use development including an emphasis on research and technology firms; Internet-search giant Google recently announced it would build a major campus at the site. Design and construction will continue through at least 2014.

The majority of redevelopment on NASA's land will occur in the NASA Research Park (NRP), a 213-acre parcel on the southwest part of the site. Plans for development include the restoration of existing historical buildings, as well as adding nearly two million square feet of educational, office, research and development, museum, conference center, housing, and retail space. Also being developed as part of the project is 28 acres of a 95-acre parcel on the north side of the site called "The Bay View." This area is slated for predominantly housing uses, in addition to supporting retail, childcare, and other services. The remainder of Bay View will remain as open space and natural habitat.

Because the NASA land is federally owned, it is exempt from city or county codes that dictate parking requirements, as well as other development restrictions. Despite the lack of restrictions, the NRP project sought from the beginning to reduce the impact of traffic on surrounding streets and neighborhoods—with the goal of keeping driving at least 32 percent below the typical rates by Santa Clara County residents.

Had the site been developed using typical minimum parking ratios, it would have needed 7,542 parking spaces. Instead, the TDM plan calls for 5,200 spaces, with parking ratios determined by the actual number of people expected to be on-site.

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A TDM plan was developed for the NRP and Bay View, using a range of trip reduction strategies to ensure that parking demand can be accommodated in fewer spaces The TDM plan will be binding on partners and other tenants at the NRP and Bay View developments, pursuant to the provisions of the environmental permits.

Some of the many innovative TDM strategies to achieve the plan's goals include:

NASA Research Park and Bay View

Profile:

- Partially redeveloped 1500-acre former military base with significant open space
- 1,120 town home apartments for 3,300 residents
- 810 dormitory-style housing units for 1,560 students
- Renovation of 600,000 square feet of historic buildings
- Addition of more than three million square feet of new housing, office, and retail space
- 5,200 parking spaces, 32 percent less than typical development codes require

Strategies:

- Mix uses to reduce vehicle trips
- Bicycle and pedestrian facilities and shuttle bus
- Parking pricing policies
- Specific TDM goals for commuting trips, including 32 percent fewer vehicle trips than area average

Benefits:

- Reduced traffic impact on surrounding communities
- Less pavement reduces impact on natural habitat
- Convenient housing and commuting options for residents and employees
- Reducing unnecessary parking saves $3 million annually

■ Supportive site design, including housing, retail, and office space in close proximity; bicycle paths and bike parking; a network of sidewalks and paths;

■ Oh-site employees and students get priority for purchasing on-site homes

■ Site-wide shuttle bus program and bus pass;

■ Partners, lessees, & tenants are required to pass on the cost of parking or offer parking cash-out;

■ Parking fees structured so the less you park, the less you pay: o discount for monthly parking; hourly spaces; low rates for carpoolers

■ 75 percent of all spaces shared between land uses.

The TDM plan allows for adjusting the price of parking to balance demand with supply. This flexibility provides revenue for TDM programming while ensuring efficient use of the parking. The TDM program means significant cost savings for developers, while reducing the environmental impact and improving the pedestrian environment of the future campus.

Without the TDM program, the development would have needed an additional 2,342 parking spaces, at a cost of about $3 million annually. Parking fees cover all costs of providing parking and the TDM program, a benefit to both the developer and surrounding communities: The TDM program requires that those who park pay for the parking supply. Travelers who want to drive can park, while travelers who choose not to drive do not have to pay for it.

The land itself is a brownfield—formerly contaminated by its military use—as well as an environmentally sensitive habitat—home to the burrowing owl, a California species of special concern. The development focuses on remediation, preservation, and environmental sustainability. The development plan

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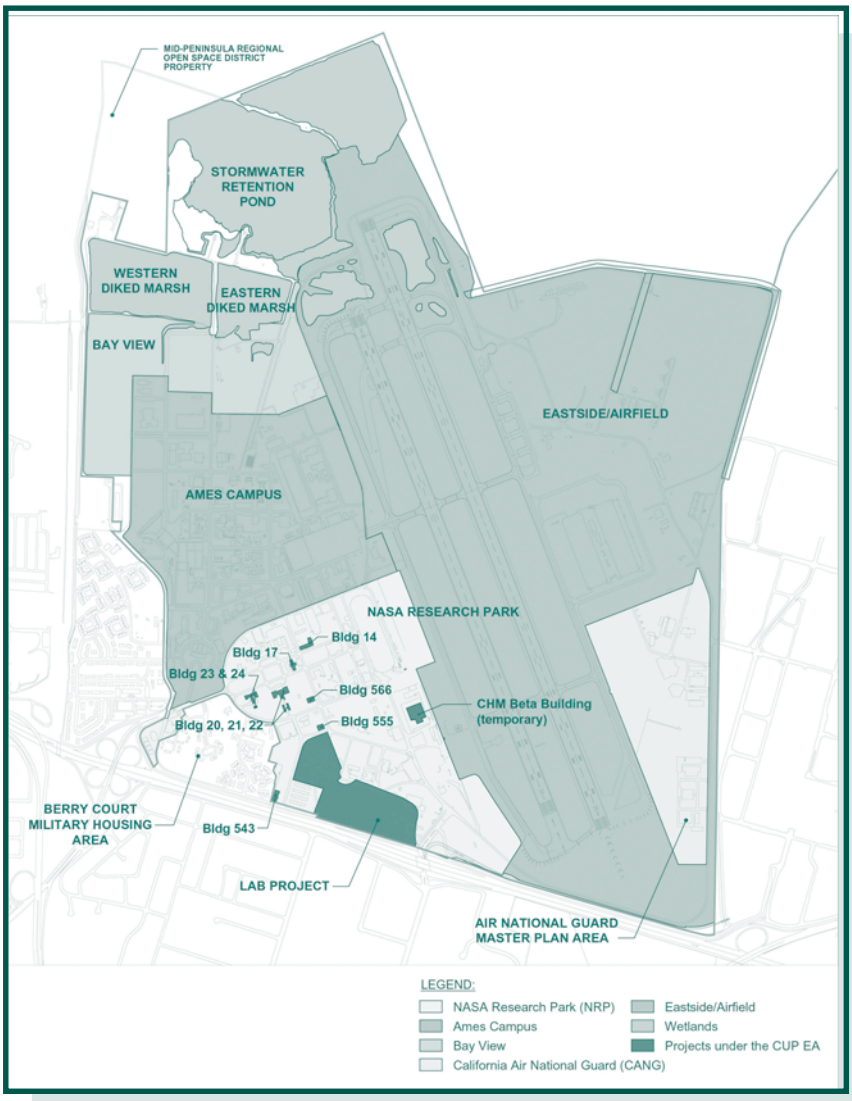
goes a step further to ensure conservation for a sustainable future—it incorporates energy efficiency, water conservation, transportation demand management, and seismic safety. This is a striking change from typical development patterns in the area.

The NRP TDM plan will reduce impervious pavement, an element of development that can damage nearby ecosystems because of reduced habitat, limited rainwater re-absorption, and increased polluted stormwater runoff. Reduced parking in the NRP saves land, which contributes to the project's 81 acres of preserved land for the endangered burrowing owl.

By combining uses on the property and offering on-site employees and students priority for purchasing homes, the development will not only reduce the need for people to commute from out of the region, but will sharply reduce internal vehicle trips. The development will be home to nearly 5,000 people, at least half of whom will work or study on the campus. These employees will be able to find services on site, instead of having to run errands off site on their lunch breaks. NASA has committed to offering a minimum of 10 percent of the homes on site at prices affordable to its employees. The reduced parking is not an end in itself. It underscores the emphasis on better urban design and improved walkability, improving the quality of life of residents,



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employees, students, and visitors.

Reduced Parking Requirements: Wilton Manors, Florida
The Shoppes of Wilton Manors

In the city of Wilton Manors, in Broward County, parking reductions were partly responsible for enabling a financially deteriorating neighborhood shopping center to be redeveloped into a successful mixed-use development, featuring restaurants, art galleries, and other entertainment uses, as well as professional offices. At its peak in the 1960s, the shopping center housed a Grand Union supermarket, a bank, a fast food restaurant, and many other stores. In the 1990s, the shopping center lost several businesses, reducing the tenant occupancy rate to 30 percent.

The Shoppes of Wilton Manors

Profile:
- Redevelopment of neighborhood shopping center
- Converted to an entertainment destination
- Eliminated construction of 390 unnecessary parking spaces

Strategies:
- Zoning overlay district recognizes lower demand for parking
- Off-site shared parking facilities

Benefits:
- Buildings preserved for rental, rather than demolished for parking
- Saved $1.9 million in construction costs
- Increased property values and city revenues
- Helped inspire nearby redevelopment

Southeast Florida, comprising Palm Beach, Broward, and Dade Counties, is one of the fastest growing regions of the United States. Projections for 2015 suggest that the population will reach 6.2 million people, an increase of over 50 percent from 1990. With the growing population and increasing development, fragile ecosystems are being lost and water supplies threatened. Communities and this region are seeking to reverse these trends by developing compact, mixed-use, walkable places. Reducing parking requirements is one element of southeast Florida's move toward smart growth and development.

To accommodate redevelopment of the shopping center and revitalize the area, the city teamed with a private development company, Redevco, creating a public/private partnership to transform the property. Because a host of "big box" retail stores had recently located in outlying areas, this property could not support additional retail stores. Instead, the city and Redevco identified an untapped market niche—entertainment, cultural attractions, and restaurants. To enable these uses, the city created a new zoning overlay district that not only changed zoning requirements to allow arts and entertainment uses, but also exempted the developer from standard parking requirements by allowing shared parking in planned off-site public parking structures. The new zoning district also allowed outside cafes and seating to make the restaurants more inviting and attractive.

Under the city's generic parking requirements, art and entertainment uses would have required 390 new parking spaces, in addition to the existing spaces at the site required for existing retail. Construction of the additional

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390 parking spaces would have cost approximately $1.9 million and would have also necessitated demolition of existing buildings, further increasing redevelopment costs and eliminating rental income from the lost buildings. Reducing the parking requirements and allowing shared parking reduced the development costs enough to make the redevelopment financially feasible.

The Shoppes of Wilton Manors now boasts full occupancy and rental rates of $32 per square foot (up from $8 per square foot). These two complementary factors—increased occupancy and increased rental rates—account for an increase in total annual rental income of $26 million, or 12 times its former rental income.

In addition to the financial success of the project, the revitalization of the Shoppes of Wilton Manors has provided other benefits to the community. The project has stimulated adjacent economic development. An office building next door that was vacant for 18 months now houses a law firm with 100 employees, many of whom frequent the restaurants and entertainment facilities at the Shoppes of Wilton Manors. Property values in the surrounding area are also improving; rental rates have almost doubled, from $6 to between $11 and $14 per square foot of leased space. The increased property value of the Shoppes of Wilton Manors—increasing by more than 10 times the initial value, from $226,000 to over $3.3 million—will add an estimated $80,000 in property tax revenues to the city. In addition, the other private investments along Wilton Drive have increased city-wide property tax revenues by 10 percent. Storefront and landscaping improvements make the area more attractive. Criminal activity has dropped due to the increased activity and vibrancy of the area. The walkable nature of the town center is enhanced as a result of improved site access. All of these benefits contribute to an improved quality of life for local residents and business people.

Some of the key elements in Wilton Manors' success include:

- The developer's and the city's willingness and commitment to work together;
- The city's flexibility in reducing parking requirements to support different redevelopment uses;
- Substantial cost savings resulting from parking reductions, making the redevelopment financially feasible; and
- Contributing to significant secondary benefits, including increasing the tax base and design improvements, by catalyzing surrounding development.

According to Redevco executive vice president, Debra Sinkle, the project succeeded because of the public/private partnership between the city and Redevco. The city's flexibility on zoning requirements and its commitment to the project created the confidence necessary for private investment.

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TDM Program: Redmond, Washington SAFECO Insurance Company Expansion

King County Metro
King County, Washington

- Washington's most populous county, with almost 2 million residents
- Metro transit serves 75 million riders per year, and 5,000 vanpool commuters each day
- Provides TDM support services to employeers

The state of Washington's Commute Trip Reduction (CTR) law was passed in 1991 to improve air quality and mitigate traffic congestion. This transportation demand management measure targets the state's largest counties (those with populations greater than 150,000 people), requiring employers with more than 100 employees to implement programs to reduce single occupancy vehicle (SOV) trips to and from work. Through the state's CTR, employers monitor commuter travel patterns by administering employee surveys, which are written and processed by the state. The CTR established a goal of a 35- percent reduction in trips by 2005 compared to 1993 levels.

The headquarters of SAFECO Insurance Company of America is in Redmond, a suburb of Seattle in King County, one of the nine Washington counties affected by the CTR. SAFECO has responded to the CTR with an award-winning Transportation Management Plan (TMP) that includes employee transit passes, reserved parking for high occupancy vehicles (HOV), ride matching, vanpooling, and guaranteed rides home for employees at all its offices in the Seattle region.. By providing these services, SAFECO was allowed to build less parking for a recent expansion project below the city of Redmond's maximum levels.

SAFECO has undertaken a large-scale construction project to accommodate anticipated growth at its corporate headquarters in Redmond, adding three buildings (385,000 square feet of office space) and three parking structures (843 parking spaces) for the new office space. To preserve the attractive, park-like setting of the 48-acre campus and to maintain a pedestrian-friendly environment, SAFECO chose to construct all three parking structures underground. These subterranean spaces, while expensive to construct at $18,000 per space, preserve green space and make it easier to walk around the business park campus. The city of Redmond has maximum parking limits that would allow SAFECO to construct 1,155 spaces. Instead, SAFECO built 843 spaces, resulting in a parking ratio of 2.2 spaces per 1,000 square feet for the new office space. This amounts to a savings, relative to the maximum limits, of 312 parking spaces. Reducing the number of spaces allowed SAFECO to mitigate the higher cost of constructing underground parking, in addition to helping meet design goals.

While these parking reductions were not implemented as cost-cutting measures, the gross cost savings associated with the parking reductions (relative to the maximum limits) amount to $5.6 million in parking construction costs, or

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about $491,000 annually.[1]

SAFECO's exemplary TMP reduced parking demand and allowed the company to build fewer parking spaces. SAFECO targets a portion of the savings to the TMP, approximately $261,000 per year including $75,400 for transit subsidies. Combining the full cost of transportation demand management at the Redmond campus and the savings from parking reductions, SAFECO annually saves $230,000 from parking reductions. Given that SAFECO would have incurred some of the costs of transportation demand management at its Redmond campus regardless of the parking reductions, the net savings actually exceed $230,000. SAFECO's decision to increase the density of its existing property, rather than move to another (likely ex-urban) location, also avoided the cost of procuring additional land.

Under its TMP, SAFECO agrees to maintain the rate of employees driving to work alone at or below 60 percent. Since 1997, SAFECO has kept these trips to between 57 and 59 percent of total commute trips. By comparison, 81 percent of east King County commuters drive alone, and 13 percent carpool (Washington State Department of Transportation 1999). Rather than drive alone, 15 percent of SAFECO employees carpool; 12 percent use vanpool services; 8 percent use public transit; and the remaining 7 percent bicycle, walk, or telecommute.

The company also maintains information on commuter vehicle miles traveled (VMT). On average, SAFECO employees travel between 6.5 and 7 miles one way. Thus, by maintaining an average 58 percent SOV rate for its 1,700 employees, SAFECO averts as many as 4,635 VMT each day, or about 1.2 million miles each year. These VMT figures assume two people per carpool and four people per vanpool. Thus, if the carpools or vanpools transport a greater number of passengers, this reduction in VMT would be greater.

- ***Air Quality Benefits:*** The environmental benefits associated with this reduction in automobile commute miles are significant. Avoiding almost 1.2 million miles of automobile travel also avoids approximately 27.56 tons of carbon monoxide, 3.85 tons of nitrogen oxides, and 2.20 tons of hydrocarbons each year.[2]
- ***Water Quality Benefits:*** Another significant, yet less quantifiable, environmental benefit of reduced parking is the preservation of pervious surfaces to absorb rainfall and prevent polluted runoff. Increasing the amount of impervious areas through paving can alter

[1] This annual amount is only associated with construction costs and assumes constant payments, an interest rate of 7.25 percent, and a 25-year payment period per discussion with SAFECO transportation manager.

[2] Calculated using average emissions factors from EPA's Office of Mobile Sources' *Compilation of Air Pollution Emissions Factors, Volume II: Mobile Sources: (AP-42)*, which provides the following emissions factors: 21.05 grams of carbon monoxide emitted per VMT, 2.97 grams of nitrogen oxides emitted per VMT, and 1.71 grams of hydrocarbons emitted per VMT.

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the area's hydrologic system and cause runoff mixed with oil and other contaminants to pollute receiving streams, rivers, lakes, and estuaries. With approximately 40 inches of precipitation each year and many fishable streams, the King County ecosystem is especially susceptible to polluted runoff. An additional 312 parking spaces in above-ground lots would mean another 100,000 square feet of impervious surfaces.

Several key factors contributed to the success of SAFECO's program.

SAFECO Insurance Company

Profile:
- Expanded office park by 385,000 square feet
- 843 underground parking spaces, 27 percent less than typical requirement

Strategy:
- TDM plan including vanpools, transit passes, guaranteed rides home

Benefits:
- Eliminating unnecessary parking saves $230,000 annually
- Employees avoid commuting costs and receive transit benefits
- Employees drive about 1.2 million miles less per year
- Less driving avoids about 33 tons of pollutants per year
- Reduced pavement for parking leads to less storm water runoff

- The city of Redmond was flexible and cooperative in allowing SAFECO to increase density on the existing property.
- SAFECO has an environmentally responsible corporate ethic of reducing parking below the maximum limits and staying in Redmond rather than relocating.
- Frequent and reliable public transit through King County Metro enables SAFECO employees to use alternative modes of transportation even when commuting from other towns in the county.
- SAFECO did not require outside financing. SAFECO's transportation management director believes that, had the project required outside funding, lenders might have resisted making loans unless more parking was provided in the development plan.

Shared Parking and In-Lieu Fees: Long Beach, California Embassy Suites at the D'Orsay Promenade

The city of Long Beach, California, recognizes that creating high-quality downtown development requires balancing the costs and supply of parking with other community goals, including economic development and walkability. In its Downtown Parking Management Plan, the city's redevelopment agency promotes small- and large-scale urban development by allowing for shared parking and in-lieu parking fees. The types of development projects eligible for these parking alternatives include non-residential new construction on lots less than 22,500 square feet, additions or rehabilitation to existing build-

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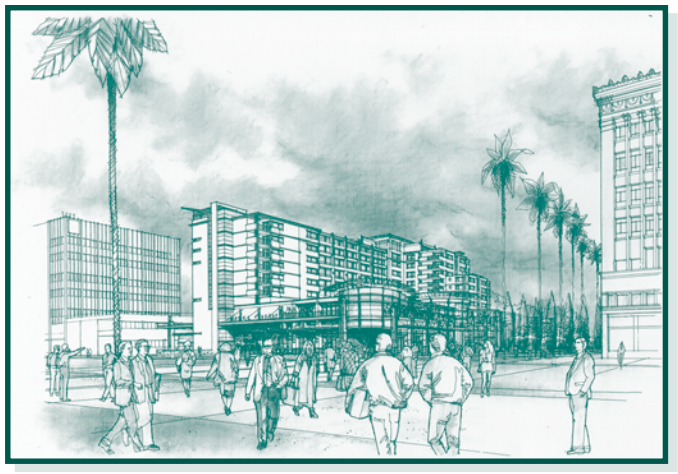
ings, and renovation of historic landmark buildings.



The four-star Embassy Suites at the D'Orsey Promenade, which was proposed to the city in 1998, provides an example of how cities can use parking reductions to facilitate redevelopment. The proposed D'Orsay Hotel included a 162-room boutique hotel with 35,000 square feet of retail space. The property, on a three-block pedestrian walkway in downtown Long Beach was previously a surface parking lot.

Other development proposals for this property had been made to the city, but fell through in part due to the financial burden imposed by the city's minimum parking requirements. They would have required the developer to construct one parking space per hotel room and four spaces per 1,000 square feet of gross floor area (GFA) of retail space, totaling 302 spaces. With construction costs of $16,000 per parking space, the parking costs would have totaled $4.83 million, making the project fiinancially infeasible.

The developer worked with the city, which conducted a traffic study to assess parking demand at other Long Beach downtown hotels. The city's planning department determined that this mixed-use hotel and retail development did not require the minimum number of parking spaces and modified the requirements in part by allowing the hotel and retail to share the available

Modified Parking Requirements for the D'Orsay Hotel

	Requirement	Gross Floor Area (GFA)	# of Spaces Required	Cost per Space	Total Cost (millions)
Generic Requirements					
Retail	4 spaces/1,000 square feet GFA	35,000 square feet	140	$16,000	$2.24
Hotel	1 space/room	162 rooms	162	$16,000	$2.59
Total	--	--	**302**		**$4.83**
Revised Requirements					
Retail	3 spaces/1,000 square feet GFA	35,000 square feet	105	$16,000	$1.68
Hotel	0.70 spaces/room	162 rooms	113	$16,000	$1.81
Total	--	--	**218**		**$3.49**
Revised Requirements and In-Lieu Fees					
Retail & Hotel On-Site	N/A	N/A	162	$16,000	$2.59
Retail & Hotel Off-Site	N/A	N/A	56	$3,000	$0.168
Total (With In-Lieu Fees)	--	--	**218**		**$2.76**

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spaces. The plan reduced the retail parking space required to three spaces per 1,000 square feet. The hotel's valet parking system allowed the reduction of parking requirements for the hotel space, to 113 spaces for the 162 rooms. These modifications reduced the number of required spaces by 84.

However, parking construction costs still made the project financially infeasible. Even with the revised requirements, the 218 parking spaces for this project would cost $3.49 million to build. Upholding its mission to encourage urban revitalization, the city of Long Beach Redevelopment Bureau agreed to further adjust the parking requirements by charging in-lieu fees in places of 56 of the required spaces. The in-lieu fee was $3,000 per parking space plus an additional $50 per space per month to cover parking operating and maintenance expenditures. The city is obligated to provide those parking spaces near the hotel.

D'Orsay Hotel

Profile:
- Boutique hotel with retail space on former downtown parking lot
- 162 parking spaces, 47 percent less than typical requirement

Strategy:
- Parking study to assess market demand
- Shared parking
- In-lieu fees to provide off-site parking

Benefits:
- Eliminating unnecessary parking saved $2 million in construction costs, making project financially feasible
- Provides new shopping and work opportunties downtown
- Adds $300,000 in new tax revenues annually, to be used for further revitalization projects

As shown in the accompanying table, the revised parking requirements decreased the developer's parking construction costs by over $2 million, with $730,000 of the savings coming from the in-lieu fee arrangement. This reduction made the entire project financially feasible. These cost savings significantly improved the projected financial net returns for the proposed project and ultimately facilitated revitalization of the surrounding area.

The hotel is expected to generate approximately $300,000 annually in additional property tax revenues for the city. Because this property is in an economically troubled area qualified to receive special assistance as a "California Redevelopment Project Area," the property tax revenue generated from the project will be directed back into the area for further redevelopment and infrastructure improvements. In addition, the state will receive revenues from California's 8.25 percent sales tax, and the city will receive revenues from the 10 percent hotel tax. The D'Orsay Hotel will give Long Beach residents an active and pedestrian friendly downtown with multiple amenities. Infill redevelopment like the D'Orsay Hotel and other projects may help to reduce development pressures on outlying areas and encourage additional redevelopment.

This successful redevelopment was made possible by several elements:

- The city of Long Beach's flexibility and recognition that parking is expensive and consumes valuable land. This enabled the developer to negotiate the reduced parking requirements and in-lieu fees that made the project feasible.
- Combining two types of innovative parking strategies (shared parking and in-lieu fees). This was necessary to make the development

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project financially feasible.

- Conducting a development-specific traffic study to estimate the number of parking spaces needed for development. The study of other downtown Long Beach hotels showed that applying the city's parking standards would have resulted in an excess supply of parking at the D'Orsay Hotel.

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United States
Environmental Protection
Agency

Development, Community and Environment Division
(1807T)
EPA 231-K-06-001
http://www.epa.gov/smartgrowth
January 2006

SARB_015851

Attachment A to Resolution No. 2002-022

Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate Implementation Provisions for the Region's Bacteria Objectives and to incorporate the Santa Monica Bay Beaches Wet-Weather Bacteria TMDL

Adopted by the California Regional Water Quality Control Board, Los Angeles Region on December 12, 2002.

Amendments:

List of Figures, Tables and Inserts
Add under Chapter 7, Section 7-4 (Santa Monica Bay Beaches Bacteria TMDL):
Tables

7-4.4. Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only): Elements
7-4.5. Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only): Final Allowable Exceedance Days by Beach Location
7-4.6. Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only): Interim Compliance Targets by Jurisdictional Groups
7-4.7. Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only): Significant Dates

Chapter 3. Water Quality Objectives, "Bacteria, Coliform"

Add under "Implementation Provisions for Water Contact Recreation Bacteria Objectives"

The single sample bacteriological objectives shall be strictly applied except when provided for in a Total Maximum Daily Load (TMDL). In all circumstances, including in the context of a TMDL, the geometric mean objectives shall be strictly applied. In the context of a TMDL, the Regional Board may implement the single sample objectives in fresh and marine waters by using a 'reference system/antidegradation ap□roach' or 'natural sources exclusion approach' as discussed below. A reference system is defined as an area and associated monitoring point that is not impacted by human activities that potentially affect bacteria densities in the receiving water body.

These approaches recognize that there are natural sources of bacteria, which may cause or contribute to exceedances of the single sample objectives for bacterial indicators. They also acknowledge that it is not the intent of the Regional Board to require treatment or diversion of natural water bodies or to require treatment of natural sources of bacteria from undeveloped areas. Such requirements, if imposed by the Regional Board, could adversely affect valuable aquatic life and wildlife beneficial uses supported by natural water bodies in the Region.

Under the reference system/antidegradation implementation procedure, a certain frequency of exceedance of the single sample objectives above shall be permitted on the basis of the observed exceedance frequency in the selected reference system or the targeted water body, whichever is less. The reference system/anti-degradation approach ensures that bacteriological water quality is at least as good as that of a reference system and that no degradation of existing bacteriological water quality is permitted where existing bacteriological water quality is better than that of the selected reference system.

Under the natural sources exclusion implementation procedure, after all anthropogenic sources of bacteria have been controlled such that they do not cause or contribute to an exceedance of the single sample objectives and natural sources have been identified and quantified, a certain frequency of exceedance of the single sample objectives shall be permitted based on the residual exceedance frequency in the specific water body. The residual exceedance frequency shall define the background level of exceedance due to natural sources. The 'natural sources exclusion' approach may be used if an appropriate reference system cannot be identified due to unique characteristics of the target water body. These approaches are

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consistent with the State Antidegradation Policy (State Board Resolution No. 68-16) and with federal antidegradation requirements (40 CFR 131.12).

The appropriateness of these approaches and the specific exceedance frequencies to be permitted under each will be evaluated within the context of TMDL development for a specific water body, at which time the Regional Board may select one of these approaches, if appropriate.

These implementation procedures may only be implemented within the context of a TMDL addressing municipal storm water, including the municipal storm water requirements of the Statewide Permit for Storm Water Discharges from the State of California Department of Transportation (Caltrans), and non-point sources discharges. These implementation provisions do not apply to NPDES discharges other than MS4 discharges.[1]

Chapter 7. Total Maximum Daily Loads (TMDLs) Summaries, Section 7-4 (Santa Monica Bay Beaches Bacteria TMDL)

Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only)*

This TMDL was adopted by the Regional Water Quality Control Board on December 12, 2002.

This TMDL was approved by:

The State Water Resources Control Board on [Insert Date].
The Office of Administrative Law on [Insert Date].
The U.S. Environmental Protection Agency on [Insert Date].

The following table summarizes the key elements of this TMDL.

[1] Municipal storm water discharges in the Los Angeles Region are those with permits under the Municipal Separate Storm Sewer System (MS4) NPDES Program. For example, the MS4 permits at the time of this amendment are the Los Angeles County Municipal Storm Water NPDES Permit, Ventura County Municipal Storm Water NPDES Permit, City of Long Beach Municipal Storm Water NPDES Permit, and elements of the statewide storm water permit for the California Department of Transportation (Caltrans).

Attachment A to Resolution No. 2002-022

Table 7-4.4. Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only): Elements

Element	Key Findings and Regulatory Provisions
Problem Statement	Elevated bacterial indicator densities are causing impairment of the water contact recreation (REC-1) beneficial use at many Santa Monica Bay (SMB) beaches. Swimming in waters with elevated bacterial indicator densities has long been associated with adverse health effects. Specifically, local and national epidemiological studies compel the conclusion that there is a causal relationship between adverse health effects and recreational water quality, as measured by bacterial indicator densities.
Numeric Target *(Interpretation of the numeric water quality objective, used to calculate the waste load allocations)*	The TMDL has a multi-part numeric target based on the bacteriological water quality objectives for marine water to protect the water contact recreation (REC-1) use. These targets are the most appropriate indicators of public health risk in recreational waters. These bacteriological objectives are set forth in Chapter 3 of the Basin Plan, as amended by the Regional Board on October 25, 2001. The objectives are based on four bacterial indicators and include both geometric mean limits and single sample limits. The Basin Plan objectives that serve as numeric targets for this TMDL are: 1. Rolling 30-day Geometric Mean Limits a. Total coliform density shall not exceed 1,000/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. c. Enterococcus density shall not exceed 35/100 ml. 2. Single Sample Limits a. Total coliform density shall not exceed 10,000/100 ml. b. Fecal coliform density shall not exceed 400/100 ml. c. Enterococcus density shall not exceed 104/100 ml. d. Total coliform density shall not exceed 1,000/100 ml, if the ratio of fecal-to-total coliform exceeds 0.1. These objectives are generally based on an acceptable health risk for marine recreational waters of 19 illnesses per 1,000 exposed individuals as set by the US EPA (US EPA, 1986). The targets apply throughout the year. The final compliance point for the targets is the wave wash[2] where there is a freshwater outlet (i.e., publicly-owned storm drain or natural creek) to the beach, or at ankle depth at beaches without a freshwater outlet. Implementation of the above bacteria objectives and the associated TMDL numeric targets is achieved using a 'reference system/anti-degradation approach' rather than the alternative 'natural sources exclusion approach' or strict application of the single sample objectives. As required by the CWA and Porter-Cologne Water Quality Control Act, Basin Plans include beneficial uses of waters, water quality objectives to protect those uses, an anti-degradation policy, collectively referred to as water quality standards, and other plans and policies necessary to implement water quality standards. This TMDL and its associated waste load allocations, which shall be incorporated into relevant permits, are the vehicles for implementation of the Region's

[2] The wave wash is defined as the point at which the storm drain or creek empties and the effluent from the storm drain initially mixes with the receiving ocean water.

Element	Key Findings and Regulatory Provisions
	standards. The 'reference system/anti-degradation approach' means that on the basis of historical exceedance levels at existing shoreline monitoring locations, including a local reference beach within Santa Monica Bay, a certain number of daily exceedances of the single sample bacteria objectives are permitted. The allowable number of exceedance days is set such that (1) bacteriological water quality at any site is at least as good as at a designated reference site within the watershed and (2) there is no degradation of existing shoreline bacteriological water quality. This approach recognizes that there are natural sources of bacteria that may cause or contribute to exceedances of the single sample objectives and that it is not the intent of the Regional Board to require treatment or diversion of natural coastal creeks or to require treatment of natural sources of bacteria from undeveloped areas. The geometric mean targets may not be exceeded at any time. The rolling 30-day geometric means will be calculated on each day. If weekly sampling is conducted, the weekly sample result will be assigned to the remaining days of the week in order to calculate the daily rolling 30-day geometric mean. For the single sample targets, each existing shoreline monitoring site is assigned an allowable number of exceedance days during wet weather, defined as days with 0.1 inch of rain or greater and the three days following the rain event. (A separate amendment incorporating the Santa Monica Bay Beaches Dry-Weather Bacteria TMDL addressed the allowable number of summer and winter dry-weather exceedance days.)
Source Analysis	With the exception of isolated sewage spills, storm water runoff conveyed by storm drains and creeks is the primary source of elevated bacterial indicator densities to SMB beaches during wet weather. Because the bacterial indicators used as targets in the TMDL are not specific to human sewage, storm water runoff from undeveloped areas may also be a source of elevated bacterial indicator densities. For example, storm water runoff from natural areas may convey fecal matter from wildlife and birds or bacteria from soil. This is supported by the finding that, at the reference beach, the probability of exceedance of the single sample targets during wet weather is 0.22.
Loading Capacity	Studies show that bacterial degradation and dilution during transport from the watershed to the beach do not significantly affect bacterial indicator densities at SMB beaches. Therefore, the loading capacity is defined in terms of bacterial indicator densities, which is the most appropriate for addressing public health risk, and is equivalent to the numeric targets, listed above. As the numeric targets must be met in the wave wash and throughout the day, no degradation allowance is provided.
Waste Load Allocations (for point sources)	Waste load allocations are expressed as the number of sample days at a shoreline monitoring site that may exceed the single sample targets identified under "Numeric Target." Waste load allocations are expressed as allowable exceedance days because the bacterial density and frequency of single sample exceedances are the most relevant to public health protection.

Element	Key Findings and Regulatory Provisions
	For each shoreline monitoring site and corresponding subwatershed, an allowable number of exceedance days is set for wet weather. The allowable number of exceedance days for a shoreline monitoring site for each time period is based on the lesser of two criteria (1) exceedance days in the designated reference system and (2) exceedance days based on historical bacteriological data at the monitoring site. This ensures that shoreline bacteriological water quality is at least as good as that of a largely undeveloped system and that there is no degradation of existing shoreline bacteriological water quality. All responsible jurisdictions and responsible agencies[3] within a subwatershed are jointly responsible for complying with the allowable number of exceedance days for each associated shoreline monitoring site identified in Table 7-4.5 below. The three Publicly Owned Treatment Works (POTWs), the City of Los Angeles' Hyperion Wastewater Treatment Plant, Los Angeles County Sanitation Districts' Joint Water Pollution Control Plant, and the Las Virgenes Municipal Water Districts' Tapia Wastewater Reclamation Facility, discharging to Santa Monica Bay are each given individual WLAs of zero (0) days of exceedance during wet weather.

[3] For the purposes of this TMDL, "responsible jurisdictions and responsible agencies" are defined as: (1) local agencies that are responsible for discharges from a publicly owned treatment works to the Santa Monica Bay watershed or directly to the Bay, (2) local agencies that are permittees or co-permittees on a municipal storm water permit, (3) local or state agencies that have jurisdiction over a beach adjacent to Santa Monica Bay, and (4) the California Department of Transportation pursuant to its storm water permit.

Element	Key Findings and Regulatory Provisions
***Load Allocations** (for nonpoint sources)*	Because all storm water runoff to SMB beaches is regulated as a point source, load allocations of zero days of exceedance are set in this TMDL. If a nonpoint source is directly impacting shoreline bacteriological quality and causing an exceedance of the numeric target(s), the permittee(s) under the Municipal Storm Water NPDES Permits are not responsible through these permits. However, the jurisdiction or agency adjacent to the shoreline monitoring location may have further obligations as described under "Compliance Monitoring" below.
Implementation	The regulatory mechanisms used to implement the TMDL will include primarily the Los Angeles County Municipal Storm Water NPDES Permit (MS4 Permit), the Caltrans Storm Water Permit, the three NPDES permits for the POTWs, the authority contained in sections 13267 and 13263 of the Water Code, and regulations to be adopted pursuant to section 13291 of the Water Code. Each NPDES permit assigned a waste load allocation shall be reopened or amended at reissuance, in accordance with applicable laws, to incorporate the applicable waste load allocation(s) as a permit requirement. The implementation schedule will be determined on the basis of the implementation plan(s), which must be submitted to the Regional Board by responsible jurisdictions and agencies within two years of the effective date of the TMDL (see Table 7-4.7). After considering the implementation plan(s), the Regional Board shall amend the TMDL at a public hearing and, in doing so, will adopt an individual implementation schedule for each jurisdictional group (described in paragraph 3 below) that is as short as possible taking into account the implementation approach being undertaken. Responsible jurisdictions and agencies must clearly demonstrate in the above-mentioned plan whether they intend to pursue an integrated water resources approach.[4] If an integrated water resources approach is pursued, responsible jurisdictions and agencies may be allotted up to an 18-year implementation timeframe, based on a clear demonstration of the need for a longer schedule in the implementation plan, in recognition of the additional planning and time needed to achieve the multiple benefits of this approach. Otherwise, at most a 10-year implementation timeframe will be allotted, depending upon a clear demonstration of the time needed in the implementation plan. The subwatersheds associated with each beach monitoring location may

[4] An integrated water resources approach is one that takes a holistic view of regional water resources management by integrating planning for future wastewater, storm water, recycled water, and potable water needs and systems; focuses on beneficial re-use of storm water, including groundwater infiltration, at multiple points throughout a watershed; and addresses multiple pollutants for which Santa Monica Bay or its watershed are listed on the CWA section 303(d) List as impaired. Because an integrated water resources approach will address multiple pollutants, responsible jurisdictions can recognize cost-savings because capital expenses for the integrated approach will implement several TMDLs that address pollutants in storm water. An integrated water resources approach shall not only provide water quality benefits to the people of the Los Angeles Region, but it is also anticipated that an integrated approach will incorporate and enhance other public goals. These may include, but are not limited to, water supply, recycling and storage; environmental justice; parks, greenways and open space; and active and passive recreational and environmental education opportunities.

Element	Key Findings and Regulatory Provisions
	include multiple responsible jurisdictions and responsible agencies. Therefore, a "primary jurisdiction," defined as the jurisdiction comprising greater than fifty percent of the subwatershed land area, is identified for each subwatershed (see Table 7-4.6).[5] Seven primary jurisdictions are identified within the Santa Monica Bay watershed, each with a group of associated subwatersheds and beach monitoring locations. These are identified as "jurisdictional groups" (see Table 7-4.6). The primary jurisdiction of each "jurisdictional group" shall be responsible for submitting the implementation plan described above, which will determine the implementation timeframe for the subwatershed. A jurisdictional group may change its primary jurisdiction by submitting a joint, written request, submitted by the current primary jurisdiction and the proposed primary jurisdiction, to the Executive Officer requesting a reassignment of primary responsibility. Two jurisdictional groups may also choose to change the assignment of monitoring locations between the two groups by submitting a joint, written request, submitted by the current primary jurisdiction and the proposed primary jurisdiction, to the Executive Officer requesting a reassignment of the monitoring location. If an integrated water resources approach is pursued, the jurisdictional group(s) must achieve a 10% cumulative percentage reduction from the total exceedance-day reduction required for the group of beach monitoring locations within 6 years, a 25% reduction within 10 years, and a 50% reduction within 15 years of the effective date of the TMDL. These interim milestones for the jurisdictional group(s) will be re-evaluated, considering planning, engineering and construction tasks, based on the written implementation plan submitted to the Regional Board two years after the effective date of the TMDL (see Table 7-4.7). If an integrated water resources approach is not pursued, the jurisdictional group(s) must achieve a 25% cumulative percentage reduction from the total exceedance-day reduction required for the group of beach monitoring locations within 6 years, and a 50% reduction within 8 years of the effective date of the TMDL (see Table 7-4.7). For those beach monitoring locations subject to the antidegradation provision, there shall be no increase in exceedance days during the implementation period above that estimated for the beach monitoring location in the critical year as identified in Table 7-4.5. The final implementation targets in terms of allowable wet-weather exceedance days must be achieved at each individual beach location no later than 18 years after the TMDL's effective date if an integrated water resources approach is pursued, or no later than 10 years after the TMDL's effective date if an integrated water resources approach is not pursued. In addition, the geometric mean targets must be achieved for each individual beach location no later than 18 years or 10 years after the effective date, respectively, depending on whether a integrated

[5] Primary jurisdictions are not defined for the Ballona Creek subwatershed or the Malibu Creek subwatershed, since separate bacteria TMDLs are being developed for these subwatersheds.

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Element	Key Findings and Regulatory Provisions
	water resources approach is pursued or not.

Element	Key Findings and Regulatory Provisions
Margin of Safety	The TMDL is set at levels that are exactly equivalent to the applicable water quality standards along with the proposed reference system/antidegradation implementation procedure. An implicit margin of safety is included in the supporting water quality model by assuming no dilution between the storm drain and the wave wash, the point of compliance. This is a conservative assumption since studies have shown that there is a high degree of variability in the amount of dilution between the storm drain and wave wash temporally, spatially and among indicators, ranging from 100% to 0%.
Seasonal Variations and Critical Conditions	Seasonal variations are addressed by developing separate waste load allocations for three time periods (wet weather, summer dry weather and winter dry weather) based on public health concerns and observed natural background levels of exceedance of bacterial indicators. (The two dry-weather periods are addressed in the Santa Monica Bay Beaches Dry-Weather Bacteria TMDL.) The critical condition for this bacteria TMDL is wet weather generally, when historic shoreline monitoring data for the reference beach indicate that the single sample bacteria objectives are exceeded on 22% of the wet-weather days sampled. To more specifically identify a critical condition within wet weather in order to set the allowable exceedance days shown in Tables 7-4.5 and 7-4.6, the 90th percentile 'storm year'[6] in terms of wet days is used as the reference year. Selecting the 90th percentile year avoids a situation where the reference beach is frequently out of compliance. It is expected that because responsible jurisdictions and agencies will be planning for this 'worst-case' scenario, there will be fewer exceedance days than the maximum allowed in drier years. Conversely, in the 10% of wetter years, it is expected that there may be more than the allowable number of exceedance days.
Compliance Monitoring	Responsible jurisdictions and agencies as defined in Footnote 2 shall conduct daily or systematic weekly sampling in the wave wash at all major drains[7] and creeks or at existing monitoring stations at beaches without storm drains or freshwater outlets to determine compliance.[8] At all locations, samples shall be taken at ankle depth and on an incoming wave. At locations where there is a freshwater outlet, during wet weather, samples should be taken as close as possible to the wave wash, and no further away than 10 meters down current of the storm drain or outlet.[9] At locations where there is a freshwater outlet, samples shall be taken when the freshwater outlet is flowing into the surf zone. If the number of exceedance days is greater than the allowable number of exceedance days for any jurisdictional group at the interim implementation milestones the responsible jurisdictions and agencies

[6] For purposes of this TMDL, a 'storm year' means November 1 to October 31. The 90th percentile storm year was 1993 with 75 wet days at the LAX meteorological station.

[7] Major drains are those that are publicly owned and have measurable flow to the beach during dry weather.

[8] The frequency of sampling (i.e., daily versus weekly) will be at the discretion of the implementing agencies. However, the number of sample days that may exceed the objectives will be scaled accordingly.

[9] Safety considerations during wet weather may preclude taking a sample in the wave wash.

Element	Key Findings and Regulatory Provisions
	shall be considered out-of-compliance with the TMDL. If the number of exceedance days exceeds the allowable number of exceedance days for a target beach at the final implementation deadline, the responsible jurisdictions and agencies within the contributing subwatershed shall be considered out-of-compliance with the TMDL. Responsible jurisdictions or agencies shall not be deemed out of compliance with the TMDL if the investigation described in the paragraph below demonstrates that bacterial sources originating within the jurisdiction of the responsible agency have not caused or contributed to the exceedance. If a single sample shows the discharge or contributing area to be out of compliance, the Regional Board may require, through permit requirements or the authority contained in Water Code section 13267, daily sampling in the wave wash or at the existing open shoreline monitoring location (if it is not already) until all single sample events meet bacteria water quality objectives. Furthermore, if a beach location is out-of-compliance as determined in the previous paragraph, the Regional Board shall require responsible agencies to initiate an investigation, which at a minimum shall include daily sampling in the wave wash or at the existing open shoreline monitoring location until all single sample events meet bacteria water quality objectives. If bacteriological water quality objectives are exceeded in any three weeks of a four-week period when weekly sampling is performed, or, for areas where testing is done more than once a week, 75% of testing days produce an exceedence of bacteria water quality objectives, the responsible agencies shall conduct a source investigation of the subwatershed(s) pursuant to protocols established under Water Code 13178. If a beach location without a freshwater outlet is out-of-compliance or if the outlet is diverted or being treated, the adjacent municipality, County agency(s), or State or federal agency(s) shall be responsible for conducting the investigation and shall submit its findings to the Regional Board to facilitate the Regional Board exercising further authority to regulate the source of the exceedance in conformance with the Porter-Cologne Water Quality Control Act.

Note: The complete staff report for the TMDL is available for review upon request.

Attachment A to Resolution No. 2002-022

Table 7-4.5. Final Allowable Wet-Weather Exceedance Days by Beach Location

Beach Monitoring Location	Estimated no. of wet weather exceedance days in critical year (90th percentile)*	Final allowable no. of wet weather exceedance days (daily sampling)*
DHS 010 - Leo Carrillo Beach, at 35000 PCH	17	17
DHS 009 - Nicholas Beach- 100 feet west of lifeguard tower	14	14
DHS 010a - Broad Beach	15	15
DHS 008 - Trancas Beach entrance, 50 yards east of Trancas Bridge	19	17
DHS 007 - Westward Beach, east of Zuma Creek	17	17
DHS 006 - Paradise Cove, adjacent to west side of Pier	23	17
DHS 005 - Latigo Canyon Creek entrance	33	17
DHS 005a - Corral State Beach	17	17
DHS 001a - Las Flores Beach	29	17
DHS 001 - Big Rock Beach, at 19900 PCH	30	17
DHS 003 - Malibu Point	18	17
DHS 003a - Surfrider Beach (second point)- weekly	45	17
S1 - Surfrider Beach (breach point)- daily	47	17
DHS 002 - Malibu Pier- 50 yards east	45	17
S2 - Topanga State Beach	26	17
DHS 101 - PCH and Sunset Bl.- 400 yards east	25	17
DHS 102 - 16801 Pacific Coast Highway, Bel Air Bay Club (chain fence)	28	17
S3 - Pulga Canyon storm drain- 50 yards east	23	17
DHS 103 - Will Rogers State Beach- Temescal Canyon (25 yrds. so. of drain)	31	17
S4 - Santa Monica Canyon, Will Rogers State Beach	25	17
DHS 104a - Santa Monica Beach at San Vicente Bl.	34	17
DHS 104 - Santa Monica at Montana Av. (25 yrds. so. of drain)	31	17
DHS 105 - Santa Monica at Arizona (In front of the drain)	31	17
S5 - Santa Monica Municipal Pier- 50 yards southeast	35	17
S6 - Santa Monica Beach at Pico/Kenter storm drain	42	17
DHS 106 - Santa Monica Beach at Strand St. (In front of the restrooms)	36	17
DHS 106a - Ashland Av. storm drain- 50 yards north	39	17
S7 - Ashland Av. storm drain- 50 yards south	22	17
DHS 107 - Venice City Beach at Brooks Av. (in front of the drain)	40	17

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Attachment A to Resolution No. 2002-022

Beach Monitoring Location	Estimated no. of wet weather exceedance days in critical year (90th percentile)*	Final allowable no. of wet weather exceedance days (daily sampling)*
S8 - Venice City Beach at Windward Av.- 50 yards north	13	13
DHS 108 - Venice Fishing Pier- 50 yards south	17	17
DHS 109 - Venice City Beach at Topsail St.	38	17
S11 - Dockweiler State Beach at Culver Bl.	23	17
DHS 110 - Dockweiler State Beach- south of D&W jetty	30	17
S12 - Imperial HWY storm drain- 50 yards north	17	17
DHS 111 - Hyperion Treatment Plant One Mile Outfall	18	17
DHS 112 - Dockweiler State Beach at Grand Av. (in front of the drain)	25	17
S10 - Ballona Creek entrance- 50 yards south	34	17
S13 - Manhattan State Beach at 40th Street	4	4
S14 - Manhattan Beach Pier- 50 yards south	5	5
DHS 114 - Hermosa City Beach at 26th St.	12	12
S15 - Hermosa Beach Pier- 50 yards south	8	8
DHS 115 - Herondo Street storm drain- (in front of the drain)	19	17
S16 - Redondo Municipal Pier- 50 yards south	14	14
DHS 116 - Redondo State Beach at Topaz St. - north of jetty	19	17
S17 - Redondo State Beach at Avenue I	6	6
S18 - Malaga Cove, Palos Verdes Estates-daily	3	3
LACSDM - Malaga Cove, Palos Verdes Estates-weekly	14	14
LACSDB - Palos Verdes (Bluff) Cove, Palos Verdes Estates	0	0
LACSD1 - Long Point, Rancho Palos Verdes	5	5
LACSD2 - Abalone Cove Shoreline Park	1	1
LACSD3 - Portuguese Bend Cove, Rancho Palos Verdes	2	2
LACSD5 - Royal Palms State Beach	6	6
LACSD6 - Wilder Annex, San Pedro	2	2
LACSD7 - Cabrillo Beach, oceanside	3	3

Notes: * The compliance targets are based on existing shoreline monitoring data and assume daily sampling. If systematic weekly sampling is conducted, the compliance targets will be scaled accordingly. These are the compliance targets until additional shoreline monitoring data are collected prior to revision of the TMDL. Once additional shoreline monitoring data are available, the following will be re-evaluated when the TMDL is revised 1) estimated number of wet-weather exceedance days in the critical year at all beach locations, including the reference system(s) and 2) final allowable wet-weather exceedance days for each beach location.

Table 7-4.6. Interim Compliance Targets by Jurisdictional Group

Jurisdiction Group	Primary Jurisdiction	Additional Responsible Jurisdictions & Agencies	Subwatershed(s)	Monitoring Site(s)***	Interim Compliance Targets as Maximum Allowable Exceedance Days during Wet Weather*,**		
					10% Reduction Milestone	25% Reduction Milestone	50% Reduction Milestone
1	County of Los Angeles	Caltrans Malibu City of Los Angeles (Topanga only) Calabasas (Topanga only)	Arroyo Sequit	DHS 010	221	212	197
			Carbon Canyon	none			
			Corral Canyon	DHS 005a			
			Encinal Canyon	DHS 010a#			
			Escondido Canyon	none			
			Las Flores Canyon	DHS 001a			
			Latigo Canyon	DHS 005			
			Los Alisos Canyon	none			
			Pena Canyon	none			
			Piedra Gorda Canyon	DHS 001			
			Ramirez Canyon	DHS 006			
			Solstice Canyon	none			
			Topanga Canyon	S2			
			Trancas Canyon	DHS 008			
			Tuna Canyon	none			
			Zuma Canyon	DHS 007			
2	City of Los Angeles	Caltrans County of Los Angeles El Segundo (DW only) Manhattan Beach (DW only) Culver City (MDR only) Santa Monica	Castlerock	none	342	324	294
			Dockweiler	S11, DHS 110, S12, DHS 111, DHS 112			
			Marina del Rey	DHS 107, S8#, DHS 108, DHS 109			
			Pulga Canyon	S3, DHS 103			
			Santa Monica Canyon	S4			
			Santa Ynez Canyon	DHS 101, DHS 102			

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Attachment A to Resolution No. 2002-022

Jurisdiction Group	Primary Jurisdiction	Additional Responsible Jurisdictions & Agencies	Subwatershed(s)	Monitoring Site(s)***	Interim Compliance Targets as Maximum Allowable Exceedance Days during Wet Weather***		
					10% Reduction Milestone	25% Reduction Milestone	50% Reduction Milestone
3	Santa Monica	Caltrans City of Los Angeles County of Los Angeles	Santa Monica	DHS 104a, DHS 104, DHS 105, S5, S6, DHS 106, DHS 106a, S7	257	237	203
4	Malibu	Caltrans County of Los Angeles	Nicholas Canyon	DHS 009#	14	14	14
5	Manhattan Beach	Caltrans El Segundo Hermosa Beach Redondo Beach	Hermosa	S13#, S14#, DHS 114#, S15#	29	29	29
6	Redondo Beach	Caltrans Hermosa Beach Manhattan Beach Torrance County of Los Angeles	Redondo	DHS 115, S16#, DHS 116, S17#	58	57	56

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Jurisdiction Group	Primary Jurisdiction	Additional Responsible Jurisdictions & Agencies	Subwatershed(s)	Monitoring Site(s)***	Interim Compliance Targets as Maximum Allowable Exceedance Days during Wet Weather***		
					10% Reduction Milestone	25% Reduction Milestone	50% Reduction Milestone
7	Rancho Palos Verdes	Caltrans City of Los Angeles Palos Verdes Estates Redondo Beach Rolling Hills Rolling Hills Estates Torrance County of Los Angeles	Palos Verdes Peninsula	S18#, LACSDM#, LACSDB#, LACSD1#, LACSD2#, LACSD3#, LACSD5#, LACSD6#, LACSD7#	36	36	36

Notes: *Interim milestones will be re-calculated during the revision of the TMDL based on shoreline monitoring data collected from the wave wash and a re-evaluation of the most appropriate reference system and reference year. Furthermore, if an integrated water resources approach is pursued, as demonstrated by the implementation plans to be submitted to the Regional Board by the primary jurisdictions within two years of the effective date of the TMDL, the interim milestones will be re-evaluated on the basis of the implementation plan, considering planning, engineering and construction tasks. **Interim milestones for the Malibu and Ballona shoreline monitoring locations will be identified in subsequent bacteria TMDLs to be developed for these two watersheds. ***Monitoring sites are those shoreline locations currently monitored by the City of Los Angeles, County Sanitation Districts of Los Angeles County, and the Los Angeles County Department of Health Services at the time of adoption of this TMDL by the Regional Board. This list does not preclude the establishment of additional monitoring stations. For those subwatersheds without an existing shoreline monitoring site, responsible jurisdictions and agencies must establish a shoreline monitoring site if there is measurable flow from a creek or publicly owned storm drain to the beach during dry weather. # For those beach monitoring locations subject to the antidegradation provision, there shall be no increase in exceedance days during the implementation period above that estimated for the beach monitoring location in the critical year as identified in Table 7-4.5.

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Table 7-4.7. Santa Monica Bay Beaches Bacteria TMDL (Wet Weather Only): Significant Dates

Date	Action
120 days after the effective date of the TMDL	Pursuant to a request from the Regional Board, responsible jurisdictions and responsible agencies must submit coordinated shoreline monitoring plan(s) to be approved by the Executive Officer, including a list of new sites* and/or sites relocated to the wave wash at which time responsible jurisdictions and responsible agencies shall select between daily or systematic weekly shoreline sampling.
20 months after the effective date of the TMDL	Responsible jurisdictions and agencies shall provide a draft written report to the Regional Board outlining how each intends to cooperatively (through Jurisdictional Groups) achieve compliance with the TMDL. The report shall include implementation methods, an implementation schedule, and proposed milestones.
Two years after effective date of TMDL	Responsible jurisdictions and agencies shall provide a written report to the Regional Board outlining how each intends to cooperatively (through Jurisdictional Groups) achieve compliance with the TMDL. The report shall include implementation methods, an implementation schedule, and proposed milestones. Under no circumstances shall final compliance dates exceed 10 years for non-integrated approaches or 18 years for integrated water resources approaches. Regional Board staff shall bring to the Regional Board the aforementioned plans as soon as possible for consideration.
4 years after effective date of TMDL	The Regional Board shall reconsider the TMDL to: (1) refine allowable wet weather exceedance days based on additional data on bacterial indicator densities in the wave wash and an evaluation of site-specific variability in exceedance levels, (2) re-evaluate the reference system selected to set allowable exceedance levels, including a reconsideration of whether the allowable number of exceedance days should be adjusted annually dependent on the rainfall conditions and an evaluation of natural variability in exceedance levels in the reference system(s), (3) re-evaluate the reference year used in the calculation of allowable exceedance days, and (4) re-evaluate whether there is a need for further clarification or revision of the geometric mean implementation provision.

Attachment A to Resolution No. 2002-022

Date	Action
Significant Dates for Responsible Jurisdictions and Agencies *Not* Pursuing an Integrated Water Resources Approach	
6 years after effective date of the TMDL	Each defined jurisdictional group must achieve a 25% cumulative percentage reduction from the total exceedance-day reductions required for that jurisdictional group as identified in Table 7-4.6.
8 years after effective date of the TMDL	Each defined jurisdictional group must achieve a 50% cumulative percentage reduction from the total exceedance-day reductions required for that jurisdictional group as identified in Table 7-4.6.
10 years after effective date of the TMDL	Final implementation targets in terms of allowable wet-weather exceedance days must be achieved at each individual beach as identified in Table 7-4.5. In addition, the geometric mean targets must be achieved for each individual beach location.
Significant Dates for Responsible Jurisdictions and Agencies Pursuing an Integrated Water Resources Approach to Implementation	
6 years after effective date of the TMDL	Each defined jurisdictional group must achieve a 10% cumulative percentage reduction from the total exceedance-day reductions required for that jurisdictional group as identified in Table 7-4.6.
10 years after effective date of the TMDL	Each defined jurisdictional group must achieve a 25% cumulative percentage reduction from the total exceedance-day reductions required for that jurisdictional group as identified in Table 7-4.6.
15 years after effective date of the TMDL	Each defined jurisdictional group must achieve a 50% cumulative percentage reduction from the total exceedance-day reductions required for that jurisdictional group as identified in Table 7-4.6.
18 years after effective date of the TMDL	Final implementation targets in terms of allowable wet-weather exceedance days must be achieved at each individual beach as identified in Table 7-4.5. In addition, the geometric mean targets must be achieved for each individual beach location.

Notes: *For those subwatersheds without an existing shoreline monitoring site, responsible jurisdictions and agencies must establish a shoreline monitoring site if there is measurable flow from a creek or publicly owned storm drain to the beach during dry weather.

Attachment B to Resolution No. 2002-022

Amendment to the Water Quality Control Plan – Los Angeles Region to Revise the Santa Monica Bay Beaches Dry-Weather Bacteria TMDL

Adopted by the California Regional Water Quality Control Board, Los Angeles Region on December 12, 2002.

Amendments:

Chapter 7. Total Maximum Daily Loads (TMDLs) Summaries
Santa Monica Bay Beaches Bacteria TMDL (Dry Weather Only)*

Table 7-4.3. Santa Monica Bay Beaches Bacteria TMDL (Dry Weather Only): Significant Dates

Date	Action
120 days after the effective date of the TMDL	Responsible jurisdictions and responsible agencies must submit coordinated shoreline monitoring plan(s), including a list of new sites or sites relocated to the wave wash at which time responsible jurisdictions and responsible agencies will select between daily and weekly shoreline sampling.
120 days after the effective date of the TMDL	Responsible jurisdictions and responsible agencies must identify and provide documentation on 342 potential discharges to Santa Monica Bay beaches listed in Appendix C of the TMDL Staff Report dated January 11, 2002. Documentation must include a Report of Waste Discharge (ROWD) where necessary. Responsible jurisdictions and responsible agencies must identify and provide documentation on potential discharges to the Area of Special Biological Significance (ASBS) in northern Santa Monica Bay from Latigo Point to the County line. Cessation of the discharges into the ASBS shall be required in conformance with the California Ocean Plan.
~~2~~ 4 years after effective date of TMDL	Re-open TMDL to re-evaluate allowable winter dry weather exceedance days based on additional data on bacterial indicator densities in the wave wash, a re-evaluation of the reference system selected to set allowable exceedance levels, and a re-evaluation of the reference year used in the calculation of allowable exceedance days.
3 years after effective date of the TMDL	Achieve compliance with allowable exceedance days as set forth in Table 7-4.2a and rolling 30-day geometric mean targets during summer dry weather (April 1 to October 31).
6 years after effective date of the TMDL	Achieve compliance with allowable exceedance days as set forth in Table 7-4.2a and rolling 30-day geometric mean targets during winter dry weather (November 1 to March 31).

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
2	R	Alamitos Creek	20540041					
				Mercury		7.1	Miles	2006
				TMDL will be developed as part of the Santa Clara Basin Watershed Management Initiative. Additional monitoring and assessment is needed.				
					Mine Tailings			
2	L	Anderson Reservoir	20530050					
				Mercury		1013	Acres	2019
					Source Unknown			
				PCBs (Polychlorinated biphenyls)		1013	Acres	2019
					Source Unknown			
2	C	Aquatic Park Beach	20340010					
				Indicator bacteria		0.18	Miles	2019
				This listing was made by USEPA for 2006.				
					Source Unknown			
2	L	Bon Tempe Reservoir	20113020					
				Mercury		120	Acres	2019
					Source Unknown			
2	R	Butano Creek	20240031					
				Sedimentation/Siltation		3.6	Miles	2019
				Impairment to steelhead habitat.				
					Nonpoint Source			
2	L	Calero Reservoir	20540031					
				Mercury		334	Acres	2006
				TMDL will be developed as part of the Santa Clara Basin Watershed Management Initiative. Additional monitoring and assessment is needed.				
					Surface Mining			
					Mine Tailings			
2	C	Candlestick Point	20440011					
				Indicator bacteria		1.6	Miles	2019
				This listing was made by USEPA for 2006. This listing includes the area of Candlestick Point at Jackrabbit Beach, Windsurfer Circle, and Sunnydale Cove.				
					Source Unknown			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
2	E	Carquinez Strait	20710020				
				Chlordane		5657 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				DDT		5657 Acres	2008
					Nonpoint Source		
				Dieldrin		5657 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		5657 Acres	2019
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		5657 Acres	2019
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		5657 Acres	2019
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6, 7,8,-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Mercury		5657 Acres	2006
				Current data indicate fish consumption and wildlife consumption impacted uses. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		5657 Acres	2006
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) (dioxin-like)		5657 Acres	2019
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		
				Selenium		5657 Acres	2019
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.		
					Industrial Point Sources		
					Agriculture		
2	E	Castro Cove, Richmond (San Pablo Basin)	20660014				
				Dieldrin (sediment)		71 Acres	2008
					Urban Runoff/Storm Sewers		
					Point Source		
				Mercury (sediment)		71 Acres	2006
					Urban Runoff/Storm Sewers		
					Point Source		
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)		71 Acres	2019
					Urban Runoff/Storm Sewers		
					Point Source		
				Selenium (sediment)		71 Acres	2019
					Urban Runoff/Storm Sewers		
					Point Source		
2	B	Central Basin, San Francisco (part of SF Bay, Central)	20440010				
				Chlordane		40 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				DDT		40 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		40 Acres	2019
				This listing was made by USEPA.			
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Dioxin Compounds (including 2,3,7,8-TCDD)		40 Acres	2019
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.		
					Atmospheric Deposition		
				Exotic Species		40 Acres	2019
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		40 Acres	2019
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.		
					Atmospheric Deposition		
				Mercury		40 Acres	2006
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.		
					Industrial Point Sources		
					Minor Industrial Point Source		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				Mercury (sediment)		40 Acres	2006
					Urban Runoff/Storm Sewers		
					Point Source		
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)		40 Acres	2019
					Urban Runoff/Storm Sewers		
					Point Source		
				PCBs (Polychlorinated biphenyls)		40 Acres	2006
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR / POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) (dioxin-like)	**40 Acres**	**2019**
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.		
				Unknown Nonpoint Source		
				Selenium	**40 Acres**	**2019**
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.		
				Industrial Point Sources		
				Agriculture		
				Natural Sources		
				Exotic Species		
2	**C**	**Chicken Ranch Beach**	**20114033**			
				Indicator bacteria	**0.17 Miles**	**2008**
				This listing was made by USEPA for 2006.		
				Source Unknown		
2	**C**	**China Camp Beach**	**20610010**			
				Indicator bacteria	**0.08 Miles**	**2019**
				This listing was made by USEPA for 2006.		
				Source Unknown		
2	**C**	**Crissy Field Beach**	**20340010**			
				Indicator bacteria	**0.8 Miles**	**2019**
				This listing was made by USEPA for 2006. This listing includes the east and west areas of Crissy Field.		
				Source Unknown		
2	**L**	**Del Valle Reservoir**	**20430024**			
				Mercury	**1022 Acres**	**2019**
				Source Unknown		
				PCBs (Polychlorinated biphenyls)	**1022 Acres**	**2019**
				Source Unknown		
2	**C**	**Golden Hinde Beach**	**20114033**			
				Indicator bacteria	**0.11 Miles**	**2008**
				This listing was made by USEPA for 2006.		
				Source Unknown		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
2	R	Guadalupe Creek	20540050					
				Mercury		8.1	Miles	2006
				TMDL will be developed as part of the Santa Clara Basin Watershed Management Initiative. Additional monitoring and assessment is needed.				
					Mine Tailings			
2	L	Guadalupe Reservoir	20540040					
				Mercury		63	Acres	2006
				TMDL will be developed as part of the Santa Clara Basin Watershed Management Initiative. Additional monitoring and assessment is needed.				
					Surface Mining			
					Mine Tailings			
2	R	Guadalupe River	20540050					
				Mercury		18	Miles	2006
				TMDL will be developed as part of the Santa Clara Basin Watershed Management Initiative. Additional monitoring and assessment is needed.				
					Mine Tailings			
2	C	Hearts Desire Beach	20114033					
				Indicator bacteria		0.38	Miles	2008
				This listing was made by USEPA for 2006.				
					Source Unknown			
2	E	Islais Creek	20440010					
				Ammonia		46	Acres	2019
					Industrial Point Sources			
					Combined Sewer Overflow			
				Chlordane (sediment)		46	Acres	2008
					Industrial Point Sources			
					Combined Sewer Overflow			
				Dieldrin (sediment)		46	Acres	2008
					Industrial Point Sources			
					Combined Sewer Overflow			
				Hydrogen Sulfide		46	Acres	2019
					Industrial Point Sources			
					Combined Sewer Overflow			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)		46	Acres	2019
					Industrial Point Sources			
					Combined Sewer Overflow			
				Sediment Toxicity		46	Acres	2019
					Source Unknown			
2	L	Lafayette Reservoir	20732010					
				Mercury		114	Acres	2019
					Source Unknown			
				PCBs (Polychlorinated biphenyls)		114	Acres	2019
					Source Unknown			
2	R	Lagunitas Creek	20113020					
				Nutrients		17	Miles	2019
				Tributary to Tomales Bay. TMDLs will be developed as part of evolving watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
				Sedimentation/Siltation		17	Miles	2009
				Tributary to Tomales Bay. TMDLs will be developed as part of evolving watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
2	L	Lake Chabot (Alameda Co)	20420030					
				Chlordane		312	Acres	2019
					Source Unknown			
				DDT		312	Acres	2019
					Source Unknown			
				Dieldrin		312	Acres	2019
					Source Unknown			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				Mercury		312	Acres	2019
					Source Unknown			
				PCBs (Polychlorinated biphenyls)		312	Acres	2019
					Source Unknown			
2	L	Lake Herman	20721030					
				Mercury		108	Acres	2019
				Additional monitoring and assessment needed. Problem due to historical mining.				
					Surface Mining			
2	L	Lake Merced	20210010					
				Low Dissolved Oxygen		299	Acres	2019
				This listing was made by USEPA.				
					Source Unknown			
				pH		299	Acres	2019
				This listing was made by USEPA.				
					Source Unknown			
2	L	Lake Merritt	20420040					
				Organic Enrichment/Low Dissolved Oxygen		142	Acres	2019
				This listing was made by USEPA.				
					Source Unknown			
				Trash		142	Acres	2019
					Urban Runoff/Storm Sewers			
2	C	Lawsons Landing	20112030					
				Indicator bacteria		3.2	Miles	2008
				This listing was made by USEPA for 2006.				
					Source Unknown			
2	E	Marina Lagoon (San Mateo County)	20440040					
				Coliform Bacteria		169	Acres	2019
					Urban Runoff/Storm Sewers			
					Nonpoint Source			
2	C	McNears Beach	20610010					
				Indicator bacteria		0.18	Miles	2019
				This listing was made by USEPA for 2006.				
					Source Unknown			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
2	C	Millerton Point	20112032				
				Indicator bacteria		0.25 Miles	2008
				This listing was made by USEPA for 2006.			
					Source Unknown		
2	E	Mission Creek	20440010				
				Ammonia		8.5 Acres	2019
					Industrial Point Sources		
					Combined Sewer Overflow		
				Chlordane (sediment)		8.5 Acres	2008
					Industrial Point Sources		
					Combined Sewer Overflow		
				Dieldrin (sediment)		8.5 Acres	2008
					Industrial Point Sources		
					Combined Sewer Overflow		
				Hydrogen Sulfide		8.5 Acres	2019
					Industrial Point Sources		
					Combined Sewer Overflow		
				Lead (sediment)		8.5 Acres	2019
					Industrial Point Sources		
					Combined Sewer Overflow		
				Mercury (sediment)		8.5 Acres	2019
					Industrial Point Sources		
					Combined Sewer Overflow		
				PAHs (Polycyclic Aromatic Hydrocarbons)		8.5 Acres	2019
					Industrial Point Sources		
					Combined Sewer Overflow		
				PCBs (Polychlorinated biphenyls) (sediment)		8.5 Acres	2006
					Industrial Point Sources		
					Combined Sewer Overflow		
				Silver (sediment)		8.5 Acres	2019
					Industrial Point Sources		
					Combined Sewer Overflow		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				Zinc (sediment)		8.5	Acres	2019
					Industrial Point Sources			
					Combined Sewer Overflow			
2	R	Napa River	20650010					
				Nutrients		65	Miles	2008
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
				Pathogens		65	Miles	2006
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
				Sedimentation/Siltation		65	Miles	2006
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Construction/Land Development			
					Land Development			
					Urban Runoff/Storm Sewers			
2	L	Nicasio Reservoir	20113012					
				Mercury		829	Acres	2019
					Source Unknown			
2	B	Oakland Inner Harbor (Fruitvale Site, part of SF Bay, Central)	20420040					
				Chlordane		0.93	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			
				Chlordane (sediment)		0.93	Acres	2008
					Source Unknown			
				DDT		0.93	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Dieldrin		**0.93 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		**0.93 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		**0.93 Acres**	**2019**
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		**0.93 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Mercury		**0.93 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		**0.93 Acres**	**2006**
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		**0.93 Acres**	**2019**
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (sediment)		**0.93 Acres**	**2006**
				This listing covers non dioxin-like PCBs. Interim health advisory for fish; uncertainty regarding water columnconcentration data.			
					Source Unknown		

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SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Sediment Toxicity		**0.93 Acres**	**2019**
					Source Unknown		
				Selenium		**0.93 Acres**	**2019**
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significantcontributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic speciesmay have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaupand scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.			
					Industrial Point Sources		
					Agriculture		
					Natural Sources		
					Exotic Species		
2	**B**	**Oakland Inner Harbor (Pacific Dry-dock Yard 1 Site, part of SF Bay, Central)**	**20420040**				
				Chlordane		**1.8 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Chlordane (sediment)		**1.8 Acres**	**2008**
					Source Unknown		
				Copper (sediment)		**1.8 Acres**	**2019**
					Source Unknown		
				DDT		**1.8 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		**1.8 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin (sediment)		**1.8 Acres**	**2008**
					Source Unknown		
				Dioxin Compounds (including 2,3,7,8-TCDD)		**1.8 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		**1.8 Acres**	**2019**
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		

SARB_015881

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Furan Compounds		1.8 Acres	2019
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Lead (sediment)		1.8 Acres	2019
					Source Unknown		
				Mercury		1.8 Acres	2006
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				Mercury (sediment)		1.8 Acres	2006
					Source Unknown		
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)		1.8 Acres	2019
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		1.8 Acres	2006
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		1.8 Acres	2019
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (sediment)		1.8 Acres	2006
					Source Unknown		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				Selenium		1.8	Acres	2019
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.			
					Industrial Point Sources			
					Agriculture			
					Natural Sources			
					Exotic Species			
				Zinc (sediment)		1.8	Acres	2019
					Source Unknown			
2	C	Pacific Ocean at Baker Beach	20340010					
				Indicator bacteria		0.45	Miles	2019
				This listing was made by USEPA for 2006. This listing includes the area of Baker Beach at Lobos Creek, Horseshoe Cove NW and NE.				
					Source Unknown			
2	C	Pacific Ocean at Bolinas Beach	20130011					
				Indicator bacteria		0.39	Miles	2019
				This listing was made by USEPA for 2006.				
					Source Unknown			
2	C	Pacific Ocean at Fitzgerald Marine Reserve	20221012					
				Coliform Bacteria		0.46	Miles	2019
					Nonpoint Source			
2	C	Pacific Ocean at Muir Beach	20130013					
				Indicator bacteria		0.2	Miles	2019
				This listing was made by USEPA for 2006.				
					Source Unknown			
2	C	Pacific Ocean at Pacifica State/Linda Mar Beach	20221011					
				Coliform Bacteria		0.87	Miles	2019
				Linda Mar and San Pedro beaches are the areas affected.				
					Urban Runoff/Storm Sewers			
					Nonpoint Source			

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
2	C	Pacific Ocean at Pillar Point	20221012				
				Mercury		0.62 Miles	2019
					Source Unknown		
2	C	Pacific Ocean at Pillar Point Beach	20221012				
				Coliform Bacteria		1.1 Miles	2019
					Nonpoint Source		
2	C	Pacific Ocean at Rockaway Beach	20221011				
				Coliform Bacteria		0.29 Miles	2019
					Urban Runoff/Storm Sewers		
					Nonpoint Source		
2	C	Pacific Ocean at Venice Beach	20222011				
				Coliform Bacteria		0.38 Miles	2019
					Nonpoint Source		
2	R	Pescadero Creek	20240013				
				Sedimentation/Siltation		26 Miles	2019
				If California Department of Fish and Game and the National Marine Fisheries Service find that for this water body fish populations are not impacted, the State Water Board supports removing this water body and pollutant from the list.			
					Nonpoint Source		
2	R	Petaluma River	20630020				
				Diazinon		22 Miles	2005
				Data source: Abelli-Amen, Petaluma Tree Planters, 1999.			
					Urban Runoff/Storm Sewers		
				Nutrients		22 Miles	2019
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.			
					Agriculture		
					Construction/Land Development		
					Urban Runoff/Storm Sewers		
				Pathogens		22 Miles	2019
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.			
					Agriculture		
					Construction/Land Development		
					Urban Runoff/Storm Sewers		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				Sedimentation/Siltation		22	Miles	2019
					Agriculture			
					Construction/Land Development			
					Urban Runoff/Storm Sewers			
2	R	Petaluma River (tidal portion)	20630040					
				Diazinon		1.1	Miles	2005
				Data source: Abelli-Amen, Petaluma Tree Planters, 1999.				
					Urban Runoff/Storm Sewers			
				Nickel		1.1	Miles	2019
				Exceedance of California Toxic Rule dissolved criteria and National Toxic Rule total criteria; elevated water and sediment tissue levels.				
					Municipal Point Sources			
					Urban Runoff/Storm Sewers			
					Atmospheric Deposition			
				Nutrients		1.1	Miles	2019
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Construction/Land Development			
					Urban Runoff/Storm Sewers			
				Pathogens		1.1	Miles	2019
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Construction/Land Development			
					Urban Runoff/Storm Sewers			
2	R	Pomponio Creek	20240020					
				Coliform Bacteria		7.1	Miles	2019
					Nonpoint Source			
2	B	Richardson Bay	20312010					
				Chlordane		2439	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Coliform Bacteria		**2439 Acres**	**2019**
				Affected area, Waldo Point Harbor, is less than 10% of embayment; source has been positively identified as substandard sewage systems in some houseboat areas; extensive local control program in place with significant water quality improvements.			
					Urban Runoff/Storm Sewers		
					Septage Disposal		
					Boat Discharges/Vessel Wastes		
				DDT		**2439 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		**2439 Acres**	**2008**
				This listing was made by USEPA.			
					Unknown Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		**2439 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		**2439 Acres**	**2019**
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		**2439 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6, 7,8,-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Mercury		**2439 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		**2439 Acres**	**2006**
				This listing covers non dioxin-like PCBs. Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) (dioxin-like)		2439 Acres	2019
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		
2	E	Sacramento San Joaquin Delta	20710010				
				Chlordane		41736 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				DDT		41736 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		41736 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		41736 Acres	2019
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		41736 Acres	2019
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		41736 Acres	2019
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6, 7,8,-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Mercury		41736 Acres	2006
				Current data indicate fish consumption and wildlife consumption impacted uses. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Nonpoint Source		

SARB_015887

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Nickel		**41736 Acres**	**2019**
				This listing was made by USEPA.			
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		**41736 Acres**	**2006**
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		**41736 Acres**	**2019**
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		
				Selenium		**41736 Acres**	**2019**
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place. Another source is exotic species.			
					Industrial Point Sources		
					Agriculture		
					Natural Sources		
					Exotic Species		
2	**B**	**San Francisco Bay, Central**	**20312010**				
				Chlordane		**70992 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				DDT		**70992 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		**70992 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		**70992 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		**70992 Acres**	**2019**
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		

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SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Furan Compounds		**70992 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.		
					Atmospheric Deposition		
				Mercury		**70992 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.		
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		**70992 Acres**	**2006**
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		**70992 Acres**	**2019**
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.		
					Unknown Nonpoint Source		
				Selenium		**70992 Acres**	**2019**
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.		
					Industrial Point Sources		
					Agriculture		
					Natural Sources		
					Exotic Species		
2	**B**	**San Francisco Bay, Lower**	**20410010**				
				Chlordane		**92274 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		

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SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				DDT		**92274 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		**92274 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		**92274 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.		
					Atmospheric Deposition		
				Exotic Species		**92274 Acres**	**2019**
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		**92274 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6, 7,8,-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.		
					Atmospheric Deposition		
				Mercury		**92274 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources: water quality objective exceedances. Elevated sediment levels and elevated tissue levels.		
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		**92274 Acres**	**2006**
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		**92274 Acres**	**2019**
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.		
					Unknown Nonpoint Source		

SARB_015890

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
2	B	San Francisco Bay, South	20510000				
				Chlordane		9204 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				DDT		9204 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				Dieldrin		9204 Acres	2008
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		9204 Acres	2019
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		9204 Acres	2019
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		9204 Acres	2019
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Mercury		9204 Acres	2006
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs frompoint sources: water quality objective exceedances. Elevated sediment level and elevated tissue levels.			
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		9204 Acres	2006
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		

SARB_015891

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) (dioxin-like)		9204	Acres	2019
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.				
					Unknown Nonpoint Source			
				Selenium		9204	Acres	2019
				A formal health advisory has been issued by OEHHA for benthic-feeding ducks in South San Francisco Bay. This health advisory clearly establishes that water contact recreation beneficial use (REC-1) is not fully supported and standards are not fully met.				
					Agriculture			
					Domestic Use of Ground Water			
2	R	San Francisquito Creek	20550040					
				Sedimentation/Siltation		12	Miles	2008
				Impairment to steelhead habitat.				
					Nonpoint Source			
2	R	San Gregorio Creek	20230014					
				Coliform Bacteria		11	Miles	2019
					Nonpoint Source			
				Sedimentation/Siltation		11	Miles	2019
				Impairment to steelhead habitat.				
					Nonpoint Source			
2	B	San Leandro Bay (part of SF Bay, Central)	20420040					
				Chlordane		588	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			
				Dieldrin		588	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			
				Dioxin Compounds (including 2,3,7,8-TCDD)		588	Acres	2019
					Atmospheric Deposition			
				Exotic Species		588	Acres	2019
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.				
					Ballast Water			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Furan Compounds		**588 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.		
					Atmospheric Deposition		
				Lead (sediment)		**588 Acres**	**2019**
					Source Unknown		
				Mercury		**588 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.		
					Industrial Point Sources		
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				Mercury (sediment)		**588 Acres**	**2006**
					Source Unknown		
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)		**588 Acres**	**2019**
					Source Unknown		
				Pesticides (sediment)		**588 Acres**	**2019**
					Source Unknown		
				Zinc (sediment)		**588 Acres**	**2019**
					Source Unknown		
2	**B**	**San Pablo Bay**	**20610010**				
				Chlordane		**68349 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				DDT		**68349 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		

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SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Dieldrin		**68349 Acres**	**2008**
				This listing was made by USEPA.			
					Nonpoint Source		
				Dioxin Compounds (including 2,3,7,8-TCDD)		**68349 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.			
					Atmospheric Deposition		
				Exotic Species		**68349 Acres**	**2019**
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.			
					Ballast Water		
				Furan Compounds		**68349 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6, 7,8,-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.			
					Atmospheric Deposition		
				Mercury		**68349 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Municipal Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				Nickel		**68349 Acres**	**2019**
				This listing was made by USEPA.			
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		**68349 Acres**	**2006**
				This listing covers non dioxin-like PCBs.Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		**68349 Acres**	**2019**
				The specific dioxin like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5,-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
				Selenium		68349	Acres	2019
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.			
					Industrial Point Sources			
					Agriculture			
					Natural Sources			
					Exotic Species			
2	L	San Pablo Reservoir	20660012					
				Chlordane		784	Acres	2019
					Source Unknown			
				Dieldrin		784	Acres	2019
					Source Unknown			
				Heptachlor epoxide		784	Acres	2019
					Source Unknown			
				Mercury		784	Acres	2019
					Atmospheric Deposition			
				PCBs (Polychlorinated biphenyls)		784	Acres	2019
					Source Unknown			
				Toxaphene		784	Acres	2019
					Source Unknown			
2	R	San Pedro Creek	20221011					
				Coliform Bacteria		2.4	Miles	2019
					Urban Runoff/Storm Sewers			
					Nonpoint Source			
2	R	San Vicente Creek	20221012					
				Coliform Bacteria		3.8	Miles	2019
					Nonpoint Source			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
2	L	Shadow Cliffs Reservoir	20430080					
				Mercury		90	Acres	2019
					Source Unknown			
				PCBs (Polychlorinated biphenyls)		90	Acres	2019
					Source Unknown			
2	R	Sonoma Creek	20640050					
				Nutrients		30	Miles	2008
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Construction/Land Development			
					Land Development			
					Urban Runoff/Storm Sewers			
				Pathogens		30	Miles	2006
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Construction/Land Development			
					Land Development			
					Urban Runoff/Storm Sewers			
				Sedimentation/Siltation		30	Miles	2008
				TMDL will be developed as part of ongoing watershed management effort. Additional monitoring and assessment needed.				
					Agriculture			
					Construction/Land Development			
					Land Development			
					Urban Runoff/Storm Sewers			
2	L	Soulajule Reservoir	20112012					
				Mercury		49	Acres	2019
					Source Unknown			
				PCBs (Polychlorinated biphenyls)		49	Acres	2019
					Source Unknown			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
2	R	Stevens Creek	20550020					
				Toxicity		20	Miles	2019
					Source Unknown			
2	L	Stevens Creek Reservoir	20550031					
				Chlordane		85	Acres	2019
					Source Unknown			
				Dieldrin		85	Acres	2019
					Source Unknown			
				Mercury		85	Acres	2019
					Source Unknown			
				PCBs (Polychlorinated biphenyls)		85	Acres	2019
					Source Unknown			
2	B	Suisun Bay	20710020					
				Chlordane		25335	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			
				DDT		25335	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			
				Dieldrin		25335	Acres	2008
				This listing was made by USEPA.				
					Nonpoint Source			
				Dioxin Compounds (including 2,3,7,8-TCDD)		25335	Acres	2019
				The specific compounds are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD. This listing was made by USEPA.				
					Atmospheric Deposition			
				Exotic Species		25335	Acres	2019
				Disrupt natural benthos; change pollutant availability in food chain; disrupt food availability to native species.				
					Ballast Water			

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

SAN FRANCISCO REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Furan Compounds		**25335 Acres**	**2019**
				The specific compounds are 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF. This listing was made by USEPA.		
					Atmospheric Deposition		
				Mercury		**25335 Acres**	**2006**
				Current data indicate fish consumption and wildlife consumption impacted uses. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.		
					Industrial Point Sources		
					Resource Extraction		
					Atmospheric Deposition		
					Natural Sources		
					Nonpoint Source		
				Nickel		**25335 Acres**	**2019**
				This listing was made by USEPA.			
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		**25335 Acres**	**2006**
				This listing covers non-dioxin-like PCBs. Interim health advisory for fish; uncertainty regarding water column concentration data.			
					Unknown point source		
				PCBs (Polychlorinated biphenyls) (dioxin-like)		**25335 Acres**	**2019**
				The specific dioxin-like compounds are 3,4,4,5-TCB (81), 3,3,3,3-TCB (77), 3,3,4,4,5-PeCB (126), 3,3,4,4,4,4-HxCB (169), 2,3,3,4,4-PeCB (105), 2,3,4,4,5-PeCB (114), 2,3,4,4,5-PeCB (118), 2,3,4,4,5-PeCB (123), 2,3,3,4,4,5-HxCB (156), 2,3,3,4,4,5-HxCB (157), 2,3,4,4,5,5-HxCB (167), 2,3,3,4,4,5,5-HpCB (189). This listing was made by USEPA.			
					Unknown Nonpoint Source		
				Selenium		**25335 Acres**	**2019**
				Affected use is one branch of the food chain; most sensitive indicator is hatchability in nesting diving birds, significant contributions from oil refineries (control program in place) and agriculture (carried downstream by rivers); exotic species may have made food chain more susceptible to accumulation of selenium; health consumption advisory in effect for scaup and scoter (diving ducks); low TMDL priority because Individual Control Strategy in place.		
					Industrial Point Sources		
					Natural Sources		
					Exotic Species		

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USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
2	T	Suisun Marsh Wetlands	20723000					
				Metals		66339	Acres	2019
				Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
					Flow Regulation/Modification			
				Nutrients		66339	Acres	2019
				Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
					Flow Regulation/Modification			
				Organic Enrichment/Low Dissolved Oxygen		66339	Acres	2019
				Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
					Flow Regulation/Modification			
				Salinity/TDS/Chlorides		66339	Acres	2019
				Additional monitoring and assessment needed.				
					Agriculture			
					Urban Runoff/Storm Sewers			
					Flow Regulation/Modification			
2	B	Tomales Bay	20114033					
				Mercury		8545	Acres	2010
				Current data indicate fish consumption and wildlife consumption impacted uses: health consumption advisory in effect for multiple fish species including striped bass and shark. Major source is historic: gold mining sediments and local mercury mining; most significant ongoing source is erosion and drainage from abandoned mines; moderate to low level inputs from point sources.			
					Mine Tailings			
				Nutrients		8545	Acres	2019
				TMDL will be developed as part of ongoing watershed management effort. Tributary streams, Lagunitas Creek and Walker Creek, must be managed first. Additional monitoring and assessment needed.				
					Agriculture			
				Sedimentation/Siltation		8545	Acres	2008
				TMDL will be developed as part of ongoing watershed management effort. Tributary streams, Lagunitas Creek and Walker Creek, must be managed first. Additional monitoring and assessment needed.				
					Agriculture			
					Upstream Impoundment			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS REQUIRING TMDLS

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
2	R	Walker Creek	20112013				
				Mercury		16 Miles	2006
				Tributary to Tomales Bay. TMDLs will be developed as part of evolving watershed management effort. Additional monitoring and assessment needed.			
					Surface Mining		
					Mine Tailings		
				Nutrients		16 Miles	2019
				Tributary to Tomales Bay. TMDLs will be developed as part of evolving watershed management effort. Additional monitoring and assessment needed.			
					Agriculture		
				Sedimentation/Siltation		16 Miles	2009
				Tributary to Tomales Bay. TMDLs will be developed as part of evolving watershed management effort. Additional monitoring and assessment needed.			
					Agriculture		

ABBREVIATIONS

REGIONAL WATER QUALITY CONTROL BOARDS

1	North Coast
2	San Francisco Bay
3	Central Coast
4	Los Angeles
5	Central Valley
6	Lahontan
7	Colorado River Basin
8	Santa Ana
9	San Diego

WATER BODY TYPE

B =	Bays and Harbors
C =	Coastal Shorelines/Beaches
E =	Estuaries
L =	Lakes/Reserviors
R =	Rivers and Streams
S =	Saline Lakes
T =	Wetlands, Tidal
W=	Wetlands, Freshwater

CALWATER WATERSHED

"Calwater Watershed" is the State Water Resources Control Board hydrological subunit area or an even smaller area delineation.

GROUP A PESTICIDES OR CHEM A

aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene



Fundamentals of Urban Runoff Management

TECHNICAL AND INSTITUTIONAL ISSUES

2nd Edition | 2007

Earl Shaver
Richard Horner
Joseph Skupien
Chris May
Graeme Ridley

NALMS

SARB_015901

Fundamentals of Urban Runoff Management: Technical and Institutional Issues

2nd Edition, 2007

By: Earl Shaver
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Produced in cooperation with the
U.S. Environmental Protection Agency

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Acknowledgement

The North American Lake Management Society (NALMS) support for this effort is most appreciated. NALMS' mission is to forge partnerships among citizens, scientists, and professionals to foster the management and protection of lakes and reservoirs for today and tomorrow. Lakes and reservoirs are used more now than ever and water pollution is a key problem in maintenance of lake health. NALMS supports the development, communication, and use of excellent science and cutting-edge management to further lake protection goals.

We hope this manual will provide information that can be used to further NALMS' goals.

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Preface

In 1994, the Watershed Management Institute, through the Terrene Institute and in conjunction with the U.S. Environmental Protection Agency (EPA), published *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. That manual combined technical and institutional information to provide a handy resource for practitioners and regulators for both erosion and sediment control and stormwater management. The manual was well received.

As luck would have it, in 2001 several of the original authors met up at a conference, and began to discuss the amount of new information available and our desire to update the previous work. The idea was planted and communication between the original authors began. Most of the authors wanted to contribute so we went about looking for a vehicle for distribution. As two of the previously involved organizations were not available, discussions began with the North American Lake Management Society (NALMS) which felt the manual would provide a resource for its members and anyone working with stormwater impacts on aquatic habitats. Discussion began with the EPA for funding assistance, which was subsequently approved.

If the new information represented only an evolution or increase in the data available, this book would probably not have been pursued. Rather, there has been a significant shift in program direction that represents a movement from the historic mitigation-based approach for stormwater treatment to a more source-based approach. The main reason for this shift in thinking is based on an increased recognition that streams are a valued aquatic resource that should be protected.

This change in thinking necessitated a philosophical shift from larger stormwater practices on streams to the use of practices on individual subdivisions and even individual lots. Linking stormwater goals to aquatic resource protection mainly necessitated this change in approach. Much more information continues to become available to demonstrate the significant shift necessary to protect and enhance aquatic resources. We are pleased that this new edition of *Fundamentals of Urban Runoff Management* can play a role in that shift.

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CHAPTER 1

Introduction

Discussion

To begin, this chapter sets out some of the reasons for updating *Fundamentals of Urban Runoff Management*. These include:

- The shifting emphasis and impacts of stormwater management programs and regulations;
- The Storm Water Phase II Rule published on December 8, 1999, which greatly expanded the scope and coverage of the Phase I program;
- The increased emphasis on the Total Maximum Daily Load (TMDL) approach to stormwater management;
- Changing hydrologic approaches that increasingly consider long-term continuous simulation of rainfall to more accurately size BMPs;
- The increase in the quantity and quality of water data;
- The increased prominence of biomonitoring and biocriteria; and
- New and improved stormwater management practices.

Shifting Program Emphasis

When the original *Fundamentals* manual was written in 1994, programs were focused on limiting peak discharges and providing water quality treatment. The performance of practices for quality treatment was more assumed than realized. In addition, there was little widespread documentation of practice performance and the relationships between hydrology and water quality. Aquatic ecosystems were also not recognized to any great degree. There was an assumption that removal of contaminants would be good for the environment, but at the time few studies had been done to verify the accuracy of that assumption. There has since been significant work done in this regard, with one of the studies (Horner et al., 2001) assessing the effectiveness of structural practices to protect stream aquatic resources from a watershed-wide perspective. They make a number of interesting statements, although some need to be further documented. Key findings were:

- Until watershed total impervious area exceeds 40 per cent, biological decline was more strongly associated with hydrologic fluctuation than with chemical water and sediment quality decreases. Accompanying hydrologic alteration was loss of habitat features, such as large woody debris and pool cover, and deposition of fine sediments.
- Structural BMPs at current densities of implementation demonstrated less potential than the non-structural methods (riparian buffers, vegetation preservation) to forestall resource decline as urbanization starts and progresses. There was a suggestion in the data, however, that more thorough coverage would offer substantive benefits in this situation. Moreover, structural BMPs were seen to help prevent further resource deterioration in moderately and highly developed watersheds. Analysis showed that none of the options is without limitations, and widespread landscape preservation must be incorporated to retain the most biologically productive aquatic resources.

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- Structural BMPs can make a substantive contribution to keeping stream ecosystem health from falling to the lowest levels at moderately high urbanization and, with extensive coverage, to maintaining relatively high biotic integrity at light urbanization.

Clearly, we are finding that you cannot separate water quantity and water quality issues if aquatic resource protection is a program goal. Some people, mainly from an anecdotal perspective, have recognized this, but now increasing amounts of literature support that fact. What has clearly come out of recent research is the relationship of land use to aquatic system health and well-being: it isn't just pollutants that are an issue.

Phase II Storm Water Rule

The Storm Water Phase II Rule published on December 8, 1999 greatly expanded the extent of the Phase I program. This was done by requiring operators of municipal separate storm sewer systems (MS4s) and operators of small construction sites (greater than one acre) to obtain National Pollutant Discharge Elimination System (NPDES) permits that implement programs and practices to control polluted stormwater runoff.

The expansion of Phase II is directed toward municipalities with populations under 100,000, which were not covered in Phase I. There are a number of variations to the general requirement, best set out in fact sheets developed by the EPA (Storm Water Phase II Final Rule Fact Sheet Series).

The bottom line is that most municipalities and federal facilities in the U.S. are now covered by the Storm Water Program and must implement programs and practices that control stormwater runoff. The minimum control measures required by the EPA as essential to an effective stormwater management program are:

- Public education and outreach on stormwater impacts;
- Public involvement/participation;
- Construction site stormwater runoff control;
- Post-construction stormwater management in new development and redevelopment;
- Pollution prevention/good housekeeping for municipal operations; and
- Illicit discharge detection and elimination.

Increased Emphasis on the TMDL Approach

The Total Maximum Daily Load (TMDL) approach to stormwater management has existed for a number of years (originally identified in the *Clean Water Act*, 1972). For various reasons TMDLs have now assumed much more priority on a national and state basis than was the case historically. A number of TMDLs done around the country are now serving as templates to be followed. The approach is evolving fairly rapidly with new guidance information available almost on a routine basis.

Biannually, states, territories, and authorized tribes must list those impaired waters that do not meet applicable water quality standards. Lists submitted to the EPA must identify the pollutants that cause the impairment and the water bodies targeted for TMDL development. TMDLs must then be established at levels necessary to achieve applicable water quality standards, along with a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

A TMDL specifies the amount of a particular pollutant that may be introduced into a water body and allocates the total allowable pollutant load among sources. The TMDL provides a roadmap for efforts to attain and maintain state water quality standards. TMDLs consider both point and nonpoint source pollutant loadings in determining the overall state of a receiving system and allow prioritization of efforts to achieve compliance with water quality standards.

The core of a TMDL is a computer model or simulation that predicts outcomes for various pollutants on a watershed basis. Most models in use today have been around for quite some time and are generally understood in terms of data entry and model process. Where improved data is especially important in the TMDL process is for pollutant loadings from various land uses and performance data for BMP treatment expectations. More data is absolutely essential if the TMDL process is to provide for a reasonable consideration of alternatives in a given watershed and selection of a preferred approach. There are huge issues related to funding, both public and private, and the anticipated outcome must be defined as much as possible.

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Changing Hydrologic Approaches

While stormwater management has historically relied on event-based approaches to BMP design, more practitioners are now considering long-term continuous simulation of rainfall to accurately size BMPs. By considering actual long-term rainfall records in a given area, a better gauge of performance may be obtained. Analysis of continuous rainfall data over a given time, possibly supplemented by simulation of much longer terms, may give a different performance expectation than would be expected using an event-driven sizing approach. This will have a major influence on models used for analysis and on existing design standards and sizing methodologies.

Better Water Quality Data

Water quality data is becoming much more available than was the case historically. In the past, early monitoring was based to a very large extent on the results of the National Urban Runoff Program (NURP) done in the late 1970s and early 1980s. The NURP study provided a national perspective on water quality issues, but there are now many other studies done in the U.S. and around the world, notably Australia, Canada, England, New Zealand, and a number of European countries.

Another excellent source of water quality data for practice performance is the International Stormwater Management Best Management Practices Database, which provides access to BMP performance data for about 200 studies conducted over the past 15 years. This data was compiled by the Urban Water Resources Research Council of the American Society of Civil Engineers (ASCE) to provide consistent and scientifically defensible data for BMP designs and related performance. That information is available at www.bmpdatabase.org.

In addition, considerable research is being done on the performance of wetland systems, filter systems, and newer practices such as rain gardens. Many proprietary practices are also becoming more commonly used. The development of proprietary systems will continue; this should be encouraged, subject to collection of good monitoring data that would justify their use. Some of that data is already available.

Increased Prominence of Biomonitoring and Biocriteria

While there remains an important role for chemical monitoring, biological indicators are increasingly recognized as a necessary component of stormwater monitoring and assessment.

Chemical monitoring provides a picture over the period monitoring is done, while sediment sampling provides a rate of accumulation. Biological monitoring adds to the picture by providing an overall health rating of the receiving system, including a compilation of the effects of stressors on aquatic organisms, a perspective that is not available through chemical or sediment monitoring. As such, it can be considered the third leg of the monitoring stool: without all three legs the picture is not complete.

Improved and New Practices

Stormwater Management

This is an exciting time to be considering stormwater management and means of reducing impacts related to society's use of land. Initial stormwater management efforts focussed on control of water quantity related to flooding impacts. Flood control programs were generally initiated in response to a local flooding event and involved channel modifications, detention dams, or floodplain regulation. As the issue of water quality became more recognized, the existing infrastructure of flood control programs was generally modified to incorporate water quality concerns.

The approach at the time was to modify existing water quantity practices to also provide water quality improvement; however, the overall design philosophy was still directed toward large, on-line stormwater treatment systems that first and foremost provided control of downstream flooding and through design approaches (wet ponds) provided water quality treatment. There was little consideration of the stream or receiving system as an important resource. That lack of importance changed in the early 1990s. It was also recognized that one practice could not provide treatment for a wide range of pollutants: filter systems, wetlands, and biofiltration practices were all investigated for pollutant reduction.

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As a result, stormwater management has become a very different entity than it was in the 1980s. There is much more emphasis on practices at the headwaters of perennial streams, and practices are being much more targeted to the pollutants generated through specific land use activities than was done historically.

Finally, there are new practices being developed as variations of their historic counterparts. Filter systems are being used with filter media other than sand, infiltration practices are being considered on a wider basis, and newer practices (at least from a U.S. perspective) such as rain gardens, green roofs, and water re-use are being advocated. These really are exciting times.

Erosion and Sediment Control

Erosion and sediment control practices have not evolved to the same extent as those for stormwater. The suite of practices in use has remained pretty much the same since the early 1970s. That can't be good. Other components that have more recently begun to emerge consider temporary and permanent revegetation, phasing work to limit open areas, and chemical flocculation of sediment ponds to provide for enhanced sediment discharge reduction, especially of clay soils. More attention to erosion and sediment control practices is needed for improved treatment to be achieved.

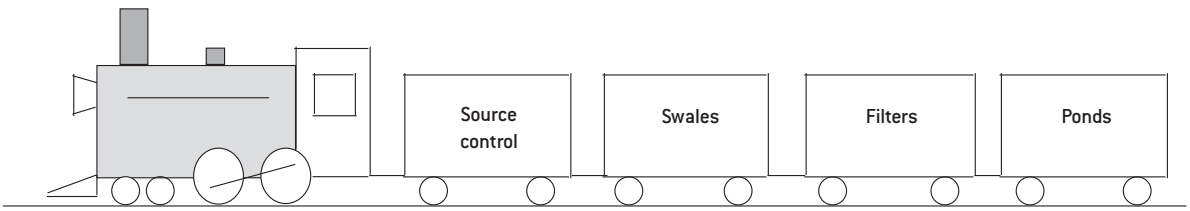
Where From Here

As both our understanding and practices evolve, more emphasis will be placed on the "treatment train" concept, where several types of stormwater practices are used together and integrated into a comprehensive stormwater management system. Although this is obvious when multiple issues are considered (such as stormwater quantity, quality and aquatic ecosystem protection), it is also sometimes needed when considering a single issue. For example, stormwater quality may include a variety of contaminants to be managed, but processes that facilitate one type of pollutant in one practice may not facilitate removal of a pollutant in another phase (liquid versus particulate). The treatment train approach to stormwater management will become increasingly important to reduce overall stormwater impacts on the urban environment.

For erosion and sediment control programs, technology must improve and approaches further refined for aquatic resource protection to be realized. An aggressive stormwater management program will not realize its goals if the receiving systems are severely impacted during the construction phase of a project. In addition to significant sediment loads, the amount of stormwater exiting a construction site can be significantly increased, causing downstream channel instability concerns. Erosion and sediment control must be given greater attention by regulators and designers. It is a positive step, therefore, that the Phase II program is also emphasizing erosion and sediment control on smaller sites than did the Phase I program.

Most importantly, if we are to reverse the existing trend of aquatic and terrestrial destruction that so defines traditional development, we must alter our existing approach to land use. There may be areas of significant habitat, groundwater recharge, or steep slopes where intensive land development is simply not appropriate. Those areas should protected, regardless of their location, and urban planners should instead insist on higher densities in other areas. Stream corridors should be protected, riparian cover established (or re-established), water re-use emphasized to reduce the use of potable water in addition to reducing stormwater runoff, and the use of green roofs should be expanded,

Figure 1-1: Stormwater Treatment Train



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especially for redevelopment opportunities. Finally, stormwater management implementation should be done as an integral component of site development and as an urban retrofit.

We are approaching a point where we now have the tools to eliminate further declines in receiving systems, and in a number of situations actually improve on existing conditions.

Concluding Thoughts

Stormwater management has historically been an afterthought – when thought of at all – to the site development process. Development tends to first lay out streets, lots, and public areas, and then consider how to deal with any required stormwater management concerns. As long as stormwater management remains an afterthought, even the best resource protection intentions are doomed to fail.

In the same regard, we too often design for minimum standards in environmental areas, with no factor of safety. If a code says to stay out of wetlands, we stay out of them, barely. In the same regard, if we have a design standard of 80 per cent reduction in TSS, that is what designers will design for – very seldom does someone intentionally design for a higher standard. We really ought to consider a factor of safety in land development to allow for better assurance of a desired outcome.

We must also recognize that we have not yet fulfilled our potential understanding of how best to protect the environment. We are learning, and we hope to apply our increasing knowledge to better outcomes, but stormwater management is an inexact science and there are huge pressures on land use, along with infrastructure provision, to be considered. We aren't alone in our efforts, although it may seem like it at times. People all around the world are dealing with the same problems and developing innovative solutions we have not yet thought of.

All of us have never-ending jobs in teaching other staff members, politicians, members of the design and construction community, and the public. At the same time, we must never cease to be students, always willing to learn and apply new information and insight for the betterment of the environment.

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CHAPTER 2

Water Quantity Impacts of Urban Land Use

Urban runoff is a by-product of the land's interaction with rainfall. Since, by definition, urban runoff remains on and moves along the land's surface, it is the most visible of the many forms into which rainfall is converted. This chapter provides the technical fundamentals of the rainfall-runoff … process. It also describes ways that land development alters this process and quantifies some of the adverse impacts.

So began Chapter 2 of the 1994 edition of *Fundamentals of Urban Runoff Management*. And while it still can serve as the opening paragraph of this new Chapter 2, our technical knowledge of both urban runoff hydrology and the effects of land use change has grown considerably in the intervening years. As a result, the technical content of this new chapter goes beyond the original version, including new and updated topics. However, in presenting this technical information, the chapter's goal remains the same: to present the information not as an end in itself, but so as to assist in the development of urban runoff management programs. The arrival of the EPA's Stormwater Phase II Final Rule in 1999, which requires municipalities and other entities to develop such programs by 2003, highlights the value of such assistance.

The volume of stormwater runoff produced by a rain event, the rates, velocities, and depths at which it flows, and the pollutants that it carries depend on several factors. In addition to the quantity, intensity, and duration of the rain itself, the resultant runoff will be determined by the characteristics, condition, and relative areas of the various surfaces on which it falls. As explained in detail in the following sections, these characteristics include the type of surface cover, the surface slope, and the texture, density, and permeability of the surface and subsurface soils. Conditions that affect stormwater runoff also include the thickness and quality of the surface cover and the amount of water already stored both on the surface and within the soil profile.

Conversely, stormwater runoff also affects the surfaces upon which it is created and/or that it flows across. These effects include both the deposition of pollutants captured from the atmosphere by the falling rain and the mobilization and removal of pollutants previously stored on the surfaces. The most readily visible effects are erosion and sedimentation, where forces created by the moving runoff become large enough to dislodge, suspend, and transport soil particles and associated pollutants downstream. This process continues until slower velocity areas are encountered, whereupon the particles drop out of the runoff and back onto the surface. Depending on the type and character of the surface cover, this process of dislodging soil particles and mobilizing pollutants can be aided by the impact of the falling raindrops themselves. Further erosion, sedimentation, and pollutant loading can occur downstream in swales, channels, streams, and rivers, depending on the rate, depth, velocity, and duration of the runoff flowing in them.

From the above, three key conclusions can already be reached:

- Since the volume, rate, and velocity of runoff from a particular rain event will depend upon the characteristics of the surfaces on which the rain falls, changes to these surfaces can significantly change the resultant runoff volume, rate, and velocity. Changes normally associated with land development and urbanization that increase

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impervious cover and decrease soil permeability can significantly increase runoff.

- Since pollutant mobilization and soil erosion are the direct result of excessive runoff rates and durations, changes in land surfaces can also significantly increase both surface and channel erosion rates and runoff pollutant loadings.
- In developing urban runoff management programs, the greater the knowledge of the rainfall-runoff process, the more effective the resultant program will be.

While the details of the rainfall-runoff process are highly complex and much remains to be learned about them, the fundamentals are readily understandable, particularly when presented in a direct, concise manner. That is the goal of this chapter. Equipped with the information presented here, those involved in developing urban runoff management programs at all levels, as well as those responsible for complying with them, can base their efforts on a sound understanding of the basic hydrologic processes at the core of their program.

This chapter provides readers with basic information on the rainfall-runoff process. It also highlights some of the important unknowns and uncertainties of the process and recommends ways to acknowledge and account for them in computation methods and program requirements. Using this information, the chapter also provides information on the adverse impacts land use change and urbanization can have on runoff quantity and the damaging consequences of excessive increases in runoff rates, volumes, and velocities.

Next, the chapter utilizes this rainfall-runoff information to illustrate how various practices can either avoid or control such impacts. This broad approach not only helps ensure that decisions made during the development of an urban runoff management program are based on an informed understanding of runoff fundamentals, but also helps readers to better understand the more technically complex topics presented in subsequent chapters.

The chapter concludes with a list of recommended textbooks, research papers, and other references. These works were selected from a constantly growing body of technical information on urban runoff and the impacts of land use change based upon their seminal or definitive role in the field of urban runoff management. In light of the chapter's broad scope and emphasis on learning the fundamentals first, these references can be used to expand readers' knowledge beyond the pages of this book.

It is important to note that, as our understanding of urban runoff processes and impacts continues to grow, so does the scope and requirements of the programs we've developed to manage them. Following along and, at times, inspiring this growth has been an increasing emphasis on and understanding of runoff fundamentals. It is this greater understanding that has allowed us to progress from relatively simple runoff quantity controls in the 1970s to the integrated quantity and quality programs of today. It has also allowed us to expand the scope and applicability of both our mathematical models and the various measures and practices we can now use to implement their findings. For example, the growing use of nonstructural measures and low-impact development practices essentially began with a detailed re-examination of the fundamental principles of the hydrologic cycle which, in turn, became the basis for their design and implementation. Therefore, it is hoped that the runoff fundamentals presented in this chapter will continue to inspire and direct the development of urban runoff programs with ever greater scopes, goals, and accomplishments.

Reality vs. Theory

In most complex technical matters, differences exist between reality and theory. That is because theories developed to explain or simulate reality can only go so far. Typically, there are aspects of reality that are not entirely understood and, therefore, are either ignored or simplified in the theory. Recognizing these differences is important when developing and implementing a technology-based regulatory program such as one that manages urban runoff. The "real" runoff processes that occur during an actual storm event can be extremely complex and can be influenced by an equally complex, highly variable set of factors and circumstances. Due to this complexity, the theories on which we base our runoff computations and models cannot include all aspects and factors.

For example, the mechanics of infiltration that govern the amount and rate at which rain will enter a soil (and therefore the amount and rate that will become runoff) are difficult to precisely discern. They can include the forces that govern the movement of water entering and moving through the void spaces within

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the soil as well as the intensity of the rainfall, the sizes, shapes, and chemical characteristics of the soil particles, the number and size of the void spaces between the soil particles, the amount of moisture already stored within the soil void spaces at the onset of rainfall, the slope and relative smoothness of the soil surface, and the type and character of the cover on the surface. Further complications include the fact that many of these forces and factors typically change over time, not only from storm to storm, but during a single storm event. This inherent complexity of the process, coupled with the complexity and variability of the factors that influence it, makes it difficult to develop a comprehensive theory that can precisely predict the resultant runoff from a specific rainfall event.

At first glance, this difficulty in precisely predicting runoff volumes, rates, and velocities from rainfall events does not bode well for the development of a regulatory program intended to effectively manage that runoff and its impacts. However, an awareness of these difficulties and the complexities, uncertainties, and variability that cause them can help us develop assumptions, simplifications, and representative values that enable us to overcome these difficulties and produce accurate, reliable, and safe runoff estimates. This ability further underscores how important it is for runoff management program developers to possess an understanding of runoff fundamentals.

Generally, there are three analytic techniques typically employed to overcome the complexities and uncertainties of estimating runoff and produce safe, usable results. The first involves analyzing the various processes that help convert rainfall to runoff and determining the relative influence each of their many factors may have on the process's outcome. Those parameters that are found to exert very small influence on the outcome or answer are typically dropped from further consideration in the computations or, if their presence is needed for mathematical rigor, they are assigned a nominal value. At times, factors that have minimal influence individually but, when combined, can have a meaningful and estimable effect on the outcome are grouped together and assigned a value that reflects that combined influence. Such factors are often referred to as lumped parameters in recognition of their combined contribution to the outcome. Mathematical models that utilize such parameters to estimate runoff from rainfall are known as lumped parameter models.

The second analytic technique that is used at times to address the complexities and uncertainties normally associated with runoff computations is an outgrowth of the first technique. Following the identification and analysis of the factors or parameters that influence the various rainfall-runoff processes, those factors that are found to exert a meaningful influence are further analyzed for the ways and amounts in which they do so. Sometimes called sensitivity analysis, this procedure fixes the value or influence of all other significant factors and then allows the parameter in question to vary over a range of possible or probable values. Each time the parameter value changes by a certain percentage of its total value range, both the qualitative and quantitative effects of such a change on the outcome or answer are noted. Once the entire range of parameter values is evaluated, the parameter's influence can be assessed. This assessment can indicate to the runoff modeler how much the outcome or answer will vary due to certain changes in parameter value. The assessment also indicates which direction (i.e., higher or lower) the answer will move. For example, does an increase in parameter value cause the answer to similarly increase or, in fact, to decrease? While direction influences can be readily determined for certain parameters in simple, generally steady-state rainfall-runoff models merely by analyzing their basic equations and algorithms, more complex, dynamic models may require more extensive sensitivity analysis.

Once the sensitivity and direction of a model parameter is understood, the second analytic technique then assigns it a value that the runoff modeler considers to be both a) reasonably representative of its typical value for the circumstances under consideration, and b) safe for the application or action that the model results will be used for. "Typical" values in many models are usually determined from representative numbers of actual parameter measurements taken either in the field or the laboratory. "Safe" values are based upon the parameter's directional influence and the acceptable risk inherent in the application of its results.

For example, in designing a stormwater facility to reduce peak runoff rates and pollutant loads from a land development site, a key design parameter would be the ability of the site's soils under developed conditions to infiltrate rainfall. While there may be extensive data available to the designer upon which to select a typical infiltration value, the designer may also allow the desire for a safe value (and, consequently, a safe design) to influence the final selection. As a result, the designer may select an infiltration rate for the developed site that is somewhat lower than the typical value, knowing that

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its use value will result in greater runoff volume and peak rate to the facility which, in turn, would require a somewhat larger facility size than if the typical value was selected. Once again, the selection of a safe parameter value may be a matter of experience and professional judgment when using simple, generally steady-state rainfall-runoff models or may require extensive statistical analysis when using more complex ones.

Selection of safe design parameters may also be complicated by the design itself. For example, in the design described above, the selected infiltration rate for the site soils under developed conditions was lower than the actual or typical rate in order to achieve a conservative facility design. However, let's assume that the required peak outflow rate from the facility could not exceed the peak rate from the site in existing or predeveloped conditions. In computing this predeveloped peak rate, use of a lower than actual soil infiltration value would not be considered safe, since it would result in a peak rate from the predeveloped site (and, therefore, the stormwater facility under developed site conditions) that was greater than the actual predeveloped site rate. In order to select a safe value, the designer would instead need to select a soil infiltration rate for the predeveloped site that was actually higher than the actual value.

As illustrated by these examples, a stormwater facility designer must understand the basics of the rainfall-runoff process in order to consistently select safe parameter values. We cannot be sure that our assumptions, computations, and, ultimately, our runoff management programs are inherently safe unless we understand the fundamental aspects of urban runoff well enough to identify all pertinent factors and parameters and understand their effects. This conclusion once again revisits the "learn the fundamentals first" theme of this chapter.

It should be noted that the use of a "safe" parameter value cannot typically be relied on to address process complexity and uncertainty when attempting to estimate runoff from actual rain events. Such events are often described as "historic" events to distinguish them from synthetic design storms, which are typically based upon a hypothetical arrangement of rainfall depths, intensities, and durations that are often used to design stormwater facilities. Estimating runoff from actual rainfall events is often necessary to demonstrate the accuracy of a particular rainfall-runoff model or to provide feedback that can be used to improve its accuracy. Such procedures are known as model calibration and verification, where a model's algorithms and/or parameter values are adjusted so that its predicted outcomes match the recorded outcomes from actual or historic storm events. Once so adjusted (or calibrated), the model is then used to predict the outcomes for one or more additional historic storms. The predicted results from the calibrated model are then compared with the additional storms' recorded outcomes to verify or validate that the model remains accurate for storms other than the one by which it was calibrated. When estimating outcomes for actual rain events, the selection of model parameter values must usually be based only on the parameter's actual value (or values) during the actual event, a process that requires considerably more understanding of the rainfall-runoff process and usually event-specific records of parameter data.

The third analytic technique addresses the complexities and uncertainties normally associated with runoff computations by including such uncertainties in the runoff computations. To do so requires a rainfall-runoff model that will simulate a large number of storm events. While doing so, the model will allow the value of the uncertain parameter to vary from event to event or even within a particular event based upon the way the parameter may be expected to vary in reality. Such variations may follow a particular pattern (e.g., exponentially or logarithmically) so that, while the actual parameter value for a particular rain event may not be known, the overall range of values and the pattern by which the parameter value varies within that range is known or can be reasonably estimated. Equipped with such information and utilizing a technique known as Monte Carlo simulation (Pitt and Voorhees, 1993), the model will allow the parameter value to vary within the known range and pattern either randomly or in accordance with prescribed probabilities. The results produced by the model can then be statistically analyzed to determine an appropriate answer. Depending upon the parameter, such variations in parameter value can represent a more accurate way to address parameter value uncertainty than selecting typical and/or safe values. However, use of Monte Carlo simulations requires the use of generally more sophisticated rainfall-runoff models and long-term rainfall input data. Further discussion of such models is presented in later sections of this chapter.

In summary, the above section presented the following ideas and information:

- Inherent complexities in the rainfall-runoff process lead to differences between the theories, equations, and models we use to estimate runoff

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rates and volumes and the actual amounts that may occur;

- To safely address these differences, we utilize both our understanding of rainfall-runoff fundamentals and techniques such as sensitivity analysis to select equation or model input parameters that will produce answers that are accurate and safe; and
- In certain instances where appropriate data and models are available, we may actually allow an input parameter to vary during the computations rather than using a single value for it. Known as Monte Carlo simulation, it produces a range of possible answers that can then be statistically analyzed to produce an accurate and safe answer.

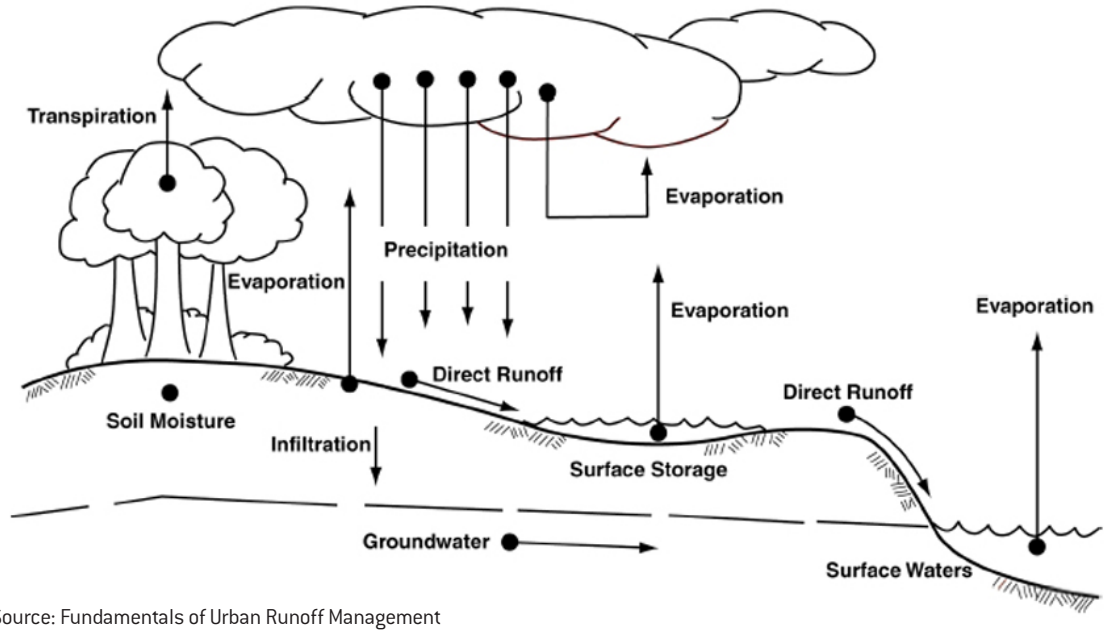
Finally, the role of urban runoff management program developers should not be overlooked in the above. That's because the theories, equations, models, and input parameter values they choose to incorporate into their programs will influence and even require designers to follow certain procedures, include certain parameters, and/or select certain data values. As such, it is just as important for the program developer to understand the fundamentals of the rainfall-runoff process.

The Rainfall-Runoff Process

As described in the chapter's opening paragraph, runoff represents a by-product of the land's interaction with rainfall. As such, changes in the character or cover of the land can cause changes in runoff volumes, rates, and velocities. However, to better understand the rainfall-runoff process, it is important to realize that it is only a portion of a larger, cyclical process that is constantly taking place. This process, known as the hydrologic cycle, involves all of the forms water can take as it continually moves on, above, and within the earth.

The hydrologic cycle is illustrated in Figure 2-1. Due to its cyclical nature, there are no starting or ending points in the hydrologic cycle, just points along the way as water moves between the earth's surface and atmosphere, changing its form as necessary. Selecting the atmosphere as a starting point, Figure 2-1 demonstrates how water vapor is converted into rainfall and other forms of precipitation and is pulled by gravity toward the earth's surface. On the way, some of the precipitation may be converted back to water vapor and remain suspended in the atmosphere, while the remainder continues to fall. Upon reaching the earth's surface, precipitation can follow one of several routes. It can be stored in surface depressions or infiltrate into

Figure 2-1: The Hydrologic Cycle



Source: Fundamentals of Urban Runoff Management

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the soil. Once there, it can be taken up by plant roots and, through the transpiration process, returned to the atmosphere as water vapor or remain in the soil as soil moisture.

Other infiltrated precipitation may continue to move down, again by gravity, until it reaches the groundwater table, which can then re-emerge on the surface as flow in waterways. Precipitation stored on the surface can be evaporated into the atmosphere, along with that intercepted by vegetation. Finally, a certain amount of the original precipitation can become runoff, moving across the earth's surface to waterways and bodies, including the oceans. Once there, evaporation can then return the water to the atmosphere, where precipitation can resume.

It is important to recognize two basic aspects of the hydrologic cycle. First, the movement of water from the atmosphere to the earth is exactly balanced by its movement in the opposite direction. We know this is true because, as noted in the 1994 *Fundamentals of Urban Runoff Management*, the skies would get very cloudy or inland property owners would eventually have ocean or lakeside views if it weren't. From the standpoint of urban runoff management, we can use this mass balance to help estimate how much water may exist in each of the hydrologic cycle's available forms, including runoff.

Second, due to the interaction between all of the various water forms within it, the hydrologic cycle is not easily separated into discrete components. Depending on actual conditions, the precipitation that became runoff from a parking lot may join flow in an adjacent stream, or moisture in the soil surrounding the lot, or groundwater moving below the lot. In fact, the water that was originally parking lot runoff and then groundwater may eventually become flow in the stream or evaporate back into the atmosphere where the precipitation originated.

Despite its complexity and interrelationships, experience and research has demonstrated that, to be successful, an urban runoff management program must not only be based upon an understanding of the hydrologic cycle, but must also utilize as many water forms and processes within the cycle as possible. As such, it is no longer sufficient to target and regulate only the runoff process. Instead, the program must also utilize the infiltration, transpiration, and even the evaporation processes to optimal levels in order to manage urban runoff and prevent the adverse runoff impacts of the land use changes caused by urbanization. Coordinated use of all available hydrologic cycle components and processes allows a program to move beyond simple runoff control to true runoff management, limiting the amount of rainfall that becomes runoff to begin with as well as managing the runoff that is ultimately created. In doing so, the program can also provide protection of groundwater resources, waterway and wetland baseflows, and soil moisture levels necessary for healthy vegetated covers.

In summary, the above section presented the following ideas and information:

- The hydrologic cycle represents the complex, interrelated movement of water in various forms on, above, and under the earth's surface.
- Despite its complexity, there are fundamental concepts and processes in the hydrologic cycle that can be readily grasped and utilized.
- To be successful, an urban runoff management program must be based upon the hydrologic cycle and utilize as many of its concepts and processes as possible.

Runoff Estimation: Typical Parameters

As noted above, the actual process by which rainfall is converted to runoff is complex with variable and, at times, unknown factors. Fortunately, from years of research, experimentation, and experience, the essential factors or parameters that most strongly govern or influence the process have been identified. These fundamental or typical parameters are described below.

Rainfall

Since runoff is considered its by-product, rainfall can readily be considered the most significant factor in estimating runoff. Actual rainfall amounts and patterns measured at gages are used to estimate the runoff from real or historic rain events. Hypothetical or synthetic design rainstorms are frequently used for design and regulatory purposes. Actual rainfalls can also be used to check the results produced by a design storm method or can even serve as the design storm itself if it has the appropriate magnitude, duration, and probability. This

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is particularly true for long-term rainfall records, which can provide superior results to design storms in certain instances (James and Robinson, 1982). As a result, the use of such rainfall records can be expected to grow in the future, particularly in the analysis and management of runoff quality, as more data becomes available and computer programs are developed to utilize it. Long term records may also serve as a valuable indicator of climate change impacts on rainfall, in which care must be taken in their use.

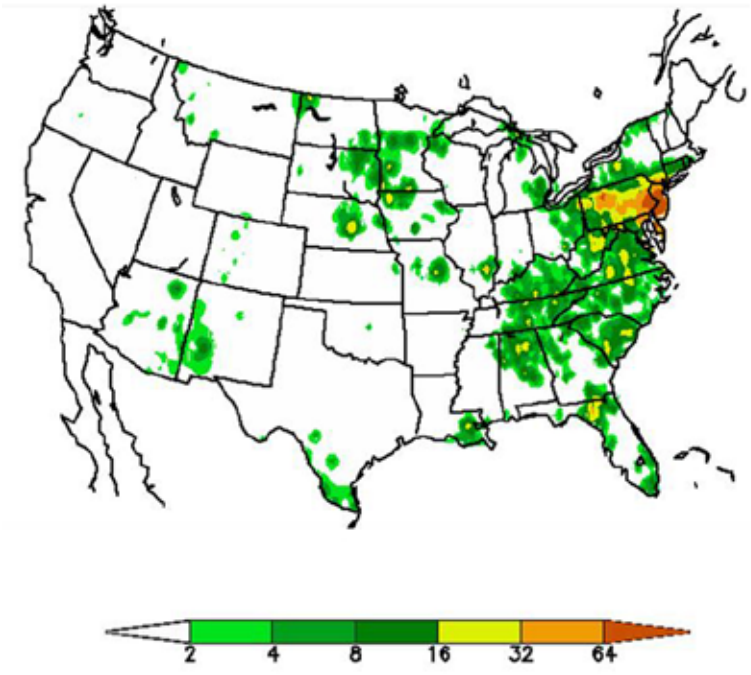
In general, our interest in rainfall not only focuses on real and hypothetical events, but also on both small and large rainfall amounts. From statistical analyses and experience, we know that small rainfalls occur much more frequently than large ones. As such, relatively small rainfalls are typically associated with runoff pollution and erosion problems and their associated environmental consequences, while larger rainfalls are typically associated with flooding and its associated threat to lives and property. The following examples highlight these various interests and the use of data from real rainfall events.

Figure 2-2 depicts radar-based total rainfall estimates in the United States during a 24-hour period ending at 8 a.m. on July 13, 2004. From the scale at the bottom of the figure, it can be seen that the greatest rainfall occurred in the northeastern United States, particularly in New Jersey and Delaware. Figure 2-3 presents a more detailed view of the rain event in this area. As can be seen in the figure, 24-hour rainfall totals of more than 11 inches fell in Kent County, Delaware, and more that 13 inches fell in Burlington County, New Jersey. As documented by the National Weather Service (NWS), U.S. Geological Survey (USGS), and the N.J. Department of Environmental Protection, this rain event resulted in record or near-record flooding on several southern New Jersey waterways, including Rancocas Creek and the Cooper River. The rain also led to the failure of 21 dams in Burlington County. An analysis of the rain event in the county by the NWS indicated that the event had an estimated average recurrence interval or frequency of approximately 1,000 years. As described later in this chapter, such an event would statistically have only a 0.1 percent chance of occurring in any given year.

Rainfall data from such an extreme rain event is not only useful in analyzing the runoff, flooding, and damage caused by the event itself. The data may also be used to evaluate the design of dams, spillways, and other hydraulic structures produced through the use of hypothetical design rainfall events or, where appropriate, may even serve as the design storm itself. Such use would depend upon the total depth, duration, and probability of the actual rain event compared with the required design frequency of the structure.

At the opposite end of the rainfall depth and frequency spectrum, data from much smaller and more

Figure 2-2: 24-Hour Rainfall in Millimeters Ending 8 a.m., July 13, 2004



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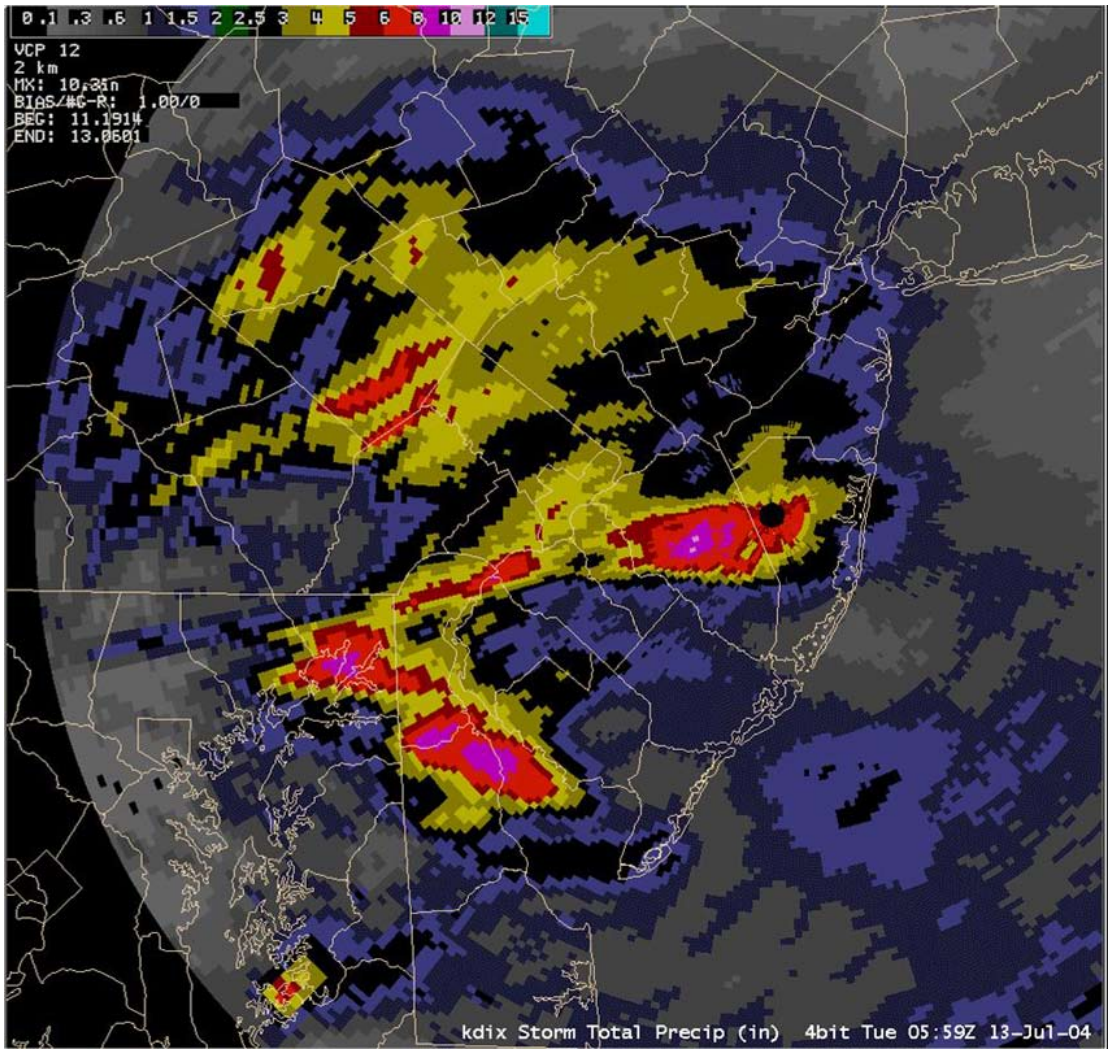
common rain events can also be used in the analysis and design of certain hydraulic structures. As described above, such rainfalls are not typically associated with structures intended to withstand the effects of a very large, rare rainfall event, such as a dam's spillway. Instead, they would be intended to reduce pollutant loadings in runoff and waterway flows or prevent surface or waterway erosion. Such rainfall data can also be used to evaluate the impacts that land development practices and policies have on producing pollution and erosion problems in the first place.

Figure 2-4 depicts the rainfall depth from approximately 750 storm events recorded at Newark Liberty International Airport in Newark, New Jersey between 1982 and 1992. It was taken from the long-term precipitation records contained in the computer program WinSLAMM – Source Loading and Management Model (Pitt and Voorhees, 1993). Such data can be used in programs like WinSLAMM and the EPA's Stormwater Management Model (SWMM) to estimate runoff amounts over the long periods of time which problems such as runoff pollution and erosion typically take to manifest. Assuming that the length and accuracy of the rainfall data is sufficient, structure designs and practice evaluations based upon such data can be considerably more robust than those based upon hypothetical or synthetic design storms (James, 1995).

This increased robustness is due to the uncertainties associated with the rainfall-runoff process noted above and the ways in which they are addressed differently

Figure 2-3: 24-Hour Rainfall in New Jersey-Delaware, July 12-13, 2004



Source: National Weather Service, Mt. Holly, New Jersey Forecast Office

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through the use of long-term rainfall records versus single-event design storms. When using a hypothetical design storm approach, decisions must be made as to the total amount of rain, how long it will fall, how it will vary in intensity (if at all) over this duration, how long it has been since the previous rain fell and, if significant, in what time of year the event will occur. Such decisions must be made by the designer or modeler, either actively through the development of an appropriate design storm or by default through the selection of a previously developed, standardized design storm often specified by an urban runoff management program. Selecting fixed values for each of these factors can and often will affect the resultant runoff estimate.

However, when using a suitably long and accurate record of actual rainfall, these decisions do not have to be made. Instead, the long-term rainfall record contains all of these factors, and its use allows them to vary over a naturally-occurring range of values. The result is a similarly varied series of runoff estimates that reflect this natural range of conditions. Analyzing this resultant runoff series with relatively simple statistical techniques can then produce results for a storm with a particular depth, frequency, duration, etc.

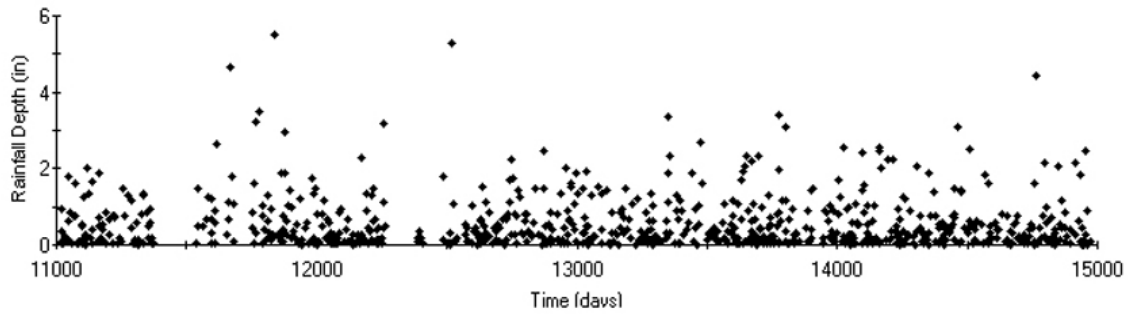
Despite this enhanced robustness or accuracy and its applicability to a range of analytic and design problems, the use of actual rainfall data, either from single, extreme events or over long time periods, is not without its problems. First and foremost is the availability of such data. While the number of recording rain gages in the United States is constantly increasing along with their reliability and data accessibility, there still remain many areas with inadequate gage coverage.

Second, the data record available must be sufficiently long for the intended use. Even the design of practices or facilities that must control the runoff from relatively high-frequency, low-depth rain events can require up to five to ten years of continuous rainfall data. The design of facilities such as dams and flood control works to control much lower frequency, higher recurrence interval events would typically require several decades of data at a minimum, unless one or more events in the available record can be accurately designated as statistically extreme. In these cases, such as the one illustrated in Figure 2-3, such extreme events may be used, with suitable caution, as design storms or, more typically, to supplement or evaluate the results produced by a hypothetical design storm.

Third, the data must have been recorded in time increments suitable for the event analysis or facility design in question. As explained more fully in following sections, rainfall data that has been recorded in time increments that approach or even exceed the length of time it will take for an area of land to respond to rainfall may be suitable for estimating total runoff volumes from rainfall events, but are generally not appropriate for predicting peak runoff rates or runoff hydrograph shapes. Use of such data can cause rounding and other errors that can lead to underestimated peak runoff rates, hydrographs, and, in certain models, runoff volumes (James and Robinson, 1982; Pitt and Voorhees, 2003).

An additional problem typically cited in the past with using actual rainfall data, particularly long-term records, was difficulty inputting, storing, and processing large amounts of rainfall data. It should be noted that this problem has been largely eliminated through the vastly larger data storage capacities and higher data processing

Figure 2-4: Rainfall Data for Newark, New Jersey, 1982 to 1992



Source: WinSLAMM Version 8.7

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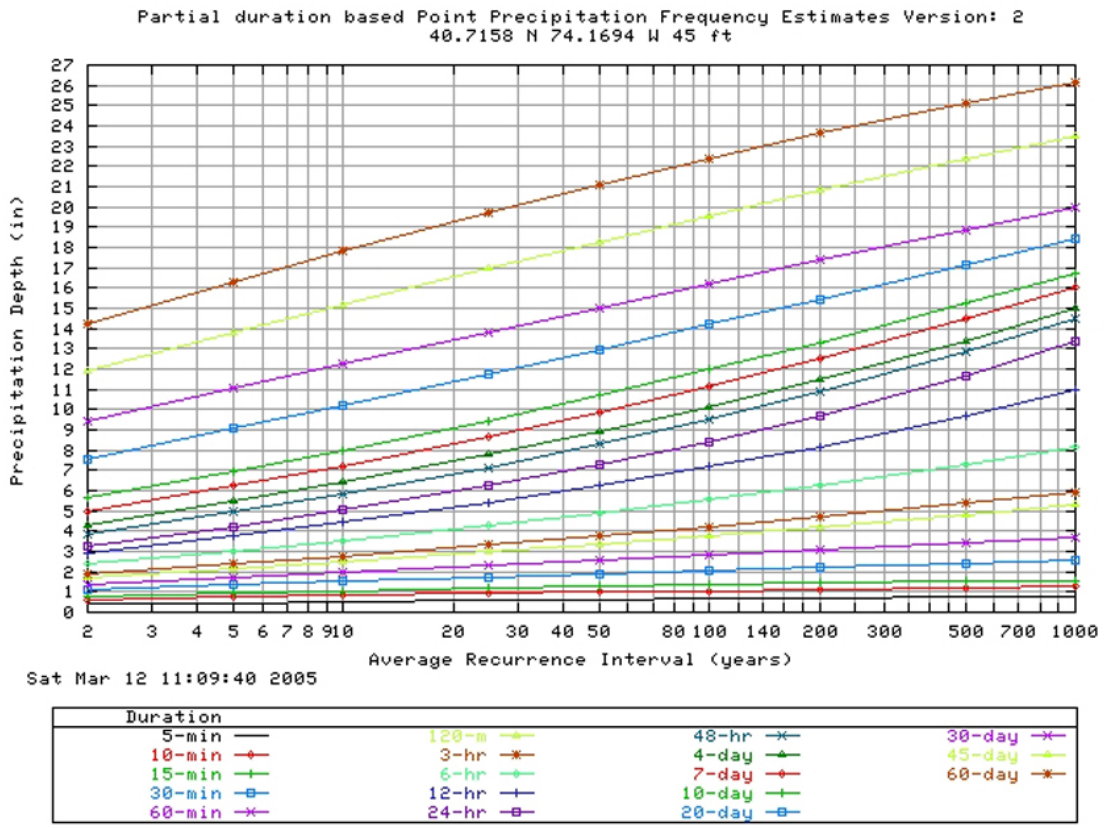
speeds of modern computers. If any computer-related problems remain in this area, it may be in the relatively limited number of computer programs that can accept long-term rainfall data.

As a result, the use of hypothetical or synthetic design storms in urban runoff management programs remains relatively high. The data used to develop such storms is obtained from statistical compilations and extrapolations of real rainfall data collected over a statistically significant period of time. Figure 2-5 presents such a compilation. It depicts rainfall depth-duration-frequency curves for Newark, New Jersey based on hourly rainfall collected at Newark Liberty International Airport between 1948 and 2000. The curves predict the expected rainfall depth for a given period of rainfall and storm frequency, with the storm frequency expressed as an average exceedance probability in years. For example, the expected 100-year, 1-hour rainfall depth at the airport would be approximately 2.8 inches, while similar frequency storms for 2-, 6-, and 24-hour periods would have depth of approximately 3.8, 5.5, and 8.4 inches, respectively. Similar curves can be developed for average rainfall intensity, which is obtained by dividing the rainfall depth by the rainfall period.

The curves in Figure 2-5 were developed by the Hydrometeorological Design Studies Center (HDSC) of the National Weather Service and were published in 2004 in the National Oceanic and Atmospheric Administration's (NOAA) *Atlas 14 – Precipitation Frequency Estimates*. Rainfall data for this and other U.S. locations is available at the HDSC Precipitation Data Frequency Center (PFDS) at http://hdsc.nws.noaa.gov/hdsc/pfds/. Additional rainfall data is also available through various publications and agencies throughout the country.

Rainfall data such as that shown in Figure 2-5 can be used in a variety of ways. If the total rainfall depth for a specific storm frequency and rainfall period is needed (for example, to estimate total runoff volume to a stormwater facility), the depth can be taken directly from charts or associated tables like the one in Figure 2-5. As described above, the depth can also be converted

Figure 2-5: Rainfall Depth-Duration-Frequency Data for Newark, New Jersey



Source: NOAA Atlas 14 – Precipitation Frequency Estimates

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to an average rainfall intensity in instances where a peak runoff rate is required (for example, to select the appropriate size of a storm sewer).

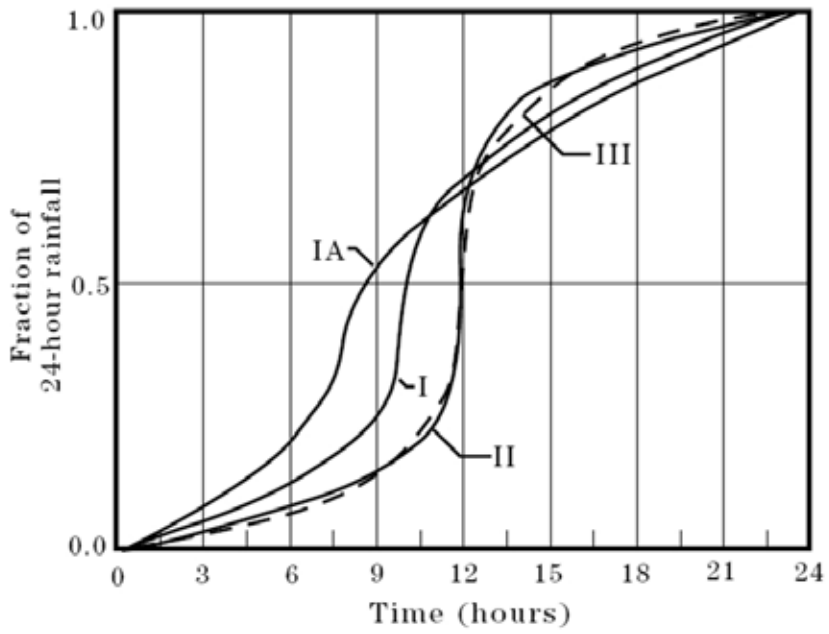
In addition, rainfall data like that shown in Figure 2-5 can be used to construct an entire hypothetical design storm. Such storms are typically needed when some or all of the runoff hydrograph (a depiction of how the runoff rate varies with time) is needed, not just the total runoff volume or peak runoff rate. Hydrographs are typically necessary for the analysis or design of any drainage area or stormwater facility where the variation of runoff rate over time is critical. Such areas include two or more subareas of a larger watershed that are added together to determine a combined peak rate or hydrograph. Time-sensitive stormwater facilities include wet ponds and detention basins.

The rainfall data in Figure 2-5 could be used, for example, to construct a 24-hour, 100-year hypothetical design storm for Newark by allowing the rain intensity to vary in such a way that the various 100-year rainfalls for durations less than 24 hours occur over the storm's total 24-hour duration. For example, such a storm would have maximum 1-, 2-, 6- and 12-hour rainfalls of 2.8, 3.8, and 5.5 inches respectively falling within its total 24-hour rainfall of 8.4 inches. It should be noted that, as shown in Figure 2-5, each of these rainfall-duration combinations have a 100-year frequency.

Figure 2-6 depicts the temporal distribution of four hypothetical design storms that are regularly used for drainage area runoff analysis and stormwater facility design. All four storms have varying rainfall intensities over their 24-hour length. They were developed by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture and are used in NRCS rainfall-runoff methods and models. They have also been adopted for use by many urban runoff management programs throughout the country. Coordinates of the various NRCS design storm events can be obtained from the NRCS State Conservation Engineer in each state.

As shown in Figure 2-6, the rainfalls associated with each of the four NRCS hypothetical design storms is expressed as a percent of the total 24-hour rainfall. As such, an entire design storm for a given frequency can be computed simply by selecting a 24-hour rainfall depth with that frequency and applying it over the 24-hour period to the various rain depths in the appropriate design storm. An example of such a design storm with a 100-year frequency for Newark, New Jersey is shown in Figure 2-7. It was developed by multiplying the

Figure 2-6: NRCS Design Storm Distributions



Source: NRCS Technical Release 55

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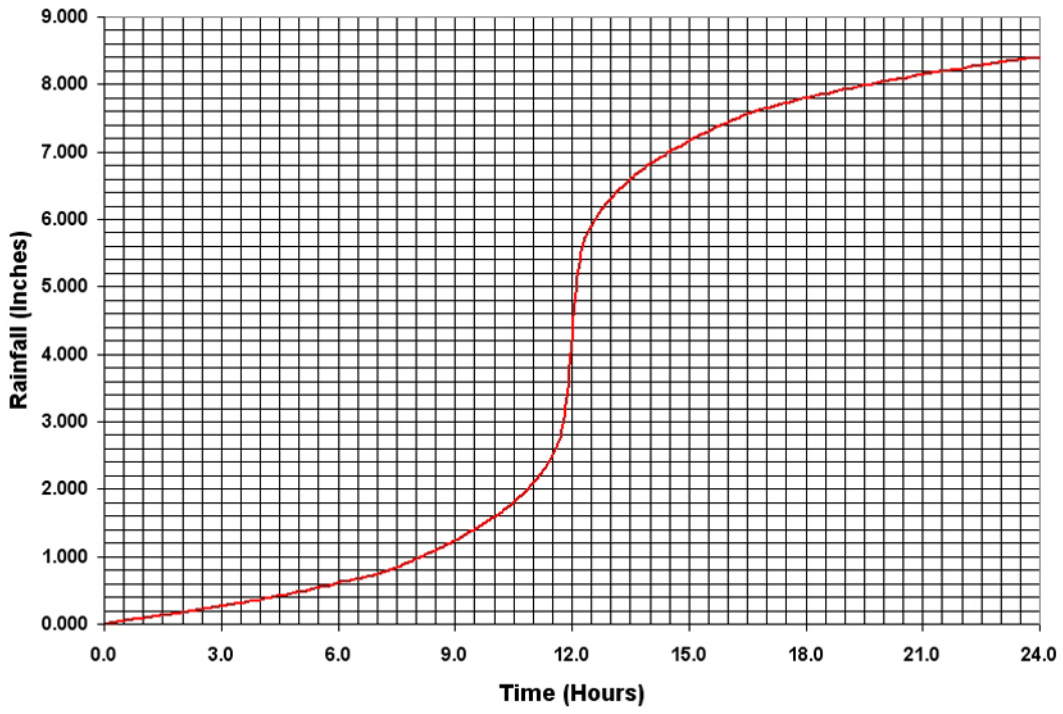
100-year frequency, 24-hour rainfall for Newark by the various rainfall depths shown in Figure 2-6 for the Type III design storm which the NRCS has designated as the most appropriate of the four design storms shown in Figure 2-6 for the city.

There are some interesting and helpful observations that can be made about the four different NRCS design storm distributions shown in Figure 2-6, all of which would have the same total rainfall at the end of the 24-hour event. First, it can be seen that the Types II and III storms are distributed more or less symmetrically about the storm's 12-hour midpoint, while Types I and IA are not. Second, in the Type II and III storms, the rain falls at lower intensities at the beginning and end of each storm (evidenced by the relatively flat slope of the curves between hours 0 and 9 and between hours 15 and 24) than the Type I and IA storms. As a result of these lower starting and ending rainfall intensities, the Type II and III storms have greater intensities during their middle periods and these high intensity periods last longer than the Type I and IA. In fact, as can be seen in Figure 2-7, fully 50 percent of the total rain depth of 8.4 inches falls in the middle two hours (between hours 11 and 13) of the Type III storm for Newark, New Jersey. Finally, the high-intensity rainfall periods in the Type II and III storms occur later than the Types I and IA. As a result of these differences, the Type II and III design storms can be expected to produce higher peak runoff rates than the Type I and IA storms for the same total 24-hour rainfall. This illustrates the complexities and influences that must be considered when developing or selecting a hypothetical design storm.

In addition to the four NRCS design storms, several other hypothetical design storm distributions have been developed and adopted by various jurisdictions and agencies with urban runoff management programs. These include the City of Austin, Texas; the State of New Jersey; the South Florida Water Management District, and the U.S. Army Corps of Engineers. And as additional rainfall data is collected and statistically analyzed, modifications to existing hypothetical distributions or the development of entirely new ones may be necessary in the future.

Finally, our discussion of rainfall would not be complete without mentioning rain that may have fallen during prior storms. While most of the runoff from a storm may have long since drained away, some is likely to still be present as soil moisture or stored in surface depressions in the drainage area. The exact amount of such water, referred to as the antecedent rainfall or

Figure 2-7: NRCS 100-Year Type III Design Storm for Newark, New Jersey



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moisture condition, can influence the amount of runoff from a subsequent design storm by affecting how much of that storm's rain can infiltrate into the soil or be stored in the depressions. As such, its effect must be quantified in all rainfall-runoff computations.

Antecedent moisture conditions are particularly critical when recreating real storm events or analyzing both real and design storms with relatively low rainfall depths. For real storms, the antecedent moisture conditions can be estimated from the rainfall data for the antecedent period. When using a design storm, however, many runoff estimating methods assume for simplicity that average antecedent conditions exist in a drainage area prior to the start of the design storm. As a result, the frequency of the runoff event will equal that of the rainfall that produced it, an occurrence that is not always true. Such assumptions highlight the advantage of using long-term rainfall data, where the actual antecedent rainfall condition for each storm can be directly estimated from the prior event's data. More sophisticated methods allow the analyst to vary the antecedent condition to judge its sensitivity to the answer or to increase the conservatism or "safety" (as discussed above) of the answer.

In summary, the above subsection presented the following ideas and information:

- In estimating runoff, rainfall from both actual and hypothetical storm events may be used;
- Various hypothetical design storms have been developed and are used in many runoff estimation methods and runoff management programs;
- Hypothetical design storms can produce reliable results, particularly for large, relatively infrequent storms where the depth of the rainfall dominates the rainfall-runoff process;
- Conversely, design storms may be less reliable for smaller, more frequent storms where antecedent rainfall, climate, soil type, slope, and cover have greater influence on the resultant runoff;
- Design storms may need periodic updating or replacement as additional rainfall data is collected and analyzed;
- Data from actual rain events may be used to supplement or check design storm results;
- Suitable, actual rain data may also be used for design purposes, provided it represents a sufficiently long period of time or severity of storm;
- The use of long-term rain data to estimate runoff from smaller, more frequent storms is increasing as more suitable data and computer models become available; and
- Long term rain data may also serve as an indicator of climate change on rainfall. If verified, such effects must be taken into consideration when using such data.

Time

Time plays a critical role in the actual rainfall-runoff process and, as such, plays a similar role in the various theoretical methods used to simulate it. This is not surprising, since the gravitational, thermodynamic, and other natural forces involved in the creation of runoff from rainfall are constantly changing with, and therefore influenced by, time. These influences can be exceptionally complex. The following discussion presents a simplified description of how time affects runoff estimates.

Two fundamental measures or lengths of time are important when performing runoff estimates from rainfall. The first is the runoff response time of the drainage area to a rainfall input. This response time indicates how quickly the runoff created by a given amount of rain drains to the outlet of the drainage area and how quickly the rate of that runoff will change as the rainfall rate changes. In more sophisticated estimating methods, this response time may also affect the volume of runoff produced by the rain.

Several terms and definitions can be used to describe this response time; most are applicable to a particular runoff estimating technique. The most common term is Time of Concentration (TC), which the USDA Natural Resources Conservation Service and others define as the time it takes runoff (once it has begun) to flow from the most distant point in the drainage area to the drainage area's outlet. Numerous procedures, equations, and nomographs are available for estimating TC, including those presented in Chapter 3 of the *NRCS Technical Release 55 – Urban Hydrology for Small Watersheds* (TR-55), which is used as the hydrologic basis of many urban runoff management programs.

Regardless of the method used to estimate TC, it is important to recognize its direct effect on the resultant rate of runoff, including the peak rate. As noted above, TC is a measure of how quickly the runoff from a given

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amount of rain throughout a drainage area can flow to the area's outlet. Stated differently, it represents how much time it takes the runoff produced throughout the drainage area to concentrate at the outlet. The more quickly a fixed volume of runoff can concentrate at the outlet, the more runoff will exist at any point in time at that outlet. As such, the TC will directly affect the overall shape of the runoff hydrograph, including the peak runoff rate. The shorter the TC, the higher the runoff rate, including the peak. In light of these effects, it can be seen that whether we seek to estimate a peak runoff rate or an entire runoff hydrograph for a given rainfall, we must compute a reasonably accurate estimate of TC.

In computing runoff peaks and hydrographs, TC can also assist us in another way. Since most rainfall data, whether for a real event or hypothetical design storm, is rarely provided in a continuous form over time but rather in discrete time increments, we must assume an average rate of rainfall will occur during each of these time increments. Since TC is a measure of how quickly the rate of runoff will vary due to changes in rainfall rate, we can use it to determine how small of a time increment we must divide our rain event into to produce an accurate runoff peak or hydrograph.

For example, a drainage area that takes six hours to respond at its outlet to rain falling within it will show little change in runoff rate from a change in rainfall intensity lasting only a few minutes. Therefore, using a time increment of 30 to 60 minutes (during which rain is assumed to fall at an average rate) would be appropriate. However, using a 30-minute time increment for a drainage area that responds in 15 minutes would not be appropriate, since the assumption of a uniform rainfall rate during each 30-minute storm increment would mask any shorter-term variations in rainfall rate that would have a significant effect on the resultant runoff rate. Such time increment-induced errors are examples of the "rounding errors" described above that may occur in the use of actual rainfall data. This also illustrates the problem that can be encountered when attempting to find actual rainfall data in sufficiently short time increments.

The second fundamental period of time in rainfall-runoff computations is the effective event time. When computing only a peak runoff rate from a drainage area, this time is typically based upon the time the area can respond to rainfall and, as a result, can be set equal to the drainage area's TC. When performing such computations, therefore, we are interested only in a period of rainfall within a longer storm event; namely, the period with the greatest rainfall rate or intensity. For example, if we wish to estimate the peak 10-year rate of runoff from a drainage area in Newark, New Jersey with a 30-minute TC, we would use a 10-year recurrence interval, 30-minute rainfall of 1.5 inches from Figure 2-5.

However, if we wish to estimate the total runoff volume for a 10-year storm event, the effective event time will have to include the entire storm duration in order to obtain the total rain depth. While such times are readily available when using data from actual rain events, they must be carefully selected when using a hypothetical design storm. For example, while Figure 2-5 indicates that a 10-year, 1.5-inch period of rainfall would last for 30 minutes (see previous paragraph), it gives no indication of the total duration or depth of the storm in which that 1.5-inch, 30-minute rainfall would occur, other than the fact that it would last for at least 30 minutes. However, it could also be part of a longer, much larger storm event.

In addition, when designing certain runoff treatment or control practices such as infiltration basins, the effective event time may also include some additional period of time following the end of the rainfall event. This additional time, known as the inter-event dry period (Wanielista and Yousef, 1993), reflects the time by which the practice artificially prolongs or extends a drainage area's response time (through its slow release of stored runoff) and, therefore, the effective event time. As a result, when developing or selecting an appropriate hypothetical design storm to estimate total runoff depth, judgment must be used to ensure that the total event time is appropriate for the design or analysis at hand.

In summary, the above subsection presented the following ideas and information:

- Time plays a critical role in the rainfall-runoff process and the various methods and models used to simulate it.
- This role includes influencing the various rates of runoff that may occur during a rain event, including the peak runoff rate, and, in certain methods, the total volume of runoff.
- There are two fundamental lengths of time that are important when performing rainfall-runoff computations.
    - The first one is the time a drainage area takes to respond to the rain falling within it. This time, typically expressed as the

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area's Time of Concentration, can be used to both estimate peak runoff rates and determine the maximum time interval that rainfall data should be divided into to produce reliable hydrograph estimates.

  - The second one is the effective rainfall event time. When estimating peak runoff rates, this time is typically based upon a drainage area's rainfall response time as expressed by its Time of Concentration.

- When estimating total runoff volume, however, the effective event time must span the entire rainfall event in order for a total rainfall depth to be obtained.
- When designing runoff management practices such as infiltration basins that artificially extend an area's response time, the effective event time may include an additional period of time beyond the total rainfall duration known as the inter-event dry period.

Drainage Area

The concept of drainage area is fundamental to any rainfall-runoff analysis. It is the area that contributes runoff to a particular point in a drainage system typically referred to as the drainage area's outlet. For this reason, it may also be known as a watershed, since it represents the area that "sheds" water or rainfall to the outlet. However, this term is typically applied to larger areas draining to streams and rivers. Catchment is another term used at times instead of drainage area, as it represents the area that "catches" rainfall and delivers a portion of it as runoff to the outlet.

Both a drainage area's size and various characteristics about its soils, cover, slope, and response time are typically used to estimate runoff from rain falling within it. Of these, the drainage area size is a primary consideration. It is usually determined from a combination of topographic maps, waterway and storm sewer plans, and field reconnaissance. Most runoff estimating methods assume a linear relationship between drainage area and runoff volume. Therefore, a 20 percent error in estimating a drainage area's size will, among other impacts, directly result in a similar error in the estimated runoff volume. This relationship is important when determining the required accuracy of drainage area size computations and the required time and effort to achieve it.

Two important drainage area characteristics for estimating runoff are its shape and slope. As discussed above, a drainage area's response time will influence the rate of runoff from a given rain event, with shorter response times producing greater runoff rates than longer ones. A drainage area with generally steep slopes can therefore be expected to respond faster to rainfall and concentrate a greater amount of runoff over a given period of time. Similarly, the length that the runoff must travel to the drainage area's outlet can also affect the response time, with elongated drainage areas with relatively longer travel lengths typically producing lower runoff rates than more rounded ones with shorter travel lengths.

It is important, however, to avoid over-generalizing the effects of drainage area shape and slope on runoff rates, particularly for complex drainage areas and watersheds with multiple branches or tributaries. Each drainage area within an overall watershed has its own unique shape, slope, flow length, and complexity, all of which can have a direct effect on response time and resultant runoff rates. Therefore, a representative response time, typically expressed as its Time of Concentration, should be estimated as accurately as possible for each drainage area based upon these characteristics.

The variation in ground surface within portions within a drainage area, particularly those that create surface depressions and other irregularities, can also have a direct effect on the area's response time, runoff rate, and even runoff volume. Depending upon their depth and size, surface depressions can slow the rate of runoff movement and concentration as well as store a portion of the runoff. This not only increases the drainage area's peak runoff rate but the runoff volume as well. Such runoff delays and storage, in combination with such factors as antecedent rainfall, surface wetting, soil infiltration, and interception by vegetation, typically are greatest at the inception of rainfall and as such produce an effect known as initial abstraction. This is the amount of initial rainfall that must occur before runoff at the drainage area outlet begins. Depending on a drainage area's surface depressions and irregularities, along with its soils and covers, the initial abstraction can significantly affect the volume of runoff and the size and timing of its peak rate. Therefore, the effects of initial abstraction should not be overlooked, particularly for small rainfall depths where the initial abstraction amount is a significant percentage of the total rainfall.

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In summary, the above subsection presented the following ideas and information:

- The concept of a drainage area that catches rainfall and drains the resultant runoff to its outlet is fundamental to runoff estimation.
- Most runoff estimation methods assume a linear relationship between drainage area size and runoff volume.
- In general, the slope and shape of a drainage area can influence the rate of runoff, including the peak rate.
- Localized surface irregularities, in combination with soil and cover characteristics, can store or abstract an initial amount of rainfall and both delay the start of runoff and reduce runoff volume and rates.

Soils

The surface and subsurface soils within a drainage area can play a direct role in determining the volume and rate of runoff from rainfall. As a result, various soil characteristics are included in most runoff estimating methods. These characteristics include the texture, structure, permeability, thickness, and moisture content of the various layers within the soil profile. Soil texture, structure, and thickness can help determine how much rain a soil can absorb and retain, with granular soils such as sands possessing greater storage capacity than silts and clays. Similarly, a thin layer of soil on top of bedrock will have less storage capacity than a deeper soil with similar texture. Permeability will affect the rate at which rainfall can enter and move through a soil and, therefore, the volume and rate of any resultant runoff. A soil's moisture content at the start of rainfall is not only a measure of its available storage capacity but can also influence its permeability rates. Rain falling on a pervious drainage area whose soils are saturated from antecedent rain events can produce runoff volumes and rates similar to a drainage area that is largely impervious.

Soil texture, permeability, and thickness data can be found in numerous sources, including laboratory tests of soil samples taken from various drainage area locations. County Soil Surveys, developed cooperatively by the USDA Natural Resources Conservation Service and various state agencies, are generally reliable sources of such information. Depending upon the Survey date, the drainage area size, the required degree of accuracy, and the sensitivity of soil characteristics in the selected runoff estimation method, field verification of Soil Survey information may be necessary. Such verification can also be used to assess soil structure, which can also influence resultant runoff amounts.

The relationship between soil texture and permeability should be noted. The relatively large percentage of void space within granular soils such as sands creates not only significant storage volume but also relatively high permeability rates. As a result of these two features, sands can be expected to produce less runoff volume than silts or clays, which have less void space and permeability. In certain instances, this relationship can permit a soil's permeability to be estimated from its texture.

As discussed above, soil permeability, texture, and moisture content in combination with vegetation and surface depressions and irregularities can also affect the amount of initial rainfall that is abstracted before runoff begins. This initial abstraction can significantly affect the volume of runoff and the size and timing of its peak rate. Therefore, the effects of drainage area soils on initial

Table 2-1: Summary of Ocean County, New Jersey Soil Compaction Study Results

Study Site	Mean Bulk Density (g/cm3)	Mean Permeability (in/hr)
Woods	1.42	15
Cleared Woods	1.83	0.13
Subdivision Lawn 1	1.79	0.14
Subdivision Lawn 2	2.03	0.03
Athletic Field	1.95	0.01
Single House	1.67	7.1

Source: Ocean County Soil Conservation District et al., 1993

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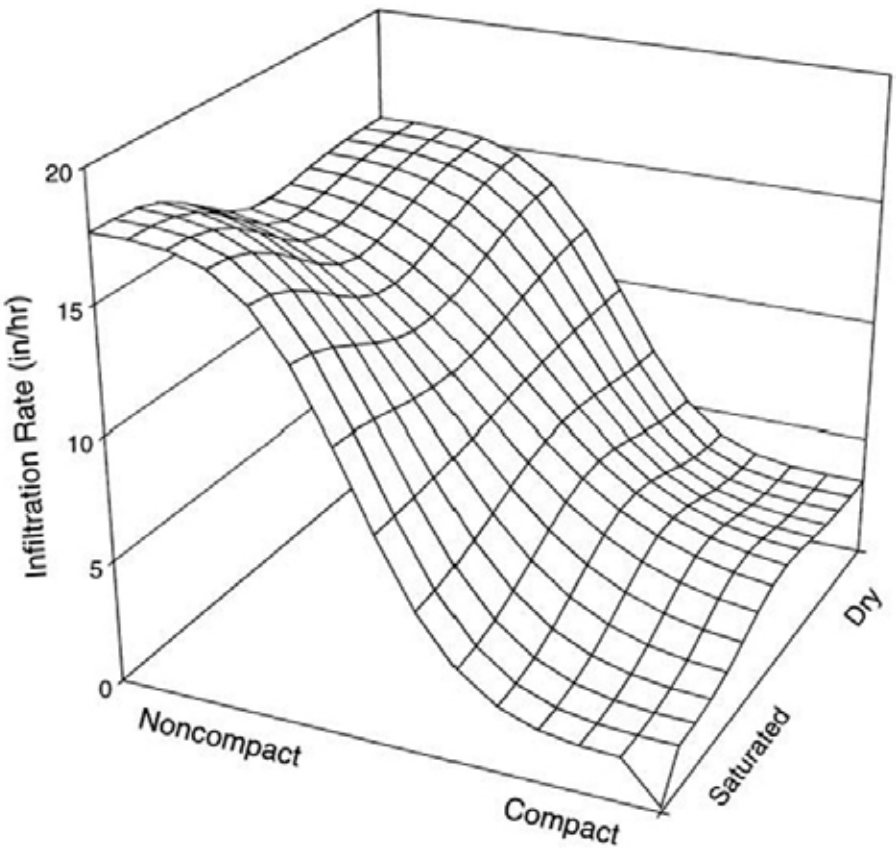
abstraction should not be overlooked, particularly for small rainfall depths.

Finally, research continues to confirm that compaction can significantly modify or damage a soil structure, resulting in decreasing storage volumes and permeability rates and increased runoff. Research conducted in New Jersey (Ocean County Soil Conservation District et al., 2001) demonstrated that soils compacted either by construction equipment or post-construction use can experience significant reductions in permeability. A summary of this research is shown in Table 2-1. It compares the bulk density (as a measure of soil structure) and permeability rates of soils with generally similar sandy soil textures at various sites. The Woods site shown in the table represents an undisturbed condition with natural soil structure. The Cleared Woods site represents a disturbed condition where the vegetation and organic ground layer have been cleared by heavy equipment without significant regrading. The Subdivision Lawns 1 and 2 and Athletic Field sites represent highly disturbed areas where both clearing and regrading by heavy equipment have occurred. The bulk density and permeability values summarized in the table are the mean of three replications in a soil layer 20 inches below the surface.

As shown in the table, the mean soil permeability of the Cleared Woods and Subdivision Lawn 1 are approximately 100 times lower than the 15 inches per hour mean permeability at the undisturbed Woods site. Greater reductions can be seen at the Subdivision Lawn 2 and Athletic Field sites, where mean permeabilities ranging from 500 to 1000 times lower than the Woods site were measured. The mean permeabilities for the various disturbed sites are similar to those found for impervious areas such as roads, highways, and parking lots (Pitt, 1991).

Further research in Alabama into the effects of compaction on both sandy and clayey soils (Pitt et al.,

Figure 2-8: Alabama Compaction Test Results for Sandy Soils



Source: Pitt et al., 1999

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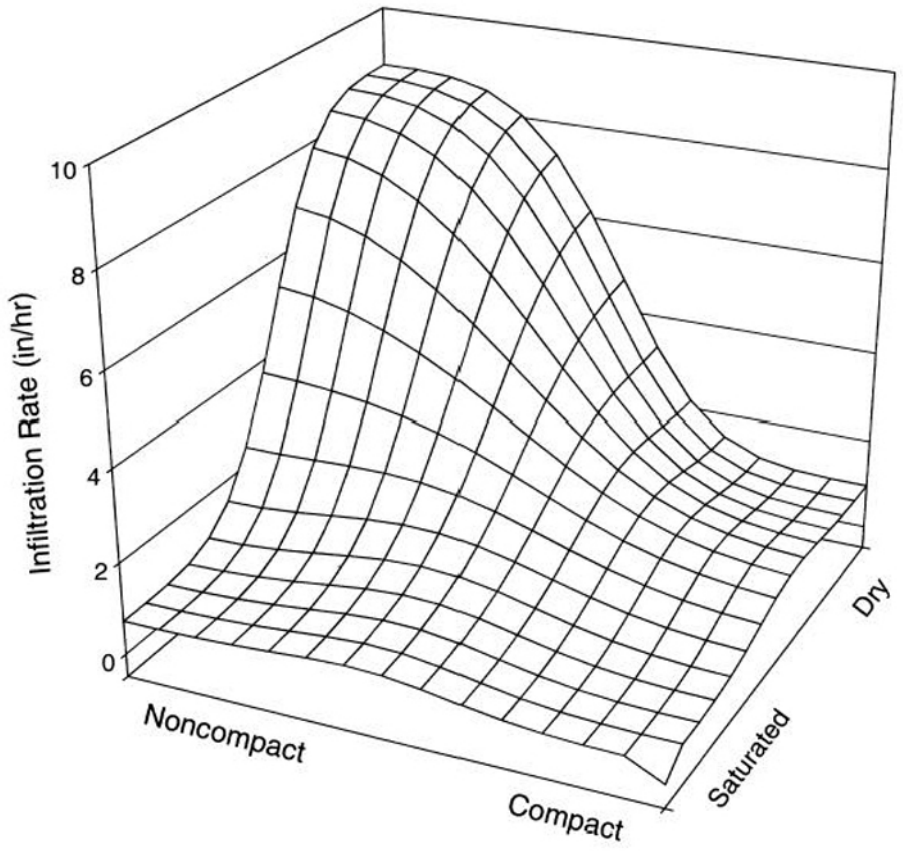
1999) confirmed the impacts to sandy soils previously demonstrated in Ocean County. Based upon more than 150 infiltration tests in disturbed urban soils, this research also demonstrated that such effects were generally independent of soil moisture in such soils. However, the research also found that, while compaction had similar effects on clayey soils with low moisture content, these effects were of minor significance when the moisture content approached saturated levels. A graphical summary of this research is shown in Figures 2-8 and 2-9.

From the results shown in Table 2-1 and Figures 2-8 and 2-9, it is felt that the effects of compaction on the rainfall-runoff process can no longer be ignored, particularly for sand and other coarse grained soils. As a result, inclusion of appropriate factors in runoff estimation methods is warranted when predicting runoff from a future, developed drainage area with such soils. However, this may require additional research data in order to reliably predict the degree of expected compaction and its impacts on soil permeability and runoff. Further study of the long-term effects of compaction, and whether natural weathering processes can restore some or all of the lost soil structure and permeability, are also required. Until such research is concluded, the results of the New Jersey and Alabama studies and a conservative or "safe" design approach may be used as guidance.

Potential measures to address the adverse impacts of soil compaction may be found in the results for the Single House site shown on the bottom row of Table 2-1. According to the Ocean County Study report, this site was not constructed through widespread regrading with heavy equipment typical of large tract construction, but instead through limited regrading with relatively light construction equipment. According to the results in Table 2-1, the lawn area at this site had a mean permeability rate of 7.1 inches per hour. While this is less than half the tested mean of 15 inches per

Figure 2-9: Alabama Compaction Test Results for Clayey Soil



Source: Pitt et al., 1999

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hour for woods, it nevertheless represents a relatively high permeability rate, particularly in comparison with the other, more highly disturbed sites in the table. This relatively high disturbed site permeability rate may indicate that the adverse impacts of compaction may be avoided or reduced through the use of site design techniques and construction practices and equipment that minimize site disturbance, regrading, and construction equipment weight and movement.

The Alabama research also presents a potential measure to address soil compaction through the addition of large amounts of compost to the soil. Tested on a glacial till soil, this measure was shown to significantly increase soil permeability at the expense, however, of an increase in nutrients in the runoff. Such soils also produced superior turf with little or no need for maintenance fertilization.

In summary, the above subsection presented the following ideas and information:

- Soil characteristics such as texture, permeability, and thickness can greatly influence the rainfall-runoff process and are therefore included in most runoff estimation methods.
- These characteristics can affect both the amount of initial rain that must fall before runoff begins and the total volume and peak rate of runoff.
- The general relationship between soil texture and permeability may allow the latter to be estimated from the former.
- Soil moisture content at the start of rainfall can significantly modify a soil's storage capacity and permeability rate.
- Compaction can also significantly modify a granular soil's undisturbed storage capacity and permeability rate.

Land Cover

In addition to the soils at and below the land surface within a drainage area, the type of cover on the soils' surface directly affects the rainfall-runoff process and is an important factor in most runoff estimation methods. Land covers can range from none (i.e., bare soil) to vegetated to impervious. Important vegetation characteristics include type, density, condition, extent of coverage, degree of natural residue or litter at the base, and degree of base surface roughness. Important impervious surface characteristics also include surface roughness, age and condition, connectivity, and the presence of cracks and seams. Connectivity describes whether runoff from an impervious surface can flow through a direct connection to a downstream swale, gutter, pipe, channel, or other concentrated flow conveyance system, or whether the runoff can flow onto and be distributed over a downstream pervious area, where a portion can infiltrate into the soil. As a result, unconnected impervious surfaces typically produce less runoff volume than directly connected ones.

All of the above characteristics can affect the volume of resultant runoff by influencing the amount of rainfall that is either stored on the land and vegetated surfaces or infiltrated into the soil. These characteristics can also affect a drainage area's response time or Time of Concentration and, consequently, the rate and duration of runoff. For example, TC equations developed by the NRCS indicate that runoff flowing as sheet flow across relatively smooth impervious surfaces will travel approximately 10 times faster than it would across a wooded area. The surface storage and delaying effects of land cover, particularly vegetation, can also help increase the amount of initial abstraction, thereby decreasing the runoff volume from a drainage area.

Land cover data sources, frequently used in combination, include field reconnaissance, aerial photographs, satellite imagery, and geographic information system (GIS) databases for existing drainage area conditions. Land cover under proposed or future conditions can be estimated from zoning maps, development regulations, proposed land development plans, and build-out analyses.

In estimating runoff from rainfall, it is interesting to compare the different responses from the impervious portions of a drainage area with those with pervious land covers such as turf grass, woods, or even bare soil. At the start of rainfall, the initial abstractions of both the impervious and pervious surfaces must be overcome before runoff begins. While the initial abstractions for typical impervious covers like roofs, roadways, parking lots, and sidewalks are considerably less than for areas with pervious covers, they nevertheless exist (Pitt and Voorhees, 1993). However, having a lower value, the initial abstraction for the impervious surfaces is overcome first, and the impervious surfaces will begin to produce runoff. This will continue until the larger initial abstraction of the pervious covers is also overcome. At this point, both the impervious and pervious portions of a drainage area will produce runoff.

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Once runoff has started, it is generally accepted that its amount will increase exponentially as rainfall continues. This nonlinear relationship between rainfall and the runoff it produces is more pronounced for pervious land covers than impervious ones, which typically have a near constant or linear rainfall-runoff response once runoff begins. These different initial abstractions and rainfall-runoff responses result in the relative percentage of runoff produced from each type of cover varying considerably, depending upon the total rainfall amount.

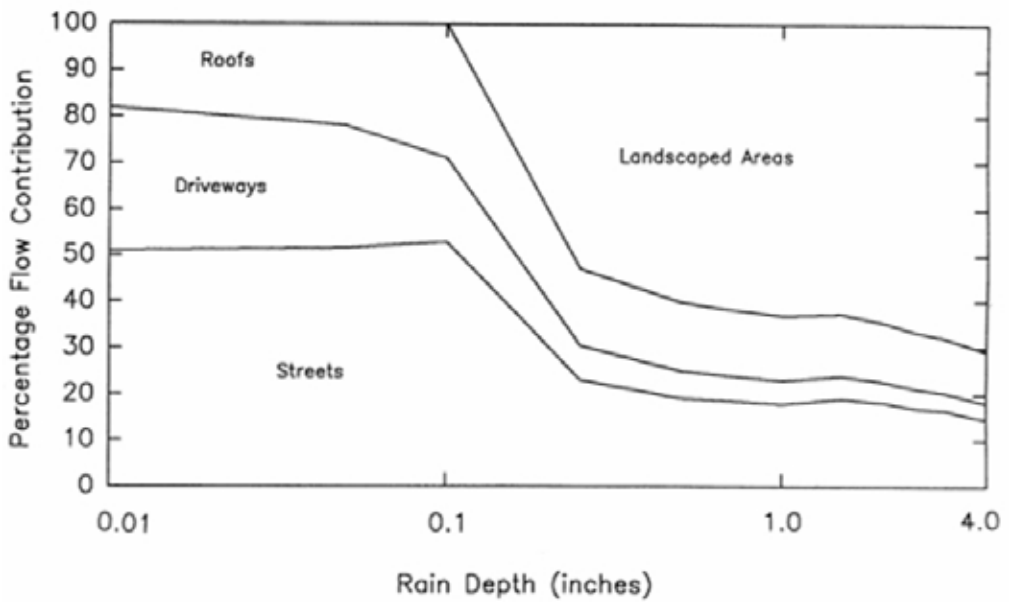
This difference is illustrated in Figure 2-10. It depicts the relative percentage of total runoff volume produced for a given amount of rain from various runoff source areas at a typical medium density residential housing site with clayey soils. As shown in the figure, site runoff would be entirely comprised of runoff from those site areas with impervious covers (i.e., streets, driveways, and roofs) from the start of rainfall until approximately 0.1 inches have fallen. However, as rainfall continues and overcomes the initial abstraction of the site's pervious landscaped areas, runoff from these areas also begins. When the rainfall has reached approximately 1 inch, approximately 50 percent of the site runoff is produced by these pervious areas. This increase in runoff percentage continues as rainfall continues, reaching approximately 70 percent at a total rainfall depth of 4 inches.

Such relationships are useful to urban stormwater management programs because they identify the critical runoff source areas that have the greatest impact on various program objectives. If a program objective is to address the runoff quality and pollution impacts caused predominantly by small, frequent rainfalls, then the control of impervious surfaces and the runoff from them is important. If flood or erosion control is critical, then all land covers may be important, since they all contribute important percentages of the total site runoff during the larger rainfall normally associated with these types of problems.

In summary, the above subsection presented the following ideas and information:

- The type, character, extent, and condition of the various land covers within a drainage area can have a significant effect on initial rainfall abstractions and resultant runoff volumes, rates, and durations.
- There are typically many sources of land cover data, including aerial photographs, GIS databases, field reconnaissance, and land development plans.

Figure 2-10: Relative Runoff Contributions from Various Source Areas at Medium Density Residential Site with Clayey Soils



Source: Pitt and Voorhees, 1993

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- Pervious and impervious covers respond differently to rainfall. The relative percentage of the total runoff from each varies with the total amount of rainfall.
- Impervious areas typically produce the majority of runoff from small rainfalls, while the percentage from pervious areas typically increases with increasing rainfall.
- Runoff from impervious areas can also vary, depending upon their roughness, condition, and connectivity. Directly connected impervious areas can produce significantly more runoff volume than unconnected ones.

Runoff Estimation: Methods and Models

There are numerous methods currently available to estimate runoff from rainfall. In general, most methods will include some if not all of the parameters described in the previous section. Exactly what method to utilize and what parameters to include typically depends upon available parameter data and the desired results.

Using desired results as a basis, runoff estimation techniques can be broadly grouped into the following three categories:

1. Runoff Volume Methods
2. Peak Runoff Rate Methods
3. Runoff Hydrograph Methods

Each category will generally utilize certain parameters and equations and, therefore, will require certain types and ranges of data. A brief description of each category is presented below. As can be seen from the descriptions, the number of parameters increases as we proceed down the list.

Runoff Volume Methods

When an estimate of runoff volume is desired, typical parameters include total rainfall, drainage area size, and soil and land cover characteristics. Soil characteristics will generally include estimates of initial abstraction amounts, soil infiltration rates, and some measure of antecedent moisture condition. Infiltration rates may be fixed at a constant rate or may vary throughout the event, typically in an exponential manner. A more sophisticated method may include consideration of drainage area slope. A similarly sophisticated method may also include rainfall intensity and total storm duration, although, in general, time-based parameters are not included, particularly those based upon a single design storm. However, runoff volume estimating methods which utilize long-term rainfall data will typically consider time in the form of interevent dry periods and the amount of soil moisture depletion that may occur during each one.

Peak Runoff Rate Methods

Methods that produce estimates of peak runoff rate from a given storm event typically include all or most of the parameters utilized in runoff volume methods. However, as the term "rate" implies, time plays a more important role and, consequently, more time-based parameters are typically included. These include an estimate of the drainage area's Time of Concentration as well as the peak rainfall intensities over this period. Simplified methods utilize a single, average rainfall intensity over the entire TC while more sophisticated ones allow the use of several, shorter-term intensities within the overall TC.

Runoff Hydrograph Methods

When an entire runoff hydrograph is desired, additional time-based parameters and data are required in addition to the parameters used in runoff volume or peak runoff rate methods. First, since a runoff hydrograph is a measure of runoff rate resulting from all or a portion of a rainfall event, rainfall data throughout the entire event is required, typically divided into time periods equal to at least 20 percent to 25 percent of the drainage area's TC. In addition, some measure of the movement of runoff through the drainage area over time is also required. Once again, simplified methods typically assume a linear relationship, while more sophisticated ones utilize a nonlinear one based upon such mathematical techniques as unit hydrographs and kinematic wave equations.

In comparing the above descriptions of the three general runoff estimation methods, several observations can be made. First, as noted above, the number of time-based parameters increases as we move from estimating runoff volume to peak rates and then entire

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runoff hydrographs. This relationship can tell us which type of method is needed when designing or analyzing a particular stormwater management facility or practice. That is, a stormwater management measure such as an infiltration basin that is relatively insensitive to the rate of runoff inflow can often be designed from estimates of total runoff volume only. However, designing a stormwater facility such as a detention basin that is sensitive to the rate of runoff inflow will typically require a runoff hydrograph.

This relationship between stormwater facility type and required runoff method can also guide us toward the type of rainfall data that may be utilized in facility design. Since records of total storm depth are generally more available than records of incremental rainfall over short time increments, an infiltration basin designer will be much more likely to have a choice between actual long-term rainfall data and a single design storm approach than a detention basin designer would. Similarly, the designer of a stormwater facility to control the runoff from relatively small, frequent rainfalls is more likely to be able to choose between a long-term data and a design storm approach than the designer of a facility to control runoff from large, relatively infrequent events. This is because the first designer requires a relatively short period of rainfall record, which is presently more available than the longer-term records required by the second designer.

In addition, as noted above, the number and range of included parameters increases as we move from the runoff volume estimation methods to the runoff peak and then the runoff hydrograph methods. This increasing data and computational complexity can also signal a decrease in the certainty of the estimates produced by these methods. As a result, whether using long-term data or a single design storm approach, we can generally expect our estimates of total runoff volume to be more reliable and accurate than our estimates of peak runoff rate and, to an even greater extent, entire runoff hydrographs. This realization should guide our selection of design parameters and facility features so that the inherent safety of the facility design increases with decreasing estimation certainty.

Finally, as our concerns for runoff quality and the environment have grown, there has been an increasing interest in estimating the runoff from relatively small rainfalls. In recognition of this interest, it is important to note a second categorization of runoff estimation methods that is based upon the range of applicable rainfall depths. At the time of the 1994 publication of the original *Fundamentals of Urban Runoff Management*, the NRCS Runoff Equation and its variants had become the standard method for estimating runoff volume from rainfall. As clearly stated in various NRCS publications such as TR-55, this method was and remains intended for runoff depths of 0.5 inches or more. In many instances, this would require a minimum total rainfall depth of approximately two to three inches which, in many locations, would have an average frequency or recurrence interval of one year or more.

While these rainfall depths and frequencies typically represented the lower limits of interest or jurisdiction of runoff management programs in 1994, research and experience has pointed toward the need to manage the runoff from smaller rainfall amounts in order to optimize control of runoff quality and water ecosystem problems (Pitt and Voorhees, 1993). Therefore, it has likewise become important to develop and utilize newer runoff estimation methods suitable for these lower rainfall depths. Equations such as those developed by Pitt and Voorhees and by the Center for Watershed Protection for the State of Maryland have been shown to be particularly reliable for such rainfall depths. Use of the NRCS Runoff Equation for runoffs less than the official NRCS limit, which may be necessary in certain existing runoff management programs and computer models, should only be made with caution and a thorough understanding of the method's assumptions, limitations, and sensitivities. Similar caution should be used when using a method intended for small rainfalls to estimate runoff from larger events.

In summary, the above section presented the following ideas and information:

- Runoff estimation methods can be categorized by the type of result they produce.
- In general, the three basic method types are those that estimate runoff volume, peak runoff rate, and runoff hydrographs.
- Each method utilizes a certain combination of parameters, equations, and assumptions.
- As you proceed from estimating runoff volume to peak runoff rate and then runoff hydrographs, the degree of complexity and range of parameters typically increases as well, particularly of those associated with time.
- This increased complexity can also signal a decrease in reliability of results, indicating the need for increased discretion and data accuracy

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to ensure effective and safe stormwater facilities and practices.

- The type of estimation method required to design a stormwater facility will depend upon the facility's sensitivity to changes in inflow over time.
- Methods that utilize long-term rainfall data and single design storms are both available. Which approach can be utilized will depend upon the range of rainfalls to be controlled, the facility's sensitivity to time, and the availability of suitable rainfall data and computer programs.

Impacts of Land Use Change

Typically, a land development project will result in modifications to several of the factors associated with the rainfall-runoff process. These can include replacing indigenous vegetation with both impervious land covers and planted vegetated covers such as turf grass. Such land covers are less permeable and have fewer surface irregularities and surface storage, resulting in increased runoff volumes and longer runoff durations. This problem may be compounded by increases in drainage area size through surface regrading and conveyance system construction, which can make a larger area contribute runoff to a particular location. Soil compaction during construction may further increase the volume of runoff from the turf grass and other constructed pervious areas.

The land cover changes described above can also cause significant reductions in initial abstraction, creating a lower rainfall threshold in order for runoff to begin. This lower threshold can be particularly damaging, for it results in runoff to downstream waterways from rainfalls that previously did not produce any runoff, hypothetically causing an infinite increase in the runoff from such rains. This also compounds the increased runoff volume impacts by creating a greater number of runoff producing storm events and increasing the frequency of runoff and pollutant loadings in downstream waterways.

In addition to being less permeable, impervious and turf grass land covers are typically more efficient in transporting runoff across their surfaces, resulting in decreases in a drainage area's Time of Concentration and a corresponding increase in runoff rates, including the peak runoff rate. Such increases, which can be compounded by the replacement of natural conveyance systems with more efficient constructed ones such as gutters, storm sewers, and drainage channels, can cause an increase in flow velocity in downstream waterways which, when combined with the increased flow duration, can create new or aggravate existing waterway erosion and scour.

Finally, the decrease in infiltration and resultant increase in runoff indicates that less rainfall may be entering the local or regional groundwater, resulting in the depletion or complete eradication of waterway baseflows and the lowering of the groundwater table. While research into these impacts has at times produced somewhat conflicting results (Center for Watershed Protection, 2003), the negative impacts to baseflows

Table 2-2: Land Development Impacts Example, Pre- and Post-Development Site Conditions

Development Condition	Site Land Cover	Average Initial Abstraction
Pre-developed	Woods	1.6
Post-developed	25% impervious and 75% turf grass	0.9

Table 2-3: Land Development Impacts Example, Pre- and Post-Development Runoff Volumes

Storm Frequency	24-Hour Rainfall (Inches)	Estimated Runoff Depth	
		Pre-Developed	Post-Developed
2-year storm	2.8	0.1	0.6
10-year storm	4.0	0.5	1.3

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and groundwater levels caused by land use changes have become a generally accepted tenet of urban runoff management programs.

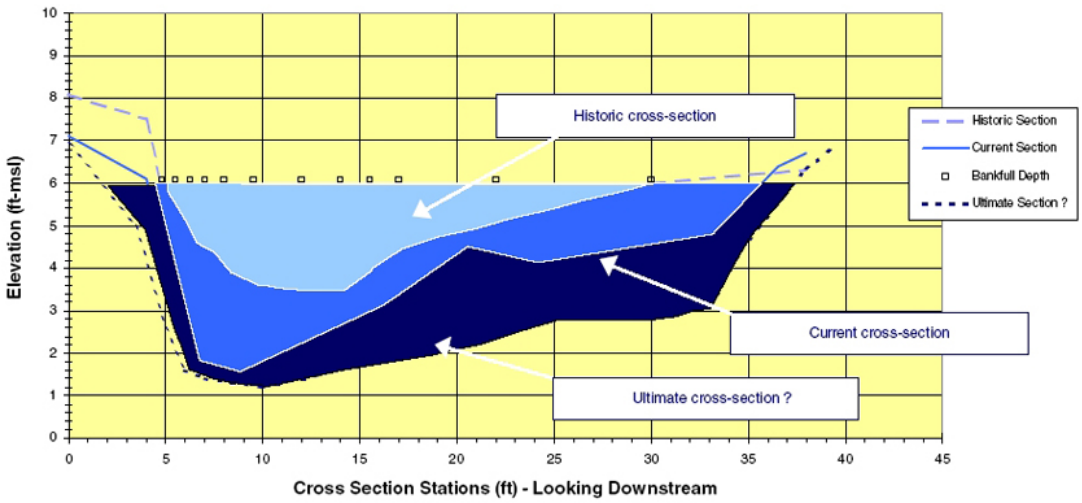
Such impacts can be quantified through a hypothetical land development example utilizing the NRCS Runoff Equation. The pre- and post-developed land uses and covers are summarized in Table 2-2. As shown in the table, the wooded land cover that exists in the pre-developed condition will be changed to a combination of 75 percent turf grass and 25 percent impervious cover that is directly connected to the site's drainage system. Our example will assume a relatively granular site soil, identified as a Hydrologic Soil Group B soil in the NRCS method, and will analyze the impacts of the site development for both a 2- and 10-year, 24-hour rainfall. The resultant pre- and post-developed runoff volumes for both storm events are summarized in Table 2-3.

A review of Table 2-2 indicates that the average initial abstraction for the post-developed site will be approximately 40 percent smaller than for the pre-developed one, decreasing by 0.7 inches from 1.6 to 0.9 inches. This means that while a minimum of 1.6 inches of rainfall is required to produce runoff from the pre-developed site, only 0.9 inches on average will be necessary under post-developed conditions. It should be noted that this post-developed initial abstraction is an average value for the combined turf grass and impervious cover site and that only approximately 0.1 inches of rain should be necessary to produce runoff from the impervious portions. This means that runoff volumes to downstream waterways are not only expected to increase but that this runoff will now be occurring from rain events between approximately 0.1 and 1.6 inches that previously produced no site runoff or waterway flow. This will significantly increase the number of times when runoff and associated pollutants will be flowing to and through downstream waterways.

A review of Table 2-3 indicates the extent of the estimated runoff volume increases that can be expected due to the proposed land use change. As shown in the table, the total 2-year runoff volume from the site is estimated to increase by 500 percent following development from approximately 0.1 to 0.6 inches. The estimated 10-year volume increase, while smaller, is nevertheless significant, increasing from approximately 0.5 to 1.3 inches or by approximately 160 percent. This also indicates that the quantity impacts of land use change are more acute for smaller, more frequent rainfalls – a distinct problem for waterways that are particularly sensitive to such storm events.

The potential impacts of this increased frequency and volume of development site runoff to downstream waterways is illustrated in Figure 2-11, which depicts the changes to a stream cross section in Maryland between 1950 and 2000 (Center for Watershed Protection, 2003). As shown in the figure, both the width and depth of the cross section have increased considerably between

Figure 2-11: Effects of Urbanization on Maryland Stream Cross Section



Source: Center for Watershed Protection, 2003

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the 1950 or "Historic" configuration and the 2000 or "Current" condition. It should be noted that, over this time period, sufficient land development has occurred in the stream's drainage area to increase the total impervious land cover from approximately 2 percent to 27 percent. The "Ultimate" cross section shown in the figure is an estimate of the final cross section size in response to this degree of urbanization. Additional research indicates that stream channel areas can enlarge by two to eight times due to drainage area urbanization (Center for Watershed Protection, 2003).

In addition to channel cross section enlargement, other physical impacts of increased runoff volumes, rates, frequencies, and durations include (Center for Watershed Protection, 2003):

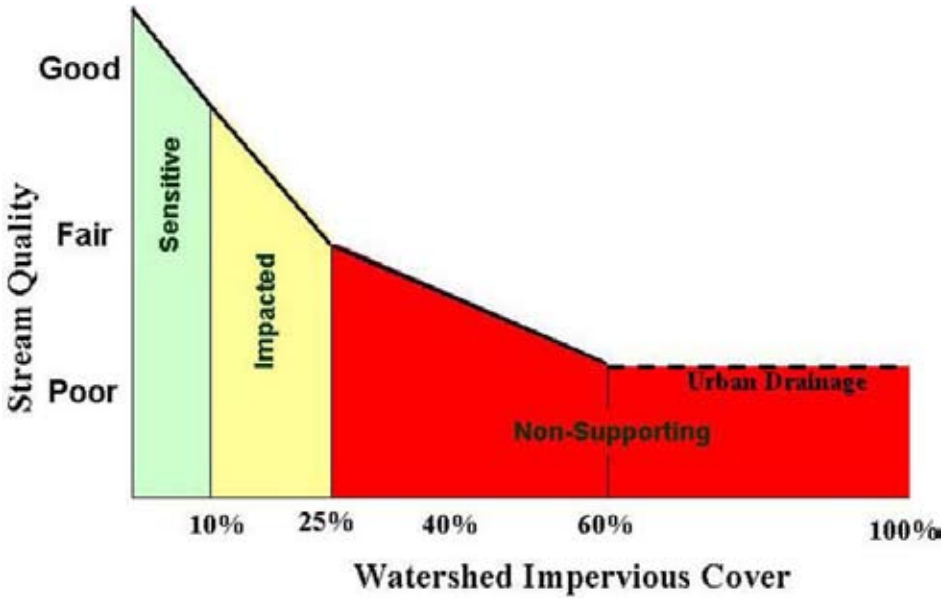
- Channel bank undercutting;
- Channel bottom incision;
- Loss of aquatic habitat;
- Increase in sediment yield and transport;
- Loss of riparian cover; and
- Increase in water temperature.

Utilizing the results from a number of research studies, the Center for Watershed Protection has developed a relatively simple model that demonstrates a direct relationship between drainage area urbanization (as measured by the percentage of impervious land cover in the drainage area) and the general quality of the stream to which the area's runoff drains. This model is depicted in Figure 2-12. It indicates that as total impervious cover in a drainage area increases, the quality of the stream decreases. This model has been widely adopted as a predictor of the adverse effects that can occur if drainage area development continues in an unmanaged or unregulated way.

In summary, the above section presented the following ideas and information:

- Land use changes can increase impervious land cover, decrease soil permeability and vegetated cover, reduce initial abstractions, and shorten runoff response times.
- Such changes can result in increased volumes, rates, durations, and frequencies of surface runoff and waterway flows.

Figure 2-12: Center for Watershed Protection's Impervious Cover Model



Source: Center for Watershed Protection, 2003

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- Such increases can adversely impact waterways through channel enlargement, bank undercutting, aquatic habitat destruction, increased sediment loadings, and increased water temperatures.
- Such impacts have been extensively documented through research.

Summary and Conclusions

This chapter demonstrates how an understanding of the fundamentals of the rainfall-runoff process is critical to the development and operation of an effective urban runoff management program. Such fundamentals include:

1. The rainfall-runoff process is complex, and no perfect runoff estimation methods exist.
2. However, through informed assumptions and an understanding of the fundamentals, we can generally overcome these complexities and produce reasonable, reliable, and safe runoff estimates.
3. Several types of runoff estimation methods are available, utilizing a range of parameters and data including both actual long-term rainfall data and single event design storms.
4. The type and accuracy of the required runoff estimate and the availability of the required data will largely determine the runoff estimation method to be used.
5. The impacts of land use change include increased runoff and waterway flow volumes, rates, durations, and frequencies.
6. These increases can cause significant physical damage to waterways and aquatic habitats as well as biological, chemical, and environmental damage to ground and surface waters. Further information on these quality impacts are presented in Chapters 3 and 4.
7. Management of land use changes and preservation of the rainfall-runoff process for undeveloped conditions can prevent or mitigate such damage.
8. Structural stormwater management measures can also be used to reduce or control the runoff impacts of land use changes both during and after site construction. These measures are described in detail in Chapters 8 and 9.

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CHAPTER 3

Water Quality Impacts of Urbanization

This chapter focuses on the physio-chemical aspects of water quality by examining the characteristics, sources, and patterns of urban runoff pollutants. Stormwater runoff from urbanized areas carries with it a wide variety of pollutants from diverse and diffuse sources. Based on data collected over many decades, throughout the country, it is apparent that there is a great deal of variability in urban runoff pollutant composition and concentrations. Representing all recognized classes of water pollutants, these runoff contaminants originate not only from land-use activities in the drainage area where runoff is collected but also occur as atmospheric deposition from areas outside the watershed of the receiving water body. In addition, exchanges between surface and groundwater can also be a pathway for pollutants. For example, landfill leachate or buried toxic waste can easily contaminate groundwater, which can then become a source of pollutants to surface waters. On the other hand, pollution can be transported via urban surface runoff and can result in the contamination of groundwater or surface receiving water bodies. The multiple sources of urban runoff pollution on, above, and below the surface represent a complex set of watershed conditions. They determine the effects that drainage from the watershed will have on natural receiving water, and represent a challenge for management.

The impact of stormwater runoff pollutants on receiving water quality depends on a number of factors, including pollutant concentrations, the mixture of pollutants present in the runoff, and the total load of pollutants delivered to the water body. Water pollutants often go through various physio-chemical processes before they can impact an aquatic biota. During their transport by surface waters and stormwater runoff, losses such as sedimentation can reduce the total stress burden on aquatic organisms, although the reduction may not be permanent (e.g., sediments can be resuspended). Physical, chemical, and biological processes can also cause transformations to different physical (particulate versus dissolved) or chemical (organic or inorganic) forms. Depending on the environmental conditions and the organisms involved, transformations can cause enhanced (synergistic) or reduced stress potential.

Water pollution is not the only condition in the watershed that causes ecological stress. Chief among other stresses is modified hydrology from increased stormwater runoff flow volumes and peak rates discharged from urbanized landscapes. Conversely, stress can come from decreased dry weather baseflows resulting from reduced groundwater recharge in urban areas. Finally, aquatic biota can be affected by the various stresses in whatever form they arrive. Biota may have an easier time dealing with a few rather than many stressors, especially when they act in a synergistic manner. Of course, populations of aquatic organisms do not live in isolation but interact with other species, especially in predator-prey relationships. These interactions have many implications for the ecosystem. For example, the loss of one species from a pollution problem will likely result in the decline or elimination of a major predator of that species. These and other physical or biological stressors will be discussed in detail in the next chapter.

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Background

Stormwater Pollutant Sources

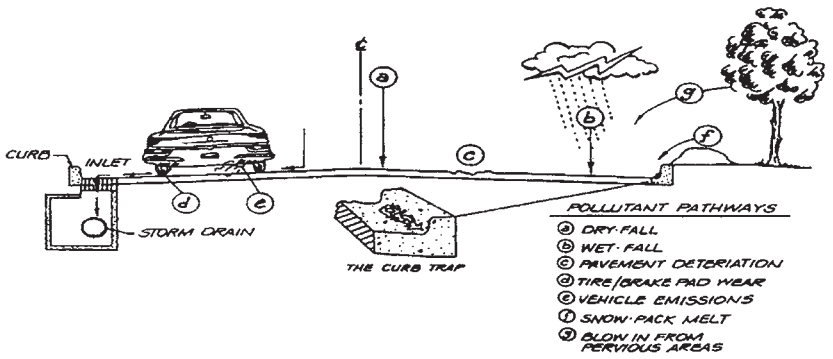
Stormwater runoff from urbanized areas is generated from a number of sources, including residential areas, commercial and industrial areas, roads, highways, and bridges. Essentially, any surface that does not have the capability to store and infiltrate water will produce runoff during storm events. These are known as impervious surfaces. As the level of imperviousness increases in a watershed, more rainfall is converted to runoff. In addition to creating greater runoff volumes, impervious surfaces (roads, parking lots, rooftops, etc.) are the primary source areas for pollutants to collect within the built environment (Figure 3-1). Runoff from storm events then carries these pollutants into receiving waters via the stormwater conveyance network. Land-use (e.g., residential, commercial, and industrial) and human activities (e.g., industrial operations, residential lawn care, and vehicle maintenance) characteristic of a drainage basin largely determine the mixture and level of pollutants found in stormwater runoff (Weibel et al., 1964; Griffin et al., 1980; Novotny and Chester, 1981; Bannerman et al., 1993; Makepeace et al., 1995; Pitt et al., 1995).

Atmospheric deposition of pollutants is typically divided into wet-fall and dry-fall components. These inputs can come from local sources, such as automobile exhaust, or from distant sources such as coal or oil power plant emissions. Regional industrial and agricultural activities can also contribute to atmospheric deposition as dry-fall. Precipitation also carries pollutants from the atmosphere to earth as wet-fall. Depending on the season and location, atmospheric deposition can be a significant source of pollutants in the urban environment. The USGS has estimated that up to 25 percent of the nitrogen entering the Chesapeake Bay likely comes from atmospheric deposition (USGS, 1999).

The types of land-use activities present in a drainage basin are also important in determining stormwater quality. The method of conveyance within the built environment is influential as well. The traditional means of managing stormwater runoff in urban areas has been to construct a network of curb-and-gutter streets, drain-inlet catch basins, and storm drain piping to collect this runoff, transport it quickly and efficiently away from the urbanized area, and discharge the stormwater into receiving waters.

Separate storm sewer systems convey only stormwater runoff. Water conveyed in separate storm sewers is frequently discharged directly to receiving waters without treatment. Stormwater can also bypass the stormwater infrastructure and flow into receiving waters as diffuse runoff from parking lots, roads, and landscaped areas. In cases where a separate storm sewer

Figure 3-1: Stormwater Runoff Pathways and Pollutant Sources



Streets provide several pathways for stormwater pollutants. Atmospheric pollutants settle or are washed onto the street during rain events (a, b). Pavement fragments also contribute to stormwater pollution (c). Vehicles contribute emissions and tire and brake pad particles (d, e). Snow collected at the street edge melts and contributes salts (f). Leaves and pollen from trees are blown into the street (g). Curb and gutter systems channel polluted stormwater directly into streams.

Source: Schueler, 1995

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system is present, sanitary sewer flows are conveyed to the municipal wastewater treatment plant (WWTP) in a separate sanitary sewer system.

In a combined sewer system, stormwater runoff may be combined with sanitary sewer flows for conveyance. During low flow periods, flows from combined sewers are treated by the WWTP prior to discharge to receiving waters. During large rainfall events, however, the volume of water conveyed in combined sewers can exceed the storage and treatment capacity of the wastewater treatment system. As a result, discharges of untreated stormwater and sanitary wastewater directly to receiving streams can occur in these systems. These types of discharges are known as combined sewer overflow (CSO) events.

Urban streets are typically significant source areas for most contaminants in all land-use categories. Parking lots and roads are generally the most critical source areas in industrial and commercial areas. Along with roads, lawns, landscaped areas, and driveways can be significant sources of pollution in residential areas. In addition, roofs can contribute significant quantities of pollutants in all land-use types (Bannerman et al., 1993). The quantity of these pollutants delivered to receiving waters tends to increase with the degree of development in urban areas.

Historically, as urbanization occurred and storm drainage infrastructure systems were developed in this country, the primary concern was to limit nuisance and potentially damaging flooding due to the large volumes of stormwater runoff that were generated. Little, if any, thought was given to the environmental impacts of such practices on water quality. Due to the diffuse nature of many stormwater discharges, it is difficult to quantify the range of pollutant loadings to receiving waters that are attributable to stormwater discharges. Awareness of the damaging effects stormwater runoff is causing to the water quality and aquatic life of receiving waters is a relatively recent development, as is stormwater quality treatment.

Stormwater Runoff Pollutants

Stormwater runoff from urban areas can contain significant concentrations of harmful pollutants that can contribute to adverse water quality impacts in receiving streams. Impacts on beneficial uses can include such things as beach closures, shellfish bed closures, limits on fishing, and limits on recreational contact in waters that receive stormwater discharges. Contaminants enter stormwater from a variety of sources in the urban landscape. In general, these pollutants degrade water quality in receiving waters associated with urbanizing watersheds. Stormwater pollution is often a contributing factor where there is an impairment of beneficial use and/or an exceedance of criteria included in water-quality standards (WQS).

Research has identified stormwater runoff as a major contributor to water quality degradation in urbanizing watersheds (Field and Pitt, 1990; Makepeace et al., 1995; Pitt et al., 1995; Herricks, 1995; CWP, 2003). Stormwater or urban runoff typically contains a mixture of pollutants, including the following major constituents:

- Sediment;
- Nutrients (nitrogen and phosphorus);
- Chlorides ;
- Trace metals ;
- Petroleum hydrocarbons ;
- Microbial pollution ; and
- Organic chemicals (pesticides, herbicides, and industrial).

Sediment is one of the most common and potentially damaging pollutants found in urban runoff. Sediment pollutant levels can be measured as Total Suspended Solids (TSS) and/or Turbidity. TSS is a measure of the total mass of suspended sediment particles in a sample of water. The combination of flow and TSS gives a measure of sediment load carried downstream. Turbidity measures the scattering of light by suspended sediment particles in a water sample. Turbidity and TSS in stormwater runoff can vary significantly from region to region, as well as within a local area, depending on the sources of sediment contributing to the runoff load. The size distribution of suspended particles, as well as the composition of particulate (e.g. organic vs. inorganic) can have a significant influence on the measured turbidity or TSS of a water sample. Current research indicates that particle size distribution (PSD) may be an important parameter to measure when evaluating the sediment component in surface waters or stormwater runoff (Bent et al. 2001; US-EPA 2001; Burton and Pitt 2002).

Sediment in stormwater runoff can come from the wash-off of particulate material from impervious surfaces in already urbanized areas and/or from active construction sites in urbanizing areas. Streets, parking

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lots, lawns, and landscaped areas have been identified as the primary source areas for sediment in the urban environment (CWP, 2003). Construction site runoff has the potential to contain very high levels of sediment, especially if proper erosion and sediment control (ESC) best management practices (BMP) are not employed. The TSS concentration from uncontrolled construction sites can be more than 150 times greater than that found in natural, undeveloped landscapes (Leopold, 1968). Uncontrolled runoff from construction sites has been shown to have a TSS ranging from 3,000 to 7,000 mg/l (CWP, 2003). When proper ESC BMP techniques are utilized, the TSS level can typically be reduced by at least an order of magnitude, if not more (CWP, 2003).

Nutrients (nitrogen and phosphorous) are essential elements in all aquatic ecosystems. However, when these nutrients are found at excessive levels, they can have a negative impact on aquatic systems. Common sources of nutrients such as nitrates and phosphates include chemical fertilizers applied to lawns, golf courses, landscaped areas, and gardens. Residential lawns and turf areas (e.g., sports fields, golf courses, and parks) in urbanizing watersheds have been shown to be "hot spots" for nutrient input into urban runoff (CWP, 2003). In general, lawns and turf areas contribute greater quantities of nutrients than other urban source areas. In fact, research suggests that nutrient concentrations in runoff from lawns and turf areas can be as much as four times greater than those from other urban nutrient source areas (Bannerman et al., 1993; Steuer et al., 1997; Waschbusch et al., 2000; Garn, 2002).

Sources of nutrients such as nitrates and phosphates include chemical fertilizers applied to lawns, golf courses, landscaped areas, and gardens. In addition, nutrient pollution can originate from failing septic systems or from inadequate treatment of wastewater discharges from an urban WWTP. Atmospheric deposition of nutrient compounds from industrial facilities or power generation plants is also a source of nutrients in the built environment. Soil erosion and other sediment sources can also be significant nutrient sources, as nutrients often tend to be found in particulate form. Research indicates that human land-use activity can be a significant source of nutrient pollution to stream and wetland ecosystems (Bolstad and Swank, 1997; Sonoda et al., 2001; Brett et al., 2005). Many studies have linked nutrient levels in runoff to contributing drainage area land uses, with agricultural and urban areas producing the highest concentrations (Chessman et al., 1992; Wernick et al., 1998; USGS, 1999). Snowmelt runoff in urban areas can also contain elevated levels of nutrients (Oberts, 1994).

Excessive nutrient levels in urban runoff can stimulate algal growth in receiving waters and cause nuisance algal blooms when stimulated by sunlight and high temperatures. The decomposition that follows these algal blooms, along with any organic matter (OM) carried by runoff, can lead to depletion of dissolved oxygen (DO) levels in the receiving water and bottom sediments. This can result in a degradation of habitat conditions (low DO), offensive odors, loss of contact recreation usage, or even fish kills in extremely low DO situations.

Nitrate is the form of nitrogen found in urban runoff that is of most concern. The nitrate anion (NO_3) is not usually adsorbed by soil and therefore moves with infiltrating water. Nitrates are present in fertilizers, human wastewater, and animal wastes. Nitrate contamination of groundwater can be a serious problem, resulting in contamination of drinking water supplies (CWP, 2003). High nitrate levels in drinking water can cause human health problems.

Phosphates (PO_4) are the key form of phosphorus found in stormwater runoff. Phosphates in runoff exist as soluble reactive phosphorus (SRP) or orthophosphates, poly-phosphates, and as organically bound phosphate. The poly-form of phosphates is the one that is found in some detergents. Orthophosphates are found in sewage and in natural sources. Organically bound phosphates are also found in nature, but can also result from the breakdown of phosphorus-based organic pesticides. Very high concentrations of phosphates can be toxic.

Chlorides are salt compounds found in runoff that result primarily from road de-icer applications during winter months. Sodium chloride (NaCl) is the most common example. Although chlorides in urban runoff come primarily from road deicing materials, they can also be found in agricultural runoff and wastewater. Small amounts of chlorides are essential for life, but high chloride levels can cause human illness and can be toxic to plants or animals.

Metals are among the most common stormwater pollutant components. These pollutants are also referred to as trace metals (e.g., zinc, copper, lead, chromium, etc.). Many trace metals can often be found at potentially harmful concentrations in urban stormwater runoff (CWP, 2003). Metals are typically associated with industrial activities, landfill leachate, vehicle maintenance, roads, and parking areas (Wilber and Hunter,

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1977; Davies, 1986; Field and Pitt, 1990; Pitt et al., 1995). In one study in the Atlanta (GA) metropolitan area, zinc (Zn) was found to be the most significant metal found in urban street runoff (Rose et al., 2001). Similar results were found in the Puget Sound (WA) region (May et al., 1997). A study in Michigan found that parking lots, driveways, and residential streets were the primary source areas for zinc, copper, and cadmium pollution found in urban runoff (Steuer et al., 1997).

Most of the metal contamination found in urban runoff is associated with fine particulate (mostly organic matter), such as is found deposited on rooftops, roads, parking lots, and other depositional areas within the urban environment (Furguson and Ryan, 1984; Good, 1993; Pitt et al., 1995; Stone and Marsalek, 1996; Crunkilton et al., 1996; Sutherland and Tolosa, 2000). However, a significant fraction of copper (Cu), cadmium (Cd), and zinc (Zn) can be found in urban runoff in the dissolved form (Pitt et al., 1995; Crunkilton et al., 1996; Sansalone and Buchberger, 1997).

Petroleum hydrocarbon compounds are another common component of urban runoff pollution. Hydrocarbon sources include vehicle fuels and lubricants (MacKenzie and Hunter, 1979; Whipple and Hunter, 1979; Hoffman et al., 1982; Fram et al., 1987; Kucklick et al., 1997; Smith et al., 1997). Hydrocarbons are normally attached to sediment particles or organic matter carried in urban runoff. The increase in vehicular traffic associated with urbanization is frequently linked to air pollution, but there is also a negative relationship between the level of automobile use in a watershed and the quality of water and aquatic sediments. This has been shown for polycyclic aromatic hydrocarbon (PAH) compounds (Van Hoffman et al., 1982; Metre et al., 2000; Stein et al., 2006). In most urban stormwater runoff, hydrocarbon concentrations are generally less than 5 mg/l, but concentrations can increase to 10 mg/l in urban areas that include highways, commercial zones, or industrial areas (CWP, 2003). Hydrocarbon "hot spots" in the urban environment include gas stations, high-use parking lots, and high-traffic streets (Stein et al., 2006). A Michigan study showed that commercial parking lots contributed over 60 percent of the total hydrocarbon load in an urban watershed (Steuer et al.,

Table 3-1: Pollutants Commonly Found in Stormwater and Their Forms

Pollutant Category	Specific Measures
Solids	Settleable solids Total suspended solids (TSS) Turbidity (NTU)
Oxygen-demanding material	Biochemical oxygen demand (BOD) Chemical oxygen demand (COD) Organic matter (OM) Total organic carbon (TOC)
Phosphorus (P)	Total phosphorus (TP) Soluble reactive phosphorus (SRP) Biologically available phosphorus (BAP)
Nitrogen (N)	Total nitrogen (TN) Total kjeldahl nitrogen (TKN) Nitrate + nitrite-nitrogen (NO3+NO2-N) Ammonia-nitrogen (NH3-N)
Metals	Copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), arsenic (As), nickel (Ni), chromium (Cr), mercury (Hg), selenium (Se), silver (Ag)
Pathogens	Fecal coliform bacteria (FC) Enterococcus bacteria (EC) Total coliform bacteria (TC) Viruses
Petroleum hydrocarbons	Oil and grease (OG) Total petroleum hydrocarbons (TPH)
Synthetic organics	Polynuclear aromatic hydrocarbons (PAH) Pesticides and herbicides Polychlorobiphenols (PCB)

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1997). Lopes and Dionne (1998) found that highways were the largest contributor of hydrocarbon runoff pollution.

Microbial pollution includes bacteria, protozoa, and viruses that are common in the natural environment, as well as those that come from human sources (Field and Pitt, 1990; Young and Thackston, 1999; Mallin et al., 2000). Many microbes are naturally occurring and beneficial, but others can cause diseases in aquatic biota and illness or even death in humans. Some types of microbes can be pathogenic, while others may indicate a potential risk of water contamination, which can limit swimming, boating, shellfish harvest, or fish consumption in receiving waters. Microbial pollution is almost always found in stormwater runoff, often at very high levels, but concentrations are typically highly variable (Pitt et al., 2004). Sources of bacterial pollution in the urban environment include failing septic systems, WWTP discharges, CSO events, livestock manure runoff, and pet waste, as well as natural sources such as wildlife. Young and Thackston (1999) showed that bacterial concentrations in stormwater runoff were

Table 3-2: Pollutants Commonly Found in Stormwater and Their Sources

Pollutant	Potential Sources
Hydrocarbons (gasoline, oil, and grease)	Internal combustion engines Automobiles Industrial machinery
Copper (Cu)	Building materials Paints and wood preservatives Algicides Brake pads
Zinc (Zn)	Galvanized metals Paints and wood preservatives Roofing and gutters Tires
Lead (Pb)	Gasoline Paint Batteries
Chromium (Cr)	Electro-plating Paints and preservatives
Cadmium (Cd)	Electro-plating Paints and preservatives
Pesticides	Agriculture and grazing Residential and commercial use
Herbicides	Agriculture and grazing Residential and commercial use Roadside vegetation maintenance
Organic compounds	Industrial processes Power generation
Bacteria and pathogens	Human sewage Livestock manure Domestic animal fecal material
BOD	Agriculture and grazing Human sewage
Nutrients (N and P)	Agriculture and grazing Lawn and landscape fertilizer
Fine sediment	Agriculture and grazing Timber harvest Pavement wear Construction sites Road sanding

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directly related to the level of watershed and impervious surface area. Mallin and others (2000) also found that bacterial pollution problems were much more common in urbanized coastal watersheds than in undeveloped catchments. There is also evidence that microbial populations can survive and possibly even grow in urban stream sediments and in sediments found in storm sewer systems, making the stormwater infrastructure a potential source of microbial pollution (Bannerman et al., 1993; Steuer et al., 1997; Schueler, 1999).

Pesticides, herbicides, and other organic pollutants are often found in stormwater flowing from residential and agricultural areas throughout the U.S. (Ferrari et al., 1997; USGS, 1999; Black et al., 2000; Hoffman et al., 2000). Among the many pesticides and herbicides commonly found in urban runoff and urban streams are the following:

- Diazinon;
- Chlorpyrifos;
- Chlordane
- Carbaryl;
- Atrazine;
- Malathion;
- Dicamba;
- Prometon;
- Simazine; and
- 2,4-D.

Toxic industrial compounds such as PCBs can also be present in urban runoff (Black et al., 2000). Studies in Puget Sound confirm these findings (Hall and Anderson, 1988; May et al., 1997; USGS, 1997; Black et al., 2000). In many cases, even banned pesticides such as DDT or other organo-chlorine based pesticides (e.g., chlordane and dieldrin) can be found in urban stream sediments. The EPA estimates that nearly 70 million pounds of pesticides and herbicides are applied to lawns and other surfaces within the urban environment of the U.S. each year (CWP, 2003). These pesticides or herbicides vary in mobility, persistence, and potential aquatic impact. Many pesticides and herbicides are known or suspected carcinogens and can be toxic to humans and aquatic biota. However, most of the known health effects require exposure to higher concentrations than are typically found in the urban environment. However, the health effects of chronic exposure to low levels of pesticides and herbicides are generally unknown (Ferrari et al., 1997).

In urban runoff, most pollutants are associated with fine sediment or other natural particulates (e.g., organic matter). This condition differs between the specific pollutants. For example, depending on overall chemical conditions, each metal differs in solubility. For in-stance, lead (Pb) is relatively insoluble, while zinc (Zn) is relatively soluble. The nutrients phosphorus (P) and nitrogen (N) typically differ substantially from one sample to another in dissolved and particulate forms.

In addition to pollutants, other water quality characteristics affect the behavior and fate of contaminants in receiving water. These characteristics include:

- Temperature – critical to the survival of cold-water organisms. Temperature also affects solubility and ion mobility;
- PH – an expression of the relative hydrogen ion concentration on a logarithmic scale of 0-14, with a pH < 7.0 being acidic, a pH of 7.0 being neutral, and a pH > 7.0 representing basic conditions;
- Dissolved oxygen (DO) – a measure of molecular oxygen dissolved in water, critical to the survival of aerobic aquatic biota. In addition, DO levels can affect the release of chemically bound constituents from sediments;
- Alkalinity or acid neutralizing capacity (ANC) – the capacity of a solution to neutralize acid of a standard pH, usually the result of its carbonate and bicarbonate ion content, but conventionally expressed in terms of calcium carbonate equivalents;
- Hardness – an expression of the relative concentration of divalent cations, principally calcium (Ca) and magnesium (Mg), also conventionally expressed in terms of calcium carbonate equivalents; and
- Conductivity – a measure of the ability to conduct an electrical current as a result of its total content of dissolved substances.

These physio-chemical characteristics can affect pollutant behavior in several ways. For example, metals generally become more soluble as pH drops below neutral and hence become more bioavailable to organisms (Davies, 1986). Alternatively, the chemical elements creating hardness work against the toxicity of many heavy metals. Low DO levels can also make some metals more soluble. Anaerobic conditions in lake bottoms often lead to the release of phosphorus from sediments, as iron changes from the ferric to the

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ferrous form (Welch, 1992). As discussed earlier, most of the pollutant composition of urban stormwater runoff stems from particulate material or fine sediment from surface soil erosion (e.g., construction site erosion) and from wash-off of solids accumulated on impervious surfaces throughout the urban environment (e.g., streets, highways, parking lots, and rooftops).

Pollutant Fate and Transport

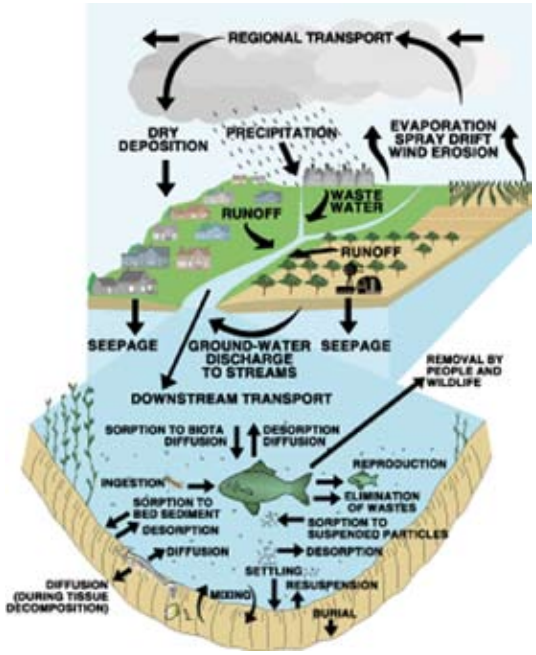
In general, the primary transport mechanism for most urban pollutants is stormwater runoff. The physio-chemical effects of watershed urbanization tend to be more variable than the hydro-geomorphic or physical habitat impacts discussed previously. As indicated above, stormwater can contain a variety of pollutants and the pollutants typically found in stormwater come from a variety of sources (see Tables 3-1 and 3-2). These pollutants most often occur as mixtures of physio-chemical constituents, which depend on the land uses found in the contributing drainage basin as well as the type and intensity of human activities present. In general, the more intense the level of urbanization, the higher the pollutant loading, and the greater the diversity of land-use activities, the more diverse the mixture of pollutants found in stormwater runoff.

The transport and fate mechanisms of stormwater pollutants in receiving waters tend to be highly variable and site-specific. Pollutants are often transported from source areas (roads, parking lots, lawns, etc.) to receiving waters via roadside ditches, stormwater pipes, or by atmospheric deposition (Figure 3-2). In general, the concentration of pollutants found in stormwater runoff is much higher than that found in receiving waters, due mostly to dilution and removal mechanisms. There is evidence of a "first flush" effect for some constituents such as metals and hydrocarbons, especially in highly impervious and connected drainage areas (Pitt et al., 1995; Sansalone and Buchberger, 1997; Pitt et al., 2004).

As was discussed earlier, most stormwater pollutants are typically found in particulate form, attached to fine sediment particles and organic matter (Pitt et al., 1995). This is especially true for nutrients, organics, and metals. In most cases, the particulate forms of toxic pollutants, such as metals tend to be less "bio-available" (Herricks, 1995).

Sedimentation is the most common pollutant fate or removal mechanism because many pollutants tend to be associated with fine particulate material and/or organic matter (Pitt et al., 1995). However, pollutants can also be transformed from particulate form to dissolved form due to changes in water chemistry (pH, hardness, DO, etc.) at the sediment-water interface. Microbial activity can also transform toxic compounds, such as heavy metals, in sediments from inorganic forms to more toxic organic forms, which also tend to be more soluble (Herricks, 1995). In addition, scouring of sediments during stormflow events and associated changes in water chemistry during these sporadic events can mobilize polluted sediments and release toxic substances into the water column where biological uptake can occur. Large quantities of sediments can be transported by stormflows in urbanizing creeks, resulting in resuspension and redeposition of pollutants. Because of the potential for accumulation of pollutants in sediment and the potential of sediments as sources of toxics, polluted sediments likely play an important role in many of the biological impacts associated with stormwater runoff. In general, most pollutants, especially metals, are found in particulate forms within the water column, or sediments and pollutant concentrations tend to be higher for smaller sediment particle sizes (Novotny and Chester, 1989; Ferguson and Ryan, 1984; Herricks, 1995; Makepeace et al., 1995; Pitt et al., 1995).

Figure 3-2: Pollutant Movement in the Hydrologic Cycle



Source: USGS, 1999

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Table 3-3 summarizes urban runoff pollutant sources and shows that most pollutant categories have diverse sources. Likewise, the major sources emit contaminants in most pollutant categories. The atmosphere also contributes some pollution to runoff. Thus, urban runoff is a multifaceted and complex problem to manage.

Quantifying Urban Runoff Pollutants

Urban Runoff Measurement

The concentrations of water-quality constituents tend to be highly variable, depending on a number of environmental factors. These factors may include:

- Drainage basin area or potential runoff volume;
- Drainage system characteristics (e.g., piping, ditches, etc.);
- Drainage basin land use and land cover (LULC);
- Rainfall volume, intensity, and antecedent dry period;
- The presence of pollutant source areas or "hot spots"; and
- Pollutant deposition or build-up rates.

Water pollutants are typically quantified by concentrations and loadings. Concentration is the mass of pollutant per unit volume of water sample, usually expressed as mg/l or ug/l. It is a measure of the pollutant content at the instant the sample is taken. If the pollutant level is higher than an aquatic organism can tolerate, the concentration represents an acute effect that could be lethal or affect the performance of some physiological function as long as the concentration persists. The effects of pollutant concentrations have been established through bioassays exposing test organisms in standard laboratory procedures. However, these simple, static tests completely omit the dynamic patterns and other complexities associated with urban runoff. Toxicity of pollutants will be discussed in more detail in Chapter 4.

Loading is the mass of pollutants delivered to a water body over a period of time and is usually given on an annual basis as kg/yr or lbs/yr. When ascribed to a particular land use, loading is sometimes termed yield or simply export per unit area of the land use (kg/ha-y or lbs/acre-y). It represents the cumulative burden over the extended period and hence the potential chronic effects on receptor organisms. With few exceptions (e.g., phosphorus loading to lakes), testing has not established the biological significance of loadings and the way they are delivered to a water body. Thus, loading is mainly used to make comparisons, for example, of total pollutant burden before and after development or with and without a certain control strategy. Pollutant loadings are also the basis for regulation under the Total Maximum Daily Load (TMDL) program that is part of the CWA.

Table 3-3: Urban Runoff Pollutant Sources and Constituents

Pollutant source	Solids	Nutrients	Pathogens	Oxygen Demand	Metals	Oils	Organics
Soil erosion	x	x		x	x		
Fertilizers		x					
Human waste	x	x	x	x			
Animal waste	x	x	x	x			
Vehicle fluids	x		x	x	x	x	
Internal combustion						x	
Vehicle wear	x			x	x		
Household chemicals	x	x		x	x	x	x
Industrial processes	x	x		x	x	x	x
Paints and preservatives					x	x	
Pesticides				x	x	x	

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A quantitative estimate of water quality is needed to assess impacts from development actions or to predict the benefits of a management plan. This estimation process is sometimes called water quality modeling, although the term modeling is sometimes restricted to computer-based approaches. Water quality assessments are often based on annual pollutant loading estimates, although short-term loadings or concentrations are sometimes used. Long-term loadings tend to diminish the large fluctuations to which short-term phenomena are subject. Therefore, we can generally estimate long-term loading with more assurance than concentrations. Water quality sampling methods and monitoring programs will be covered in Chapter 5.

Urban Runoff Patterns

Because of the difficulty in determining runoff pollutant concentrations during dynamic flow conditions, the expense of sampling, and the analysis required to produce even a partial picture, the accepted practice is to determine an event-mean concentration (EMC). The event-mean concentration (EMC) is the concentration of a particular constituent that is representative of a specific environmental condition, usually with respect to a specific storm event. The NURP study defined the EMC as the total mass of pollutant contained in a runoff event divided by the total volume of runoff or flow for the event. The EMC can also be found by analyzing a single sample composited from a series of samples taken at points throughout the runoff event and combined in proportion to the flow rate existing at the time of sampling. This is often termed a flow-proportional or flow-weighted composite sample (EPA, 1997). The flow or runoff pattern of an event is customarily pictured on a hydrograph, which is a graph of flow rate (water volume per unit time) versus time. The integrated area under the curve is the total event runoff volume; the product of volume and EMC is the pollutant loading for the event. The sum of loadings for all events in an interval (e.g., a year) represents the cumulative pollutant burden during that time. In addition to its expediency, basing impact assessment on the EMC is justified from a biological standpoint because the EMC best represents the cumulative toxicity that organisms are exposed to during a storm event.

Based on the inherent variability of stormwater pollutant composition, the concentrations of water quality constituents are often estimated based on probability (i.e., the ability to state the probability of exceeding any selected concentration) or using statistically valid estimations of actual concentrations. Estimating the probability of concentrations can theoretically be used to estimate maximum or any other level, but it is usually restricted to the EMC. As stated earlier, an EMC is the concentration of a particular constituent that is representative of a specific environmental condition. For example, the EMC of TSS in a stream during a storm event could be based on multiple flow-weighted composite storm samples. Generally, to estimate an EMC, a large data -set is required to establish the underlying probability distribution for the locale or, alternatively, an assumption of the distribution and a smaller local data set to fit the distribution.

Most water quality studies have demonstrated that urban runoff pollutant concentrations typically fit a "log-normal" probability distribution (i.e., their logarithms are normally distributed). This is the characteristic distribution of data in cases where the distribution range is much higher than the mean and most values are in the lower portion (Little et al., 1983).

While pollutant magnitudes in urban runoff typically follow characteristic patterns over short and long time spans, they vary greatly over space and time. The short term can be defined as a period of hours during one or a sequence of storm events. Measurements at discrete points through such a period often reveal a pattern of pollutant concentration that is higher during the beginning of the storm event and tapering off as the storm continues. The so-called "first flush" of runoff during the first minutes often contains a relatively high concentration of contaminants, which then drops substantially and fluctuates at a lower level for the remainder of the runoff event. Analysis of climatological data throughout the U.S. indicates that most of the total annual runoff is produced by numerous small storms and the initial runoff from large storms. Theoretical reasons and some empirical demonstrations indicate that the majority of pollutant loadings for some constituents are generated by these smaller flow volumes (Burton and Pitt, 2002).

The first flush sometimes does not appear, or is less pronounced, when rainfall is not intense or follows soon after an earlier storm that cleans the surfaces. In addition, recent studies have shown that the first flush effect is usually only observed in highly impervious drainage areas such as parking lots or roads (Pitt et al., 2004). It has also been demonstrated that the first flush

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phenomenon may only be applicable to certain pollutants, including metals, hydrocarbons, and fine sediment (Pitt et al., 2004). In some cases, a secondary spike can also appear if a sudden burst of intense rain drives material off surfaces not completely cleaned by the initial runoff. In summary, runoff concentrations can assume an almost infinite variety of patterns depending on rainfall intensity, antecedent dry period (ADP) length and conditions, pollutant deposition during the ADP, and surface characteristics in the drainage basin.

Urban Runoff Pollution Characteristics

Several studies have attempted to quantify the level of various constituents in urban runoff. As mentioned earlier, these levels tend to vary depending on the land-use and human activities found in the contributing drainage area. The earliest comprehensive study of the water quality characteristics of urban runoff was the EPA (1983) National Urban Runoff Program (NURP). Between 1978 and 1983, EPA examined stormwater quality from separate storm sewers in different land uses. The NURP project studied 81 outfalls in 28 communities throughout the U.S. and included the monitoring of approximately 2,300 storm events. The data was compiled for several land-use categories, although most of the information was obtained from residential lands. Table 3-4 summarizes the NURP findings. NURP also produced graphs for each pollutant to determine the EMC at each site and the EMC medians from all sites nationwide (EPA, 1983). These plots can help estimate concentration exceedance probabilities at other locations. Such estimates are best made with specific site data including rainfall patterns, land-use data, geological data, and other characteristics similar to those of the location of interest. Using a regional or nationwide database is less satisfactory. Local stormwater data may be available from National Pollutant Discharge Elimination System (NPDES) monitoring programs.

Since NURP, other important studies have been conducted that characterize stormwater. The USGS National Water Quality Assessment (NAWQA) Program examined runoff quality from more than 1,100 storms at nearly 100 monitoring sites in 20 metropolitan areas (USGS, 1999). Table 3-5 summarizes the general findings of the USGS studies with respect to surface water quality. These USGS studies investigated specific urban pollutants including nutrients, metals, pesticides, and herbicides. The NAWQA studies also identified a close relationship between land use and water quality in agricultural and urban areas.

As an example, the NAWQA program found that insecticides such as diazinon and malathion were commonly found in surface water and stormwater in urban areas (USGS, 1999). This research found that almost every urban stream sampled had concentrations of insecticides that exceeded at least one EPA guideline or water-quality standard. Most urban streams had concen-

Table 3-4: Pollutants Commonly Found in Stormwater and Their Sources

	NURP Mean EMC	NURP Mean EMC
Pollutant	Median Urban Site	90th Percentile Urban Site
TSS (mg/l)	141-234	424-671
BOD (mg/l)	10-13	17-21
COD (mg/l)	73-92	157-198
TP (mg/l)	0.37-0.47	0.78-0.99
SRP (mg/l)	0.13-0.17	0.23-0.30
TKN (mg/l)	1.68-2.12	3.69-4.67
NO2-N (mg/l)	0.76-0.96	1.96-2.47
Total Cu (ug/l)	38-48	104-132
Total Pb (ug/l)	161-204	391-495
Total Zn (ug/l)	179-226	559-707

Notes: EMC = Event Mean Concentration; TSS = Total Suspended Solids; BOD = Biological oxygen Demand; COD = Chemical oxygen Demand; TP = Total Phosphorus; SRP = Soluble Reactive Phosphorus; TKN = Total Kjeldahl Nitrogen

Source: NURP, 1983

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trations that exceeded a water-quality guideline in 10 to 40 percent of samples taken throughout the year (USGS, 1999). Urban streams also had the highest frequencies of occurrence of DDT, chlordane, and dieldrin (all of these compounds have been banned from use in the U.S. for decades) in sediments and fish tissue (USGS, 1999). In the Puget Sound region, the mixture of pesticides found in urban streams was directly related to the type of land use found in the contributing upstream drainage area (Ebbert et al., 2000). The NAWQA studies also found that the highest levels of organochlorine compounds, including pesticides and PCBs, were found in aquatic sediment and biota in urban areas (USGS, 1999). The main source of these complex mixtures of insecticides found in urban streams was identified as business, household, or garden use in developed areas, with urban runoff being the primary transport mechanism into urban streams and other receiving waters. A study in the Puget Sound region that correlated retail sales of specific pesticides with levels of those same pesticides found in local streams confirms this finding (Bortleson and Ebbert, 2000).

The NAWQA research also found that concentrations of phosphorus exceeded the EPA target goal (TP<0.1 mg/l) for the control of nuisance algal growth in over 70 percent of the urban receiving waters tested (USGS, 1999). As mentioned above, excessive algal or aquatic plant growth due to nutrient enrichment can lead to low levels of DO (hypoxia), which can be harmful to aquatic biota. Urban runoff can contain high levels of nutrients in the form of fertilizers washed off lawns and landscaped areas. In most cases in the NAWQA studies, enrichment of receiving waters occurred in small watersheds dominated by agricultural, urban, or mixed land use (USGS, 1999). The NAWQA research also found that nitrate contamination of groundwater aquifers and drinking water supplies had the potential to be a human health risk in urbanizing areas with high nitrate concentrations in stormwater runoff.

The Federal Highway Administration (FHWA) also analyzed stormwater runoff from 31 highways in 11 states during the 1970s and 1980s (FHWA, 1995). Other regional databases also exist, mostly using local NPDES data. Other studies have confirmed the NURP findings and improved the level of knowledge with regard to stormwater pollution impacts (Field and Pitt, 1990; Bannerman et al., 1993; Makepeace et al., 1995; Pitt et al., 1995). Table 3-6 illustrates the range of pollutant levels for typical urban runoff from a number of studies.

Highway runoff is often viewed as a separate and distinct form of stormwater. Because vehicle traffic tends to be the predominant pollution source in the highway environment, runoff from roads tends to have a characteristic signature (Novotny, 2003). Several studies have been conducted to characterize highway runoff (Stotz, 1987; Driscoll et al., 1990; Barrett et al., 1998; Wu et al., 1998; Kayhanian and Borroum, 2000; Pitt et al., 2004). In general, runoff from urban highways with greater average daily traffic (ADT) volumes tends to have higher pollutant concentrations than runoff from less-traveled highways (lower ADT). Most research studies have not found any direct correlation between ADT alone and pollutant concentrations for the great majority of pollutants (Masoud et al., 2003). However, ADT is almost always one of the more influential factors in determining runoff pollutant composition and concentration. Other parameters determining the quality of highway runoff include those that control pollutant build-up and wash-off. In addition to ADT, these factors include drainage catchment area and land use, antecedent dry period between storm events, and rainfall intensity and volume. Table 3-6 shows data from highways in comparison to other urbanized areas.

In a study in Southern California (Tiefenthaler et al., 2001), samples of stormwater runoff from parking lots

Table 3-5: Relative Levels of Pollution in Streams Throughout the U.S.

WQ Parameter	Urban Areas	Agricultural Areas	Undeveloped Areas
Nitrogen	Medium	Medium-high	Low
Phosphorus	Medium-high	Medium-high	Low
Herbicides	Medium	Medium-high	Low
Pesticides	Medium-high	Low-medium	Very low
Metals	High	Medium	Very low
Toxic Organics	High	Medium	Very low
Source: USGS, 1999			

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were analyzed for a number of metals including Fe, Zn, Cu and Pb as well as polycyclic aromatic hydrocarbons (PAH). These metals and PAH had the highest mean concentrations of any constituents analyzed. Zinc (Zn) was found in particularly high concentrations, which were 3 times higher after dry periods. These pollutants were found to accumulate regardless of how much the parking lot was used or maintained. In this study, all of the samples from parking lot runoff contained toxins, and all samples of parking lot runoff were toxic. (Tiefenthaler et al., 2001). In addition, the longer the antecedent dry period before a storm event, the higher

Table 3-6: Typical Levels of Metals Found in Stormwater Runoff (ug/L)

Metal	Stormwater Median (90th Percentile)[a]	Mean (sd)[b]	Median (COV) Urban Stormwater[c]	Range for Highway Runoff[d]	Range for Parking Lot Runoff[e]
Zinc (Zn)	160 (500)	215 (141)	112.0 (4.59)	56-929	51-960
Copper (Cu)	34 (93)	33 (19)	16.0 (2.24)	22-7033	8.9-78
Lead (Pb)	144 (350)	70 (48)	15.9 (1.89)	73-1780	10-59
Cadmium (Cd)	n/a	1.1 (0.7)	1.0 (4.42)	0-40	0.5-3.3
Chromium (Cr)	n/a	7.2 (2.8)	7.0 (1.47)	0-40	1.9-10
Arsenic (As)	n/a	5.9 (2.8)	3.3 (2.42)	0-58	n/a
Mercury (Hg)	n/a	n/a	0.2 (1.17)	0-0.322	n/a
Nickel (Ni)	n/a	10 (2.8)	9.0 (2.08)	0-53.3	2.1-18
Silver (Ag)	n/a	n/a	3.0 (4.63)	n/a	n/a

Notes: n/a = not available.
Sources: [a]NURP, 1983. [b]Schiff et al., 2001. [c]Pitt et al., 2002. [d]Barrett et al., 1998. [e]SCCRP, 2001.

Table 3-7: Pollutants Commonly Found in Stormwater and Their Sources – 1983 (NURP) and 1999 Databases

Pollutant	Data Source	Mean EMC	Median EMC
TSS (mg/l)	Pooled NURP	78 174	55 113
BOD (mg/l)	Pooled NURP	14 10	12 8
COD (mg/l)	Pooled NURP	53 66	45 55
TP (mg/l)	Pooled NURP	0.32 0.34	0.26 0.27
SRP (mg/l)	Pooled NURP	0.13 0.10	0.10 0.08
TKN (mg/l)	Pooled NURP	1.73 1.67	1.47 1.41
NO2-N and NO3-N (mg/l)	Pooled NURP	0.66 0.84	0.53 0.66
Total Cu (ug/l)	Pooled NURP	14 67	11 55
Total Pb (ug/l)	Pooled NURP	68 175	51 131
Total Zn (ug/l)	Pooled NURP	162 176	129 140

EMC = Event Mean Concentration
COD = Chemical oxygen Demand
TKN = Total Kjeldahl Nitrogen
TSS = Total Suspended Solids
TP = Total Phosphorus
BOD = Biological oxygen Demand
SRP = Soluble Reactive Phosphorus

Source: Smullen et al., 1999

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the concentration of pollutants and the higher the toxicity found in runoff samples (Tiefenthaler et al., 2001). In an arid climate such as Southern California, pollutants tend to build up during extended dry periods and then be washed off during heavy rainfall events that are typical of the climate. In this study, a pronounced first flush of toxins was observed at the beginning of storm events (Tiefenthaler et al., 2001). More intense rains reduced pollutant concentrations, however. Regardless of the intensity of the storm event, most loose pollutants were washed from the parking lot surface in the first 15 minutes (Tiefenthaler et al., 2001). The first flush of TSS was the most evident at the relatively low rainfall intensity of 6 mm/hour (Tiefenthaler et al., 2001). The key factor influencing the first flush of TSS was found to be rainfall duration instead of intensity. TSS concentrations dropped during the course of the storm, however. During longer storms, greater rainfall intensity did not reduce zinc concentrations. Intensity only increased the concentration of pollutants in the first minute of the storm (Tiefenthaler et al., 2001). Results indicated that the most wash-off of pollutants from parking lots occurred during small storms. This especially includes Pb and Zn (Tiefenthaler et al., 2001).

In 1999, an analysis of stormwater data collected since the original NURP study was conducted to update the event-mean concentration (EMC) values for typical urban stormwater quality (Smullen et al., 1999). This data review found only a few major differences between the NURP data and the pooled data from three national databases (see Table 3-7). In general, the pooled data was very comparable with the NURP data, with a few notable exceptions. The study found that the level of TSS in runoff was significantly

Table 3-8: Summary of Event-Mean Concentration (EMC) Data for Stormwater Runoff in the U.S.

Pollutant	Data Source	Mean EMC	Median EMC	Number of Events Sampled
TSS (mg/l)	Smullen and Cave, 1998	78.4	54.5	3047
BOD (mg/l)	Smullen and Cave, 1998	14.1	11.5	1035
COD (mg/l)	Smullen and Cave, 1998	52.8	44.7	2639
TP (mg/l)	Smullen and Cave, 1998	0.32	0.26	3094
SRP (mg/l)	Smullen and Cave, 1998	0.13	0.10	1091
TN (mg/l)	Smullen and Cave, 1998	2.39	2.00	2016
TKN (mg/l)	Smullen and Cave, 1998	1.73	1.47	2693
NO2-N and NO3-N (mg/l)	Smullen and Cave, 1998	0.66	0.53	2016
Total Cu (ug/l)	Smullen and Cave, 1998	13.4	11.1	1657
Total Pb (ug/l)	Smullen and Cave, 1998	67.5	50.7	2713
Total Zn (ug/l)	Smullen and Cave, 1998	162	129	2234
Total Cadmium (ug/l)	Smullen and Cave, 1998	0.7	0.5	150
Total Chromium (ug/l)	Bannerman et al., 1996	4.0	7.0	164
PAH (mg/l)	Rabanal and Grizzard, 1995	3.5	N/R	N/R
Oil and Grease (mg/l)	Crunkilton et al., 1996	3	N/R	N/R
FC (cfu/100ml)	Schueler, 1999	15,000	N/R	34
Diazinon	US-EPA, 1998	N/R	0.025	326
Atrazine	US-EPA, 1998	N/R	0.023	327
MTBE	Delzer, 1996	N/R	1.6	592

Notes: EMC = Event Mean Concentration; TSS = Total Suspended Solids; FC = Fecal Coliform Bacteria; BOD = Biological oxygen Demand; COD = Chemical oxygen Demand; TP = Total Phosphorus; TN = Total Nitrogen; SRP = Soluble Reactive Phosphorus; TKN = Total Kjeldahl Nitrogen; PAH = Poly-aromatic Hydrocarbons; N/R = Not Reported

Source: CWP, 2003

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lower than in the NURP study, perhaps indicating that erosion and sediment control (ESC) best management practices (BMP) implemented since 1983 were somewhat effective. Metals were also generally lower in the 1999 study than in the NURP data, especially lead (Pb), likely due to the elimination of leaded gasoline. This study also highlighted the fact that the variability of stormwater quality can depend on contributing land use, seasonal factors (e.g., precipitation patterns), and geographic region.

The Center for Watershed Protection (CWP) has also compiled a database of national stormwater runoff water-quality data (CWP, 2003). This data is summarized in Table 3-8.

There can be significant regional differences in urban runoff water quality due to a variety of environmental factors. To a large extent, underlying geology and soils determine the natural background level of many water-quality constituents, such as nutrients or metals. In addition, soils and topography have a strong influence on erosion potential and sediment production. One of the most influential factors impacting runoff water quality are a region's precipitation characteristics. Annual rainfall, precipitation patterns, mean storm event volume, and the range of rainfall intensities all have been demonstrated to influence runoff water quality (Driver and Tasker, 1990). For example, the western U.S. tend to have distinct „wet" and „dry" seasons, whereas the eastern U.S. and Midwest generally have more dispersed, year-round precipitation. Within the western U.S., the Pacific Northwest tends to have most of its rainfall in long-duration, low-intensity storms, whereas the Southwest tends to see more short, high-intensity storm events. Because of these factors, stormwater runoff EMC levels for nutrients, sediment, and metals have a tendency to be higher in arid or semi-arid regions and to decrease slightly when annual rainfall increases (CWP, 2004).

Table 3-9: Event Mean Concentration (EMC) Values for Stormwater Runoff Pollutants for Various U.S. Climatic Regions

Location	National	Phoenix, AZ	San Diego, CA	Boise, ID	Denver, CO	Dallas, TX	Marquette, MI	Austin, TX	MD	KY	GA	FL	MN
Mean Annual Rainfall (in)	N/A	Low (7)	Low (10)	Low (11)	Low (15)	Med (28)	Med (32)	Med (32)	High (41)	High (41)	High (41)	High (41)	Snow (*)
Pollutant													
TSS (mg/l)	78	227	330	116	242	663	159	190	67	98	258	43	112
TN (mg/l)	2.39	3.26	4.55	4.13	4.06	2.70	1.87	2.35	N/R	2.37	2.52	1.74	4.30
TP (mg/l)	0.32	0.41	0.70	0.75	0.65	0.78	0.29	0.32	0.33	0.32	0.33	0.38	0.70
SRP (mg/l)	0.13	0.17	0.40	0.47	N/R	N/R	0.04	0.24	N/R	0.21	0.14	0.23	0.18
Cu (ug/l)	14	47	25	34	60	40	22	16	18	15	32	1	N/R
Pb (ug/l)	68	72	44	46	250	330	49	38	13	60	28	9	100
Zn (ug/l)	162	204	180	342	350	540	111	190	143	190	148	55	N/R
BOD (mg/l)	14	109	21	89	N/R	112	15.4	14	14.4	88	14	11	N/R
COD (mg/l)	52	239	105	261	227	106	66	98	N/R	38	73	64	112
# Sample Events	3000	40	36	15	35	32	12	78	107	21	81	66	49
Reference	1	2	3	4	5	6	7	8	9	10	11	11	12

Notes: EMC = Event Mean Concentration; COD = Chemical oxygen Demand; SRP = Soluble Reactive Phosphorus; TSS = Total Suspended Solids; TP = Total Phosphorus; N/R = Not Reported; BOD = Biological oxygen Demand; TN = Total Nitrogen

References: 1 – Smullen and Cave, 1998; 2 – Lopes et al., 1995; 3 – Schiff, 1996; 4 – Kjelstrom, 1995; 5 – DRCOG, 1983; 6- Brush et al., 1995; 7 – Steuer et al., 1997; 8 – Barrett et al., 1995; 9 – Barr, 1997; 10 – Evaldi et al., 1992; 11 – Thomas and McClelland, 1995; 12 – Oberts, 1994

Source: CWP, 2004

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In colder regions, where snow is a significant form of precipitation, snowmelt can be a major source of urban runoff pollutants (Novotny and Chester, 1981). Snow tends to accumulate during the winter, and pollutants can build up in the snowpack due to atmospheric deposition, vehicular emissions, litter, and the application of de-icing products (e.g., salt and/or sand). As a result, relatively high concentrations of some pollutants can be detected during snowmelt events and in runoff from treated roads (CWP, 2004). The main concerns with regard to the hazards of chlorides in stormwater runoff include groundwater contamination, trace metal leaching from sediments, stratification of receiving water bodies, and direct toxic effects on aquatic biota (Marsalek, 2003).

A study in Minnesota measured pollutants in urban streams and found that as much as half of the annual sediment, nutrient, hydrocarbon, and metal loads could be attributed to snowmelt runoff (Oberts, 1994). High levels of chloride (road salt), BOD, and TSS have also been reported in snowmelt runoff (La Barre et al., 1973; Oliver et al., 1974; Horkeby and Malmquist, 1977; Pierstorff and Bishop, 1980; Scott and Wylie, 1980; Novotny and Chester, 1981; Boom and Marsalek, 1988; Marsalek, 2003). Table 3-9 summarizes stormwater runoff pollutant concentrations for different climatic regions of the U.S. (CWP, 2004).

In the decades between the NURP data being collected and now, much has been accomplished with regard to urban runoff source control, the treatment of stormwater runoff, and improvements in receiving water quality. The most comprehensive analysis of stormwater runoff quality is currently underway. In 2001, the University of Alabama and the Center for Watershed Protection (CWP) were awarded an EPA Office of Water grant to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) stormwater permit holders. The initial version of this database, the National Stormwater Quality Database (NSQD, 2004) is currently available from the CWP.

In the NSQD project, stormwater quality data and site descriptions are being collected and reviewed to describe the characteristics of national stormwater quality, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas having limited data. Over 10 years of monitoring data collected from more than 200 municipalities throughout the country have a great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. This project is creating a national database of stormwater monitoring data collected as part of the existing stormwater permit program, providing a scientific analysis of the data as well as recommendations for improving the quality and management value of future NPDES monitoring efforts (Pitt et al., 2004). Table 3-10 summarizes the NSQD findings to date. Table 3-11 shows a comparison between NURP and NSQD findings. Figure 3-3 shows a sample of the NSQD findings for one common urban runoff constituent (TSS).

Urban Wetland Water Quality: Puget Sound Case Study

In a study of Puget Sound Basin freshwater wetlands (Azous and Horner, 2001), many water quality parameters exhibited upward trends with increased urbanization. Median pH levels were particularly elevated in highly urbanized wetlands while DO experienced more modest increases. Median conductivity and NH3 levels were also significantly higher in urbanized wetlands than in non-urbanized wetlands. Finally, similar rates of increase in median concentrations of total suspended solids (TSS), soluble reactive phosphorus (SRP), fecal coliforms (FC), lead (Pb) and zinc (Zn) were found with each step in the urbanization process (Azous and Horner, 2001).

In the wetlands studied, low concentrations predominated, indicating minimal water quality impacts. Concentrations of lead (Pb), however, tended to violate water quality criteria for the protection of aquatic life (Azous and Horner, 2001). In both urbanized and non-urbanized wetlands, wetland morphology type was associated with varying levels of water quality parameters. Morphology refers to the shape, perimeter length, internal horizontal dimensions, and topography of the wetland as well as to water pooling and flow patterns. Higher levels of DO, pH, conductivity, NO3+NO2-N, SRP, FC, and Pb were found in flow-through wetlands. Flow-through wetlands (FT) are channelized and have clear flow gradients, while open water wetlands (OW) contain significant pooled areas with little or no flow gradient (Azous and Horner, 2001). A large proportion of FT wetlands is found in urban areas, due to wetland

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Table 3-10: Median Values for Selected Stormwater Parameters for Standard Land-Use Categories					
WQ Parameter	Residential	Commercial	Industrial	Freeways	Open Space
TSS (mg/l)	48	43	77	99	51
BOD (mg/l)	9.0	11.9	9.0	8.0	4.2
COD (mg/l)	55	63	60	100	21
FC (mpn/100ml)	7750	4500	2500	1700	3100
NH3 (mg/l)	0.31	0.50	0.50	1.07	0.30
NO2 + NO3 (mg/l)	0.60	0.60	0.70	0.30	0.60
TKN (mg/l)	1.40	1.60	1.40	2.00	0.60
SRP (mg/l)	0.17	0.11	0.11	0.20	0.08
TP (mg/l)	0.30	0.22	0.26	0.25	0.25
Cd total (ug/l)	0.5	0.9	2.0	1.0	0.5
Cd dissolved (ug/l)	ND	0.3	0.6	0.7	ND
Cu total (ug/l)	12	17	22	35	5
Cu dissolved (ug/l)	7	8	8	11	ND
Pb total (ug/l)	12	18	25	25	5
Pb dissolved (ug/l)	3	5	5	2	ND
Ni total (ug/l)	5	7	16	9	ND
Ni dissolved (ug/l)	2	3	5	4	ND
Zn total (ug/l)	73	150	210	200	39
Zn dissolved (ug/l)	33	59	112	51	ND

Notes: TSS = Total Suspended Solids; BOD = Biochemical Oxygen Demand; COD = Chemical Oxygen Demand; FC = Fecal Coliform; TKN = Total Kjeldahl Nitrogen; SRP = Soluble Reactive Phosphorus; TP = Total Phosphorus; ND = Not Detected

Source: NSQD, 2004

Table 3-11: Comparison of Median Stormwater Quality for NURP and NSQD								
WQ Parameter	Overall		Residential		Commercial		Open Space	
	NSQD	NURP	NSQD	NURP	NSQD	NURP	NSQD	NURP
COD (mg/l)	53	65	55	73	63	57	21	40
TSS (mg/l)	58	100	48	101	43	69	51	70
Pb total (ug/l)	16	144	12	144	18	104	5	30
Cu total (ug/l)	16	34	12	33	17	29	5	11
Zn total (ug/l)	116	160	73	135	150	226	39	195
TKN (mg/l)	1.4	1.5	1.4	1.9	1.60	1.18	0.60	0.97
NO2 + NO3 (mg/l)	0.60	0.68	0.60	0.74	0.60	0.57	0.60	0.54
TP (mg/l)	0.27	0.33	0.30	0.38	0.22	0.20	0.25	0.12
SRP (mg/l)	0.12	0.12	0.17	0.14	0.11	0.08	0.08	0.03

Notes: COD = Chemical Oxygen Demand; TSS = Total Suspended solids; TKN = Total Kjeldahl Nitrogen; TP = Total Phosphorus; SRP = Soluble Reactive Phosphorus

Source: NSQD, 2004

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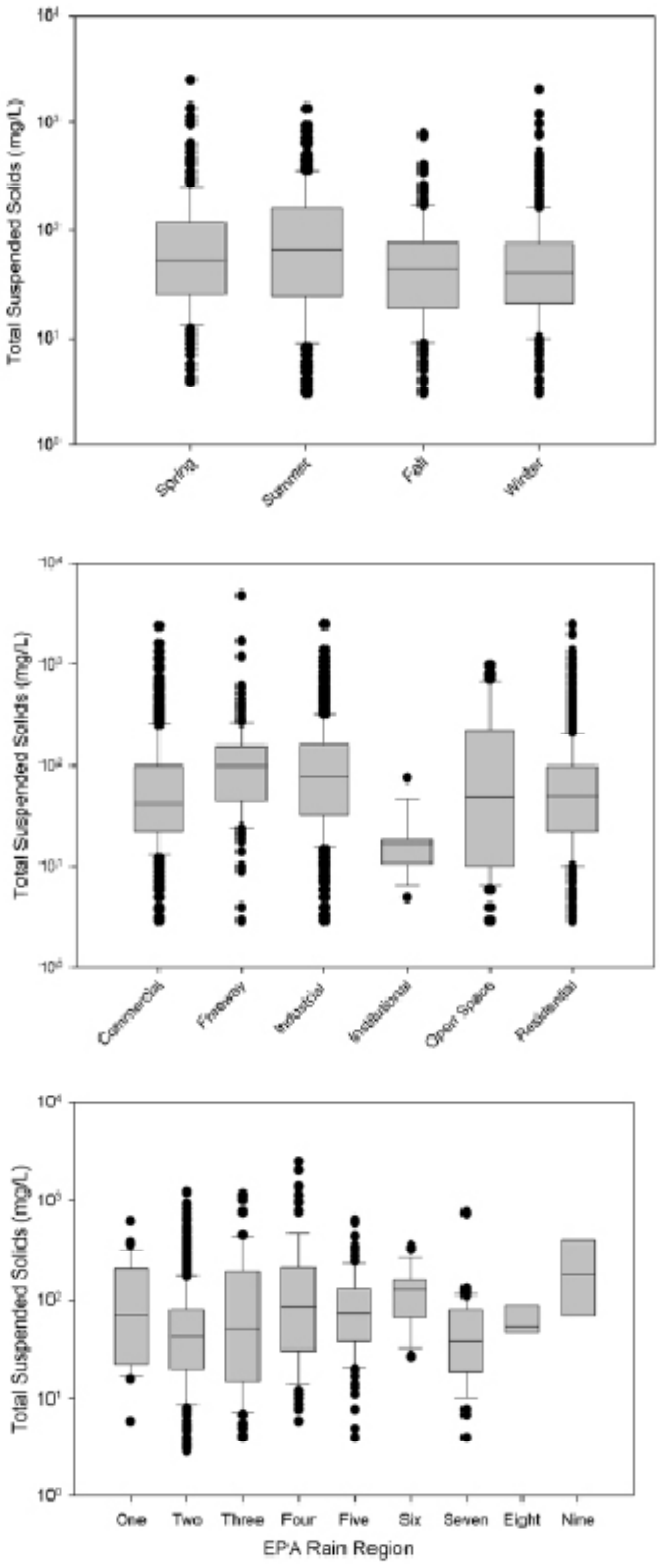
filling, stream channelization, and higher peak runoff flows, and this may help explain why pollutant levels trends are higher in these wetlands (Azous and Horner, 2001).

In the Puget Sound wetlands study, soil samples were collected once from each wetland during the summer dry period (July through September) for several years. Soil samples were taken from 3m to the side of vegetation transect lines wherever soils appeared transitional or completely different. These transitions were determined by small soil core samples or vegetation changes. Overall, two to five samples were collected from each wetland, with an average of four samples collected. The number of samples collected was related to the size and zonal complexity of the wetlands. Samples were taken from inlet zones in particular, because oxidation reduction potential (ORP) and one metal were found in significantly different levels in these locations. Soil samples were collected with a corer composed of a 10 cm (4 in) diameter ABS plastic pipe section ground to a sharp tip. A wooden rod was inserted horizontally through two holes near the top to provide leverage to twist the corer into the soil. Core samples were taken to a depth of 15 cm (6 in) and preserved by immediately placing them in bags sealed with tape. A standard 60-cm (2-ft) deep soil pit was also excavated at each sampling point not inundated above the surface. This pit was observed for depth to water table, horizontal definition (thickness of each layer and boundary type between), color (using Munsell notations), structure (grade, size, form, consistency, moistness), and the presence of roots and pores (Azous and Horner, 2001).

Sediment samples exhibited similar trends in urban and flow-through wetlands as the water quality parameters discussed previously. Median pH levels increased with each successive level of urbanization (Azous and Horner, 2001). Metals, including Pb, Zn, As (arsenic) and Cu (copper) also generally tended to increase with urbanization. As with water quality samples, sediment metal concentrations did not exceed severe effect thresholds based on the Washington State Department of Ecology. Some Cu and Pb mean and median concentrations exceeded lowest effect thresholds (Azous and Horner, 2001). While these metals tended to be found in greater concentrations in urban wetlands, they can also be found at elevated levels in non-urban wetlands.

Figure 3-3: Sample NSQD Findings



Source: NSQD, 2004

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High Cu, Pb and TPH levels were seen in the two most impacted urban wetlands (Azous and Horner, 2001). Thus, local conditions may be more important factors in determining soil metal concentrations. Possible factors include the delivery of metals via precipitation, atmospheric dry-fall, dumping of metal trash, and leaching from old constructed embankments (Azous and Horner, 2001).

The impact of human activity and development on water quality varies widely between wetlands of different urbanization levels. For moderately urbanized wetlands, there is a mixed picture. Median total dissolved nitrogen concentrations (ammonia, nitrate, and nitrite) have been found to be more than 20 times higher than dissolved phosphorus, but phosphorus is the most important factor limiting plant and algal growth. As would be expected, these wetlands exhibit slightly elevated pH levels (median pH = 6.7). Dissolved oxygen is well below saturation, at times below 4 mg/l. Dissolved substances tend to be higher than in non-urbanized wetlands but are also somewhat variable. Suspended solids are only marginally higher than in non-urbanized wetlands but are also variable (Azous and Horner, 2001).

In highly urbanized wetlands, water quality samples revealed higher nutrient levels. Unlike non-urbanized or even low-moderately urbanized wetlands, these wetlands are likely to have median NO3 + NO2-N concentrations above 100 mg/l and total phosphorus (TP) over 50mg/l (Azous and Horner, 2001). In one study, FC and EC were shown to be significantly higher in highly urbanized wetlands. Many of these wetlands were within watersheds with low-density residential development (Azous and Horner, 2001).

An effort was made to correlate water quality conditions with watershed and wetland morphological characteristics. Acidity (pH), TSS, and conductivity showed the strongest ability to predict watershed and morphology characteristics. Pollutants such as TP, Zn and FC, which are often absorbed to particulates, also exhibited strong correlations with watershed conditions and morphology (Azous and Horner, 2001). On the other hand, forest cover was the best predictor of these water quality parameters. The next best land cover predictors of water quality were the percentage of impervious surface, forest-to-wetland areal ratio and morphology (Azous and Horner, 2001). A rise in the total impervious area will facilitate the delivery of TSS and increase conductivity. TSS and conductivity are directly and indirectly harmful to wetland biological communities (Azous and Horner, 2001).

These results suggest that a range of deforestation and development exists after which water quality will become degraded. Effective impervious area, which is the amount of land drained by a storm drainage system, was more predictive of water quality than total impervious area. As total impervious area approaches a range of 4 to 20 percent and forested area declines to between 0 to 15 percent, water quality will begin to decline (Azous and Horner, 2001).

Wetlands in developing areas are especially vulnerable to erosion caused by construction, which contributes to sediment levels. During these periods, both mean and median TSS values increase, although mean values show the greatest change. After construction is completed, and more surface area is covered with structures and vegetation, these values return to their approximate values before development. The sediments contributed by this erosion carry pollutants such as phosphorus and nitrogen (Azous and Horner, 2001).

Development also affects soils in wetlands. In the Puget Sound Basin wetlands, somewhat elevated pH levels prevailed. These soils were often aerobic, although many times their redox potentials were below levels at which oxygen is depleted. Metals such as Cu, Pb and Zn were higher in developing areas but did not usually approach severe effects thresholds (Azous and Horner, 2001). In a synoptic study of 73 wetlands, about 60 percent of which were urban and the rest non-urban, Pb levels were significantly different in both the inlet and emergent zones (Azous and Horner, 2001). In some soil samples, high toxicity levels were probably caused by the extraction and concentration of naturally occurring organic soil compounds during laboratory analysis. Samples from two wetlands, however, probably contained anthropogenic toxicants because the results indicated toxicity in the absence of any visible organic material (Azous and Horner, 2001).

For each region studied in the Puget Sound area, a regression was developed between the presence of crustal metals and toxic metals in relatively unimpacted wetlands. If the concentration of a toxic metal was above a 95 percent confidence level, it was probable that the metals were of anthropogenic origin. The results of this analysis echoed those described previously for urbanized wetlands. The regressions revealed a greater degree of toxic metal enrichment in the most urban wetlands (Azous and Horner, 2001).

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Estimating Urban Runoff Pollutant Loading

The watershed assessment process provides the framework for evaluating watershed conditions and quantifying watershed characteristics (US-EPA, 2005). The objectives of the watershed assessment effort, pollution source information, and the water-quality data available largely determine what will be the most appropriate method for quantifying pollutant loading. In general, the approach chosen should be the simplest approach that meets the objectives of the watershed management program. Pollutant loading estimates are generally developed using a model or models.

Models can be useful tools for watershed and receiving-water assessments because they facilitate the analysis of complex systems and provide a method of estimating pollutant loading for a large array of land-use scenarios. Models are only as good as the data used for calibration and verification. There will always be some uncertainties present in all models and these uncertainties should be quantified and understood prior to using the selected model. Many models utilize literature-based values for water-quality concentrations to estimate pollutant loads (US-EPA 2005). Models have also become a standard part of most TMDL programs (US-EPA 1997). There are several recognized approaches used for estimating pollutant loadings for a drainage area or watershed basin. The three general approaches include:

- Unit-area loading;
- Simple empirical method; and
- Complex, computer-based models.

Unit-Area Loading

This method utilizes published *yield-values* to estimate pollutant loading for a specific land use. As mentioned earlier in this chapter, loading is the mass of pollutants delivered to a water body over a period of time and is usually given on an annual basis as kg/yr or lbs/yr. When ascribed to a particular land use, loading is sometimes termed yield or simply export per unit area of the land use (kg/ha-y or lbs/acre-y). Table 3-12 presents typical loadings for a number of pollutants and land uses. Although this table presents no ranges or statistics on the possible dispersion of these numbers when measurements are made, the variation is usually substantial from place to place in the same land use and from year to year at the same place.

This method is least likely to give accurate results because of the general lack of fit between the catchment of interest and the data collection location(s). To apply this method, consult a reference like Table 3-12, select the areal loading rate for each land use, multiply by the areas in each use, and sum the total loading for the pollutant of interest.

This method can be improved by producing some measure of uncertainty or error in the estimates. To do so, it is necessary to establish ranges of areal loadings from published literature or actual sampling, estimate

Table 3-12: Typical Pollutant Loadings (lbs/acre-yr) From Different Land Uses

Land-Use	TSS	TP	TKN	NH_3-N	NO_2-N and NO_3-N	BOD	COD	Pb	Zn	Cu	Cd
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4	0.03
Parking Lot	400	0.7	5.1	2.0	2.9	47	270	0.8	0.8	0.06	0.01
High-Density Residential	420	1.0	4.2	0.8	2.0	27	170	0.8	0.7	0.03	0.01
Medium-Density Residential	250	0.3	2.5	0.5	1.4	13	50	0.05	0.1	0.03	0.01
Low-Density Residential	65	0.04	0.3	0.02	0.1	1	7	0.01	0.04	0.01	0.01
Highway	1700	0.9	7.9	1.5	4.2	n/a	n/a	4.5	2.1	0.37	0.02
Industrial	670	1.3	3.4	0.2	1.3	n/a	n/a	0.2	0.4	0.10	0.05
Shopping Center	440	0.5	3.1	0.5	1.7	n/a	n/a	1.1	0.6	0.09	0.01

Source: Based on Table 2.5 in Burton and Pitt, 2002

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maximum and minimum and mean or median values of each pollutant, and then evaluate to determine if uncertainty or error could change the conclusions. Table 3-13 presents loading rate ranges based on unpublished data collected in the Pacific Northwest (PNW). The PNW regional data provided values for total phosphorus and total nitrogen for most land uses and all pollutants in road runoff, except fecal coliform. Accordingly, the regional data have narrower ranges than the remainder. Data such as that shown in Table 3-13 should be used with caution, because the concentrations of most pollutants vary considerably depending on regional characteristics in land use and climate, among other factors.

The use of published yield or unit-area loading values from specific sources, rather than for land-use categories, is also feasible. For example, a study in Maryland (Davis et al., 2001) examined the loading rates of metals (zinc, lead, copper, and cadmium) from several common sources in the urban environment. These included building siding and rooftops as well as automobile brakes, tires, and oil leakage. Loading estimates (mean, median, maximum, and minimum) were developed for each of these sources for all four metals (Davis et al., 2001). Specific data of this sort could be very useful for a variety of management scenarios.

Simple Empirical Method

The "Simple Method" was first developed by Schueler (1987) and further refined by the Center for Watershed Protection (CWP, 2003). This method requires data on watershed drainage area and impervious surface area, stormwater runoff pollutant concentrations, and

Table 3-13: Pollutant Loading (kg/ha-yr) Ranges for Various Land Uses

Land-Use Category		TSS	TP	TN	Pb	In	Cu	FC
Road	Minimum	281	0.59	1.3	0.49	0.18	0.03	7.1 E+07
	Maximum	723	1.50	3.5	1.10	0.45	0.09	2.8E+08
	Median	502	1.10	2.4	0.78	0.31	0.06	1 .8E+08
Commercial	Minimum	242	0.69	1.6	1.60	1.70	1.10	1.7E+09
	Maximum	1,369	0.91	8.8	4.70	4.90	3.20	9.5E+09
	Median	805	0.80	5.2	3.10	3.30	2.10	5.6E+09
Single family Low density Residential	Minimum	60	0.46	3.3	0.03	0.07	0.09	2.8E+09
	Maximum	340	0.64	4.7	0.09	0.20	0.27	1.6E+10
	Median	200	0.55	4.0	0.06	0.13	0.18	9.3E+09
Single family High density Residential	Minimum	97	0.54	4.0	0.05	0.11	0.15	4.5E+09
	Maximum	547	0.76	5.6	0.15	0.33.	0.45	2.6E+10
	Median	322	0.65	5.8	0.10	0.22	0.30	1.5E+10
Multifamily Residential	Minimum	133	0.59	4.7	0.35	0.17	0.17	6.3E+09
	Maximum	755	0.81	6.6	1.05	0.51	0.34	3.6E+10
	Median	444	0.70	5.6	0.70	0.34	0.51	2.1E+10
Forest	Minimum	26	0.10	1.1	0.01	0.01	0.02	1 .2E+09
	Maximum	146	0.13	2.8	0.03	0.03	0.03	6.8E+09
	Median	86	0.11	2.0	0.02	0.02	0.03	4.0E+09
Grass	Minimum	80	0.01	1.2	0.03	0.02	0.02	4.8E+09
	Maximum	588	0.25	7.1	0.10	0.17	0.04	2.7E+10
	Median	346	0.13	4.2	0.07	0.10	0.03	1.6E+ 10
Pasture	Minimum	103	0.01	1.2	0.004	0.02	0.02	4.8E+09
	Maximum	583	0.25	7.1	0.015	0.17	0.04	2.7E+ 10
	Median	343	0.13	4.2	0.010	0.10	0.03	1.6E+ 10

Source: Horner, 1992

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annual precipitation. With the Simple Method, land use can be divided into specific types, such as residential, commercial, industrial, and roadway. Using this data, the annual pollutant loads for each type of land use can be calculated. Alternatively, generalized pollutant values for land uses such as new suburban areas, older urban areas, central business districts, and highways can be utilized. Stormwater pollutant concentrations can be estimated from local or regional data or from national data sources. Tables 3-6 through 3-11 contain the type of data required for this method.

As has been discussed, stormwater pollutant concentrations tend to be highly variable for a number of reasons. Because of this variability, it is difficult to establish different concentrations for each land use. The original Simple Method Model used NURP data for the representative pollutant concentrations. Utilizing a more recent and regionally specific database would, in general, be more accurate for this purpose. If no regional or local data exists, the Simple Method could be utilized using a median urban runoff value, derived from NURP data (US-EPA 1982), of 20,000 MPN/100ml.

Data from other sources can supplement the NURP values, and the use of EMC data from local measurements should yield superior estimates. Pollutant load values from extensive regional or local sampling programs could be the most useful. For example, water-quality studies from Western Washington and Oregon, which are compatible, have been combined to form a data set for different land use categories in the PNW Chandler (1993 and 1994) These studies found a distinction between residential, commercial, and industrial land use-related EMC values and the results of the NURP research. On the other hand, a study that only includes a small number of EMC data cannot accurately determine average runoff concentrations and may not be useful in supplementing or replacing recognized EMC values such as the NURP data. If this is the case, previously published data sets should be used instead. Additionally, it is not always advisable to obtain additional EMC data due to the additional expenses involved. It may be better to use a cost-effectiveness analysis to determine if increasing the amount of EMC data is worth it. This is especially true in light of the fact that a great deal of data is typically available, for example from municipal NPDES stormwater permit applications, that can be used to estimate runoff concentrations from a variety of land uses.

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as (CWP, 2003):

$$L = 0.226 * R * C * A$$

where: L = Annual load (lbs)

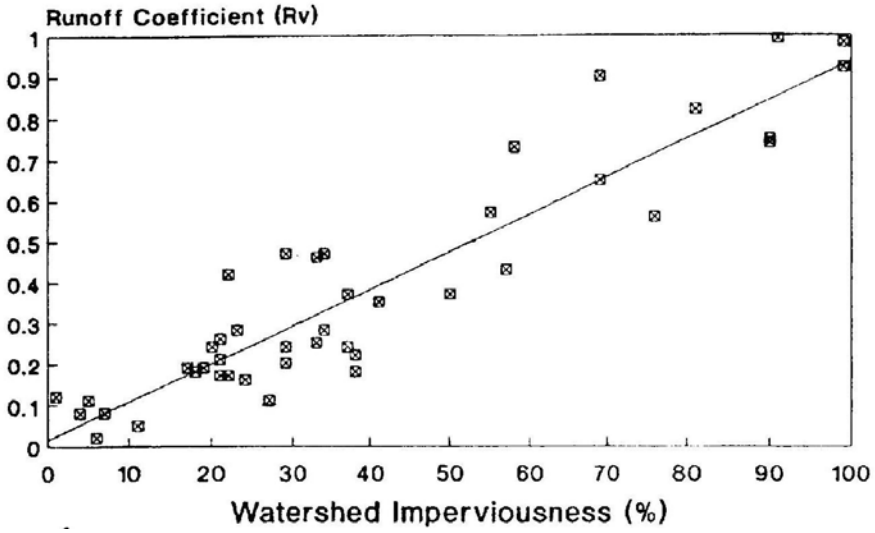
R = Annual runoff (inches)

C = Pollutant concentration (mg/l)

A = Area (acres)

0.226 = Unit conversion factor

Figure 3-4: Relationship Between Stormwater Runoff and Impervious Surface Area



Source: Schueler, 1995

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For bacteria, the equation is slightly different to account for the differences in units. The modified equation for bacteria is (CWP, 2003):

L = 1.03 *10-3 * R * C * A

where: L = Annual load (Billion Colonies)

R = Annual runoff (inches)

C = Bacteria concentration (#/100 mL)

A = Area (acres)

1.03 * 10-3 = Unit conversion factor

The Simple Method calculates annual runoff as a product of annual runoff volume and a runoff coefficient (Rv). Runoff volume is calculated as (CWP, 2003):

R = P * Pj * Rv

where: R = Annual runoff (inches)

P = Annual rainfall (inches)

Pj = Fraction of annual rainfall events that produce runoff (usually 0.9)

Rv = Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on impervious cover in the sub-watershed. This relationship is based on empirical data. Although there is some variability in the data, watershed imperviousness does appear to be a reasonable predictor of Rv (Figure 3-4). The following equation represents the best-fit line for the data set (N = 47, R2 = 0.71) based on data collected by Schueler (1987). This model uses different impervious cover values for separate land uses within a sub-watershed.

Rv = 0.05+0.9Ia

Where: Ia = Impervious fraction

Limitations of the Simple Method

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method. The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land-use and stormwater management scenarios. It provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or sub-watershed. However, it is very important not to overemphasize the precision of the results obtained. The simple method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment, or sub-watershed. More sophisticated modeling may be needed to analyze larger and more complex watersheds.

In a comparison of several PNW watersheds, Chandler (1993 and 1994) found that the Schueler (1987) Simple Model loading estimates usually agreed, within a factor of two, with estimates made by much more involved and expensive modeling procedures. Chandler (1993 and 1994) utilized the Simple Model in four case-study comparisons with more complex models, including the EPA Stormwater Management Model (SWMM) and the Hydrologic Simulation Program FORTRAN (HSPF) model. Chandler (1993 and 1994) concluded that there was no compelling reason for using complex models when estimating annual pollutant loading under most situations.

In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow volume. Typically, baseflow is negligible or non-existent at the scale of a single development site, and can be safely neglected. However, catchments and sub-watersheds do generate baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels. Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event-derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low.

Computer-Based Models

There are a wide variety of computer models available today that can be used for surface water and stormwater quality assessments. Many of these models are available in the public domain and have been developed and tested by resource agencies. Regionally or locally specific versions of many of these models are also common. In comparison to the approaches outlined previously, computer-based models provide a more complex approach to estimating pollutant loading and also often offer a means of evaluating various management alternatives (US-EPA, 2005). Detailed coverage of these models is beyond the scope of this chapter. The US-EPA *Handbook for Developing Watershed Plans* (US-EPA, 2005)

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contains a comprehensive discussion of computer-based models in Chapter 8 of that publication.

Examples of comprehensive computerized models include Stormwater Management Model (SWMM), Better Assessment Science Integrating Point and Non-Point Sources (BASINS), the Hydrologic Simulation Program Fortran (HSPF), Source Loading and Management Model (SLAMM), Storage, Treatment, and Overflow Runoff Model (STORM), and Spatially Referenced Regression on Watershed Attributes (SPARROW). These are only a few of the computer-based pollutant-loading estimation models available (see US-EPA 2005 Table 8-4 for a more complete listing).

In general, computer-based models contain hydrologic and water quality components and have statistical or mathematical algorithms that represent the mechanisms generating and transporting runoff and pollutants. The hydrologic components of both SWMM and HSPF stem from the Stanford Watershed Model, first introduced almost 25 years ago, and produce continuous hydrograph simulations. In addition to these relatively complex computer-based models, there are numerous "spreadsheet" level models that have been developed by local and regional water-quality practitioners. In almost all cases, computer-based models need to be calibrated and validated using locally appropriate water-quality data (US-EPA, 2005), which, depending on the watershed under study, can be a time-consuming and relatively costly effort.

Most computer-based models structure the water quality components on a mass balance framework that represents the rate of change in pollutant mass as the difference between pollutant additions and losses. Additions, considered to be pollutant deposition, are computed as a linear function of time. Soil erosion is usually calculated according to the Universal Soil Loss Equation (USLE). Losses are represented by a first-order wash-off function (i.e., loss rate is considered to be a function of pollutant mass present); other losses are modeled in mathematically similar ways. For example, both organic matter decomposition and bacterial die-off are considered first-order reactions. Some models, like SWMM, have both a receiving water and runoff component. These models treat some of the transformation processes that can occur in water (e.g., dissolved oxygen depletion according to the Streeter-Phelps equation or FC die-off using the Mancini equation). However, no model can fully represent all of these numerous and complex processes.

The BASINS model is a physical process-based analytical model developed by the US-EPA and typically used for watershed-based hydrologic and water-quality assessments. For example, BASINS was used to model the East Fork of the Little Miami River (Tong and Chen, 2002). The HSPF model can be used as a component of the BASINS model (Bergman et al., 2002) or as a stand-alone model (Im et al., 2003). The SPARROW model is a statistical-regression, watershed-based model developed by the USGS (Smith et al., 1997) and used primarily for water-quality modeling (Alexander et al., 2004). Many computer-based models utilize regression equations to describe pollutant characteristics (Driver and Tasker, 1990).

There are also a number of so-called "build-up and wash-off" models that simulate pollutant build-up on impervious surfaces and use rainfall data to estimate wash-off loading. The main limitation of these models is that model-controlling factors can greatly vary with surface characteristics, so calibration with actual field measurements is needed. These models can work well with calibration and can model intra-storm variations in runoff water quality, which is a key advantage. These models are often used for ranking or prioritizing, but not for predicting actual runoff water quality. SLAMM was developed to evaluate the effects of urban development characteristics and runoff control measures on pollutant discharges. This model examines runoff from individual drainage basins with particular land-use and control practices (Burton and Pitt 2002).

Most models require substantial local data to set variable parameters in the calibration and verification phases. They also require considerable technical skill and commitment from personnel. Therefore, only those prepared to commit the resources to database development and expertise should embark on using these models. Most models used today also utilize the geographic information system (GIS) for data input and presentation of results.

In many situations, the use of computer-based models may not be merited, but in other cases, it may be helpful in determining the magnitude of the water-quality problem or aid in finding a solution. Computer models can also extend data collected and enhance findings. In addition, they can be quite useful in running a variety of scenarios to help frame the water quality problem. Examples of this include worst-case, full build-out scenarios or potential BMP scenarios to estimate the effectiveness of a range of treatment options. In any case, model selection should be linked

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to the project objectives and must be compatible with the data available. In almost all cases, using the simplest model that will meet the project objectives is likely the best course to take. In all cases, models should be calibrated and verified with independent, local or regionally specific data.

A good example of a watershed-scale, computer-based model dealing with multiple water-quality parameters and their impact on receiving waters is the Sinclair-Dyes Inlet TMDL Project in the Puget Sound, Washington (Johnston et al. 2003). This model has a watershed component (HSPF) linked to a receiving-water model (CH3D) that includes dynamic loading from the contributing watershed and hydro-dynamic mixing in the receiving waters of Sinclair-Dyes Inlet. The results of this model can be viewed at www.ecy.wa.gov/programs/wq/tmdl/sinclair-dyes_inlets/index.html

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CHAPTER 4

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CHAPTER 4

Bio-physical Impacts of Urbanization on Aquatic Ecosystems

The Clean Water Act (CWA) describes water quality as the combination of chemical, physical, and biological attributes of a water body. This chapter deals mainly with the biological and physical effects of watershed development on aquatic ecosystems. Physio-chemical water quality was discussed in detail in the previous chapter. The physio-chemical effects of urbanization, commonly referred to as water pollution, are discussed in this chapter only as they apply to their impact on aquatic biota. The wide array of pollutants entering aquatic ecosystems along with urban runoff can cause numerous potential biological effects. Other biological stresses often associated with modification of the hydrologic regime or changes in physical habitat also typically accompany watershed development. The goal of this chapter is to provide a synthesis of the current scientific research that covers the cumulative effects of urbanization on aquatic ecosystems, including streams, rivers, lakes, wetlands, and estuaries. Table 4-1 summarizes the impacts of urbanization on these aquatic systems.

The majority of this chapter focuses on freshwater lotic (flowing waters) or stream-river ecosystems, but lentic (non-flowing) systems, such as lakes and wetlands, are also covered, as are estuaries and nearshore areas, to a lesser extent. As Table 4-1 shows, the impacts of urbanization include chemical effects such as degraded water quality; physical effects such as altered hydrology, degraded habitat, and modified geomorphology; and biological effects including altered biotic interactions, food web (trophic) changes, chronic (sublethal) toxicity, and acute (lethal) toxicity. This chapter also presents illustrations of the complex, interdisciplinary nature of aquatic biological impacts. Subjects covered include the role of urban runoff in lake eutrophication, metals found in stormwater runoff and their effects on aquatic organisms, thermal impacts of riparian encroachment, and the fish habitat impacts of watershed development and stormwater runoff. How the many urban stressors might affect the biota in a receiving water is very complex, imperfectly understood, and hard to forecast with assurance. The multiple stressors that often accompany urbanization can interact synergistically or antagonistically. In addition, the receptor organisms under stress can interact with one another. The sum total of these interactions within an aquatic ecosystem represents the cumulative impacts of urbanization.

Background

One of the confusing aspects of water-quality management is that often only the chemical component of water quality is considered. Water-quality criteria are the main regulatory tools used in managing receiving waters. These are typically concentrations of specific chemical pollutants set so as to protect human health and beneficial uses of receiving waters (including aquatic biota) from adverse impacts. However, relying solely on these water-quality criteria to manage urban runoff is often not an effective approach, because biological and

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Table 4-1: Summary of the Impacts of Urbanization on Aquatic Ecosystems		
Environmental Concern	**Potential Impact**	**Cause/Source**
Increase in runoff-driven peak or bankfull stream flows	Degradation of aquatic habitat and/or loss of sensitive species	Increased stormwater runoff volume due to an increase in basin imperviousness
Increase in runoff-driven flooding frequency and duration	Degradation of aquatic habitat and/or loss of sensitive species	Increased stormwater runoff volume due to an increase in basin imperviousness
Increase in wetland water level fluctuations	Degradation of aquatic habitat and/or loss of sensitive species	Increased stormwater runoff due to an increase in basin imperviousness
Decrease in dry season baseflows	Reduced aquatic habitat and less water for human consumption, irrigation, or recreational use	Water withdrawals and/or less natural infiltration due to an increase in basin imperviousness
Streambank erosion and stream channel enlargement	Degradation of aquatic habitat and increased fine sediment production	Increase in stormwater runoff driven stream flow due to an increase in basin imperviousness
Stream channel modification due to hydrologic changes and human alteration	Degradation of aquatic habitat and increased fine sediment production	Increase in stormwater runoff driven stream flow and/or channel alterations such as levees and dikes
Streambed scour and incision	Degradation of aquatic habitat and loss of benthic organisms due to washout	Increase in stormwater runoff driven stream flow due to an increase in basin imperviousness
Excessive turbidity	Degradation of aquatic habitat and/or loss of sensitive species due to physiological and /or behavioral interference	Increase in stormwater runoff driven stream flow and subsequent streambank erosion due to an increase in basin imperviousness
Fine sediment deposition	Degradation of aquatic habitat and loss of benthic organisms due to fine sediment smothering	Increase in stormwater runoff driven stream flow and subsequent streambank erosion due to an increase in basin imperviousness
Sediment contamination	Degradation of aquatic habitat and/or loss of sensitive benthic species	Stormwater runoff pollutants
Loss of riparian integrity	Degradation of riparian habitat quality and quantity, as well as riparian corridor fragmentation	Human development encroachment and stream road crossings
Proliferation of exotic and invasive species	Displacement of natural species and degradation of aquatic habitat	Encroachment of urban development
Elevated water temperature	Lethal and non-lethal stress to aquatic organisms – reduced DO levels	Loss of riparian forest shade and direct runoff of high temperature stormwater from impervious surfaces
Low dissolved oxygen (DO) levels	Lethal and non-lethal stress to aquatic organisms	Stormwater runoff containing fertilizers and wastewater treatment system effluent
Lake and estuary nutrient eutrophication	Degradation of aquatic habitat and low DO levels	Stormwater runoff containing fertilizers and wastewater treatment system effluent
Bacterial pollution	Human health (contact recreation and drinking water) concerns, increases in diseases to aquatic organisms, and degradation of shellfish harvest beds	Stormwater runoff containing livestock manure, pet waste, and wastewater treatment system effluent
Toxic chemical water pollution	Human health (contact recreation and drinking water) concerns, as well as bioaccumulation and toxicity to aquatic organisms	Stormwater runoff containing toxic metals, pesticides, herbicides, and industrial chemical contaminants
Reduced organic matter (OM) and large woody debris (LWD)	Degradation of aquatic habitat and loss of sensitive species	Loss or degradation of riparian forest and floodplain due to development encroachment
Decline in aquatic plant diversity	Alteration of natural food web structure and function	Cumulative impacts of urbanization
Decline in aquatic invertebrate diversity	Alteration of natural food web structure and function	Cumulative impacts of urbanization
Decline in amphibian diversity	Loss of ecologically important species	Cumulative impacts of urbanization
Decline in fish diversity and abundance	Loss of ecologically important species	Cumulative impacts of urbanization

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ecological impacts can occur in an ecosystem at levels well below these chemical criteria.

This dilemma can be explained by several factors characteristic of the typical urbanized environment. As discussed earlier, water quality is assessed not just by chemical criteria, but there are physical and biological aspects to consider as well. These impacts include the modification of natural hydrologic regime, geomorphic changes in ecosystem structure, the degradation of physical habitat, disruption of ecological function or processes, and the biological changes to be discussed in this chapter.

Even from the perspective of conventional chemical toxicity alone, conventional (regulatory) water-quality criteria do not represent the complex and variable exposure patterns related to urban runoff or the cumulative impacts of long-term exposure to stormwater pollutant loadings. These criteria also do not account for any physio-chemical transformations that occur in the natural or built environment. In addition, there are numerous potential interactions within the ecosystem that cannot be accounted for using chemical criteria alone. As noted in the previous chapter, stormwater pollutant concentrations are often well below acute toxicity levels as well as below chronic toxicity levels. This is typically because the quantity of urban runoff usually dilutes pollutant levels in receiving waters (see discussion in Chapter 3). However, continued stormwater runoff inputs into streams, lakes, wetlands, and estuaries, even at low contaminant concentration levels, may eventually lead to long-term biological damage. Cumulative stress from poor water quality can result in chronic toxicity effects or bioaccumulation impacts. Pollutant accumulations in aquatic sediments can also have a long-term negative impact on benthic organisms or the embryonic stages of aquatic organisms that utilize the benthic environment.

Direct and indirect (or downstream) impacts of water quality degradation are another issue related to urban runoff impacts. In most cases, both scales of impact are present. Direct impacts are those that are present in surface waters that receive stormwater runoff directly from developed (e.g. impervious) drainage areas. Studies of direct impacts tend to focus on the hydrologic or geomorphic aspects of urban runoff. Indirect impacts are those that impact receiving waters downstream of the source, such as rivers, lakes, nearshore areas, and estuaries. In general, indirect impacts are mainly due to the physio-chemical water-quality effects of urbanization, but there is some overlap between the two scales.

Hydrologic Impacts

Landscape Alteration

Urbanization is one of the most widespread and rapidly growing forms of landscape modification affecting aquatic ecosystems. Just over 5 percent of the total surface area of the U.S. is covered by development (e.g. urbanization) related land use (EOS, 2004). Although the total land area currently occupied by urbanization (i.e., residential, commercial, and industrial development) remains relatively low in comparison to agricultural or other human land-use activities, the trend toward greater urbanization continues (Elvidge et al., 2004). According to the 2000 United States Census (USCB, 2001), approximately 30 percent of the population lives in urban areas and 50 percent in suburban areas, with the remaining 20 percent in rural areas. From an ecosystem perspective, the ecological footprint of urbanization has been shown to be significant in many cases (Folke et al., 1997). For example, it has been estimated that urbanized areas produce more than three quarters of global greenhouse gas emissions (Grimm et al., 2000). Urban development and related human activities can also produce very high local extinction rates for natural biota and can often result in the spread of exotic or invasive species (McKinney, 2002).

Urbanization can be characterized as an increase in human population density, coupled with an increase in per capita consumption of natural resources and extensive modification of the natural landscape, creating a built environment that is inherently not sustainable over the long term and often continues to expand into natural areas (McDonnell and Pickett, 1990). The landscape alterations accompanying urbanization tend to be more long lasting than other human land uses. For example, throughout much of New England, native forest cover has been steadily increasing in area over the last century, restoring areas impacted by historic logging and agriculture, whereas urbanized areas of the same region continue to persist or have significantly expanded (Stein et al., 2000). Generally, in urbanizing watersheds, water pollution and stormwater runoff are related to human habitation and the resultant increase in human land uses.

Savani and Kammerer (1961) first discussed the relationship between natural land cover and developed land use with respect to the stages of urbanization. This

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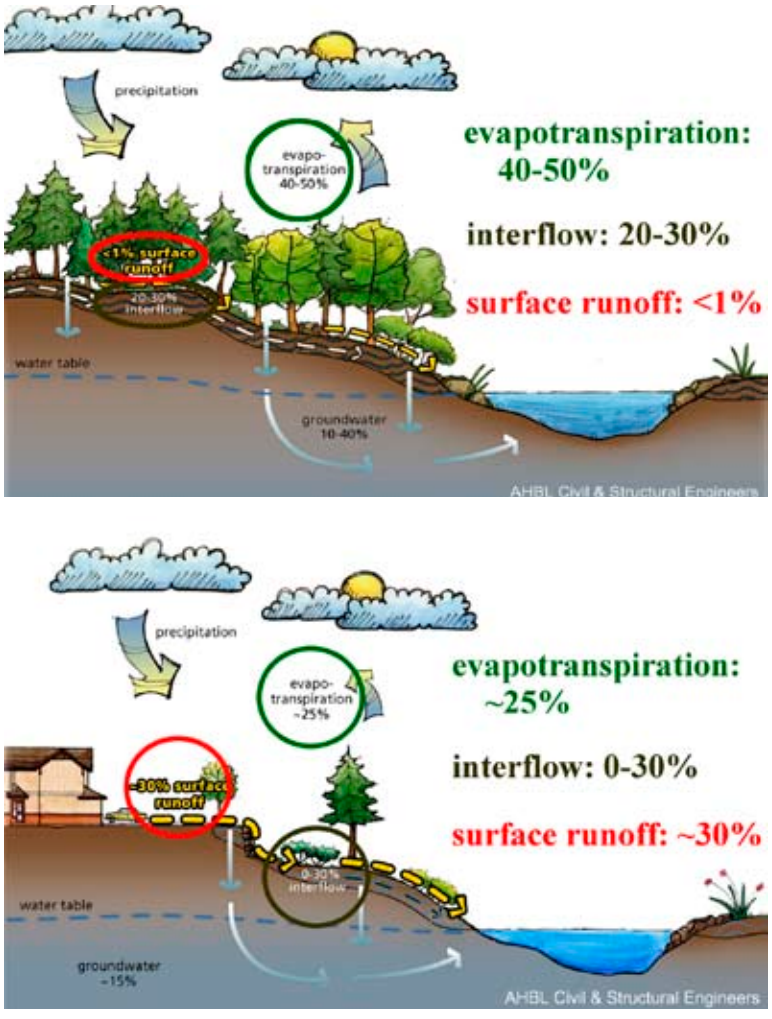
early research identified four stages of urbanization, each associated with characteristic changes in the hydrologic regime. These stages are rural, early urban (now called low-density suburban), middle urban (high-density suburban), and late urban. According to Savani and Kammerer (1961), during the rural stage of development, infiltration and evapo-transpiration are still the key components of the water cycle because the landscape is still predominantly unchanged from a hydrologic perspective. The early urban stage is characterized by large-lot development, where much of the natural vegetation is retained and impervious surfaces are just beginning to affect the basin hydrology. In the middle urban or suburban stage, impervious surfaces are beginning to dominate the landscape, with residential and commercial land uses being the most common. In the late urban stage, nearly all the natural vegetation has been removed, and impervious surfaces dominate the watershed landscape.

One of the most obvious manifestations of watershed development is the proliferation of impervious surfaces in the urbanizing landscape. Impervious surfaces can be broadly defined as any portion of the built environment that does not maintain the natural hydrologic regime. Impervious surfaces tend to inhibit or prevent infiltration and groundwater recharge. Impervious areas also tend to have less evapo-transpiration than natural areas. From a hydrologic perspective, development alters the natural landscape by removing native vegetation, disregarding local topography, and disturbing (through removal and/or compaction) the natural soil structure. Urbanization is typically accompanied by a reduction in rainfall interception, evapo-transpiration, and infiltration (Figure 4-1). Figure 4-2 shows the progression of impervious surface area and the changes in the hydrologic regime as development increases.

Impervious surfaces include roads, parking lots, sidewalks, driveways, and building rooftops. To a lesser extent, lawns, landscaped areas, golf courses, and parks can also be impervious (Schueler, 1995). These turf or landscaped areas are often directly connected to impervious areas and can contribute a significant fraction of the total runoff from built areas (Schueler, 1995). In addition, construction sites, agricultural croplands, quarries, and other areas of bare ground also contribute runoff volume. Impervious surface area tends to be correlated to human population density (Stankowski, 1972).

Although water resource degradation from urban runoff pollution is often considered the leading cause of ecological damage, this is not always the primary cause of water quality problems. The shift in the natural hydrologic regime from an infiltration-dominated scheme to one dominated by surface runoff resulting from watershed urbanization can have significant ramifications on river and stream hydrology (Dunne and Leopold, 1978). Due to the loss of infiltration, there is a reduction in groundwater recharge that can lead to lower dry-weather baseflows in surface waters. The relationship between imperviousness and runoff is

Figure 4-1: Comparison between the hydrologic regime for a natural, undeveloped watershed (upper) and an urbanized watershed in the Pacific Northwest



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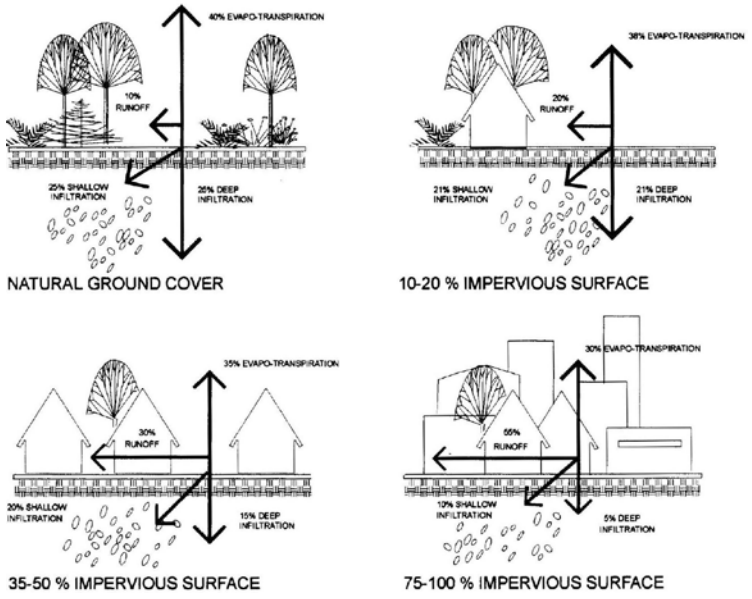
illustrated in Figure 4-3. The runoff coefficient reflects the fraction of rainfall volume that is converted to runoff. Runoff coefficient tends to closely track the percentage of impervious surface area in a given watershed, except at low levels of development where vegetation cover, soil conditions, and slope factors also influence the partitioning of rainfall. Impervious surfaces are hydrologically active, meaning they generate surface runoff instead of absorbing precipitation (Novotny and Chesters, 1981).

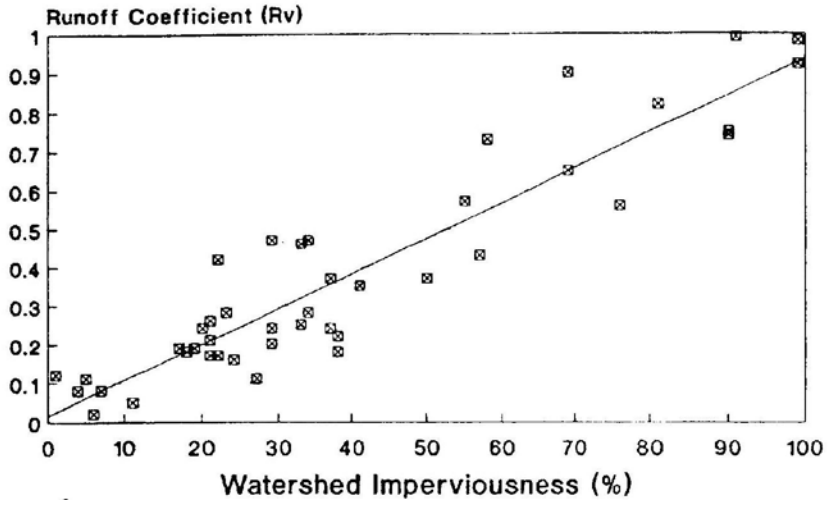
The total fraction of a watershed that is covered by impervious surface areas is typically referred to as the percent total impervious area (%TIA). The %TIA of a watershed is a landscape-level indicator that integrates several concurrent interactions influencing the hydrologic regime as well as water quality (McGriff, 1972; Graham et al., 1974; Dunne and Leopold, 1978; Alley and Veenhuis, 1983; Schueler, 1994; Arnold and Gibbons, 1996; May et al., 1997; EPA, 1997). Another impervious term commonly used in urban watershed work, especially in the modeling arena, is effective

Figure 4-2: Typical Progression of Hydrologic Changes in Urbanizing Watersheds as Imperviousness Increases With Development



Source: Schueler, 1994

Figure 4-3: Relationship Between Imperviousness and Stormwater Runoff



Source: Schueler, 1994

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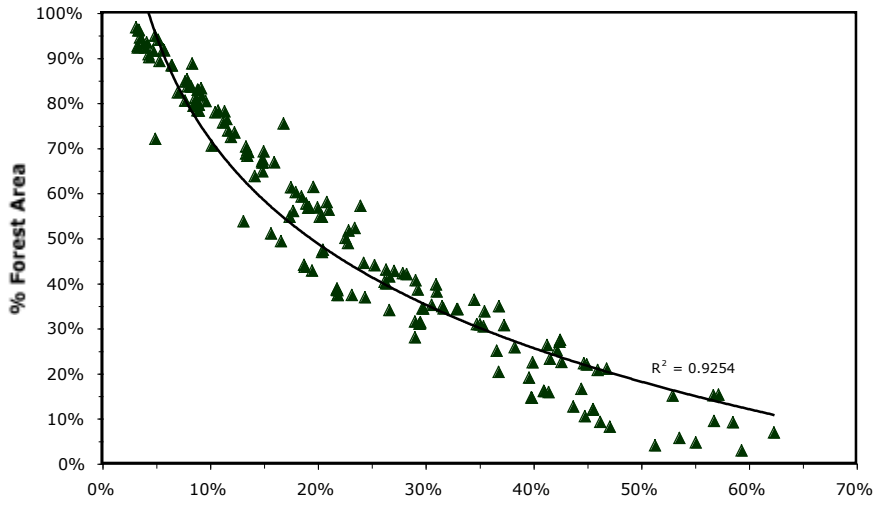
impervious area (%EIA). The %EIA is that portion of the impervious surfaces that is directly connected (via open channels or stormwater piping) to the natural drainage network (Alley and Veenhuis, 1983).

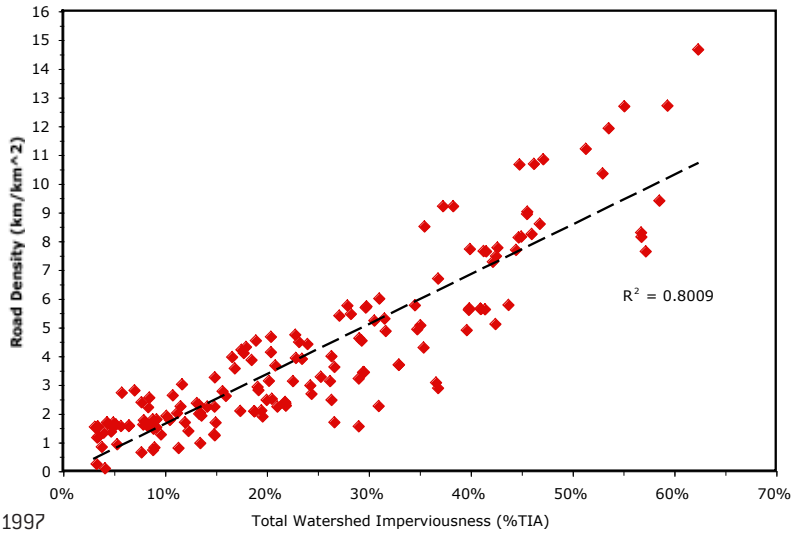
Another useful indicator of landscape-scale changes in watershed condition is the fraction of the basin that is covered by natural vegetation. In many areas, forest cover is the key parameter, but in other regions, prairie or shrub-savannah could be the key natural vegetation community. In any case, native vegetation tends to be adapted to local climate conditions and soil characteristics, making it the land cover that best supports the natural hydrologic regime. In general, urbanization tends to reduce natural vegetation land cover, while increasing impervious surface area associated with the variety of land uses present in the built environment. In most regions, the fraction of the watershed covered by natural vegetation is inversely correlated with imperviousness. For example, in the Puget Sound region of the Pacific Northwest, forest cover and imperviousness are strongly interrelated (see Figure 4-4), as are road density and imperviousness (see Figure 4-5).

Figure 4-4: Relationship Between Forest Cover and Impervious Surface Area in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

Figure 4-5: Relationship Between Road Density and Impervious Surface Area in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

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Hydrological analyses suggest that maintaining forest cover is more important than limiting impervious-area percentages, at least at rural residential densities where zoning effectively limits the range of imperviousness to relatively low levels (typically < 10 percent TIA). However, without clearing limitations, the area of natural forest cover can vary widely (Booth et al., 2002). Consequently, both types of land-cover control (i.e., forest retention and impervious limitation) are likely critical to protecting aquatic resources. In rural areas, at the lower end of the development spectrum, current research indicates that retention of forest cover may be more important than limiting impervious surfaces (Booth et al., 2002). Degraded watersheds with less than 10 percent imperviousness and less than 65 percent forest cover are common ("cleared rural"); in contrast, virtually no watersheds with more than 10 percent imperviousness that have also retained at least 65 percent forest cover ("forested urban") exist in the Puget Sound region (Booth et al., 2002).

A study from western Washington illustrates the changes in hydrologic function that occur during the development process (Burges et al., 1998). To estimate the hydrologic balance for two basins in close proximity, an approach was used combining hydrologic modeling and simple monitoring. At the time of the study, both basins were in suburban areas, but one was relatively undeveloped, while the other was suburban in land use. Before being developed, the Novelty Hill and Klahanie basins were hydrologically similar. Both study basins are in the same geological region and were once largely forested. Novelty Hill was significantly deforested, and 30 percent of the area was covered with impervious surfaces. In this study, Novelty Hill had a faster flow response, higher peak flow, and longer time of discharge. Also, there was more flow response when there was preceding wetness in the soil. For the annual water balance in this basin (the difference between precipitation and catchment outflow), 69 to 88 percent of annual precipitation left as groundwater recharge or evapo-transpiration (Burges et al., 1998). Because the soil at Novelty Hill is deeper and less disturbed than at Klahanie, it takes more precipitation to saturate. In the developed Klahanie basin, 44 to 48 percent of the annual precipitation left as catchment outflow, as opposed to about 12 to 30 percent in Novelty Hill (Burges, et al., 1998). One of the most interesting findings of this study was that runoff from what are considered pervious areas such as lawns and landscaped areas accounted for 40 to 60 percent of the total annual runoff in the developed basin (Burges et al., 1998). In addition, the loss of local depressional storage likely influences hydrologic function of lawns and landscaped areas converted from natural forested areas. This study also illustrates that imperviousness encompasses much more that just paved surfaces.

Urban Hydrologic Regime

This section focuses on changes in runoff and stream-flow because they are common in urbanizing watersheds and often cause dramatic changes in basin hydrology. Hydrologic change also influences the whole range of environmental features that affect aquatic biota-flow regime, aquatic habitat structure, water quality, biotic interactions, and food sources (Karr, 1991). Although runoff and stream-flow regime are important, they are by no means the only drivers of aquatic health.

As has been discussed, urbanization alters the hydrologic regime of surface waters by changing the way water cycles through a drainage basin. In a natural setting, precipitation is intercepted or delayed by the forest canopy and ground cover. Vegetation, depressions on the land, and soils provide extensive storage capacity for precipitation. Water exceeding this capacity travels via shallow subsurface flow and groundwater and eventually discharges gradually to surface water bodies. In a forested, undisturbed watershed, direct surface runoff occurs rarely or not at all because precipitation intensities do not exceed soil infiltration rates. Figures 4-1 and 4-2 illustrates this shift in hydrologic regime.

During the initial phases of urbanization, clearing of native vegetation reduces or eliminates interception storage and the water reservoir in soils. Loss of vegetation and "duff" (mostly composting vegetative material) from the understory takes away another storage reservoir. Site grading eliminates natural depressions. Impervious surfaces, of course, stop any infiltration and produce surface runoff. Even when surfaces remain pervious, building often removes, erodes, or compacts topsoil. The compacted, exposed soil retards infiltration and offers much less storage capacity. Development typically replaces natural drainage systems with hydraulically efficient pipe or ditch networks that shorten the travel time of runoff to the receiving water (Hirsch et al., 1990).

The many changes brought on by urbanization tend to alter streamflow patterns in characteristic ways.

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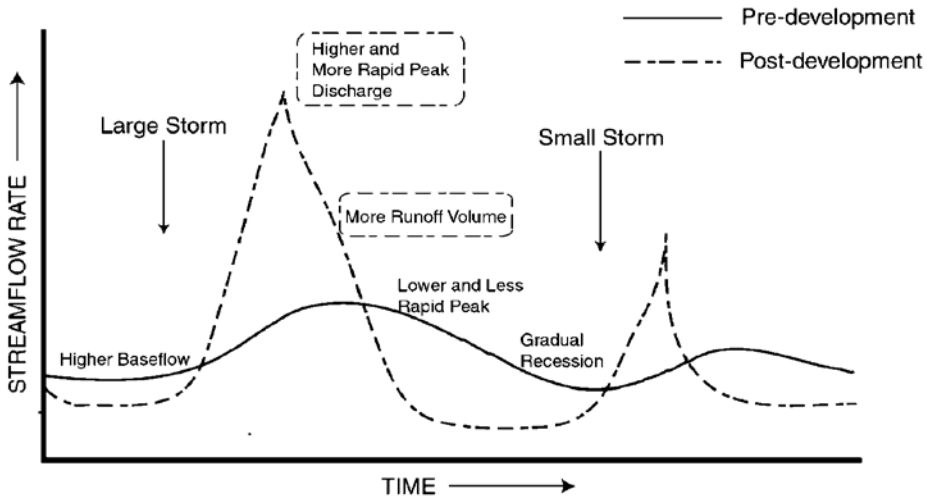
Figure 4-6 illustrates typical hydrographs (flow rate versus time) for a stream before and after watershed urbanization. The hydrograph emphasizes the higher peak flow rate of urbanized basins compared to natural landscape conditions. The area under the hydrograph curves represents the total runoff volume, which is significantly greater for the urbanized condition. In addition, there is typically less "lag time" between rainfall and runoff when more impervious surfaces exist. The construction of an engineered stormwater drainage network also invariably increases the drainage density of urbanizing basins (Graf, 1977). Typically, these engineered conveyance systems are designed to efficiently remove water from the natural drainage network and so reduce the time necessary for overland flow to reach stream channels. The net effect of these urban watershed changes is that a higher proportion of rainfall is translated into runoff, which occurs more rapidly, and the resultant flood flows are therefore higher and much more "flashy" than natural catchments (Hollis, 1975).

In general, the hydrologic changes associated with urbanization can be traced primarily to the loss of natural land cover (vegetation and soil) and the increase in impervious surfaces in the watershed (Dunne and Leopold, 1978). The impact of urbanization and impervious surfaces on watershed hydrology has been studied for many decades. Wilson (1967) studied the impact of urbanization on flooding in Jackson, Mississippi. Early research by Leopold (1968) reported that a two- to five-fold increase in peak streamflow was common in urbanizing basins, although some streams showed an even greater rise, especially in arid areas. Seaburn (1969) studied the effects of urbanization on stormwater runoff on Long Island, New York, finding similar results. Hammer (1973) also found that peak streamflows increased with greater watershed urbanization. A decline in groundwater recharge is also common in urbanizing watersheds, due to greater impervious areas and less infiltration (Foster et al., 1994). Bharuri et al., (1997) also quantified the changes in streamflow and related decreases in groundwater recharge associated with watershed urbanization in the Midwest.

Hollis (1975) studied the impact of urbanization on flood recurrence interval. This research found that, in general, floods with a return period of one year or longer are not affected by a watershed impervious level of approximately 5 percent. In addition, small flooding events and peak streamflows may be increased by up to 10 times that found under natural conditions. Hollis (1975) found that under typical (~30 percent imperviousness) urbanized conditions, 100-year floods can be doubled in magnitude due to the greater runoff volume. Finally, the hydrologic effect of urbanization tends to decline, in relative terms, as flood recurrence intervals increase (Hollis, 1975). The findings of these studies indicate that it is not uncommon for a flood event with a 10-year recurrence interval to shift to a more frequent 2-year interval. Hollis (1975) also found that the discharge rates of small, frequent floods tend to increase by a greater percentage of pre-development rates than those of large, infrequent floods.

Figure 4-6: Changes in Stream Hydrology as a Result of Urbanization



Source: Schueler, 1994

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In addition, the frequency of bankfull flows can be significantly increased in urbanizing stream basins. In western Washington State, a computer model capable of continuous simulation was used to study the hydrology of two similar watersheds (Booth, 1991). It compared a fully forested basin with a developed (approximately 40 percent impervious area) basin. The model predicted that the pre-development discharge that occurs only once in five years would occur in 39 of 40 years after urbanization. These alterations in hydrologic characteristics can result in a significant change in the disturbance regime of a typical stream ecosystem (Booth, 1991).

In a study in the Toronto area of Ontario, Canada (Snodgrass et al., 1998), the bankfull streamflow recurrence period was 1.5 years under natural conditions. Storms that result in bankfull flows were generally found to be in equilibrium with the natural resisting forces (e.g., stream bank vegetation) that tend to stabilize the stream channel. As watersheds urbanized, the streamflows that were bankfull flows occurred more frequently, up to about every 0.4 years in Toronto (Snodgrass et al., 1998).

A study in the upper Accotink Creek watershed in northern Virginia related the increase in impervious surface area from development to changes in streamflow over the period 1949 to 1994 (Jennings and Jarnagin, 2002). Over this period, the percent TIA increased from 3 percent to 33 percent. Over the same period, streamflow discharge response to precipitation events increased significantly, as did the frequency of peak events (Jennings and Jarnagin, 2002).

Other studies have shown similar results. In a stream study in Washington State, the flow rate that had been reached only once in 10 years on average before development, increased in frequency to about every two years after urbanization (Scott, 1982). In a similar study in Korea, the peak discharge of runoff increased and the mean lag time of the study stream decreased due to urbanization over a period of two decades (Kang et al., 1998).

Another important characteristic of highly impervious, urbanized watersheds is the production of runoff during even relatively small storm events. Under natural conditions, small precipitation events generally produce little, if any, runoff. This is due to the interception and evapo-transpiration of rainfall by native vegetation as well as to the absorption of rainfall by the upper soil horizon and rainfall held in natural depressions where it eventually infiltrates or evaporates. It has been estimated that natural depressional storage is typically at least 4 times that of impervious surfaces (Novotny and Chesters, 1981). A study in Australia found that the average peak discharge for urban streams was 3.5 times higher than the peak flow for rural streams (Neller, 1988).

Booth (1991) noted that in addition to high-flow peaks being amplified in urban stream hydrographs in the Puget Sound region, new peaks also appeared. These new peaks were the result of small storms, most of which produced no runoff under pre-development conditions but generated substantial flows under the urbanized condition. Therefore, it can be concluded that watershed development does more than just magnify peak flows and flooding events; it also creates entirely new high-flow events due to runoff from impervious surfaces.

Yet another characteristic of urban streams is the more rapid recession of stormflow peaks (see Figure 4-6). In addition, the baseflow conditions in urban streams are typically lower in urbanized watersheds. This has been observed for wet season baseflows in the Puget Sound region (Konrad and Booth, 2002) and in the Chesapeake Bay region (Klein, 1979). In arid regions, there may also be a noticeable decrease in dry season baseflow due to watershed development (Harris and Rantz, 1964). A study in Long Island, New York revealed the extent of seasonal hydrologic shifts in urban streams. In several undeveloped watersheds, stream baseflow constituted up to 95 percent of annual discharge. That proportion dropped to 20 percent after development (Simmons and Richard, 1982).

Rose and Peters (2001) examined streamflow characteristics that changed during the period from 1958 to 1996 in a highly urbanized watershed (Peachtree Creek), compared to less urbanized watersheds and non-urbanized watersheds, in the vicinity of Atlanta, Georgia. Data was obtained from seven U.S. Geological Survey (USGS) stream gages, 17 National Weather Service rain gages, and five USGS monitoring wells. The fraction of the rainfall occurring as runoff in the urban watershed was not significantly greater than in the less urbanized watersheds, but this ratio did decrease from the higher elevation and higher relief watersheds to the lower elevation and lower relief watersheds. For the 25 largest stormflows, the peak flows for the urban creek were 30 to 100 percent greater than the peak flows in the streams located in the less developed areas. In the urban stream, the streamflow also decreased more rapidly after storms than in the other streams. The low flow in the urban creek was 25 to 35 percent lower than in the less developed streams, likely caused by decreased infiltration

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due to the more efficient routing of stormwater and the paving of groundwater recharge areas.

In an extensive stream research project in Wisconsin, the observed decrease in stream baseflow was found to be strongly correlated with watershed imperviousness (Wang et al., 2001). Similarly, an urban stream study in Vancouver, British Columbia, Canada, monitored 11 urbanizing small-stream watersheds. Baseflow and groundwater recharge were consistently lower in watersheds with more than 40 percent impervious cover (Finkebine et al., 2000). Both of these studies found linkages between these shifts in hydrologic regime and both habitat degradation and the decline in biological integrity in the urbanizing streams.

Sheeder and others (2002) investigated the hydrograph responses to dual rural and urban land uses in three small watersheds. Two important conclusions were deduced from this investigation. First, in all cases, the researchers found two distinct peaks in stream discharge, each representing different contributing areas to direct discharge with greatly differing curve numbers and lags, representative of urban and rural source regions. Second, the direct discharge represented only a small fraction of the total drainage area, with the urban peak becoming increasingly important in relation to the rural peak as urbanization increases and the magnitude of the rain event decreases.

Nagasaka and Nakamura (1999) examined the influences of land-use changes on the hydrologic response and the riparian environment in a northern Japanese area. Temporal changes in a hydrological system and riparian ecosystem were examined with reference to land-use conversion in order to clarify the linkages between the two. The results indicated that the hydrological system had been altered since the 1970s, with increasing flood peaks of 1.5 to 2.5 times, and the time of peak flow appearances shortening by seven hours. The ecological systems were closely related to and distinctly altered by the changes that had occurred in the local land use. A similar study in southern California found comparable results (White and Greer, 2002).

Adjacent to water bodies, floodplain encroachment eliminates another storage zone needed to diminish high flows. When the channel cannot contain the greater flow, flooding results. Clearing riparian vegetation removes the wood supply that helps slow down the flow and, in many cases, prevent bed and bank erosion. Clearing also eliminates shade, refuge, and food supply. Urban residents and high streamflows remove remaining wood, further decreasing the stream's opportunity to dissipate energy without flooding or damaging the channel (Dunne and Leopold, 1978). In addition, any channel modifications (e.g., streambank armoring, levee construction, or diking) that inhibit stream-floodplain interactions can have serious consequences for downstream flooding.

Biological and Ecological Effects of Urban Hydrologic Change

As discussed above, the hydrologic impacts of watershed urbanization include the following:

- Greater runoff volume from impervious surfaces;
- Higher flood recurrence frequency;
- Less lag time between rainfall, runoff, and streamflow response;
- Higher peak streamflow for a given size storm event;
- More bankfull or higher streamflows – flashier flows;
- Longer duration of high streamflows during storm events;
- More rapid recession from peak flows;
- Lower wet and dry season baseflow levels;
- Less groundwater recharge; and
- Greater wetland water level fluctuation.

All of these characteristics represent alterations in the natural hydrologic regime to which aquatic biota have adapted over the long term. These are significant hydrologic changes that can negatively impact aquatic biota directly or indirectly. Direct impacts include washout of organisms from their preferred habitat and the physiological stress of swimming in higher flows. Indirect impacts are centered on the degradation of in-stream habitat that occurs as a result of the higher urban streamflows. These higher flows result in changes in channel geomorphology and physical habitat (to be discussed in detail in the next section), including stream bank erosion, stream channel instability, elevated levels of turbidity and fine sediment, channel widening or incision, stream bed scour, and the washout of in-stream structural elements (e.g., large woody debris or LWD).

An extensive study comparing an urban (Kelsey Creek) and a non-urban (Big Bear Creek) stream in

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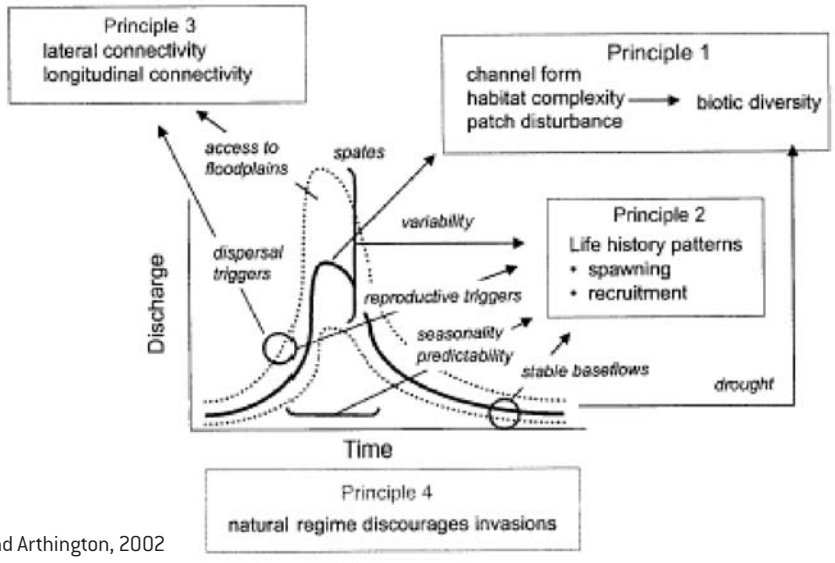
the Puget Sound region found that hydrologic changes from urbanization were the principal reasons that the urban stream failed to match its non-urban counterpart in diversity and size of salmonid fish populations and other biological indices (Pederson, 1981; Richey et al., 1981; Perkins, 1982; Richey, 1982; Scott et al., 1982). The study found that Kelsey Creek had significantly higher stormflows and flood flows, as well as lower baseflows, than Bear Creek. This shift in hydrologic regime resulted in extensive habitat degradation and stream channel alteration from the natural condition.

Another study in the Puget Sound region looked at the streamflow records of six small lowland streams over a 40-year period. Four of the study streams exhibited a significant increase in urbanization and two remained relatively undeveloped over the study period. Each of the urbanized basins experienced a significant increase in flood frequency, while the undeveloped basins showed no discernable shift in flood frequency. Salmon spawning-count data for the developed basins showed a systematic decline in salmon abundance, while the undeveloped basins showed no evidence of decline. The data implies a link between salmon population decline and either increased flood frequency or an associated degradation in habitat (Moscrip and Montgomery, 1997).

The Puget Sound Lowland Stream Research Project (May et al., 1997), one of the most comprehensive studies of the cumulative impacts of urbanization, also found that the shift in hydrologic regime in urbanizing small-stream watersheds was the primary cause of degraded habitat conditions, reduced stream biological integrity, and declining salmon diversity. In the Pacific Northwest, the importance of hydrologic alteration and its effects on stream habitats and the salmonid resource is widely recognized. A significant share of the urban runoff management effort goes into controlling water quantity to attempt to retain pre-development hydrologic patterns. With respect to resource protection, in most other urbanized areas, more attention is generally paid to quality control than to controlling quantity to maintain stream channel integrity. Yet, the same hydrologic modification problems have been noted elsewhere (Wilson, 1967; Seaburn, 1969; Hammer, 1972; Klein, 1979).

Finally, a comprehensive literature review conducted by Bunn and Arthington (2002) identifies the key principles and ecological consequences of altered flow regimes resulting from human modification of the watershed. These principles establish the linkages between flow regime and aquatic biodiversity as indicated in Figure 4-7. Their first principle is that flow is a major determinant of physical habitat in streams, which in turn determines the biotic composition of stream communities. Under this principle, channel geomorphic form, habitat structure, and complexity are determined by prevailing flow conditions. Urban examples of this have been discussed above, including the impact of flashy urban flows on benthic macroinvertebrates and native fish. The biotic communities of streams are largely determined by their natural flow regimes. This is true for aquatic insects and other macroinvertebrates (Resh

Figure 4-7: Aquatic Biodiversity and Natural Flow Regimes



Source: Bunn and Arthington, 2002

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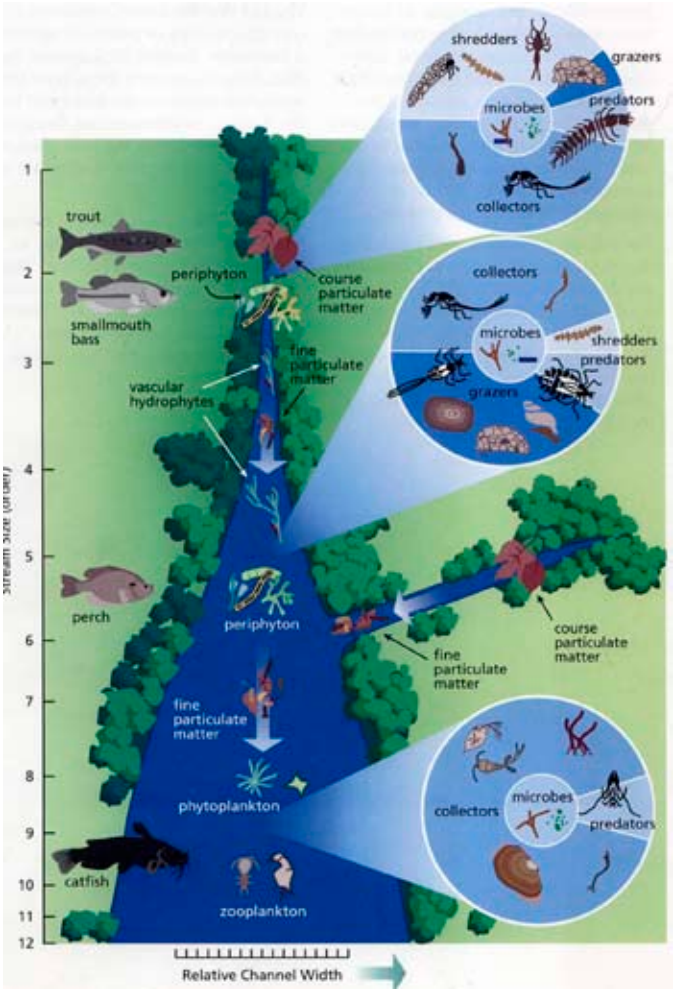
et al., 1988) as well as fish (Poff and Ward, 1989; Poff and Allen, 1995; Poff et al., 1997).

The second principle is that aquatic species have evolved life history strategies primarily in direct response to the natural flow regime (Bunn and Arthington, 2002). For example, the timing and spatial distribution of salmon migration and spawning in the Pacific Northwest is largely determined by the natural flow regimes in each watershed (Groot and Margolis, 1991).

The third principle states that the maintenance of natural patterns of longitudinal and lateral connectivity is essential to the long-term viability of many populations of aquatic biota in flowing waters (Bunn and Arthington, 2002). Lateral connectivity refers to maintaining a connection between the active stream channel and the floodplain-riparian zone (Ward et al., 1999). This connection is often severely disrupted or lost altogether in urban streams where channelization and stream bank armoring are common. Longitudinal connectivity is disrupted by fragmentation of the riparian corridor by road or utility crossings (discussed in a later section) and the construction of in-stream migration barriers. The construction of dams and diversion structures, as well as road-crossing culverts that block fish passage, can significantly influence the viability of stream fish populations. In-stream barriers can block adult migration upstream to spawn, restrict juvenile fish access to rearing or refugia habitat, and disrupt the flow of large woody debris (LWD) and organic matter (OM) within the stream ecosystem. The river continuum concept (Vannote et al., 1980) illustrates the importance of connectivity within a stream ecosystem (Figure 4-8).

Figure 4-8: River Continuum Concept



Source: Modified from Van Note et al., 1980

The fourth and final principle states that the survival of invasive, exotic, and introduced (non-native) species is facilitated by altered flow regimes (Bunn and Arthington, 2002). The most successful exotic and invasive fish are often those that are either habitat generalists or adaptable to changing conditions (Moyle, 1986). Both these strategies are favorable to survival in urbanized hydrologic regimes. In addition, the long-term persistence of invasive fish is much more likely in aquatic systems that are permanently altered by human activity, as is the case for urbanized watersheds (Moyle and Light, 1996).

Urban Freshwater Wetland Hydrology

Wetlands provide many ecological functions for the watershed in which they are located. These functions include hydrologic, ecological, and water-quality components. Wetlands provide water storage features dispersed throughout the watershed landscape. Riparian wetlands provide natural flood storage volume. Most wetlands also provide critical storage

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capacity during periods of precipitation that provides for stream and groundwater recharge during dry periods. Wetlands also provide key habitat features for a variety of wildlife species.

The King County Urban Wetland Research Project studied the impacts of urbanization on freshwater wetlands in the Puget Sound lowland eco-region (Azous and Horner, 2003). Water level gages were used to determine wetland water level fluctuation (WLF). WLF is defined as the difference between base water level (BL) prior to a storm event and the crest or maximum water level (CL) for the event (WLF = CL – BL). This research found that WLF depends on a variety of watershed and wetland characteristics, but typically exceeded the natural range when basin imperviousness reached 10 percent TIA (Taylor, 1993; Azous and Horner, 2003). Similar results were found in freshwater wetlands in New Jersey (Ehrenfeld et al., 2003) and in tidal wetlands around the country (Thom et al., 2001). In a study in Saint Paul, Minnesota, Brown (1988) found that stormwater runoff quantity was related to both the amount of impervious surface area and the wetland-lake area in a basin.

In the Puget Sound urban wetland study, the WLF caused by watershed urbanization was not found to be consistently related to plant species richness but turned out to be an important factor in certain habitat types nonetheless, most notably in emergent wetlands. The frequency and duration of freshwater wetland flooding events was related to plant richness in all Puget Sound wetlands (Azous and Horner, 2003). The highest species richness at all water depths was found in wetlands with an average of less than three flooding events per month. Wetlands with a cumulative duration of flooding events lower than three days per month also had the highest species richness (Azous and Horner, 2003). While frequency affected plant richness at all water depths, duration particularly compounded the impact of frequency on vegetation found in water over two feet deep. When frequency and duration were analyzed together, it was found that the highest richness was found in wetlands with both an average of less than three events per month and a cumulative duration of flooding that was shorter than six days per month. These two factors were found to be more important than water depth in predicting plant richness (Azous and Horner, 2003).

In the Puget Sound lowland eco-region, watershed urbanization was found to have a negative impact on both native lentic and terrestrial-breeding amphibian richness. Wetlands with increasing urbanization in their contributing watersheds were significantly more likely to have lower amphibian richness than wetlands in less urbanized or natural watersheds (Azous and Horner, 2003). This relationship was linked to increased runoff into urban wetlands as well as a resultant increased WLF. When average WLF exceeded 20 cm, the number of native amphibian species declined significantly (Azous and Horner, 2003). It is thought that the greater WLF may have a disproportionate negative impact on amphibian breeding habitat and/or higher egg-embryo mortality due to desiccation of egg masses (Azous and Horner, 2003). Urbanized land-use activity in areas immediately adjacent to wetlands (within buffer zones) also decreased native amphibian richness (Azous and Horner, 2003). In general, wetlands adjacent to larger areas of forest are more likely to have richer populations of native amphibians.

Wetland WLF and flooding can also affect the richness of bird species. Increased flooding events may inundate nesting sites and disperse pollutants that bioaccumulate in birds through the aquatic food chain (Azous and Horner, 2003). Increased runoff and high WLF can alter cover, nesting habitat, and the distribution of birds' food sources. It was not possible, however, to establish that changes in population are directly related to land use since it is difficult to control for all habitat factors besides urbanization. In general, average bird species richness was inversely related to the level of urbanization (Azous and Horner, 2003).

The findings of the Puget Sound lowland eco-region urban wetland study consistently indicated that placing impervious surface on some 10 percent of a watershed creates significantly negative hydrologic, habitat, and ecological responses (Azous and Horner, 2003). To complicate the picture, development located immediately adjacent to the wetland (wetland buffer area and surrounding development), rather than away from it, can also have a significant influence on hydrologic conditions, habitat quality, and water quality (Azous and Horner, 2003).

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Physical Impacts

Geomorphic Changes

Urbanization and the resultant hydrologic changes outlined above can cause significant alterations of natural stream morphological characteristics. The direct and indirect impacts of urbanization can affect longitudinal stream channel characteristics such as sinuosity and gradient. In addition, lateral characteristics such as stream channel bankfull width (BFW) and bankfull depth (BFD) can be altered as the stream expands to accommodate the higher runoff-driven flows brought on by watershed urbanization. Figure 4-9 illustrates the process of channel enlargement in urbanizing streams. Neller (1989) and Booth and Henshaw (2001) both reported that stream channels in urbanized watersheds had cross-sectional areas that were significantly larger than would be predicted based on catchment area and discharge alone.

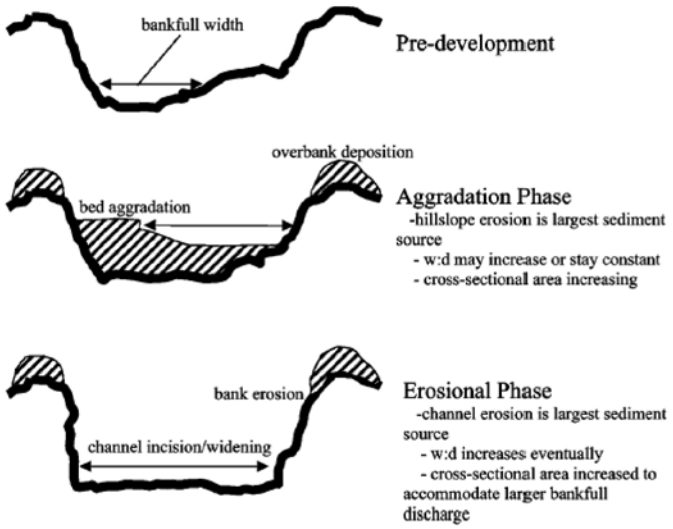
Channel enlargement can be a gradual process that follows the pace of urbanization, or it can frequently occur abruptly in response to particular storms (Hammer, 1972; Leopold, 1973; Booth, 1989; Booth and Henshaw 2001). Even in cases where the stream has been stable for many years, abrupt and sometimes massive changes in channel dimensions can occur in a single large storm once urbanization progresses to some critical level. In addition to causing accelerated channel enlargement, the higher and more frequent bankfull flows characteristic of urbanizing streams can also cause stream bank erosion, floodplain degradation, and a loss of channel sinuosity (Arnold et al., 1982).

During the construction phase of development, surface erosion of exposed areas can increase the supply of sediment available to runoff. This deposition of excess sediment can result in streambed aggradation and overbank deposition in floodplain areas. After construction is complete in a sub-basin, the external supply of sediment is reduced, but bankfull flows continue to increase as runoff from impervious surfaces increases. This can lead to increased stream bank erosion and channel enlargement as the stream tries to accommodate the increased streamflows (Paul and Meyer, 2001).

Channel enlargement tends to occur more often in urban streams that have some grade-control structures, such as in-stream LWD or road culverts. In these cases, the stream will generally erode the banks in order to widen the cross-sectional area to carry the higher urbanized flows. Culverts and other artificial grade-control structures can often cause downstream scour or upstream sediment deposition if not properly installed or maintained. Culverts in urban streams can often become migration barriers for aquatic biota such as anadromous fish or amphibians. In addition, if not properly sized for urban streamflows, culverts can cause significant localized flooding.

It has been hypothesized that urban streams will eventually adjust to their post-development hydrologic

Figure 4-9: Changes in Stream-Channel Geomorphology Due to Urbanization



Source: Neller, 1989

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regime and sediment supply. There is evidence that this is the case in some regions, such as Vancouver, British Columbia, Canada (Finkebine et al., 2000) and in the Puget Sound region (Booth and Henshaw, 2001) where some urban streams seem to have stabilized several decades after build-out was completed.

In other situations, rapid channel down-cutting, known as incision, can be especially dramatic in urbanizing streams, particularly in regions with unconsolidated soils or where in-stream (e.g., LWD) structure is lost (Shields et al., 1994). In the Pacific Northwest, incision can result when increased flow and loss of LWD that dissipates energy occur in relatively steep channels with easily erodible substrate (Booth, 1991). While all channel damage is ecologically detrimental, incision is especially problematic because it removes virtually all habitat and supplies great quantities of sediment that do further damage downstream (Booth and Henshaw, 2001).

Land-use encroachment into floodplain areas and flood-control measures such as dikes and levees can also simplify and straighten a stream channel. This can exacerbate downstream channel alterations (Graf, 1975). In addition to channel modifications carried out during urban development, many streams have residual channelization impacts from past agricultural activities. Stream bank armoring or "rip-rapping" used to mitigate stream bank erosion can actually worsen downstream flooding and stream bank erosion problems. Storm event flows are unable to spread out onto the floodplain, and the increased velocities are transferred downstream along with the elevated sediment loads. There can also be a direct loss of channel migration zone (CMZ) as well as floodplain disconnection, as stream banks are armoring and development encroaches. Trimble (1997) demonstrated that channel enlargement due to the increase in watershed urbanization-driven flows caused extensive stream bank erosion, which accounted for 66 percent of the sediment transported downstream in an urban stream in San Diego, California.

Research in several locations suggests that flows larger than a two- to five-year frequency discharge can be sufficient to create large-scale channel disruption (Carling, 1988; Sidle, 1988; Booth, 1990). More than anything else, the greatly increased incidence of these flows explains the ecological vulnerability of urban streams. In addition to stream bank erosion and streambed scour or incision, higher urban streamflows can physically destroy or wash out in-stream structural elements, such as LWD. This can have a negative feedback effect on the stream channel. As higher flows wash out more and more LWD, the channel becomes even more unstable and more susceptible to further geomorphic degradation. Under these conditions, stream channels can actually "unravel" as the combined effects of channel incision, enlargement, and erosion continue to impact the stream system (Horner et al., 1997).

Two similar studies, one in Maine (Morse, 2001) and one in the Puget Sound region (May et al., 1997), demonstrated that stream bank erosion was related to the level of watershed imperviousness and linked directly to the shift in hydrologic regime. This is not to say that stream bank erosion and other geomorphic changes are only driven by urbanization. Booth (1991) and Bledsoe (2001) both reported that geomorphic change in response to urbanization depends on other factors, such as underlying geology, vegetation structure, and soil type.

Stream bank erosion and streambed scour resulting from the urban streamflow regime described previously can result in the production of excessive quantities of fine sediment (Nelson and Booth, 2002). This increase in sediment yield can be especially acute during the construction phase of development when runoff from bare ground on construction sites can carry very high sediment loads. This change in sediment transport regime can change a stream from a meandering to a braided and aggrading channel form (Arnold et al., 1982).

The shift in sediment transport regime that typically accompanies urbanization can also result in excessive sedimentation of streambed habitats. Streambeds can also become embedded and ecologically non-functional with frequent deposits of fine sediment. In the Puget Sound region, it was found that the percentage of fine sediment in stream substrates used by salmon for spawning increased along with watershed urbanization (May et al., 1997).

When a watershed is finally fully built out, this situation can actually reverse as impervious surfaces become the dominant landscape feature. Under fully urbanized basin conditions, there is often a lack of sediment delivered to stream channels (Wolman, 1967; Booth, 1991; Pizzuto et al., 2000). Under highly urbanized conditions, streambeds can become armored and are, for the most part, ecologically non-functional (May et al., 1997).

As discussed above, the geomorphologic impacts of watershed urbanization include the following:

- Stream channel enlargement and instability;
- Stream bank erosion and fine sediment production;

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- Stream channel incision or down-cutting;
- Streambed scour and fine sediment deposition;
- Increase in streambed embeddedness;
- Riparian buffer (lateral) encroachment;
- Riparian corridor (longitudinal) fragmentation;
- Channelization and floodplain encroachment;
- Stream bank armoring and loss of CMZ;
- Increased sediment yields, especially during construction;
- Washout of in-stream LWD;
- Simplification of the natural drainage network, including loss of headwater channels and wetlands and lower drainage density;
- Modification of natural in-stream pool-riffle structure; and
- Fish and amphibian migration barriers (e.g., culverts and dams).

Degradation of Riparian Integrity

Riparian vegetation or the streamside forest is an integral component of all stream ecosystems. This is especially true of forested regions like the Pacific Northwest. A wide, nearly continuous corridor of mature forest, off-channel wetlands, and complex floodplain areas characterizes the natural stream-riparian ecosystems of the Pacific Northwest (Naiman and Bilby, 1998). Native riparian forests of the region are typically dominated by a complex, multi-layered forest of mature conifers mixed with patches of alder where disturbance has occurred in the recent past (Gregory et al., 1991). The riparian forest also includes a complex, dense, and diverse understory and ground cover vegetation. In addition, the extensive upper soil layer of forest "duff" provides vital water retention and filtering capacity for the ecosystem. A typical natural riparian corridor in the Puget Sound lowlands also includes a floodplain area, a channel migration zone (CMZ), and numerous off-channel wetlands. Natural floodplains, an unconstrained CMZ, and complex riparian wetlands are critical components of a properly functioning aquatic ecosystem (Naiman and Bilby, 1998). Organic debris and vegetation from riparian forests also provide a majority of the organic carbon and nutrients that support the aquatic ecosystem food web in these small lowland streams. In short, the riparian community (vegetation and wildlife) directly influences the physical, chemical, and biological conditions of the aquatic ecosystem. Reciprocally, the aquatic ecosystem affects the structure and function of the riparian community.

In addition to the characteristics of the riparian forest described above, the most commonly recognized functions of the riparian corridor include the following:

- Providing canopy-cover shade necessary to maintain cool stream temperatures required by salmonids and other aquatic biota. Regulation of sunlight and microclimate for the stream-riparian ecosystem (Gregory et al., 1991).
- Providing organic debris, leaf litter, and other allochthonous inputs that are a critical component of many stream food webs, especially in headwater reaches (Gregory et al., 1991; Naiman et al., 2000; Rot et al., 2000).
- Stabilizing stream banks, minimizing stream bank erosion, and reducing the occurrence of landslides while still providing stream gravel recruitment (Naiman et al., 2000).
- Interacting with the stream channel in the floodplain and channel migration zone (CMZ). Retention of flood waters. Reduction of fine sediment input into the stream system through floodplain sediment retention and vegetative filtering (Naiman et al., 2000).
- Facilitating the exchange of groundwater and surface water in the riparian floodplain and stream hyporheic zone (Correll, et al., 2000).
- Filtering and vegetative uptake of nutrients and pollutants from groundwater and stormwater runoff (Fischer et al., 2000).
- Providing recruitment of large woody debris (LWD) into the stream channel. LWD is the primary in-stream structural element and functions as a hydraulic roughness element to moderate streamflows. LWD also serves a pool-forming function, providing critical salmonid rearing, flow refugia, and enhanced instream habitat diversity (Fetherston et al., 1995; Rot, 1995; Rot et al., 2000).
- Providing critical wildlife habitat including migration corridors, feeding and watering habitat, and refuge areas during upland disturbance events (Gregory et al., 1991; Fischer et al., 2000; Hennings and Edge, 2003). Providing primary habitat for aquatic habitat modifiers such as beaver and

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many other terrestrial predators or scavengers associated with salmonid populations.

Based on the results of research in the Puget Sound region (May et al., 1997), the term *riparian integrity* was adopted to describe the conditions found in natural lowland stream-riparian ecosystems. These properly functioning conditions can serve as a template for evaluation and management of riparian areas. As used here, riparian integrity includes both structural and functional elements characteristic of the natural stream-riparian ecosystem. Land-use activities and development encroachment pressure can have a negative impact on native riparian forests and wetlands, which are intimately involved in stream ecosystem functioning. Riparian integrity includes the following components:

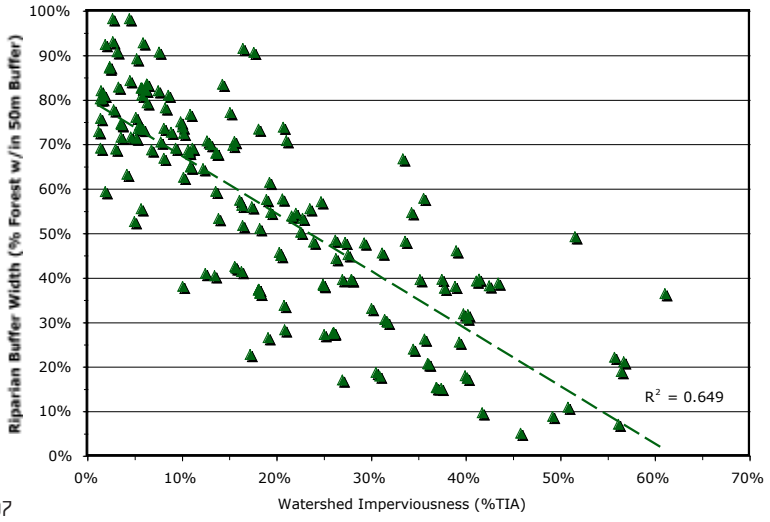
- Lateral riparian extent (so-called "buffer" width);
- Longitudinal riparian corridor connectivity (low fragmentation);
- Riparian quality (vegetation type, diversity, and maturity); and
- Floodplain and channel migration zone (CMZ) integrity.

In general, urban riparian buffers have not been consistently protected or well managed (Schueler, 1995; Wenger, 1999; Horner and May, 1999; Moglen, 2000; Lee et al., 2004). This is certainly true of the Puget Sound region (Figure 4-10). Several factors reduce the effectiveness of riparian buffers in urbanizing watersheds. The surrounding land use may overwhelm the buffer, and human encroachment continues to occur in spite of established buffer zones. Buffers that are established by regulation during the construction phase of development are rarely monitored by jurisdictional agencies. Over the long term, oversight and management of buffer areas is often taken on by property owners, who frequently are not familiar with the purpose or proper maintenance of the buffer (Booth, 1991; Schueler, 1995; Booth et al., 2002).

Ideally, the riparian corridor in a developing or developed watershed should mirror that found in the natural ecosystems of that region. Due to the cumulative impacts of past and present land use, this is often not the case (Figure 4-11). One example of this is the fragmentation of riparian corridors by roads, utility crossings, and other man-made breaks in the corridor continuity (Figure 4-12). Results from studies in the Pacific Northwest and other regions indicate that streams with a high level of riparian integrity have a greater potential for maintaining natural ecological conditions than streams with urbanized riparian corridors (May and Horner, 2000; Hession et al., 2000; Snyder et al., 2003). However, buffers can provide only a partial mitigation for urban impacts on the stream-riparian ecosystem. At some point in the development process, upland urbanization and the accompanying disturbance is likely to overwhelm the ability of buffers to mitigate for urban impacts.

There are certain problems associated with the loss of functional riparian floodplain corridors around streams

Figure 4-10: Relationship Between Riparian Buffer Width and Impervious Surface Area in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

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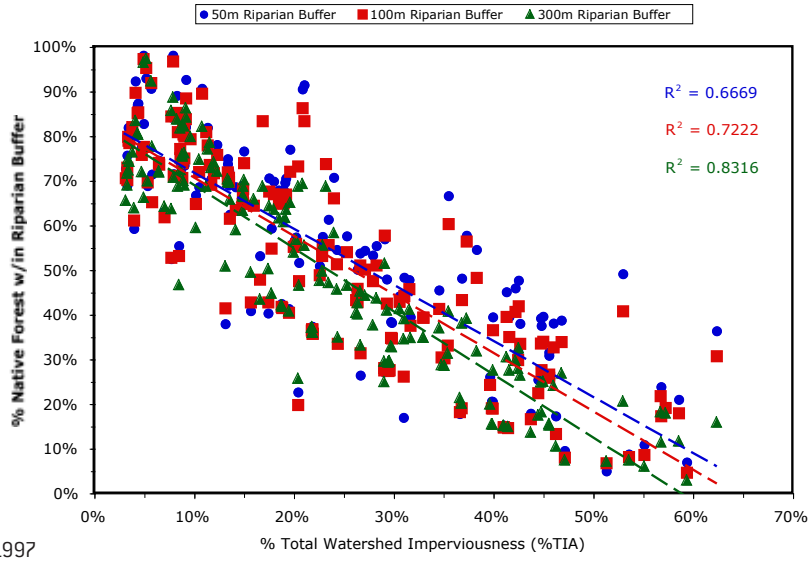
in urbanizing watersheds. These include changes in food web dynamics, higher stream temperatures, loss of instream habitat complexity (LWD), invasive species, stream bank erosion and greater inputs of sediment, excessive nutrient inputs, inflows of anthropogenic pollutants, and loss of wildlife habitat.

Stream temperature is regulated mainly by the amount of shade provided by the riparian corridor. This is an important variable affecting many instream processes such as the saturation value for dissolved oxygen (DO) in the water, OM decomposition, fish egg and embryonic development, and invertebrate life history (Paul and Meyer, 2001). Removal of riparian vegetation, reduced groundwater recharge, and the "heat island" effect associated with urbanization all can affect water temperature of streams, lakes, rivers, wetlands, and nearshore marine areas.

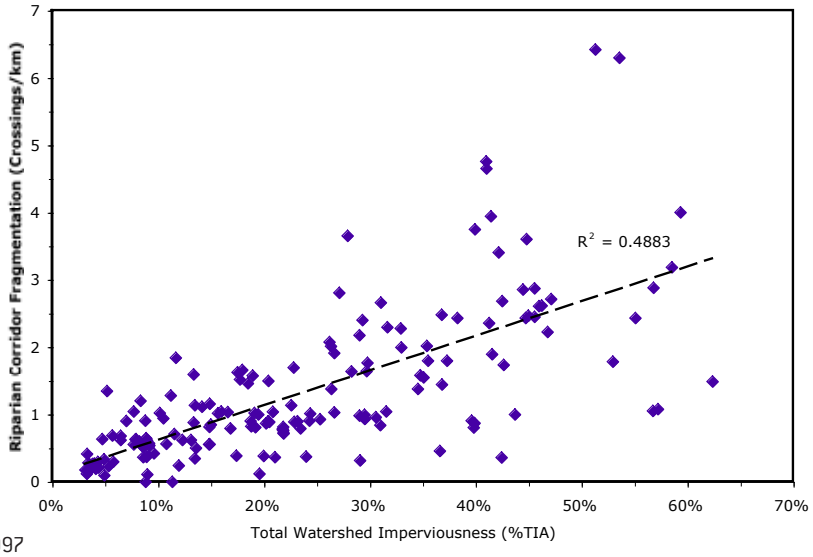
Invasive or exotic plants are another problem common to urban stream and wetland buffers. Human encroachment and landscaping activities can introduce

Figure 4-11: Relationship Between Riparian Quality and Impervious Surface Area in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

Figure 4-12: Relationship Between Riparian Corridor Fragmentation and Impervious Surface Area in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

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exotic or invasive species into the riparian zone. These plants often out-compete native species, which can result in nuisance levels of growth.

Based on our current level of knowledge, the extent and configuration of urban riparian corridor buffers needed to protect the natural structure and function of the stream-riparian ecosystem cannot be described using a simple formula. Because of regional, watershed-scale, and site-level differences, as well as political issues, this is a fairly complex problem. The ecological and socio-economic value of the resource being protected should be considered when a riparian buffer or management zone is established. In addition, the local watershed, site, and riparian vegetation characteristics must be considered as well. The type and intensity of the surrounding land use should also be factored into the equation so that some measure of physical encroachment and water-quality risk is made. Finally, the riparian functions that need to be provided should be evaluated. Figure 4-13 illustrates how this might be done (Sedell et al., 1997).

Effects of Urbanization on Stream Habitat and Biota

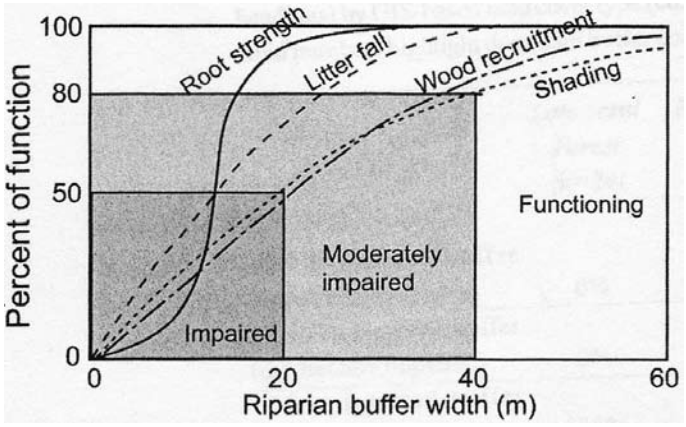
Degradation of aquatic habitat is one of the most significant ecological impacts of the changes that accompany watershed urbanization. The complex physical effects from elevated urban streamflows, stream channel alterations, and riparian encroachment can damage or destroy stream and wetland habitats. In addition to the indirect effects of habitat degradation or loss, aquatic biota can be directly affected by the cumulative impacts of urbanization.

Biological degradation is generally manifested more rapidly than physical degradation. Aquatic biota tend to respond immediately to widely fluctuating water temperatures, water quality, reduced OM inputs or other food sources, more frequent elevated streamflows, greater wetland water level fluctuations, or higher sediment loads. These stressors may prove to be fatal to some sensitive biota, impair the physiological functions of others, or encourage mobile organisms to migrate to a more habitable environment.

Ecological and biological effects of watershed urbanization include the following:

- Loss of instream complexity and habitat quality due to increase in bankfull flow frequency and duration.
- Reduced habitat due to channel modifications, and reduced baseflows causing crowding and increased competition for refuge and foraging habitat.
- Shifts in populations and communities of environmentally sensitive organisms to biota more tolerant of degraded conditions. Reduced biota abundance and biodiversity.
- Scouring and washout of biota and structural habitat elements from urban stream channels.
- Sediment deposits on gravel substrates where fish spawn and rear young and where algal and invertebrate food sources live. Reduced survival of egg and embryonic life stages.

Figure 4-13: Relationship Between Riparian Function and Buffer Width



Source: FEAMT, 1993

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- Direct loss of habitat due to the replacement of natural stream channels and wetlands with engineered drainage channels and stormwater treatment ponds.
- Loss of ecologically functional pool-riffle habitat characteristics in stream channels. Loss of deep-water cover in rearing habitat and loss of spawning habitat.
- Aesthetic degradation and loss of recreational beneficial uses.
- Direct effects of suspended sediment on aquatic organisms, like abrasion of gills and other sensitive tissues, reduced light for photosynthesis, reduced visibility for catching food and avoiding predators, and transport of metallic, organic, oxygen-demanding, bacterial, and nutrient pollutants.
- Reduction in pool area and quality. Loss of refuge habitat for adult and juvenile fish.
- Loss of riparian vegetation, resulting in stream bank erosion, loss of shading and temperature regulation, reduced leaf-litter and OM input, loss of overhanging vegetation cover, and reduced LWD recruitment.
- Loss of LWD function, including hydraulic roughness, habitat formation, and refugia habitat.
- Increased summer temperatures because of lower baseflow and less water availability for heat absorption. Decline in DO from the lower oxygen solubility of warmer water.
- Less dilution of pollutants as a result of lower baseflows, which in turn results in higher concentrations and shallower flow that can interfere with fish migrations and localized movements.
- Increased inorganic and organic pollutant loads with potential toxicity impacts.
- Increased bacterial and pathogen pollution, which can result in an increase in disease in aquatic biota and humans.
- Elevated nutrient loading and resultant eutrophication of lake, wetland, and estuarine habitats. Reduced DO as a possible result of eutrophic conditions, which in turn reduces usable aquatic habitat.
- More barriers to fish migration, such as blocking culverts and diversion dams.
- Overall loss of habitat quality, complexity, and diversity due to channel and floodplain simplification or loss.

Numerous studies have documented the effect of watershed urbanization on the degradation of instream habitat and the decline of native biota. These include research from almost all parts of country and from developed countries around the world. The earliest research efforts to study the cumulative impacts of urbanization on small-stream habitat and stream biota were conducted in the Puget Sound region (Richey, 1982; Scott, 1982; Steward, 1983) and in the Chesapeake Bay region (Ragan and Dietermann, 1975; Ragan et al., 1977; Klein, 1979). These were followed by even more comprehensive studies in the same regions and in other parts of the country. This section describes the findings of this body of research (see Table 4-2 for a research summary).

As discussed earlier, one of the most common effects of watershed urbanization on instream habitat is the loss of habitat quality, diversity, and complexity. This is the so-called "simplification" of urban stream characteristics. In undisturbed, properly functioning stream systems, the natural (mainly hydrologically driven) disturbance regime maintains the stream in a state of dynamic equilibrium. This means that the stream ecosystem is stable, but not static. Changes occur on several spatial and temporal time scales (Figure 4-14).

These changes can be small and subtle, such as a riparian tree falling into a creek (LWD recruitment) and forming a new pool habitat unit as the result of the hydro-geomorphic interaction of the streamflow and the LWD. Changes can also be large and catastrophic, such as those occurring during major flooding events that can rearrange the entire channel form of a stream system. Natural streams tend to have a level of redundancy and complexity that allows them to be resilient in responding to disturbance. Streams may change over time as a result of natural habitat-forming processes (flooding, fire, LWD recruitment, sediment transport, OM and nutrient cycling, and others), but they continue to support a complex stream-riparian ecosystem and a diverse array of native biota.

As mentioned above, the first Puget Sound stream research project compared ecological and biological conditions in an urbanized stream (Kelsey Creek) and a relatively natural stream (Big Bear Creek). Urbanized Kelsey Creek was found to be highly constrained by the encroachment of urban development, with 35

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Table 4-2: Summary of Research on Urban Stream Habitat, Water-Quality (WQ), and Biota					
Research Study	Habitat	WQ	Fish	Macro-invertebrates	Location
Ragan & Dietermann, 1975		x	x		MD
Klein, 1979	x	x	x		MD
Richey, 1982	x				WA
Pitt and Bozeman, 1982		x	x	x	CA
Steward, 1983			x		WA
Scott et al., 1986	x		x		WA
Jones and Clark, 1987		x		x	VA
Steedman, 1988				x	OT
Limburg & Schmidt, 1990		x	x		NY
Schueler & Galli, 1992			x		DC
Booth & Reinelt, 1993	x				WA
Lucchetti & Fuerstenberg, 1993			x		WA
Black & Veatch, 1994	x		x	x	MD
Weaver & Garman, 1994			x		VA
Lenat & Crawford, 1994	x	x	x	x	NC
Galli, 1994	x		x		DC
Jones et al., 1996	x	x		x	VA
Hicks & Larson, 1997	x				MA
Booth & Jackson, 1997	x				WA
Kemp & Spotila, 1997			x	x	PA
Maxted & Shaver, 1997	x			x	DE
May et al., 1997	x	x	x	x	WA
Wang et al., 1997	x		x		WI
Dali et al., 1998	x		x	x	MD
Harding et al., 1998	x		x	x	NC
Horner & May, 1999	x		x	x	WA
Kennen, 1999		x		x	NJ
MNCPPC, 2000	x		x	x	MD
Finkenbine et al., 2000	x				BC
Meyer & Couch, 2000	x		x	x	GA
Wang et al., 2000	x		x		WI
Horner et al., 2001	x		x	x	WA/TX/MD
Nerbonne & Vondracek, 2001	x		x	x	MN
Stranko & Rodney, 2001	x				MD
Wang et al., 2001	x		x		WI
Morse et al., 2002	x	x		x	ME

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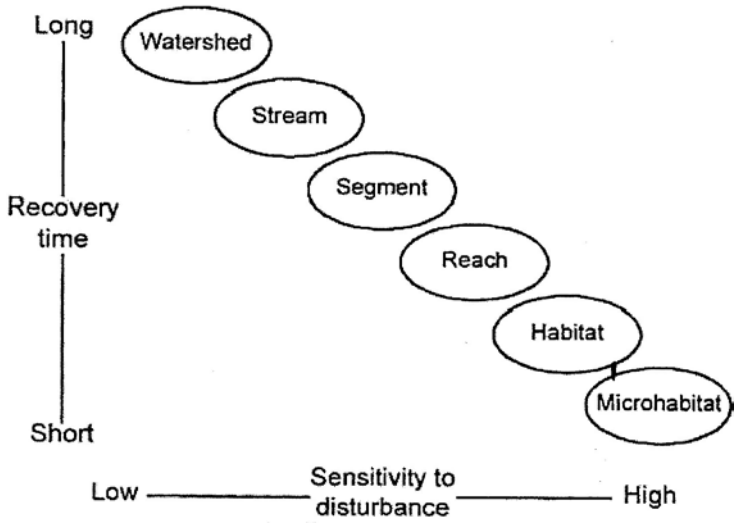
percent of the stream banks armored with "rip-rap" and the floodplain-riparian zone also highly modified. Bear Creek, on the other hand, had less than 10 percent stream bank armoring and a natural riparian corridor and CMZ. Road-crossing bridges and culverts were frequent on Kelsey Creek, but not on Bear Creek (Richey, 1982). LWD and other natural habitat complexity features common in Bear Creek were also lacking in Kelsey Creek (Steward, 1983).

In the Puget Sound comparison of urban and non-urban streams, Kelsey Creek, an urban stream, experienced twice the bed scour of its non-urban counterpart (Scott, 1982). As a consequence, sediment transport was three times as great in Kelsey Creek (Richey, 1982) and fines were twice as prevalent in its substrates (Scott, 1982). The invertebrate communities in different benthic locations produced 14 to 24 taxa in Bear Creek but only six to 14 in Kelsey Creek (Pedersen, 1981; Richey, 1982). Salmonid fish diversity also differed. Bear Creek had four salmonid species of different age-classes, whereas Kelsey Creek had only one non-anadromous species mainly represented by the 0- to 1-year age class (Scott, 1982; Steward, 1983). Although we cannot explicitly determine the relative roles of hydrology and habitat quality, much evidence shows that hydrologic alteration and the related sediment transport were most responsible for the biological effects (Richey, 1982).

Several studies in the Pacific Northwest examined various aspects of the influence of urban hydrology on salmon and salmon habitat. Data shows a significant decrease in young salmon survival in both large and small streams when events occur that are equal to or larger than the natural five-year frequency discharge. Since the frequency of events increases tremendously after urbanization, salmonids experience great difficulty in urban streams. These investigations also pointed out the relationship between urbanization level and biological integrity. The study rated channel stability along numerous stream reaches and related it to the proportion of the watershed's impervious areas. Stability was significantly higher where imperviousness was less than 10 percent (Booth and Reinelt, 1993). The study rated habitat quality along streams in two basins according to four standard measures. Marked habitat degradation occurred at 8 to 10 percent total impervious area (TIA). Population data on cutthroat trout and less tolerant coho salmon from streams draining nine catchments did not show a distinct threshold. They indicated, however, that population shifts are measurable with just a few percent of impervious area and become substantial beyond about 10 to 15 percent (Lucchetti and Fuerstenberg, 1993). Later studies in the same region confirmed this decline in salmonid abundance and diversity, as well as the degradation of salmon habitat at very low levels (5 to 10 percent TIA) of imperviousness in small urban streams (May, 1997; May et al., 1997; Horner and May, 1999).

More recent research projects in the Puget Sound region (May et al., 1997) and in Vancouver, British Columbia (Finkenbine et al., 2000) found that the degradation of instream and riparian habitat quality,

Figure 4-14: Stream Ecosystem Disturbance Regime



Source: Naiman, 1992

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diversity, and complexity are common features of urban streams. There appears to be a linear decline in most measures of habitat quality in relationship to the level of watershed urbanization or imperviousness. Instream LWD, which is a critical habitat complexity element in streams in forested watersheds, tends to become scarce when %TIA approaches the 10 to 20 percent range (May et al., 1997; Horner et al., 1997; Finkenbine et al., 2000). Streambed quality also declines as urbanization increases (May et al., 1997; Horner et al., 1997; Finkenbine et al., 2000). This decline in benthic habitat is typically characterized by higher levels of fine-sediment deposition, substrata embeddedness, streambed coarsening, and frequent streambed scour events.

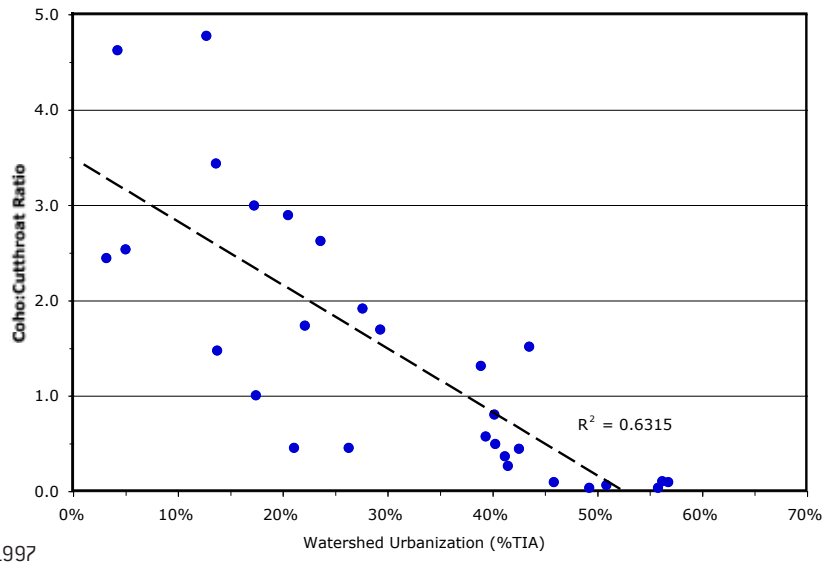
Similar to these studies in the Pacific Northwest, Morse (2003) observed that both instream habitat and water quality in small urbanizing streams in Maine declined in a linear fashion. Studies in Delaware (Maxted and Shaver, 1997), Wisconsin (Wang et al., 1997), and Minnesota (Nerbonne and Vondracek, 2001) confirm this trend. These findings have also been replicated in other countries, most notably in Australia (Davies et al., 2000) and New Zealand (Allibone et al., 2001).

This simplification of the stream channel and loss of instream habitat complexity results in a restructuring of the stream fish community in the urbanized creek. Urban impacts had a much greater impact on coho salmon (*Oncorhynchus kisutch*) than on cutthroat trout (*Oncorhynchus clarki*), which appear to be more tolerant of urban stream conditions (Scott et al., 1986). Pitt and Bissonnette (1984) and Lucchetti and Fuerstenberg (1993) also found similar results in other studies of streams in the Puget Sound lowland eco-region. Coho salmon, which normally out-compete cutthroat trout in natural streams, appear to be more sensitive to changes associated with urbanization and therefore decline in abundance as urban development increases (May, 1997; May et al., 1997; Horner et al., 1997; Horner and May, 1999). Figure 4-15 illustrates the shift in salmonid species found in urbanizing streams in the Puget Sound lowland eco-region.

Ragan and Dietermann (1975) attributed the loss of fish species diversity in urban streams in the Chesapeake eco-region of Maryland to the cumulative effects of urban development. A study in Ontario, Canada (Steedman, 1988) also found a shift in fish community structure due to the cumulative impacts of watershed land use and riparian corridor encroachment. Similar results were seen for fish community structures in New York (Limburg and Schmidt, 1990), Virginia (Weaver and Garman, 1994), Pennsylvania (Kemp and Spotila, 1997), North Carolina (Harding et al., 1998), and Georgia (Gillies et al., 2003).

A study in Mississippi found that instream habitat quality in urbanizing stream channels impacted by high-flow incision was significantly inferior to the quality of reference stream channels in undeveloped watersheds. In addition, the reference streams had greater mean

Figure 4-15: Relationship Between Stream Biological integrity, as Measured by Salmon Diversity, and Watershed Development, as Measured by Impervious Surface Area, in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

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water depths, more channel complexity in the form of woody debris, and more deep pool refuge habitat than the impacted streams. Relative to the reference streams, fish assemblages in the incised stream channels were composed of smaller fish and fewer species (Shields et al., 1994).

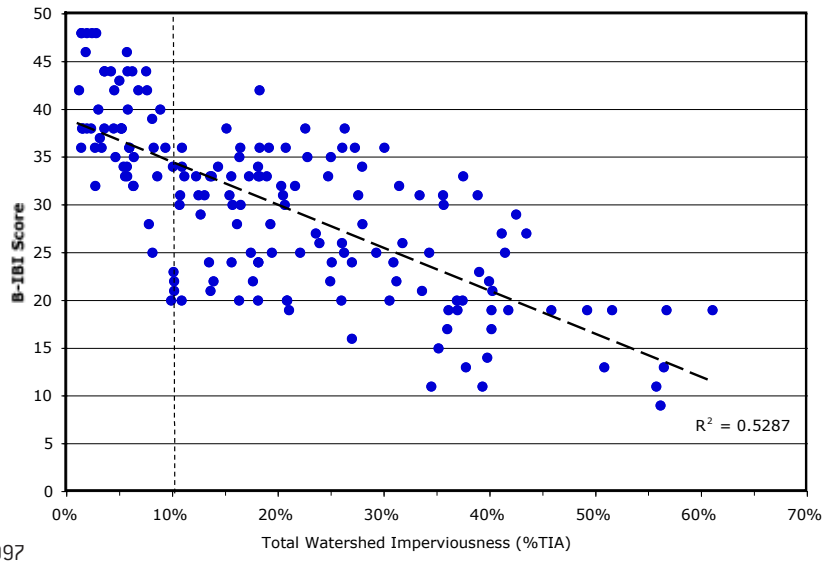
In several extensive studies of urbanizing streams in Wisconsin, a significant relationship was found between watershed land use and instream habitat as well as stream fish communities (Wang et al., 1997; Wang et al., 2000; Wang et al., 2001). In these studies, stream fish abundance and diversity both declined as watershed development increased above the 8 to 12 percent total impervious range. These studies also compared agricultural impacts to urban impacts, finding that urbanization was more severe and longer lasting. Habitat destruction and water-quality degradation were found to be the main contributing factors to the overall decline in stream ecosystem health. In addition, natural riparian vegetation (buffer) conditions had a significant influence on instream habitat conditions and appeared to at least partially mitigate some of the negative impacts of watershed urbanization (Wang et al., 2001).

A study in Washington, DC (Galli, 1991) investigated the local thermal impacts of urban runoff on stream ecosystems and reached the following conclusions:

- Air temperature was the strongest influence on stream water temperature.
- Average stream temperature increased linearly with stream sub-basin imperviousness.
- Some temperature criteria violations occurred just above 10 percent TIA and increased in severity and frequency with more imperviousness.
- All tested structural stormwater treatment facilities under best management practice (BMP) that had a surface discharge caused some violations of temperature criteria under both baseflow and storm runoff conditions.
- Based on the findings from a literature review, the investigators concluded that the thermal conditions produced by urban runoff and treatment facilities could cause succession from cold-water diatoms to warm-water filamentous green and blue-green algal species, as well as severe impacts on cold-water invertebrates and fish. A shift from cold-water community composition to warm-water organisms and exotic species is very possible in highly urbanized watersheds.

It should be noted that the life cycles of native fish can differ significantly even among closely related species. Attention must be paid to the life history specifics and habitat requirements of the various species of concern in the urban watershed being managed before any decisions are made on conservation, restoration, or mitigation of stormwater runoff impacts. Different fish carry out their migrations, reproduction, and rearing

Figure 4-16: Relationship Between Stream Biological integrity, as Measured by the Benthic-Macroinvertebrate Index of Biotic Integrity (BIBI), and Watershed Development, as Measured by Impervious Surface Area, in Urbanizing Watersheds in the Puget Sound Region of the Pacific Northwest



Source: May et al., 1997

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at different times and have freshwater stages of various lengths. Management must ensure that all life stages (egg, embryonic, juvenile, and/or adult) have the habitat conditions needed at the right time and that no barriers to migration exist.

The Ohio Environmental Protection Agency (OEPA) has an extensive database relating watershed development and land use to fish abundance and diversity. This data suggests that there are multiple levels of fish response to increasing urbanization. At the rural level of development (under 5 percent urban land use), sensitive species begin to disappear from streams. In the 5 to 15 percent urban land-use range (suburban development), habitat degradation is common and fish continue to decline in abundance and diversity. In addition, aquatic invertebrates also decline significantly. Above 15 percent watershed urbanization, habitat degradation, toxicity effects from physio-chemical water pollution, and nutrient enrichment result in severe degradation of fish fauna (Yoder et al., 1999). There have been similar findings in studies in Alabama (Onorato et al., 2000) and North Carolina (Lenat and Crawford, 1994).

The cumulative effects of urbanization, including altered hydrologic and sediment transport regimes as well as channel modifications and degraded instream habitat, were also found to cause a shift in the aquatic insect communities of urban streams in the Puget Sound region (Pedersen and Perkins, 1988; May et al., 1997; Horner and May, 1999; Morley and Karr, 2002). This relationship between watershed urbanization, stormwater runoff pollution, and aquatic insect community taxonomic composition has also been observed in small stream studies in northern Virginia (Jones and Clark, 1987; Jones et al., 1994), Pennsylvania (Kemp and Spotila, 1997), New Jersey (Kennen, 1999), and Maine (Morse, 2002). These findings have also been replicated in other countries, most notably in Australia (Walsh et al., 2001) and New Zealand (Collier and Winterbourn, 2000).

Aquatic insects and other macroinvertebrates have been found to be useful indicators of environmental conditions in that they respond to changes in natural land cover and human land use (Black et al., 2004). Overall, there tends to be a decline in taxa richness or species diversity, a loss of sensitive species, and an increase in tolerant species (such as chironomids) due mainly to the cumulative impacts of watershed urbanization: altered hydrologic and sediment transport regimes, degradation of instream habitat quality and complexity, stream bed fine sediment deposition, poor water quality, and the loss of native riparian vegetation. In many cases, the myriad of aquatic insects and benthic macroinvertebrates sampled from streams or wetlands are combined into a set of indices to standardize comparisons between stream samples. Often the mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) are combined into an "EPT" index. In some cases, multi-metric indexes have been developed that include several measures of the characteristics of the stream macroinvertebrate community. The EPA Rapid Bioassessment Protocol (RBP) and the Benthic Index of Biotic Integrity (BIBI) are examples of this (Karr, 1998). Figure 4-16 illustrates the BIBI scores for urbanizing streams in the Puget Sound lowland eco-region.

Ecological Impacts of Urban Stormwater Runoff Quality

Background

In addition to the hydrologic and physical impacts of stormwater runoff generated by the urbanization process, there are water-quality impacts to aquatic ecosystems and biota that result from exposure to the pollutants found in urban runoff. Stormwater runoff from urbanized areas is generated from a number of sources including residential areas, commercial and industrial areas, roads, highways and bridges. Essentially, as discussed earlier, any surface that does not have the capability to store and infiltrate water will produce runoff during storm events. These are the previously discussed impervious surfaces. As the level of imperviousness increases in a watershed, more rainfall is converted to runoff.

Impervious surfaces (roads, parking lots, rooftops, etc.) are the primary source areas for pollutants to collect within the built environment. Runoff from storm events then carries these pollutants into natural waters via the stormwater conveyance network. The land use (e.g., residential, commercial, and industrial) and human activities (e.g., industrial operations, residential lawn care, and vehicle maintenance) characteristic of a drainage basin largely determine the mixture and level of pollutants found in stormwater runoff (Weibel et al., 1964; Griffin et al., 1980; Makepeace et al., 1995; Pitt et al., 1995).

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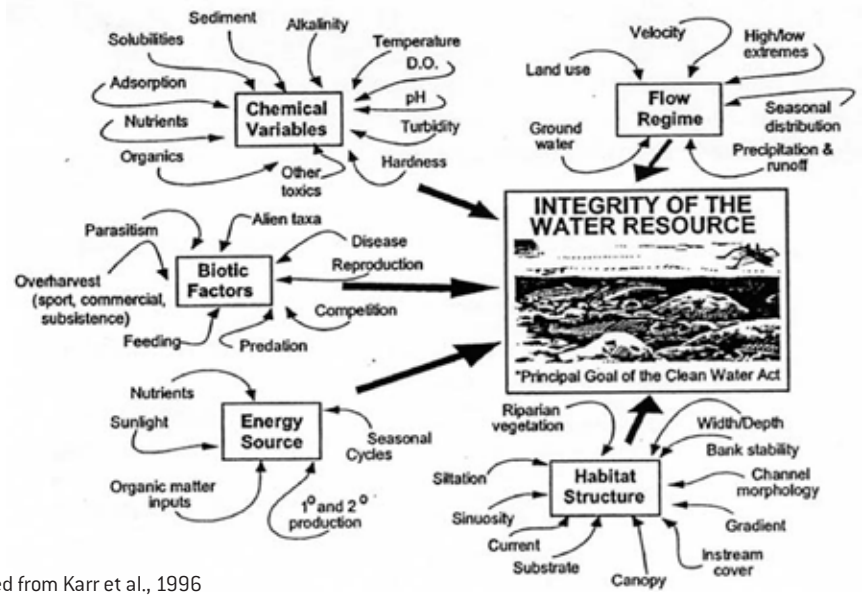
As was discussed in detail in the previous chapter, stormwater is a form of non-point source (NPS) pollution and typically contains a mixture of pollutants, including metals, petroleum hydrocarbons, and organic toxicants (i.e., pesticides, herbicides, and industrial chemicals). The National Urban Runoff Program (NURP) identified stormwater as a significant source of potentially toxic pollutants to receiving waters (EPA, 1983). Other studies have confirmed the NURP findings and improved the level of knowledge with regard to stormwater pollution impacts (Ragan and Dietermann, 1975; Pitt and Bozeman, 1982; Field and Pitt, 1990; Bannerman et al., 1993). Two of the most common stormwater pollutant components are petroleum hydrocarbon compounds and metals (e.g., zinc, copper, lead, chromium, etc.). Hydrocarbon sources include vehicle fuels and lubricants (Hoffman et al., 1984; Fram et al., 1987; Smith et al., 2000). Metals are also associated with vehicle maintenance, roads, and parking areas (Wilber and Hunter, 1977; Davies, 1986; Field and Pitt, 1990; Pitt et al., 1995). Pesticides, herbicides, and other organic pollutants are also commonly found in stormwater flowing from residential and agricultural areas (Pereira et al., 1996; USGS, 1997; Fan et al., 1998; Black et al., 2000; Foster et al., 2000; Hoffman et al., 2000). Studies in Puget Sound confirm these findings for our region (Hall and Anderson, 1986; May et al., 1997; USGS, 1997; Black et al., 2000). In many cases, even banned pesticides such as DDT or other organo-chlorine-based pesticides (e.g., chlordane and dieldrin) can be found in urban stream sediments. Toxic industrial compounds such as PCBs can also be present in urban runoff (Black et al., 2000). In general, the more intense the level of urbanization, the higher the pollutant loading, and the greater the diversity of land-use activities, the more diverse the mixture of pollutants found in stormwater runoff (Herricks, 1995; Makepeace et al., 1995; Pitt et al., 1995).

As discussed in the previous chapter, the transport and fate mechanisms of stormwater pollutants in receiving waters tend to be highly variable and site-specific. Pollutants are often transported from source areas (roads, parking lots, lawns, etc.) to receiving waters via roadside ditches, stormwater pipes, or by atmospheric deposition. In general, the concentration of pollutants found in stormwater runoff is much higher than that found in receiving waters, due mostly to dilution and removal mechanisms. In addition, most stormwater pollutants are typically found in particulate form, attached to fine sediment particles and organic matter (Pitt et al., 1995). This is especially true for nutrients, organics, and metals. In most cases, the particulate forms of toxic pollutants tend to be less "bio-available" (Herricks, 1995).

Because of the potential for accumulation of pollutants in sediment and the potential of sediments as sources of toxics, polluted sediments likely play an important role in many of the biological impacts associated with stormwater runoff. In general, most pol-

Figure 4-17: Stream Ecological Integrity Conceptual Diagram



Source: Adapted from Karr et al., 1996

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lutants, especially metals, are found in particulate forms within the water column or sediments, and pollutant concentrations tend to be higher for smaller sediment particle sizes (DePinto et al., 1980).

As discussed earlier, physical variables such as flow regime and instream habitat are important to native biota, as are chemical factors like water or sediment quality (Figure 4-17). Human activities in urbanizing watersheds can lead to both physio-chemical pollution and biophysical alterations of stream habitats. The evaluation of cumulative ecological urban impacts can be problematic where both types of stressors occur. The relative importance of one stressor as compared to another is difficult to quantify, especially when antagonistic or synergistic effects are present. For example, effects of contaminants can also be masked by instream or riparian habitat degradation. All of these variables need to be quantified in order for a complete assessment of the impact of stormwater on human health, aquatic ecosystems, and instream biota to be developed (Horner et al., 1997).

Stormwater Toxicity in Freshwater

Current stormwater monitoring and impact assessment programs indicate that the most likely cause for degradation of biological integrity in receiving waters is a combination of physical habitat degradation, changes in the hydrologic regime, food web disruptions, and long-term exposure to anthropogenic contaminants (Pitt, 2002). However, chronic or acute exposure to potentially toxic contaminants may be especially problematic for benthic organisms such as macroinvertebrates and for organisms that have a benthic life stage (e.g., salmonids during their embryonic development stage). Acute toxicity of aquatic biota due to exposure to stormwater runoff in receiving waters is rare (Pitt, 2002).

Current research appears to indicate that even when stormwater toxicity is high, it is only for short periods of time during episodic storm events. It has been hypothesized that relatively short periods of exposure to toxic compounds at the levels normally found in stormwater are not sufficient to produce mortality in aquatic organisms. This is often based on the assumption that most of the toxic chemicals found in stormwater are found in particulate form and are not bioavailable. This school of thought holds that most of the toxicity problems observed in urban receiving waters are a result of illegal discharges or dumping and that the risk from stormwater and sediment-bound toxics is low. However, this view tends to ignore the cumulative impacts of frequent exposures of organisms in receiving waters to stormwater as well as the potential release of toxics from sediments due to changes in ambient water chemistry. In reality, urban stormwater runoff has been found to cause significant receiving water impacts on aquatic biota (Burton and Pitt, 2001).

Evaluation of stormwater or receiving water quality is a complex and expensive project. The type and quantity of stormwater constituents are highly variable, depending on land use and human activities in the source area of concern. There are also numerous confounding factors that influence how stormwater interacts with receiving waters. In addition, the relationship between observed biological effects on receiving water and possible causes (including stormwater-related toxicity) are especially difficult to identify, let alone quantify. Countless antagonistic and synergistic chemical relationships exist among the constituents in stormwater runoff and receiving waters. Physio-chemical transformations can render toxic substances harmless or create toxic mixtures from individually harmless compounds. Contaminants can also be associated with suspended sediment particles or mobilized from streambed sediments due to scour during high-flow events (Mancini and Plummer, 1986). It is likely that in most situations, multiple stressors and cumulative impacts play a significant role in the decline of biological integrity.

Many studies have shown the detrimental effects of stormwater runoff on receiving water biota. However, few studies have demonstrated a direct cause-and-effect relationship between stormwater and toxicity to aquatic biota. Beginning with the National Urban Runoff Program or NURP (EPA, 1983), numerous studies have focused on determining the chemical characteristics of stormwater. An update of the NURP stormwater data was conducted in 1999 (Smullen et al., 1999). There have also been several studies on the toxicological effects of stormwater on aquatic biota.

Pitt and Bozeman (1982) studied the impacts of urban runoff on stream water quality and biological conditions in Coyote Creek in the San Francisco Bay area. The results of this study indicated that water and sediment quality were significantly degraded by urban stormwater runoff (Pitt and Bozeman, 1982). There was also some evidence of bioaccumulation of urban pollutants in plants, fish, and macroinvertebrates resident to the system (Pitt and Bozeman, 1982).

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Studies of urban streams in Bellevue, Washington examined the ecological and biological impacts of stormwater runoff (Perkins, 1982; Richey, 1982; Scott et al., 1982; Pitt and Bissonette, 1983). These studies documented the physio-chemical water quality and instream habitat degradation due to watershed development and stormwater runoff. Massive fish kills in Kelsey Creek were also observed during one of these studies. These fish kills were attributed to illegal dumping of toxic chemicals into local storm drains.

Medeiros and Coler (1984) used a combination of laboratory flow-through bioassay tests and field experiments to investigate the effects of urban stormwater runoff on fathead minnows and observed chronic effects of stormwater toxicity on growth rates in the test organisms.

Hall and Anderson (1988) studied the effects of urban land use on the chemical composition of stormwater and its toxicity to aquatic invertebrates in the Brunette River in British Columbia. This study found that land-use characteristics and the antecedent dry period between rainfall events had the greatest influence on stormwater quality and toxicity. Toxicity in this study followed the land-use sequence commercial>industrial>residential>open space (Hall and Anderson, 1988). This study also identified the "first flush" effect as being significant from a toxicity standpoint. The longer the dry build-up period between storms, the higher the pollutant load and the greater the toxicity of stormwater runoff (Hall and Anderson, 1988).

A study of stormwater toxicity in Birmingham, Alabama utilized toxicity screening as the primary detection method (Pitt et al., 1995). Of the stormwater source area samples collected, 9 percent were classified as extremely toxic, 32 percent were moderately toxic, and 59 percent showed no evidence of toxicity. Vehicle service and parking areas had the highest levels of pollutants and potential toxicants. Metals and organics were the most common toxicants found in stormwater samples.

A field study in Milwaukee, Wisconsin investigated the effects of stormwater on Lincoln Creek (Crunkilton et al., 1997). Streamside toxicity testing was conducted using flow-through aquaria with fathead minnows. In addition, instream biological assessments were conducted along with water and sediment quality measurements. The results of the flow-through tests showed no toxicity in the fathead minnows until 14 days after exposure and 80 percent mortality after 25 days of exposure, indicating that short-term toxicity testing likely underestimates the toxicity of stormwater in receiving waters.

A study in North Carolina found that stormwater runoff from vehicle service and fueling stations had consistently elevated levels of polyaromatic hydrocarbon (PAH) compounds, MTBE, and other potentially toxic contaminants (Borden et al., 2002).

Runoff from agricultural or landscaped areas can also contain significant levels of potential toxicants, especially pesticides and herbicides (Liess et al., 1999; Thomas et al., 2001; Neumann et al., 2002; Arnold et al., 2004). These toxicants are also common in stormwater runoff from residential and urban landscaped areas (Pitt et al., 1995).

Sediment contaminated by stormwater runoff also has a detrimental effect on receiving water biota. Many of the observed biological effects associated with stormwater runoff and urban receiving waters may be caused by contaminated sediments, especially those impacts observed on benthic organisms. In addition, mortality of benthic invertebrates can be high in urban streams, especially during low flow periods, suggesting that toxicity associated with exposure to contaminated sediment, concentration of toxics in the water column, and/or ingestion of contaminated OM particulate is to blame (Pratt et al., 1981; Medeiros et al., 1983; Black et al., 2000).

Studies of urban stream sediments have shown the effects of metal toxicity on early life stages of fish and invertebrates (Boxall and Maltby, 1995; Hatch and Burton, 1999; Skinner et al., 1999; Lieb and Carline, 2000). Developmental problems and toxicity have been attributed to the contaminant accumulation in sediments and the remobilization of contaminated sediments during storm events (Skinner et al., 1999). Hatch and Burton (1999) also observed significant toxicity at a stormwater outfall site where sediments were found to be contaminated by multiple stormwater-related pollutants. Lieb and Carline (2000) showed that metals were more prevalent in stream sediments downstream of a stormwater treatment pond than upstream in a natural area. However, no acute toxic effects were noted. Zinc (Rose et al., 2000) and copper (Boulanger and Nikolaidis, 2003) are the most common metals found in urban sediments contaminated by stormwater runoff. These metals can be quite mobile under typical conditions found in urban receiving waters, but in most cases, a majority of the metal ions are bound to fine sediment particles and are not generally bioavailable. Examples of elevated levels of stormwater-related toxicants accumulating in urban

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stream sediments are numerous (Pitt, 2002). The levels of metals in urban stream sediments are typically orders of magnitude greater than those in the water column (DePinto et al., 1980; Pitt and Bozeman, 1982; Scott et al., 1983; May et al., 1997). Similar results are found when analyzing marine sediments from urban estuaries with stormwater discharges (Long et al., 1996; Morrisey et al., 1997; Bolton et al., 2003).

Stormwater Toxicity in Estuarine-Nearshore Areas

The effects of watershed development and stormwater runoff extend into marine waters at the mouths of streams (sub-estuaries) and in the nearshore environment of coastal regions. As with freshwater receiving waters, these impacts include physical, chemical, and biological effects.

Several studies on the toxic effects of water pollution on salmon have been conducted in the Puget Sound region and the Lower Columbia River Estuary in the Pacific Northwest (McCain et al., 1990; Varanasi et al., 1993; Casillas et al., 1995; Casillas et al., 1998; Collier et al., 1998). In these studies, there were demonstrable chronic toxilogical effects (immuno-suppression, reduced disease resistance, and reduced growth) of PAHs, PCBs, and other organic pollutants seen in juvenile and adult salmon.

A study of the Hillsborough River in Tampa Bay, Florida investigated the impacts of stormwater runoff on estuarine biota (MML, 1984). Plants, animals, sediment, and water quality were all studied in the field and supplemented by laboratory bioassay tests. No significant stormwater toxicity-related impacts were noted.

In a study of multiple stormwater discharge sites in Massachusetts Bay, high levels of PAH compounds were found in receiving waters and estuarine sediments (Menzie et al., 2002). Land use was a critical factor in determining pollutant composition and concentrations, with urbanized areas (mixed residential, commercial, and industrial land uses) having the highest pollutant (PAH) levels. No toxicity testing was conducted.

A study of stormwater discharges from Chollas Creek into San Diego Bay, California, indicated measurable toxic effects to aquatic life (Schiff et al., 2003). This study found that a toxic plume from the freshwater creek extended into the estuary, with the highest toxicity observed closest to the creek mouth. The toxicity decreased with increasing distance from the mouth due to mixing and dilution. Toxicity identification evaluation (TIE) methods were used, and it was found that trace metals from stormwater runoff were most likely responsible for the plume's toxicity to the sea urchins used in this study (Schiff et al., 2003).

A study of the water quality impacts of stormwater runoff into Santa Monica Bay, California also identified toxic effects in the estuarine receiving waters (Bay et al., 2003). As in the San Diego study, the freshwater plume from an urbanized stream (Ballona Creek) was responsible for the toxicity observed in marine organisms. Stormwater-transported metals (mainly zinc) were identified as the most likely toxic constituent. The only toxic effects noted were chronic, not acute. As in the previously discussed study, the toxicity decreased with increasing distance from the mouth due to mixing and dilution (Bay et al., 2003). Sediments in estuarine areas were also found to be highly contaminated by stormwater pollutants (Schiff and Bay, 2003).

Several studies on the toxic effects of stormwater runoff on native biota have been conducted in the Puget Sound region. One of the first studies looked at the uptake of aromatic and chlorinated hydrocarbons by juvenile chinook (McCain et al., 1990). This study found no acute toxicity, but identified numerous potential chronic impacts on growth and survival. In a related study, juvenile chinook salmon from both a contaminated urban estuary and a non-urban estuary were studied for two years (Stein et al., 1995). Exposure to aromatic and chlorinated hydrocarbons was measured, and both PAH and PCB levels in fish from the urban estuary were significantly higher than in fish from the non-urban estuary. The results of these studies indicate that out-migrant juvenile salmon have an increased exposure to chemical contamination in urban estuaries during their residence time in these habitats. This exposure was determined to be sufficient to elicit biochemical responses and to have the potential for chronic toxicity effects (Stein et al., 1995).

Runoff from urban areas can also contain significant levels of pesticides and herbicides at levels that have been shown to be potentially toxic to native biota (Bortleson, 1997; MacCoy and Black, 1998; Voss et al., 1999; Black et al., 2000; Hoffman et al., 2000). In a study conducted by King County, Washington, pesticides and herbicides in runoff and urban streams were linked to retail sales of the same pesticides within the urban watersheds under study (Voss and Embrey, 2000). The most common pesticides and herbicides detected during storm

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events included diazinon, 2-4-D, dichlorbenil, MCPP, prometon, and trichlopyr (Voss and Embrey, 2000).

Diazinon has been shown to have neurotoxic effects on salmon (Scholz et al., 2000). At sublethal levels, it was shown to disrupt homing behavior in chinook salmon by inhibiting olfactory-mediated responses (Scholz et al., 2000). This may have significant negative consequences for the survival and reproductive success of native salmonids.

Short-term exposures to copper (such as during storm runoff events in urban areas) have also been demonstrated to have sublethal effects on coho salmon by inhibiting the olfactory nervous system (Baldwin et al., 2003). In this study, the neurotoxic effects of copper were found to be dose-dependent, having a measurable effect over a broad range of concentrations. These effects occurred rapidly upon exposure to copper. It was concluded that short-term exposures can interfere with olfactory-mediated behaviors in juvenile coho salmon and may impact survival or migratory success of native salmonids (Baldwin et al., 2003).

Impacts of Contaminated Aquatic Sediment on Benthic Organisms

At some point in their life cycle, many aquatic organisms have their principal habitat in, on, or near sediment. Examples of this include benthic macroinvertebrates that spend almost their entire larval stage in contact with sediments. In the Pacific Northwest, salmonids also spend an extensive portion of their embryonic life stage within the benthic environment of their natal stream. In addition to functioning as benthic habitat, sediments can also capture and retain pollutants introduced by urban runoff. Pollutants enter sediments in several ways. The most direct path is the settling of suspended solids. Sediments deposited by urban runoff can physically degrade the substrata by filling interstitial spaces utilized as habitat by benthic organisms or by reducing DO transfer within the benthic environment. Dissolved pollutants can also move out of solution and into sediments by such mechanisms as adsorption of metals and organics at the sediment surface ion exchange of heavy metals in water with native calcium, magnesium, and other minerals in sediments, as well as the precipitation of phosphorus (Burton and Pitt, 2002).]

Most aquatic sediments have a large capacity to receive such contaminants through these processes. Also, many of the particulate pollutants are conservative. Once in the sediment, they do not decompose or significantly change form. These conservative pollutants include refractory organic chemicals relatively resistant to biodegradation as well as all metals. Consequently, these types of pollutants progressively accumulate in sediments. Over the long term, discharge of even modest quantities of pollutants can result in sediment concentrations several orders of magnitude higher than in the overlying water. These contaminant reservoirs can be toxic to aquatic life they come in direct contact with, as well as contaminate reservoirs far beyond the benthic (bottom-dwelling) organisms by bio-magnification through the food web (Burton and Pitt, 2002).

Historically, water quality has received more attention than sediment contamination. In the past 10 to 15 years, this approach has changed because of mounting evidence of environmental degradation in areas that meet water quality criteria. However, sediment toxicity investigations are limited because we lack accepted testing methods and do not understand the factors that control contaminant bioavailability. The result is an approach that emphasizes bioassay exposure techniques, either in situ or in the laboratory, along with chemical analysis of the sediments, overlying water, and/or sediment interstitial water. Very few studies have focused on the eco-toxicology of contaminated sediments in the natural environment (Chapman et al., 1998).

Case Study: Urban Stormwater and Metal Toxicity

Metals are a significant pollution component of urban stormwater runoff and non-point source (NPS) pollution. Heavy metals are of particular interest because many cannot be chemically transformed or destroyed and are therefore a potential long-term source of toxicity in the aquatic environment (Allen et al., 2000). Although the specific metals and their concentrations may vary widely depending on the anthropogenic sources present, they are common to almost all water pollution. Many trace metals are important as micronutrients for both plants and animals, playing essential roles in metabolism and growth. These include iron (Fe), zinc (Zn), copper (Cu), and Manganese (Mn), to name a few. Nutrient requirements vary between

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species, life stages, and sexes, but normal concentrations of these micronutrient trace metals are low and typically fall within a narrow acceptable band. Exposure to concentrations outside the optimal range can have deleterious or even toxic effects. Other trace metals which are not essential, such as lead (Pb), cadmium (Cd), and mercury (Hg) can be toxic at very low levels, either acutely or due to chronic/long-term exposure. Aluminum (Al), chromium (Cr), and nickel (Ni) are also found in urban runoff.

Anthropogenic sources of metal pollution are common throughout the environment. These include industrial processes, mining, and urban storm runoff. Urban runoff can contain a wide variety of trace metals from sewage discharges, fossil-fuel combustion, automobile traffic, anti-corrosion products, and various industrial sources. In general, the concentration, storage, and transport of metals in urban runoff or streams are closely related to OM content and sediment characteristics. Fine sediment, especially organic material, has a high binding capacity for metals, resulting, as mentioned above, in generally higher levels of metal contamination in sediments than in the water column (Rhoads and Cahill, 1999).

Several studies have been conducted to characterize the levels of metals in stormwater runoff, receiving waters, and sediments (Bryan, 1974; Wilbur and Hunter, 1979; Pitt et al., 1995; May et al., 1997; Neal et al., 1997; Sansalone and Buchberger, 1997; Barrett et al., 1998; Wu et al., 1996; Wu et al., 1998; Allen et al., 2000). Generally, the levels of various metals in stormwater are quite variable and dependent on a number of factors, including background watershed characteristics, land use practices, and specific sources (see discussion in Chapter 3).

Certain urban-stream organisms, including algae, arthropods, mollusks, and annelids, have exhibited elevated levels of metal concentrations (Davis and George, 1987). Ecological responses to metals occur at all levels in the ecosystem and include the loss of sensitive taxa, both chronic and acute toxicity effects, and altered community structure.

One study (Pitt et al., 1995) of urban stormwater samples, using the Micro-Tox toxicity-screening procedure, found that less than 10 percent of samples were classified as extremely toxic, a bit over 30 percent were moderately toxic, and the majority (about 60 percent) showed no evidence of toxic effects. The Micro-Tox methodology was only used to compare relative toxicities of various samples and not as a measure of absolute toxicity or to predict long-term toxic effects of stormwater on receiving waters. It does point to the fact that in all but a few heavily polluted systems, the level of toxicants in urban runoff is typically near detection limits (Pitt et al., 1995).

The toxicity of metals to aquatic plants and organisms is influenced by chemical, physical, and biological factors. Water chemistry characteristics such as temperature, pH, alkalinity, and hardness all affect metal toxicity. Physical aspects of exposure, such as metal speciation, duration of exposure, intensity of exposure events, and inorganic or organic ligand binding, also have a significant bearing on metal toxicity (Davies, 1986). Bioavailability of metals, the life stage of the affected organisms, organism health, and the natural sensitivity of the species involved are also important determinants of metal toxicity. Aquatic toxicology data generally indicates that the ionic fraction of metals constitutes the primary toxic form (Roline, 1988).

Acute toxicity to aquatic organisms can be manifested as a wide range of effects, from reduced growth rate to mortality. Laboratory studies on the mechanism of toxicity of zinc to fish in general indicate that zinc causes death via gill hypoxia (excess mucous secretion and suffocation) and gill tissue necrosis (Davies, 1986). Osmoregulatory failure appears to be the most likely effect of acute copper toxicity. Lead and mercury affect the central nervous system coordination of activity in fish, as well as interfering with cellular osmoregulation (Pagenkopf, 1983). The metal species present in solution and the ambient water chemistry can have a significant influence on metal toxicity. Consideration of total metal concentration alone can be misleading because chemical speciation of trace metals significantly affects the bioavailability to aquatic organisms and thus the ultimate toxicity (Davies, 1986). For the most part, organisms assimilate uncomplexed metal ions more readily than complexed forms. Increases in pH, alkalinity, and hardness generally decrease metal toxicity. Hardness (Ca^{+} and Mg^{++}) has an antagonistic effect on metal toxicity in that the calcium and magnesium ions compete with metal ions for uptake sites on the gill surfaces, thus reducing the toxic effects of the metal ions (Davies, 1986). Alkalinity reduces metal toxicity through the buffering mechanism of the carbonate system. Under pH control, the carbonate and bicarbonate ions complex metal ions into soluble or insoluble, less toxic forms (Pagenkopf, 1983). In most cases, in alkaline waters, metals do not reach toxic levels until their concentration overwhelms the natural buffering capacity of the carbonate system.

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Organic ligands can also complex metal ions, thus reducing toxicity by binding metals to particulates and making them relatively non-bioavailable. Metal toxicity generally increases when ambient temperature rises, due to the combined effects of an increase in both organism metabolism and chemical activity. Light intensity may also have a synergistic affect on the toxicity of some metals.

Chronic toxicity of metals is generally most apparent in the embryonic and larval stages of aquatic organisms and the early life stages of aquatic plants. As a period of rapid development, the early life stage is the most sensitive stage of the organism's life cycle for metal toxicity in general and other toxicants as well. Embryogenesis is a particularly sensitive period for fish with regard to metals (Davies, 1986). The period of larval settlement is the critical phase in invertebrate life history, although invertebrates as a whole are generally less sensitive than fish to trace/heavy metal toxicity (Nehring, 1976; Winner et al, 1980; Pratt et al, 1981; Garie and McIntosh, 1986). Chronic and sublethal effects of metals include reduced growth rates, developmental or behavioral abnormalities, reproductive effects, interference with metabolic enzyme systems, anemia, neurological defects, and kidney dysfunction (Davies, 1986). Due to the greater sensitivity of young organisms to metals, any exposures during embryonic development or rearing periods can, apart from the immediate effects, also manifest themselves in the adult organisms. There has been some indication that fish exposure to very low levels of metals during early life stages can result in an acclimation effect, making them somewhat more resistant to future periodic exposures (Davies, 1986). As with most toxicants, metal toxicity also increases with exposure period. Therefore, the intermittent nature of urban runoff may be less harmful to some aquatic life forms than continuous exposure to elevated metal concentrations would. Bioaccumulation of metals in organisms is also highly variable, depending on the particular metal, its chemical form, the mode of uptake, and the storage mechanisms of the organism. In low alkalinity (soft) waters, most metal species are of the "free" form. In alkaline (hard) waters, more metal ions are complexed, but some portion may remain in the ionic forms, especially if the buffering capacity of the natural water is overwhelmed. System pH also plays a major role in determining the speciation of the metal forms in freshwater (Davies, 1986). The rate of chemical (metals) reactions or chemical kinetics is also important to understanding the overall metal toxicity process. Such reactions as complexation do not occur instantaneously in natural waters. In the case of stormwater, runoff time scales may not allow sufficient time for complexation to take place, thus mitigating or negating the toxicity-reducing buffering effects (Pitt et al., 1995).

The use of aquatic insects and other macroinvertebrates as indicators of the biological integrity of lotic ecosystems is not new. One of the earliest field studies (Nehring, 1976) involved using aquatic insects as biological monitors of heavy metal pollution in the analysis and prevention of fish kills. Macroinvertebrates are generally more tolerant of metal pollution than most species of fish found in western streams (salmonids, sculpins, etc.) and tend to bioaccumulate metals in proportion to the in-water concentration (Nehring, 1976). In contrast to the more mobile fish species, macroinvertebrates are relatively sessile organisms. They also constitute an important part of the lotic food web, being the primary food source of most stream fishes. This makes them a useful surrogate for the economically and culturally important fish that inhabit the streams of the western states. In addition, some species of macroinvertebrates turned out to be more sensitive to metal pollution than others. This concept of "tolerant" and "sensitive" groups/species has become an important aspect of macroinvertebrate-based indices of pollution (Winner et al., 1980). In general, stoneflies (Plecoptera) and mayflies (Ephemeroptera) are sensitive to metal pollution, caddisflies (Trichoptera) are moderately sensitive/tolerant, and midges (Chironomids) are metal pollution-tolerant (Garie and McIntosh, 1986).

Field studies into the impact of urban runoff on lotic systems often use macroinvertebrate community structure as an indicator of ecosystem degradation. Many studies have found that, although urban runoff is the causal agent of ecosystem disruption, the impacts of stormwater pollution events are not just short-term. Partitioning of pollutants, especially metals, into sediments has been shown to have long-term ecological consequences on the primarily benthic-dwelling macroinvertebrate community structure (Pratt et al, 1981). In many cases, analysis of stormwater samples will not detect significant metals either in the dissolved or particulate form, but sediment samples will show metal accumulation bound to organic and inorganic ligands (Whiting and Clifford, 1983). Urban stormwater pollution is by its nature sporadic and acts as a physical and chemical pulse on the receiving water ecosystem. Higher levels of urban pollutants, such as metals and hydrocarbons, are typically found during "flushing"

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storm events (Pitt et al., 1995). Also coincident with these elevated pollution level events is increased flow over the period of the storm. These "scouring," high-energy flows have been shown to have a negative synergistic impact on benthic populations (Borchardt and Statzner, 1990). Some benthic species tend to migrate downstream or "drift" during stormflow conditions or pollutant events, while others try to avoid exposure by burrowing into the substrate.

One of the first comprehensive studies of the effects of urban runoff on benthic macroinvertebrates in streams was conducted on the East Coast (Garie and McIntosh, 1986). This was a typical upstream (control) compared to downstream (impacted) site study. Lead, zinc, and chromium were the predominant metals found in the stormwater. Macroinvertebrate diversity (number of taxa) and changes in community composition were used as the primary measures of impact. The results of this study again showed that there are both "tolerant" and "sensitive" species with regard to metal toxicity and urban runoff impact. The study also confirmed that elevated pollutant concentrations during urban runoff storm events were short-term and transient in nature, and it was hypothesized that the real impact on macroinvertebrate communities lay in long-term exposure to metals accumulating in the benthic sediments. This points out one of the potential flaws of using macroinvertebrates as biological surrogates for fish in that fish are generally not exposed to the sediment chemistry that the benthos are. Another very comprehensive study conducted in the Pacific Northwest showed that, although macroinvertebrate community structure was significantly changed due to urbanization impacts, the fish population structure of impacted and control streams remained largely the same (Pedersen and Perkins, 1986). Apparently, salmonids feed on available benthos and do not select for specific trophic groups or species. This is not to say that a shift in benthic community structure is not a good indicator of urban impact, but one must be careful in extrapolating the results of one group of organisms to other biota, even if they are closely linked within the food web. The PNW study also demonstrated a lack of consistency when trying to use complex macroinvertebrate diversity indices to gauge the level of urban impact. Natural variability was generally too high and effectively masked any well-defined correlations.

Aquatic insect sampling and analysis has, however, been shown to be very useful as a tool for assessing other impacts of metal pollution. The usefulness of benthic macroinvertebrates as monitors of bioavailable metal concentration and long-term bioaccumulation of metals has been demonstrated (Kiffney and Clements, 1993). Still other studies have highlighted the synergistic (negative) impacts of metals and other habitat degradations on aquatic ecosystems in general (Clements, 1994; Hoiland and Rabe, 1992). Finally, the persistence of sediment metal levels and resultant long recovery times has been shown for macroinvertebrate communities exposed to prolonged pollution inputs in the field (Chadwick et al., 1985).

Urban Runoff and Eutrophication

Watershed urbanization generally leads to higher nutrient (phosphorus and nitrogen) concentrations in stormwater runoff (Omernik, 1976). Phosphorus is generally found in particulate form, but the more bioavailable, dissolved forms are also common. Nitrogen is typically found in the nitrate or ammonium form. Sources of nutrients in urbanizing catchments include lawn and garden fertilizers, wastewater (failing septic systems and WWTP discharges), and fine sediment from erosion or street runoff. Although nutrient pollution is often associated more with agricultural activities, urbanization can contribute significant quantities of nutrients to receiving waters (Omernik, 1976).

Eutrophication is the process through which excess nutrients cause overall algal biomass increases, especially during "bloom" periods. This is due to increased loading of the nutrient that had previously been in shortest supply relative to need. This limiting nutrient is usually either phosphorus or nitrogen, but most often, and most consistently, it is phosphorus in freshwater lakes. In estuarine or marine nearshore areas, nitrogen is typically the limiting nutrient. In addition to promoting larger quantities of algae, nutrient enrichment typically changes the composition of the algal community. One-celled diatoms give way to filamentous green forms, followed by blue-green forms (some toxic) with a larger nutrient supply (Welch, 1980; Welch et al., 1988; Welch et al., 1989; Welch et al., 1992).

As discussed earlier, urban areas have a number of nutrient sources, and nutrient loadings increase with the development level. Eutrophication degrades lake and estuarine ecosystems in several ways. The filamentous algae are poorer food than diatoms to herbivores because

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of their structure and, sometimes, bad taste and toxicity. Filamentous algae clog water intakes and boat propellers and form odorous masses when they wash up on beaches. They also reduce water clarity, further limiting beneficial uses. When a large biomass dies at the end of the bloom, its decomposition by bacteria creates high oxygen demand, which can result in severely depressed DO levels (Welch, 1980; Shuster et al., 1986; Walker, 1987). In addition to algal blooms and the associated negative impacts, eutrophication may result in an overall increase in other nuisance plants, including a variety of submerged or emergent aquatic macrophytes. Some of these plant communities may include invasive species such as hydrilla, Eurasian milfoil, purple loosestrife, and reed canary grass (Welch 1980).

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CHAPTER 5

Aquatic Monitoring and Program Design

Obtaining conclusive data on urban water resources and stormwater runoff is difficult and expensive. Therefore, monitoring programs that collect data must be carefully designed to be cost-effective. This chapter suggests a general process for designing programs, whether the monitoring subject is natural or runoff water, sediments, or biological community characteristics or organisms. The recommended system thus applies to the design of monitoring programs whose elements are detailed in Chapters 6 and 7.

This process originated in research to improve monitoring program design in urban runoff and related fields (Reinelt, Horner, and Castensson, 1992; Reinelt, Horner, and Mar, 1988; Mar et al., 1986). Burton and Pitt (2002) have written very extensively on all aspects of monitoring program design and execution. Their Chapter 4 covers the program design aspects of monitoring and presents a number of case studies. Some citations to that work are given in this and the two following chapters. Those who wish to pursue any subject in detail should consult Burton and Pitt, using their helpful 37-page index.

The suggested analytical process has five steps:

1. Specify monitoring program objectives;
2. Determine the level of effort to devote to the analysis;
3. Perform a systematic analysis appropriate to the problem and objectives;
4. Use the analysis results to tentatively specify monitoring program elements; and
5. Evaluate the tentative monitoring program for cost-effectiveness and finalize according to evaluation results.

Each of these steps entails numerous tasks and decisions that are essential to arriving at a well-founded monitoring program design. Ultimately, the purpose of working through these steps is to determine the best combination of program elements that will achieve the objectives with an acceptable level of assurance in the results at known cost.

Monitoring Program Design Steps

Step 1: Specify Monitoring Program Objectives

Establishing objectives for environmental monitoring is essential, even though they cannot always be specified in great detail. Thoughtful statements, agreed upon by all concerned, should guide the monitoring program design and conduct. Objectives follow from the nature of the problem or the particular decision-making need that requires data collection.

Every monitoring program should, if possible, formulate objectives at two levels, general and specific. General objectives describe what must be accomplished to solve the overall problem or meet the need. Examples are:

- Determine if a water body meets water quality standards applying to it.
- Define water quality conditions in a lake prior to shoreline development.
- Determine long-term trends in sediment accumulation of metals in a poorly flushed bay.

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- Find and quantify the contamination source that has closed a shellfish bed to harvesting.
- Calibrate and verify a specific runoff rate simulation model.
- Assess the relative health of a benthic macroinvertebrate community.

Specific objectives relate directly to measurements and produce results to meet the general objectives. Some examples related to the fourth general objective above are:

- Determine the annual fecal coliform loadings contributed by agricultural, septic drain field, and urban runoff sources.
- Identify individual sources of fecal coliform loading that should be addressed to achieve 70 percent reduction in total annual loading.

These objectives can be stated in more detail and more specifically when Step 3 of the general design process is completed. For example, more analysis could permit recasting the second specific objective as:

- Rate individual sources of fecal coliform loading in terms of annual loading generated and potential for reduction, and identify the best combination of sources to address that would lead to a 70 percent reduction in total annual loading.

This chapter emphasizes the point that an environmental monitoring program should be regarded as a type of scientific experiment. The rigor of the scientific method promotes careful design of the program to make as sure as possible that it will yield answers with a known level of certainty. Accordingly, it is sometimes appropriate to state objectives in terms of a scientific hypothesis. An example would be:

- Determine the best way to target source controls to pollution sources, with the "null hypothesis" being that the annual loadings of a pollutant do not significantly differ between Source A and Source B, and the "alternative hypothesis" being that they do differ with statistical significance.

Step 5 explores this subject further. It supplies methods that allow the monitoring program designer to judge the likelihood of the hypotheses being successfully tested with the funds available.

Objectives form the foundation for the entire monitoring program. They should be consulted frequently in its development to make sure that decisions made along the way comply with the intentions represented by objectives. At the same time, they should not be overly rigid, in case circumstances change. In some cases, new information will make it possible to sharpen the objectives. In others, the findings through analysis may point out a lack of realism in the initial objective statements and suggest how they should be modified accordingly. Ultimately, the assessment in Step 5 will determine if the objectives are achievable with an acceptable level of assurance within the funds available. If this is unlikely, it is much better to change them to something that can be met and still fulfil a purpose than to proceed with a program that has little probability of success.

Using this process ensures careful decision-making at each step and counters the tendency to use a generic monitoring strategy that may not relate to the program goals. Exercising discipline to make careful assessments is the best way to be cost-effective in monitoring.

Step 2: Determine the Level of Effort

The effort put into monitoring program design can range from relatively simple and inexpensive to thorough and costly, depending on the objectives for the particular program. The development of specific objectives is an iterative process of adjusting goals in light of the quantity and type of information available, the detail of additional information needed, the resources of the designers, and the urgency to begin monitoring.

Available information can help target new monitoring and substantially reduce costs. Therefore, designers should incorporate this information in their analysis, using techniques in this manual. Some problems may not be worth extensive effort, while others require it. For example, existing data can help determine whether there is a problem in a particular location without necessitating the expense and effort of sampling. On the other hand, monitoring to allocate resources for solving problems in a large, complex watershed may require a substantially greater level of analysis.

Even if little guidance information exists and the designer has limited time and resources, at least the basic analytical process should be applied. After developing a preliminary information base, the designer can always review the systematic analysis of the problem and objectives in more detail later.

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Step 3: Perform a Systematic Analysis

As the core of the process, Step 3 requires the most effort. The analyst should give priority to key factors thought to pertain to the issue. This systematic analysis is often referred to as a watershed analysis. The term "watershed" broadly signifies an area that drains a land surface to a point of interest. While a watershed can be a small catchment with a simple drainage system, for now we will limit the term to include only landscapes of some size and complexity draining through a network of artificial and natural conveyances to a natural water body. Thus, the analysis involves surveying watershed characteristics, identifying the most critical potential problems and sources, and highlighting the most critical places, times, and biological units that manifest these problems.

A watershed inventory involves collecting the level of data appropriate to the needs of the project. While the level of detail may vary, the inventory should include developing a basin map; identifying such features as land uses, soils, topographic information, and hydrologic data; and identifying potentially critical locations relative to the objectives adopted in Step 1. For example, if these objectives pertain to pollution sources, some possible locations of interest are earth-moving sites, industrial areas, and major traffic concentrations. If the objectives focus on aquatic resources, areas to recognize might be sites like fisheries and other productive resource areas, rare or endangered resources, and stream reaches vulnerable to major channel damage. Obtaining any available data on these features, as well as field reconnaissance, are key tasks in a watershed inventory. This includes identifying any already existing site data for possible use in Step 5 of the process.

Identifying critical problems and sources should be a systematic process of formulating a broad list and then narrowing it by prioritizing items, with the level of effort chosen in Step 2 dictating the scale of the analysis. For example, to find the principal sources of water quality deterioration in a river draining a large watershed, we may suspect that certain areas and activities need attention. However, this conclusion should be tested through some quantified, comparative estimates of pollution quantities, using models like those outlined in Chapter 3. Such models may be overly generalized, simplified, and not calibrated locally, but their purpose is not to reach a final decision but to guide the design of a monitoring program. Even with little effort, the simplest model can often bring objectivity and rigor to the analysis.

Identifying critical places, times, and receptor organisms presents a more difficult problem. We must at least conceptualize the relationship between problem and timing and the potential damage for habitats, species, and life stages. While models can sometimes help, they are usually too simple or inconvenient to be sufficient. Ideally, the specialists (e.g., water quality engineer, hydrologist) will work closely with an ecologist familiar with the water body, its ecology, and its natural history, to judge these critical factors.

It is advisable to review the original objectives for their continued appropriateness. Objectives will likely need to be modified or specified with increased knowledge.

Step 4: Tentatively Specify Monitoring Program Elements

General Considerations

If performed properly, the systematic analysis of Step 3 will provide sufficient information to give provisional shape to the monitoring program. In this step, it should be tentatively specified:

- What to sample;
- Where to sample;
- When to sample;
- How many samples to take at each site on each occasion (replicates);
- How to sample; and
- What to analyze in samples.

The philosophy behind this process is to base decisions on these program aspects on case-specific objectives and analysis. Working from prescribed sampling scopes and frequencies and standard lists of analyses should be avoided.

The list above represents the monitoring program elements that require tentative but concrete decisions, so a cost-effectiveness evaluation according to Step 5 can be conducted. Along with these basic decisions, some attention should be given at this point to the following additional elements:

- How to handle samples;
- Data quality objectives;

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- Quality assurance/quality control checks; and
- How to analyze data.

Tentative judgments on these elements of a monitoring program will be further evaluated in Step 5 for their ability to meet the objectives with a known level of assurance and cost. These will be finalized after any necessary adjustments have been made and become the monitoring program design. The following two chapters on physical and chemical monitoring and biological community and toxicity assessment present details on each element, as appropriate to each monitoring topic.

What to Sample

This monitoring program element is the most straightforward one, specifying the medium or media to sample. It refers to the water body, runoff stream, sediment, habitat, biological community, or organism(s) from which samples are to be drawn.

Where to Sample

The question where to take samples must be carefully considered with respect to the established objectives and the analysis performed under Step 3. Obviously, the more locations samples are collected from, the higher the cost will be. Thus, the decision on each sampling point must be taken with an eye to its contribution to fulfilling the objectives.

In the study of urban waters, where to sample is often dictated or strongly guided by the objective of comparing two or more spatial conditions, e.g., a location affected by runoff discharge versus an unaffected one, a location served by a best management practice (BMP) versus one that is not. In experimental parlance, the affected spot is often referred to as the "treatment" site, in the sense that its condition is "treated" by the discharge or the BMP, while the other location is frequently termed the "control" or "reference" site. Accordingly, a comparative monitoring program can be termed a "control/treatment design." The term "control" stems from laboratory experimentation, where the investigator generally has a much higher degree of influence on the situation than in studies in the natural environment. The term "reference," which implies a basis for comparison rather than maximum influence, is thus often preferred in environmental monitoring. These concepts illustrate once again that a monitoring program should be regarded as a type of scientific experiment.

The comparison of two or more conditions can, and often should, be approached very systematically as a "paired watershed" monitoring program design in which the treatment site (or each of several treatment sites) is paired with the reference site. The rationale, as well as the methods, for paired watershed monitoring have been thoroughly developed over the last 15 years. The appendix to this chapter summarizes them in some detail and gives references for those interested in more information. Ultimately, this technique entails not only spatial considerations (i.e., where to sample) but also temporal ones (i.e., when to sample). This program element will be discussed below.

When to Sample

Fulfilling objectives and keeping monitoring costs within budget depends as strongly on decisions about when to sample as on where to sample. Also, the comparison objectives for urban water monitoring studies are often temporal rather than (or in addition to) spatial; i.e., the task is to compare two or more conditions separated in time. Examples would be: comparing the health of a macroinvertebrate community before and after major development in the watershed, or comparing storm runoff event mean concentrations of pollutants before and after the institution of BMPs.

As pointed out in the appendix to this chapter, it is advisable to employ, whenever possible, a reference station or stations and a control/treatment design in conjunction with temporal comparisons. The reference serves as a basis to distinguish natural variability or some other source of effect from the treatment that is the actual focus of the study. This monitoring program design lowers the risk of attributing an outcome to the treatment that is in fact the result of one or more extraneous factors. Designs of this type are sometimes referred to as before/after, control/treatment designs (BACT).

Beyond comparisons over a certain time period, there are other important considerations that enter into the decision when to sample:

- Seasonal considerations – Numerous conditions potentially instrumental to urban water monitoring objectives vary over the year. E.g., (1) many lakes stratify thermally in the summer and, depending on the climate, in the winter as

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well, with key implications for physical, chemical, and biological conditions; (2) living organisms pass through annual life cycles that must be recognized in scheduling their sampling; (3) pollutant delivery to water bodies accelerates in high runoff periods, while pollutants already present can concentrate in less diluted form during dry periods.

- Diurnal considerations – Some key conditions vary over the course of the day. These include (1) water temperature, dissolved oxygen, and sometimes pH in response to the photosynthetic and respiratory activities of aquatic life; (2) the variation in routine most organisms display over the course of a day, which may influence the ability to sample them.
- Considerations related to flow variation – Flow can vary depending on stochastic environmental conditions (e.g., runoff pattern in response to rainfall) and more predictable circumstances under human management (e.g., flow release from a dam).

All these factors may influence the decision when to sample. It is almost always inappropriate to devise a regular sampling schedule, as often occurs when schedules are adapted to the staff's regular work schedule.

Replicates

A replicate is a duplicate sample collected and handled in exactly the same way as the initial sample. Replicates are an important part of monitoring programs, not only for quality assurance/quality control (QA/QC) purposes, but also to define potential variability introduced from various sources. This subject will be elaborated on later in the chapter. Suffice it to say for now that, just like each sampling location and occasion, each replicate adds cost. Hence the number of replicates must be carefully considered in relation to the overall objectives, specific QA/QC requirements, and the budget.

How to Sample

This question regards the choice of sampling gear and its operation, clearly factors that affect costs and the achievement of objectives. These subjects are covered in depth in Chapters 6 and 7.

What to Analyze in Samples

The question of monitoring topics also directly affects costs and outcomes. It is covered in detail in the next two chapters.

How to Handle Samples

Once decisions are made about how samples will be collected and analyzed, handling them correctly is generally tightly standardized. Proper handling procedures ensure against alteration of samples between the time of collection and analysis, which would give false results. Chapters 6 and 7 cover the subject as appropriate to each monitoring type.

Data Quality Objectives

Data quality objectives, sometimes abbreviated as DQO, are statements (generally quantitative) representing the standards to which data will be held for acceptance and consideration in data analysis. They can be regarded as part of the set of overall objectives stated in Step 1. DQO achievement is assessed through quality assurance/quality control checks. The next two chapters on specific monitoring types give examples.

Quality Assurance/Quality Control

The effectiveness and credibility of any monitoring program depends on its quality assurance/quality control program, the control exercised on a data collection to assure, to the extent possible, a sound basis for drawing conclusions. The QA/QC program provides quantitative measurements of the "goodness" of the data. The most fundamental QA/QC concepts, applying in one way or another to every type of aquatic monitoring program, are:

- Representativeness – Results are representative when they truly reflect the population of interest, as framed in the objectives. The term "population" is used here in the general sense, referring to the aggregate of units from which samples will be drawn. Some examples are: (1) For a general stormwater runoff monitoring program, the population would be the full range of runoff events (the "units") over the whole duration of flow; whereas for a first-flush program, the population would encompass the full range,

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but over just the rising limb of the hydrograph (or some selected fraction of it). (2) For a river sediment contamination monitoring program, the population would be the complete distribution of sediment types (size fractions, etc.) in the reach of interest. (3) For a stream riparian cover assessment program, the population would be the cover types (vegetation, surfaces, etc.) of the lands extending a selected distance to either side of the stream centerline (or bank-full location) over the reach of interest. The objectives help determine what would be representative within their boundaries. There is clearly a tension in monitoring program design between selecting a representative number of units on the one hand, while staying within the bounds of feasibility and affordability on the other. The analysis outlined in Step 5 is an aid in resolving this tension.

- Accuracy – Accuracy is the agreement between the measurement of a variable in a sample and its true value. The term "error" refers to the discrepancy between the measured and true values (Error = Measured value – True value). Relative error expresses the error as a percentage deviation from the true value:

  Relative error (percent) = (Error/True value) x 100

QA/QC programs assess accuracy by testing samples that have set values of the variable being measured. These tests should be done blind (without the analyst knowing the value) to avoid bias.

- Precision – Precision is the agreement among replicate measurements. It is measured in absolute terms as the standard deviation of the set of replicates. More useful is relative deviation, which is the standard deviation being expressed as the percentage of the mean of the replicate values:

  Relative deviation (percent) = (Standard deviation/ Mean of measured values) x 100

Precision can, and generally should, be assessed with both field and laboratory replicates. Field replicates are separate samples collected simultaneously at the same source location and analyzed separately. They are used to assess total sample variability (i.e., field plus analytical variability). Laboratory replicates are repeated analyses of a variable performed on the contents of a single sample. They are used to assess analytical precision. Duplicate analyses of a single sample usually suffice for well-proven procedures in the laboratory. The extent of replication depends on overall objectives, data quality objectives, and monitoring program optimization for cost effectiveness (see Step 5). In the absence of any specific considerations arising from these factors, it is common for 5 to 10 percent of field samples and 5 to 10 percent of laboratory procedures to be duplicated to get some measure of precision.

Additional QA/QC terms and procedures apply to specific monitoring types, as covered in Chapters 6 and 7. Laboratory physical and chemical analyses of water and sediment samples in particular are subject to extensive further QA/QC checks.

Regardless of the monitoring type, QA/QC is best advanced by having well-qualified and -trained personnel involved at every point in the process. The quality of laboratory service should be ensured by writing detailed contract specifications, including the QA/QC checks to be performed, standards for acceptance, and action to be taken should results be unacceptable.

Data Analysis

Thinking about data analysis early is essential to ensure that measurements produce data that can be assessed to achieve program objectives. For example, it would be fruitless to collect sediment samples along a longitudinal transect (parallel to flow) and later try to define the extent of variability in the vicinity of a particular discharge. The connection between what one is trying to learn and how one is going to use data to gain that knowledge is not always as obvious as it should be. At this stage, each stated objective should be coupled with the data analysis scheme set out in the preliminary monitoring program design. The design should be finalized after Step 5 has been performed. It is, of course, still possible to implement additional data analysis procedures that may suggest themselves later on, but starting out with a sound basic plan is highly advisable.

The data analysis options in the areas of graphing, statistics, and multivariate analyses are almost unlimited. Exploring them all is far beyond the scope of this book. Chapters 6 and 7 present some techniques that have proven to be useful.

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Step 5: Evaluate the Tentative Monitoring Program and Finalize

General Considerations

This step is an evaluation of the tentative monitoring program according to Step 4. It takes into account the total numbers of samples and analyses anticipated, as well as the allocation of effort among sampling locations and occasions, replicates, and analyses. These factors directly determine the program's cost and probable effectiveness. Monitoring programs frequently fail to provide the desired information, even when performed flawlessly, because the samples are insufficient to achieve an accepted level of statistical assurance. This failure results from a high variability in flow and natural aquatic systems that complicates monitoring. For example, variability prevents us from ascertaining with a high level of statistical confidence that an average water quality condition meets a certain criterion or that a new discharge creates a change in a biological community.

Sources of variability include spatial differences in a landscape or water body, differences over time (temporal variability), and measurement errors. Careful consideration of seasonal, diurnal, and flow-related factors in relation to the objectives, as discussed under Step 4, can help reduce this variability. Better techniques, if available, can reduce measurement errors. Otherwise, replicate samples will have to be collected in order to quantify the measurement error component. One strategy in dealing with sources of natural spatial and temporal variability, unless they are enormous, is to increase sample numbers, but this strategy raises cost.

The basic task in this step is to determine the number of samples (stations, occasions, and replicates) needed to meet the objectives, considering variability and budget limits. Using the optimal number of samples to reach a conclusion will result in either the maximum confidence level for a set budget, or in minimum cost for a set assurance level. These options, which represent two ways to maximize the monitoring program's cost-effectiveness, can only be applied if some data are already available to give statistical measures of central tendency (e.g., mean or median) and variance. In that case, statistical methods can be applied to the optimization problem.

In some cases, uncontrollable natural variability will be too great to achieve confidence in a certain program element within a feasible budget. In this case, the designer will have to either delete this element or reduce costs in other areas and redirect resources. The options are to reduce the sampling stations, occasions, replicates, the number of analyses prescribed, the costs of various program elements, or some combination thereof. This decision is often unpalatable because it can demand, for example, cutting geographic coverage or not analyzing for a water quality measure that is traditionally included. However, the designer must choose and target the program according to objectives and circumstances, rather than conduct a program that gives inconclusive or misleading answers.

Mar et al. (1986) present some straightforward strategies for optimizing monitoring program designs in common situations, which will be summarized in the following sections. Other situations may arise in designing aquatic monitoring programs, and different statistical methods exist to handle the various scenarios. Burton and Pitt (2002) summarizemany of these circumstances and techniques in their Table 5-3, with elaboration in the accompanying text. Other references with extensive coverage of the subject are Gilbert (1987) and Zar (1998).

Determining a Mean Value

Determining a mean value applies, for example, when an average water quality condition is compared to a regulatory criterion. In basic statistics, t-distribution defines the confidence interval for the mean of a normally distributed population (set of values) as estimated from a data set. The t-distribution is used to determine sample numbers if the data are demonstrated or assumed to have a normal probability distribution (Figure 5-1(A)), or if they can be transformed (e.g., by taking their logarithms) to yield a normal distribution.

Figure 5-2 presents the results of an analysis based on the t-distribution for three confidence levels. The curves show the number of samples required as a function of precision. Precision here is the ratio of the difference in the estimated and actual mean ($x - \mu$, the error that will be accepted) to the standard deviation (σ, the variation or "noise" in the data). To use the graph, the monitoring program designer consults available data to get estimates of the mean and standard deviation and decides on the acceptable error and confidence level. For the case of an acceptable error equal to the standard deviation (precision = 1) and an 80 percent confidence, for example, four samples suffice. Demanding a precision of 0.1, however, requires hundreds of samples.

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If no data are available for this exercise, monitoring program designers have several options. They can conduct a pilot program to obtain a limited data set; however, this choice would require spending time and money. The alternative is to use data from a similar location or estimate values using professional judgment. Either course has obvious drawbacks in accuracy, but both are usually superior to making an educated guess of the sample numbers and allocation with qualitative, but no quantitative, analysis. Even that option is better, though, than blindly specifying monitoring program elements without any analysis.

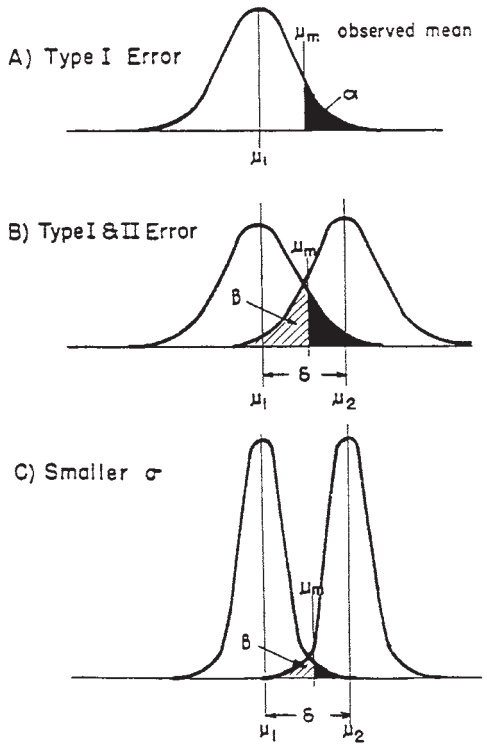
Detecting Change

Detecting change applies, for example, when the size or composition of a biological community is evaluated at two different points in time. Programs designed to detect change require different statistics than those that simply identify means. This type of problem is phrased as a statistical hypothesis test in which the null hypothesis (H_o) is that the populations are from the same distribution at both points in time; the alternative hypothesis (H_1) is that they are from different distributions.

Figure 5-1 illustrates terminology needed for this type of evaluation. The shaded area of Figure 5-1(A) represents the probability (a) of a Type I error (H_o was rejected when it was, in fact, true). Figure 5-1(B) shows distributions at both points in time, in which the difference in means represents an apparent change of magnitude (δ). The hatched area represents the probability (α) of a Type II error (H_o was accepted when it was, in fact, false). The quantity (1 – ß) is termed the power of a statistical hypothesis test. Figure 5-1(C), in comparison to the other two graphs, illustrates the variation effect, as represented by the standard deviation, on power. For a given change, δ, the power increases as the standard deviation decreases.

Figure 5-3 provides a graphic way to establish the number of samples needed to detect change. To use the

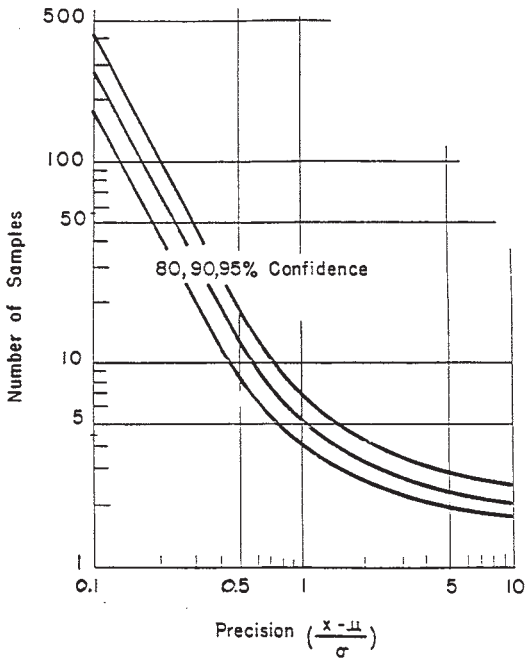
Figure 5-1: Hypothesis-Testing Fundamentals



μ_1 and μ_2 are the means of two populations of measurements; their difference represents a change δ; α and β are the probabilities of the Types I and II errors, respectively.

Source: Mar et al., 1986

Figure 5-2: Number of Samples Versus Precision



Precision is the ratio of the allowable error to the standard deviation of the population of measurements.

Source: Mar et al., 1986

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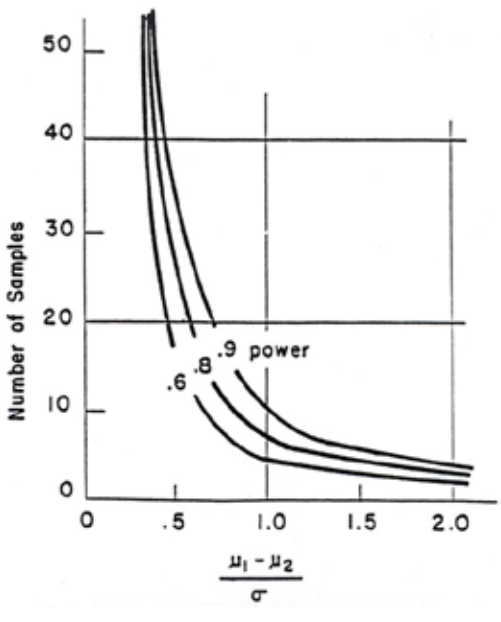
graph, the monitoring program designer consults any available data to estimate the standard deviation and decides on the magnitude of change to be detected ($\delta = \mu_1 - \mu_2$) and the power. Suppose, for example, that the objective is to detect a change of 5 units in a population previously characterized to have a standard deviation of 8 units with statistical power of 0.8. The ratio of change to standard deviation is 0.625, requiring 20 samples. This plot shows that to detect changes of less than 50 percent of the standard deviation, the program requires a large number of samples.

Monitoring Costs

The statistical methods previously illustrated show how to measure the value of added information in the form of more samples in promoting program effectiveness. To optimize the program, cost estimation must accompany these methods. Given the cost and value of added data, a trade-off analysis can be performed to obtain the most cost-effective program within the existing con-straints. Costs are accounted as follows:

$$TC = C_o + (T)(C_t) + (S)(T)(C_s) + (R)(S)(T)(C_r)$$

Figure 5-3: Power Curves Relating Number of Samples to Change to be Detected



σ is the standard deviation

Source: Mar et al., 1986

where: TC = Total cost;

C_o = Fixed overhead cost;

C_t = Fixed cost for each sampling occasion;

C_s = Cost associated with visiting each sampling station;

C_r = Cost to collect and analyze each sample;

T = Number of sampling occasions;

S = Number of sampling stations; and

R = Number of replicates on each occasion at each station.

C_o represents such costs as maintaining staff and space for the overall program to support all the work outside of going out to take samples and analyzing them (e.g., equipment inventory, monitoring program design, data analysis, reporting, administration). C_t is the cost of mobilizing for a sampling date (e.g., acquiring sampling supplies, paying a daily vehicle charge). C_s represents the expenses of travel to field locations and time spent collecting samples and delivering them to the site of analysis. Finally, C_r is the price of analyzing one sample, plus any cost, other than staff time, of the sample collection and handling process (e.g., chemical preservative). It should be noted that, regardless of these considerations concerning finances and ability to draw conclusions in the face of natural variability, some field (as well as laboratory) replicates must be taken for QA/QC purposes. If cost accounting can be done in this manner, monitoring program optimization can be performed relatively easily.

Note that (R)(S)(T) = the total number of sam-ples. For a given total, the three quantities can be varied so long as their product remains the same. If measurement error is larger than natural varia-tion, then adding replicates would reduce uncer-tainty more than adding stations or occasions. However, if spatial or temporal variation domi-nates, adding stations or occasions, respectively, would be a better strategy.

Optimization Examples

Example 1

The first example concerns selecting sample numbers to estimate mean values. Suppose three variables (A, B, and C) are to be monitored to establish their annual means at a site with 90 percent confidence. Table 5-1(a) gives variability from hypothetical pilot data and meas-

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urement costs of each. Overhead cost is equal among designs and is not considered in the calculations. This example illustrates optimizing the monitoring program for a given budget (Designs 1 and 2) and a given level of assurance (Design 3):

- Design 1 – Collect three samples for each variable (fixed cost of $420). What is the minimum error that can be attained for each variable?
- Design 2 – Collect four samples for each variable (fixed cost of $560). What is the minimum error that can be attained for each variable?
- Design 3 – A fixed error of = 40 percent of the mean is required for each variable. What design (sample numbers) provides this level of certainty at the minimum cost?

Table 5-1(b-d) summarizes the evaluation. Comparing Design 2 to Design 1 indicates that an in-creased but equal number of samples would only slightly improve the estimate of the mean for each variable. The estimate for variable B would still be highly uncertain relative to the others. However, as Design 3 shows, allocating more samples to the variable with the greatest variation, and with the most improvement results per dollar spent, provides an overall more cost-effective design. With this design, the estimate of the mean of variable B is expected to improve greatly, with some increase in the error for variable A but little for C, at about the same cost as Design 2.

In most actual cases, a simple analysis like this is insufficient, since uncertainties can result from several factors, including measurement er-rors and spatial and temporal variability. Generally, an analysis should be performed to inves-tigate each cost and variance component and their effects on the design to allocate the effort among

Table 5-1: Monitoring Program Optimization Hypothetical Example for Estimation of Means

(a) Sample Costs and Variability

Input Data	Variable A	Variable B	Variable C
Total cost per sample	$100	$10	$30
Standard deviation (% of mean)	10	100	20

(b) Design 1 (optimization for fixed budget, three samples of each variable)

Variable	Cost	Precision[a]	Error (% of Mean)[b]
A	$300	2.4	24
B	$30	2.4	240
C	$90	2.4	48
Total	$420		

(c) Design 2 (optimization for fixed budget, four samples of each variable)

Variable	Cost	Precision[a]	Error (% of Mean)[b]
A	$400	2.2	22
B	$40	2.2	220
C	$120	2.2	44
Total	$560		

(d) Design 3 (optimization for fixed allowable error of = 40 percent of the mean of each variable)

Variable	Error (% of Mean)	Precision[c]	Number of Samples[a]	Cost
A	40	4.0	3	$300
B	40	0.40	18	$180
C	40	2.0	3	$90
Total				$570

Notes:
[a] From Figure 5-2 for 90 percent confidence.
[b] Error = Precision x Standard deviation.
[c] Precision = Error/Standard deviation.

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sampling locations, occasions, and repli-cates. Example 2 illustrates this type of analysis.

Example 2

The second example concerns selecting sample numbers to determine whether or not the mean value of a variable at a particular location (one station) changes over time. A pilot sampling program estimated the standard deviation at 8 units, 10 sampling occasions, and two replicates. The standard deviation is estimated to decrease or increase by 0.5 unit with each added or subtracted sampling occasion, respectively, and to decrease or increase by 0.2 unit with each added or subtracted replicate, respectively. Change should be detectable with statistical power of 0.8. Cost components are: C_o = \$15,000; C_t = \$300; C_s = \$150; and C_r = \$500. This example illustrates optimizing the monitoring program for a given budget (Design 1) and a given level of detectability (Design 2):

- Design 1 – What is the optimum allocation of sampling occasions and replicates to minimize the detectable change for a budget of \$30,000?
- Design 2 – What is the optimum allocation of sampling occasions and replicates to minimize the cost of detecting a change of 5 units or smaller?

Table 5-2(a-b) summarizes the evaluation. In Design 1, reducing occasions in favor of replicates did not lower detectability. Increasing occasions to 16 with a single sample taken each time reduced detectability substantially. Lack of replication generally would not be acceptable for QA/QC purposes, and a replicate sample would be collected and analyzed on at least one sampling occasion, preferably two. A small budget increase or slight loss of detectability would be necessary to accommodate the replication. In Design 2, reducing occasions in favor of replicates raised cost, whereas increasing to 12 occasions without replication yielded the lowest cost. The same qualification stated for Design 1 pertains to replication.

Table 5-2: Monitoring Program Optimization Example for Determination of Change

(a) Design 1 (optimization for fixed budget of \$30,000)

Sampling Occasions	Replicates[a]	Total Samples[a]	Standard Deviation (Sd)	δ/sd[b]	δ
10	2.0	20	8.00	0.63	5.0
8	2.9	23	8.83	0.57	5.0
14	1.2	17	6.15	0.67	4.1
16	1.0	16	5.21	0.68	3.5

(b) Design 2 (optimization for fixed detectability of δ = 5 units)

Sampling Occasions	Replicates[a]	Total Samples[a]	Standard Deviation (Sd)	δ/sd[b]	Total cost
10	2	20	8.00	0.63	\$28,150
8	3	24	8.80	0.57	\$29,550
12	1	12	7.20	0.69	\$24,750

Notes: [a]Replicates were calculated using the total cost equation for the fixed budget, which yielded replicates per sampling occasion, generally not an integral number. In reality replicates would be randomly assigned to sampling occasions to produce the approximate specified allocation between occasions and replicates.
[b]From Figure 5-3 for 0.8 statistical power.

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Paired Watershed Study Design

Description of the Approach

The paired watershed approach is applicable to the assessment of both wet weather effects and technology performance and represents a means of connecting the two. The basic approach requires at least two watersheds, control and treatment, and two periods of monitoring, calibration and treatment. A control watershed is one that experiences essentially no change during both monitoring periods. It is subject to year-to-year or seasonal variations in large-scale factors, such as meteorological changes and natural biological cycles, that are beyond the control of study personnel. A treatment watershed is one in which a planned change (the "treatment") has been imposed between the two monitoring periods. This change can consist of a land development project that could potentially affect an aquatic ecosystem or application of a source control, or a structural best management practice (BMP) that could mitigate a negative effect. One control watershed can serve as a basis of comparison for treatments in different watersheds, and both types of watersheds can be replicated if desired.

During the calibration period, the two types of watersheds are treated identically, and paired data are collected. The basis (and implicit assumption) of the paired watershed approach is that these data represent a quantifiable relationship between the two types of watersheds and that this relationship is valid until a major change is made in the treatment watershed(s). The relationship is expressed as a linear regression of a variable measured in the (future) treatment case on the variable measured in the control case. It is further presumed that a new relationship will be established after application of the treatment and that this relationship can be quantified through post-treatment monitoring. The difference between the two relationships, if demonstrable through statistical analysis, will constitute a measure of the treatment effect (e.g., the impact of the development or the effectiveness of the management technique). This protocol is derived from work sponsored by the U.S. Environmental Protection Agency Office of Wetlands, Oceans, and Watersheds and performed by the Rural Clean Water Program at North Carolina State University (Clausen and Spooner 1993).

Advantages and Disadvantages

It should be noted that the data for the paired watersheds do not have to be statistically the same during the calibration period. Rather, it is the relationship between the paired observations that should remain the same over time, except under the influence of the treatment. Often, in fact, the paired data sets differ considerably. This difference, which is virtually inescapable in environmental systems, substantiates the value of a paired watershed approach: the technique does not assume initial equivalence in the two situations subject to comparison, which would rarely occur in reality; it does, however, assume a predictable relationship between the two.

The paired watershed approach has several other advantages besides avoiding the need to find systems that are initially similar in all important respects. Naturally variable factors such as weather are statistically controlled over the years of study, so that observed change can be attributed to the treatment in a cause-and-effect fashion. There is no need to measure all factors that could conceivably cause change, since their effects are embedded in the relationship derived during calibration. Also, the study can be completed in a shorter time than is generally possible in trend studies.

At the same time, the approach has some disadvantages and limitations. Response to the treatment is likely to be gradual, extending the length and cost of

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the study. Moreover, it is vulnerable to out-of-the-ordinary events like floods. Although, as mentioned above, paired watersheds do not have to be initially identical, effective application of the procedure generally requires that they be similar and in close proximity. The results will be compromised if the control watershed changes significantly during the course of the study.

Some statistical problems can arise, but they are usually avoidable if recognized and ameliorated by the monitoring program design. If, for example, the calibration period is too short, serially correlated data can result, meaning that successive observations are not independent of one another. This autocorrelation tends to increase variance and thus affect the number of observations needed to detect a difference (Gilbert, 1987; Ott, 1995). However, it is a more limiting factor in trend studies than in the demonstration of a differing relationship before and after treatment. Generally, it can be overcome by extending the calibration period over a full season, a year, or longer, depending on the objectives of the study. Another problem can occur if the treatment effect is strong enough to cause variances between the calibration and treatment periods to be unequal. Unequal variances violate the underlying assumption of the analysis of variance (ANOVA) procedure, which is applied to demonstrate the difference between the two relationships. Fortunately, ANOVA is robust, even with considerably heterogeneity of variances, so long as sample numbers are nearly equal (Zar, 1998).

Example Applications

Following are some applications for a paired watershed study design.

- Response of aquatic biota to watershed development during construction, after construction, or both;
- Comparison of sediment transport and deposition with two construction phase erosion and sediment control strategies;
- Detectability of a lawn pesticide in water and sediments with and without homeowner education;
- Storm peak flows, discharge volumes, and stream bed incision with advanced versus conventional runoff retention/detention;
- Water pollutant baseflow and storm event mean concentrations downstream of a constructed wetland with urban runoff treatment compared to downstream of an urban area without treatment;
- Fish presence and abundance downstream of a constructed wetland compared to the situation without treatment;
- Phosphorus loadings to a lake from a development with extensive roof runoff infiltration versus loadings from a development with piped roof drainage;
- Flow quantity, water pollutants, and benthic invertebrate community measures in a stream draining a watershed with state-of-the-art source and treatment controls compared to a stream draining a watershed with the legal minimum stormwater management;
- Fecal coliform concentrations in shellfish tissue from marine bays receiving flow from watersheds with and without intensive animal waste management efforts; and
- Rapid bioassessment attributes of a stream with a wide, continuous, naturally vegetated riparian zone compared to one with a narrow, disrupted, poorly vegetated riparian area.

Procedure

Monitoring Program Objectives

As with all monitoring programs, the development of objectives to guide the program design is the essential first step. For paired watershed studies, the requirements for effective utilization of the procedure, as well as its limitations as set out in this protocol, have to be recognized and formulated objectively. Once developed and refined, objectives should be used as in any other monitoring program to specify the program elements.

Watershed Selection

It is recommended that paired watersheds be selected to:

1. Be initially similar in physiographic and biological features, such as size, general morphology, slope, location, soils, and land cover;
2. Be similar in past, present, and future human influence, except for the treatment being tested;

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3. Be in a steady state at the outset of the study, meaning that they have not experienced substantial change over a number of years prior to the study;
4. Be small enough to make uniform treatment throughout the treatment watershed possible; and
5. Have a stable channel at the measurement point, especially for flow monitoring.

Frequently, circumstances (e.g., a development proposal that has been approved for a specific plot of land) will dictate which watershed is to be the control and which one is to be the treatment location. If there is flexibility, any possible bias can be avoided by assigning control and treatment status randomly, for example by coin toss.

Calibration Period

Perform the monitoring program designed for the calibration period and obtain a data set of paired observations in the control and future treatment watersheds. Analyze the data as follows. It is most convenient to use a computerized statistical analysis package for most of the calculations.

1. Test to determine whether or not the data are normally distributed using a procedure such as the Schapiro-Wilk test (Zar, 1998). If the distribution is not normal, logarithmically transform the data and test for normality again. Most water quality and hydrologic data associated with stormwater runoff have been found in previous investigations to be log-normally distributed (Novotny and Olem, 1994). In the absence of testing, this distribution is usually a safe assumption for this type of data.
2. Using the log-transformed data, test for the equality of variances between watersheds using the F-test (Zar, 1998).
3. Examine residual plots to check for independence of errors (Zar, 1998).
4. Derive regression equations for each measurement variable (e.g., flow, water quality concentration or mass loading, a biological variable) in the form:

   $T = b_0 + (b_1)(C) + e$

   where T and C are the logarithms of values of measurement variables for future treatment and control watersheds, respectively; b_0 and b_1 are regression coefficients representing intercept and slope, respectively; and e is the residual error.
5. Test the statistical significance of the regression relationships by ANOVA. The test assumes that regression residuals are normally distributed, have equal variances between treatments, and are independent, as tested in Steps 1-3. If a relationship is not significant, either additional calibration monitoring should be performed to attempt to derive a significant relationship, or the variable should be discarded in favor of another one with a significant relationship.
6. Test to determine if sufficient calibration sample numbers have been collected to detect a difference of a given size, should one occur during treatment.

a. Decide on the fraction, f, of the mean value of the measurement variable during the calibration period that should be detectable after treatment. Base the selection on the objectives of the study, experience, and feasibility. The smaller the desired detectable difference, the more samples will be required in both calibration and treatment periods.

   For example, if a pollutant event mean concentration (EMC) in a stream is EMC_1 = 30 μg/L before treatment, and the goal is to reduce EMC to EMC_2 = 10 μg/L by installing a BMP, f = 0.67 represents the change that needs to be detected to determine whether or not the goal was achieved. There is no point in specifying a smaller f, at the cost of more sampling, for this objective.

b. Express the difference, d, that is to be detected in EMC_1 as d = (f)(log EMC_1), since the data have presumably been log-transformed.

c. Obtain the mean square residual variance, S_{yx}^2, from the regression significance test performed in Step 5.

d. Obtain the F-statistic from statistical tables. For n_1, the degrees of freedom for the numerator mean square, use (a –1), where a is the number of watersheds. If a control/treatment pair is being studied, (a – 1) = 1. If a control and two treatment watersheds are being investigated, (a – 1) = 2, etc. For n_2, the degrees of freedom for the denominator mean square, use ($n_1 + n_2 – a$), where n_1 is the number of samples taken during

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the calibration period and n_2 is the number of samples to be taken during the treatment period (assumed at this point to be equal to n_1 for one treatment watershed, 2 x n_1 for two treatment watersheds, etc.). For a, the probability of the Type I error, it is most common to use 0.05.

e. Compute the ratio S_{yx}^2/d^2.

f. Compute the quantity: $[(n_1)(n_2)/(n_1 + n_2)]\{1/[F(1 + (F/(n_1 + n_2 - 2)))]\}$.

g. If the ratio computed in Step d is greater than the quantity computed in Step e, there are an insufficient number of samples to detect the specified difference. In that case, it is necessary to elect some combination of the following strategies: (1) specify a larger detectable difference, if consistent with objectives; (2) schedule more calibration period samples; and/or (3) schedule more treatment period samples.

7. Test to determine if residual errors about the regression are smaller than the expected BMP effect, which indicates how much deviation from the calibration regression is necessary for the treatment data to be significantly different.

Treatment Period

Perform the monitoring program designed for the treatment period and obtain a data set of paired observations in the control and treatment watersheds. Analyze the data as follows, again using a convenient statistical analysis package.

1. Derive new regression equations representing the treatment period for each measurement variable (e.g., flow, water quality concentration or mass loading, a biological variable) in the same form as for the calibration period.
2. Perform the same tests on the data as specified in Steps 1-3 for the calibration period.
3. Test the statistical significance of the treatment regression relationships by ANOVA. The test assumes that regression residuals are normally distributed, have equal variances between treatments, and are independent, as tested in Step 2. If a relationship is not significant, either additional treatment monitoring should be performed to attempt to derive a significant relationship, or the variable should be discarded in favor of another one with a significant relationship.
4. Perform an analysis of covariance (ANCOVA) comparing the calibration and treatment regression relationships. This analysis will demonstrate the significance of the differences between calibration and treatment regression equations overall and between their slopes and intercepts. The treatment effect is considered to be significant if these differences are significant, but insignificant (at least under the test conditions) otherwise.

Displaying and Interpreting Results

It is useful to graph deviations from expected values as if there were no treatment effect as a function of time during the treatment period. There is often interest in expressing the percentage difference in mean values with and without treatment, especially to express the effectiveness of a BMP. The analyses should be performed as follows:

1. Compute expected values without treatment from the calibration regressions.
2. Subtract the values from Step 1 from the observed values in the treatment watershed.
3. Plot versus time, obtaining a graph that visually illustrates the trend created by the treatment effect.
4. Compute the means of expected values without treatment, found in Step 1, and the means of observed values in the treatment watershed. Then find the percentage increase or decrease compared to the expected mean represented by the observed mean. It is not appropriate to make this calculation based on the observed values in the control watershed during either the treatment or calibration period, because generally, the control and treatment watersheds are not equivalent, even without the treatment effect.

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CHAPTER 6

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CHAPTER 6

Physical and Chemical Monitoring

Flow Monitoring

Introduction

Flow, or discharge, is a basic hydraulic characteristic affecting morphological development of stream channels, flooding behavior, bed and bank erosion, and sediment deposition. It therefore is a principal governing factor in habitat development. Furthermore, flow directly affects aquatic organisms through its velocity, against which fish must swim and non-motile organisms maintain their attachment. Flow is expressed in terms of its instantaneous rate, volume per unit time in units such as meters/second (m/s) and feet/second (ft/s), and the total volume over a designated period of time.

Measurements of flow rate, volume, or both are needed for many purposes in urban water resources work. Hydrologic studies require these data to determine the generation of surface runoff in response to precipitation. Water quality investigations need flow measurements to estimate pollutant mass loading (mass per unit time), the product of pollutant concentration and flow rate. Biological tasks sometimes need flow information for purposes such as assessing if minimum instream flows required for biota are being provided.

Performing these monitoring tasks can require flow measurement in controlled or uncontrolled open channels. In hydraulics, an "open channel" is any conveyance where flow is not constrained or under pressure. Therefore, closed pipes and culverts are open channels if they are not flowing full, a normal situation in runoff conveyance systems. When the geometry is regular and absolutely stable, the conveyance is termed "controlled," as in pipes, culverts, many lined ditches, and channels where a weir or flume can be installed. Otherwise, the channel is "uncontrolled," the situation usually found in natural streams.

Controlled open channel flow monitoring is performed using some type of flow meter. Flow meters actually detect stage and convert that reading to flow rate using an equation. In controlled flow, the equation is a standard formulation for the primary flow control device.

Flow meters are also used in long-term gauging of uncontrolled channels, if there is a way to relate stage sensed by the meter to discharge. In streams and rivers, the relationship is generally, according to a stage-discharge relationship developed at a location, expected to remain stable. If a continuous gauging record is not needed to achieve the monitoring objectives, a staff gage in conjunction with a stage-discharge relationship provides the observer with a flow rate estimate. In smaller conveyances, discharge is usually estimated from stage readings using the standard equation of open channel flow, Manning's equation. For short-term monitoring and developing a stage-discharge relationship in uncontrolled channels, the options are measuring with a current meter or a tracer.

There are also situations in urban water resources monitoring programs where pipes are submerged or flow full; in other words, they are not open channels. In these situations, which are often termed surcharged pipes, different equipment and measures must be used. While many types of flow meters exist for these pressurized flows, the most appropriate ones for situations encountered in urban water resources monitoring are ultrasonic Doppler and electromagnetic devices.

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Flow Surveys in Uncontrolled Open Channels

Current Meter Method

Current meters measure flow velocity. Their use involves measurements in a number of segments across the channel and at one or two depths, depending on the total depth. Flow rate can then be estimated as the product of velocity and segment cross-sectional area and summed over all segments. A series of such determinations over time allows approximation of total flow volume during the period. The current meter method is most appropriate in natural streams and other relatively wide-open channels that can be divided into a number of segments. The technique is less accurate in very narrow channels that cannot be so subdivided, because the banks create edge effects that exert disproportionate influence. If narrow channels cannot be controlled using a weir or flume, flow rate can be estimated using Manning's equation (covered under *Using Flow Meters in Controlled and Uncontrolled Open Channels*).

Relating flow rate estimates over a range of flow conditions to water surface elevation produces a stage-discharge relationship. This relationship then allows calibrating a flow meter for continuous gauging or a staff gage for non-automated readings. The problem is that it is difficult to perform enough current meter surveys to generate a complete stage-discharge relationship, particularly with the difficult working conditions and relative rarity of high-flow events.

Newer current meters are digital, while mechanical meters are still in use too. Whatever current meter is selected, it should be able to measure velocities down to 0.03 m/s (0.1 ft/s) in depths as little as 0.1 m (0.3 ft), preferably less. All meters must be recalibrated at least once a year.

Mechanical current meters are simple and durable instruments. Some newer mechanical meters measure stage and velocity simultaneously, eliminating the need for calculating a stage-discharge relationship (Burton and Pitt, 2002). Direct-reading, digital instruments automatically calculate flow rate in the segment using mean velocity at each measurement point and the segment cross-sectional area of the subsection. The most advanced digital current meters use Doppler measurements of sonic pulses reflected as sound waves from particles in the water moving toward the meter. These meters have been more expensive and less durable than alternative instruments but have improved in these respects recently (Burton and Pitt, 2002). Figure 6-1 pictures a propeller-type instrument with digital readout. Refer to Appendix A to this chapter for the recommended measuring procedure using a current meter.

Proper site selection improves the accuracy of flow measurements at all discharge levels. Consider the following criteria when establishing a discharge measurement station. However, all criteria listed can rarely be met. Be aware of the site's limitations and possible effects on measurement. The station should be located in a channel reach (i.e., longitudinal section) with the following characteristics:

Figure 6-1: Turbo-Propeller Digital Current Meter



Presented as an example only and does not constitute endorsement of the product by the U.S. Environmental Protection Agency or the North American Lake Management Society

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- Generally, the channel should be straight for 100 m (328 ft) upstream and downstream of the measuring location; for smaller streams of only a few meters in width, the straight section should be at least 20 times the width upstream and downstream.
- Flow should be confined to one channel at all discharge stages (i.e., the channel should contain no surface or subsurface bypasses).
- The bed should be subject to minimal scour and relatively free of plant growth.
- Banks should be stable, high enough to contain maximum flows to be measured, and free of brush.
- The station should be located at a sufficient distance upstream so that flow from tributaries and tides does not affect stage-discharge measurements.
- All discharge stages should be measurable within the reach, but it is not necessary to measure low and high flows at the same cross section within the reach.
- The site should be readily and safely accessible.

The specific cross section in which a station is located within a channel reach should have the following characteristics:

- Banks should be relatively high and stable.
- The channel should be straight with parallel banks.
- Depth and velocity must meet minimum requirements for the method and instruments used.
- The bed should be relatively uniform, with minimal boulders and without heavy aquatic growth.
- Flow should be uniform and free of eddies, slack water, and excessive turbulence.
- Sites should not be located downstream of areas with rapid changes in stage or velocity.

Tracer Methods

Tracers include biodegradable, non-toxic, fluorescent dyes and salts that are detectable by photometric and conductometric measurements, respectively. Rhodamine WT fluorescent dye has been a common choice, because it has a lower detection limit, is less toxic, has lower sorption to particles, and decays more slowly than other options (Burton and Pitt, 2002). Flow rate is calculated from the tracer's travel time or degree of dilution.

Although tracer surveys can be less convenient and more time-consuming in natural waters compared to current meter methods, they are more precise (Burton and Pitt, 2002). Tracers can be indispensable in shallow streams, especially those with irregular bottoms where traditional current meters are difficult or impossible to use. Other applications of tracers are the measurement of transport and diffusion of discharge into receiving waters and the determination of retention time.

Flow Meters in Controlled and Uncontrolled Open Channels

Where the water surface in an open channel is perfectly parallel to the channel bottom, the flow is termed "normal." A primary control device, such as a weir or flume, is usually needed to produce normal flow. Where it exists, an automatic, recording flow meter programmed with a standard weir or flume equation can be used to register flow rates and volume. Otherwise, the channel is uncontrolled, and the water surface has an irregular profile. In this situation, using a flow meter requires programming into the meter a stage-discharge relationship derived either from a current meter or tracer survey or, more commonly, Manning's equation.

Flow meters detect stage in several different ways. Most common in urban water resources monitoring are meters that sense depth by releasing a regularly spaced stream of air bubbles at the channel invert and detecting the back pressure resisting the bubble release, which varies with depth as a consequence of the static head of water (Figure 6-2). This type of meter is relatively easy to use and is usually not affected by wind, turbulence, foam, air temperature gradients, or drying between events. However, it is susceptible to error when current velocity exceeds 1.5 to 1.8 m/s (5 to 6 ft/second), a result of the Bernoulli effect of pressure drop around an obstruction in high velocity flow. Also, this meter should not be used when the channel bottom slope exceeds 5-7 percent.

Three other methods of sensing depth are also in fairly frequent use (see Figure 6-2): (1) the shaft encoder, a counter-weighted float on a pulley that sends an electronic signal to a data logger; (2) the pressure transducer,

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which converts static pressure to an electronic signal transmitted to a data logger, and (3) the ultrasonic sensor. These flow meters can also control an automatic sampler to collect flow-proportional composite samples. The shaft encoder requires a standpipe housing removing it from the influence of velocity. Pressure transducers can be upset by contaminants, drying between events, and sudden temperature changes. A number of agents can interfere with an ultrasonic sensor, including surface-fouling materials or organisms, wind, noise, turbulence, foam, and air temperature gradients. Compensation routines and shifting from sound to the electromagnetic spectrum can alleviate some of these problems. All these options should only be used in preference to a bubbler-type meter where these interferences are absent or can be countered in some way. They do offer possible alternatives for high velocity flows.

In non-normal flow, Manning's equation is usually employed to estimate flow rates from a stage record, in preference to developing a stage-discharge relationship with current meter measurements. As pointed out earlier, covering the full flow range and accuracy in relatively small channels is problematic with current meters. The fundamental form of Manning's equation is:

$$Q = A R^{O.67} s^{0.5}/n$$

where: Q = Flow rate (m^3/s);

A = Channel cross-sectional area (m^2);

R = Hydraulic radius (m) = A/wetted perimeter;

s = Water surface slope (m/m); and

n = Manning's roughness coefficient (dimensionless).

In the English system of units, a multiplier of 1.49 on the right side of the equation gives Q in ft^3/s if geometric variables are in ft or ft^2:

$$Q = 1.49 A R^{O.67} s^{0.5}/n$$

Because of uncertainties in estimating slope, depth, and n, the latter of which comes from textbook tables, the accuracy obtained from using Manning's equation is not as great as with a weir or flume. In addition, care should be taken when using the equation for low-flow events, when channel roughness, and therefore n, have more influence than in higher flow. When using Manning's equation as the basis for flow rate determination, place the selected stage sensor in the channel where:

- The cross section is uniform;
- The slope and roughness are constant;
- The channel is free of rapids, bends, abrupt falls, contractions, expansions, and backwater; and
- The channel is straight for at least 60 m (200 ft) upstream.

Because of uncertainties in estimates of slope, depth, and roughness, flow rate determinations using Manning's equation can lack accuracy, especially in an irregular geometry like a natural stream. Also, using Manning's equation is best avoided when measuring flow in channels that convey high solids loads, generally flow quite shallow, or both.

The options are to use a weir or flume, preferably, or to calibrate a stage-discharge relationship from current readings. These options are easier if the conveyance is above ground. If the flow in question is confined in a

Figure 6-2: Bubble Flow Meter, Shaft Encoder, and Pressure Transducer



Bubbler Flow Meter



Shaft Encoder



Pressure Transducer

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pipe or culvert, it may be possible to obtain a flume that can be inserted in an existing manhole or, more expensively, to install a plastic manhole that contains a flume. These devices are made in a number of different flume sizes and types.

Weirs and flumes are devices designed to establish a predictable and accurate relationship between flow and stage by controlling hydraulic conditions at the measurement point. Basic textbooks on fluid mechanics and hydraulics present standard equations to convert stage readings to flow rate. They also cover control device installation and other conditions that must exist to maximize accuracy.

A weir is a planar object, usually a vertical plate, built across the channel so that water flows over the top edge or through a regular opening (notch). The three most common opening geometries are rectangular, trapezoidal (known as a Cipoletti weir), and triangular (V-notch) (Figure 6-3). Each type has a unique discharge equation linking flow to water height above the notch low point, which is programmed into the software of the flow meter. Weirs are easily fabricated from inexpensive materials and can be used in an irregularly shaped channel, a situation in which a standard equation would be difficult to apply reliably. On the other hand, weirs can retain sediments that alter the environment, and they can cause flooding and overflow past the notch with higher than expected flow, invalidating the weir equation. Also, free fall of water over the weir is a prerequisite for validity. Weirs are often inappropriate in a natural stream because of potentially negative biological effects, especially blockage of fish movements.

A flume is a specially built reach of channel, sometimes a prefabricated insert, that has a converging section, a throat, and a diverging exit section. The flume's area, slope, or both are designed to differ from those of the channel, inducing velocity increase and corresponding water surface level change. Flumes are less subject than weirs to problems with sediment deposition, flooding, and overflow. Several flume configurations are available off the shelf, with the H flume being the most common because of proven performance, relatively low cost, and a wide range of relatively accurate measurement capability at flows commonly experienced in urban water monitoring (approximately 0.01 to 1 m^3/s = 0.35 to 35 ft^3/s). H flumes (Figure 6-3) are available from suppliers for typically encountered ranges. Designs are also available for smaller flows (HS flume) and larger ones (HL flume). Like weirs, each flume type has a characteristic discharge equation that can be programmed in the flow meter. It is usually impossible or inadvisable to mount a flume in a natural stream.

Surcharged Pipe Instrumentation

Ultrasonic Doppler velocity sensors measure the shift in frequency of waves reflecting off particles in the flow and convert the measurements to an estimate of the average particle velocity. High or changing solids concentrations, air bubbles, and foulants can interfere with them.

Electromagnetic velocity sensors operate under Faraday's principle, in which a conductor (water) moving through an electromagnetic field generates a voltage proportional to the velocity. They are less subject to the problems affecting ultrasonic meters but can be upset by electrical noise.

Figure 6-3: V-Notch Weir and H-flume (with Instrument Shelter)



V-Notch Weir



H-flume (with Instrument Shelter)

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There is no alternative to using one of these instruments in a surcharged case. They can also be used in open channel flow and are generally more accurate than flow meters relying on a stage-discharge relationship. However, their purchase cost is higher.

Water Quality Monitoring

Introduction

The essential tasks in sampling natural waters and runoff are to obtain a sample that properly represents the water of interest according to the program objectives, and to prevent its deterioration and contamination before and during analysis. These tasks break down into sample collection, sample handling, sample analysis, and quality assurance/quality control (QA/QC). Sample collection, in turn, involves considerations of what, where, and when to sample; how many samples to take; and how to sample. Thoughtful, thorough planning and performance of these steps should produce representative samples and fulfil the objectives. The following section outlines how to organize these tasks. At the end, it also covers data analysis.

In preparing for sampling, a good, helpful laboratory can save a lot of work and ensure that field personnel are properly equipped to take valid samples in return for the business. Many states now certify laboratories for water quality analysis. A lab should be chosen based on experience or trusted recommendations. When preparing for sampling, ask the laboratory to provide the proper sample containers for the analyses they will perform and (of crucial importance) to clean those containers as designated in U.S. Environmental Protection Agency (1983) and American Public Health Association (1998) procedures to avoid contamination that will invalidate the sample. Obtain one or more coolers that will be adequate in size to transport all samples on ice after collection until they reach the laboratory.

A single container can typically be used to hold samples that will be analyzed for several variables with compatible preservatives. For example, conductivity, pH, total suspended solids, and turbidity analyses can usually be performed on samples from one container, and all nutrient analyses can usually be performed on samples from a second container. Appendix B specifies sample containers for common water quality variables as well as other information that will be considered later.

Preparations should also consider QA/QC, covered in detail below. At the preparation stage, it is necessary to pick up extra containers for field replicates and field blanks. A field replicate is a repeated sample, taken at exactly the same spot in exactly the same way, immediately after the primary sample. The general rule is to select randomly 5 to 10 percent of samples for field replication. The random selection can be made by assigning each sampling location and occasion an identifying number and then using a random number generator on a calculator to pick the 5 to 10 percent to be replicated. A field blank is simply a container of distilled water that is carried into the field and returned to the laboratory without disturbance. Its purpose is to indicate if transport has introduced contamination to samples. The field blank should be part of the lab's standard QA/QC procedures for pathogen samples and sometimes for nutrient work.

Sampling personnel should give close attention to safety considerations. Some key ones are:

- Do not allow effluents, contaminated receiving waters, sharp underwater objects, or chemical reagents to contact skin; use rubber boots and gloves.
- Do not enter confined spaces, which may have inadequate air flow and concentrated harmful gases. If the objectives require sampling in such areas, obtain the services of a crew with special training and all of the right equipment.
- Use a proper tool to remove manhole covers, and never leave an open manhole unattended.
- Wear a hard hat if there is any possibility of falling objects.
- Wear a reflective vest if there is traffic near the sampling area, and set up rubber traffic cones if necessary to divert vehicles far enough away.
- When sampling, do not enter a channel with a velocity greater than 75 cm/s (2.5 ft/s) or deeper than waist height; sample from a bank or bridge instead. Have a safety rope ready in all cases when personnel enter the water.

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Sample Collection

What and Where to Sample

Once monitoring objectives are well defined, what and where to sample are fairly straightforward considerations; one samples the water body or runoff stream at the place or places where information can answer the questions represented by the objectives. The principal consideration in this regard comes up when paired sampling is performed. As pointed out in Chapter 5, pairing monitoring stations is advantageous in reducing or eliminating the confounding effects of variability on interpreting results. Paired stations can be on different water bodies or different points on the same water body, one affected and one unaffected by a certain condition. Paired stations must be selected carefully to be as similar as possible in all respects except the effect being studied. Refer to the appendix to Chapter 5 for guidance in station selection and other aspects of paired monitoring program designs.

When to Sample

Deciding when to sample is a key and intricate consideration in obtaining representative samples that will serve the defined monitoring program objectives. Natural water bodies and stormwater runoff experience substantial variability over time. This variability must be accounted for to get reliable answers to the questions the program sets out to answer. The chief sources of temporal variability over extended time spans are seasonal changes and stochastically varying meteorological events. Over shorter time intervals, variability is a function of such phenomena as diurnal light and temperature fluctuations and differing precipitation intensity during the course of storms.

To make good decisions about when to sample, there is simply no substitute for working out beforehand what one wants to learn and, following this, what conditions must be observed to gain the desired knowledge. In most cases, an appropriate sampling schedule will not be uniform over time, since the events creating the conditions of interest are very rarely uniform either. It will therefore almost always be necessary to emphasize certain periods over others to accomplish the objectives within cost limitations. In a stormwater runoff study, for instance, emphasis might be placed on times of highest runoff, when pollutant delivery is greatest, and of lowest flow, when pollutants concentrate most.

Since stochastic meteorological events drive many of the cases of interest in urban water resources monitoring, randomly selecting sampling occasions should be seriously considered. For estimating total suspended solids concentrations and mass loadings, Leecaster, Schiff, and Tiefenthaler (2002) compared two random sampling program designs versus three schemes stratified by season or storm size. They found that simple random sampling of all storms or of medium and large storms had the lowest standard error and the least bias in estimating concentrations, although these designs yielded no advantage in loading estimation.

While randomization can be appropriate in many situations, the program may be best served by having some limiting criteria. For example, it would not be a good use of resources to mobilize for sampling every storm, when some would not have enough precipitation to produce runoff, and some would come with a very short dry period since the preceding runoff. The best course could be to deviate from strict randomization to attain an emphasis that best serves objectives. This strategy would be a stratified random design. For the example of emphasizing periods of highest and lowest runoff, the stratification would allocate more samples to each of these intervals than to times of intermediate flows. The storms within each period would then be selected randomly.

In general, then, it is a practical necessity to have weather forecasts to target the most productive sampling times for the given objectives and anticipate their start. Weather service or university websites, an independent weather forecasting consultant, or some combination of these can be used for this purpose. Since it is very difficult to predict accurately the depth, intensity, and duration of rainfall, it is recommended that the monitoring team be prepared to work during any storm that has a high probability of generating the amount and pattern of rainfall designated for sampling.

Criteria for storms that will be targeted for sampling are commonly established according to the following factors: minimums in rainfall quantity anticipated to be necessary to produce enough runoff to sample, storm duration, and antecedent period without measurable rain. How these criteria should be set numerically depends on local experience, hydrologic modeling, or both. Somewhat typical criteria, as minimums, are 0.15 to 0.25 inch (4 to 6 mm) of expected rain, 1 to 3 hours in duration, and 48 to 72 preceding hours without measurable rain.

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A related issue is how long to continue monitoring. An outer limit for many programs relying on sample composites over time is 24 hours, because maximum holding times prescribed for some constituents in water will be exceeded if processing does not start shortly beyond that point. If the quantities of interest are relatively stabile, though, the time can be extended to get more complete coverage of a hydrograph. The minimum sampling time is best judged in terms of collecting a minimum number of aliquots in a composite and covering a designated minimum proportion of a total hydrograph before flow returns to the pre-existing condition. Typical criteria are at least 8 to 12 aliquots and 75 to 90 percent of the hydrograph.

How Many Samples to Take

Another issue that affects representativeness in sampling is the question on how many different occasions to take samples at each site. This decision is highly influenced by the available budget as well as by the objectives. Making the decision is a classic use for the statistically based methods for choosing sample numbers presented in Chapter 5.

The main difficulty in using these statistical methods concerns the pilot data set, which must be available to define variability. Site-specific data are often not available, and even reliable data from a similar setting may be lacking. Therefore, the temptation to use more arbitrary rules to select sample numbers is strong. Professional judgment based on extensive local experience is the best fallback if there are no suitable pilot data. Site- and case-specific factors have a strong bearing on the sample size necessary to meet the program's objectives.

Thompson et al. (1997) randomly selected from historical highway runoff records to create alternative test sequences of runoff events. They calculated mean concentrations of total suspended solids, total dissolved solids, total organic carbon, and zinc, as well as their 95 percent confidence intervals. The researchers compared results from these test monitoring programs with the actual sequences to see how quickly the sample mean approached the mean of the population established historically. They found that estimates of the means became approximately constant after 20 samples and that variances also stabilized. While Thompson et al. (1997) concluded that approximately 15 to 20 samples are required to provide reasonable mean concentration estimates of these water quality variables, they also cautioned about the possible influence of factors like seasonality on the numbers and allocation of samples.

How to Sample

General Considerations

Water can be collected manually or with automatic samplers in several ways, each with advantages and disadvantages:

- Grab samples – collected once per sampling occasion at a location, usually manually;
- Discrete samples – collected at a series of specific points in time at a location;

Figure 6-4: Multiple-Variable Probe and Data Logger



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- Composite samples – made up by combining a number of samples taken at different times or locations (vertically or horizontally distributed) to represent a time interval or a spatial area; and
- Continuous samples – made up by collecting a fraction of all passing flow to produce an uninterrupted composite sample.

Grab sampling is low-cost but tends not to be very representative because of the temporal and spatial variability usually associated with urban water resources and stormwater runoff. Thorough coverage with discrete samples provides the most complete picture of water quality but creates a large and often unaffordable analytical burden.

Continuous sampling is entirely feasible, using single- or multiple-purpose electronic probes and associated recording instrumentation (termed datasondes), for a number of variables: dissolved oxygen, temperature, pH, conductivity, salinity, total dissolved solids, and oxidation-reduction potential (Figure 6-4). For other variables, continuous sampling is problematic because many substances are impossible to detect electronically at environmental concentrations. Samples must usually be accumulated in an automatic sampler, retrieved, and delivered to a laboratory for analysis. This rather labor-intensive process might be manageable for variables with relatively long allowed holding times, but it is usually impracticable for those that must be filtered, analyzed, or both while very fresh. In these cases, which represent much of the monitoring of urban water resources and runoff, the best strategy is often to take a composite sample over a period of hours and repeat it on other occasions to form a representative database that meets objectives.

With composite sampling being a mainstay in urban water monitoring, the basis for compositing is an important question. Given the temporal variability that usually occurs, collecting aliquots for the composite at equal time intervals is generally not representative. A much better basis is compositing in proportion to flow; i.e., weighting individual samples in the composite in direct proportion to how much of the total flow they represent. For this purpose, usually a flow meter is used in conjunction with an automatic sampler, which triggers sample collection according to flow registration. The section *Automatic Samplers: General Considerations* below further discusses flow-proportional compositing. If there is a flow record, it is possible to produce flow-proportional composites manually. Then flow-proportional subsample volumes are extracted from samples previously taken at equal time intervals and combined.

Whether water samples are taken with manual or automatic samplers, care should be taken to select equipment that does not change the characteristics of the sample through contact with parts made of contaminating materials. Modern automatic water samplers use Teflon, stainless steel, and non-reactive plastics in tubing and other parts that come in contact with sample water.

An important consideration in sampling is to obtain sufficient quantity for the anticipated analyses. In manual sampling, it is normally easy to collect more than enough volume. Quantity becomes more of an issue in setting up automatic samplers, both to represent the event well and collect sufficient volume. The section *Automatic Samplers: Programming Considerations* below covers how to resolve this issue. Appendix B gives amounts required for common analyses. It is always a good idea to collect excess sample volume, if possible, to allow for rinsing instrument sensors with the sample itself, replicating analyses for QA/QC purposes, and re-analyzing if QA/QC criteria are violated. The best rule is to collect 2.5 times the total recommended volume for all anticipated analyses, but actually obtaining that quantity may not be possible in automatic sampling.

In addition to the duties associated with collecting samples, personnel visiting sampling stations should always take copious field notes. These observations are often invaluable later in understanding and interpreting results. The records should include, as appropriate:

- Date;
- Time of sample collection or visit;
- Name(s) of sampling personnel;
- Weather and flow conditions preceding and during visit;
- Number and type of samples collected;
- Calibration results for field instrumentation;
- Field measurements;
- Log of photographs taken;
- Comments on the working condition of the sampling equipment;
- Deviations from sampling procedures; and
- Unusual conditions (e.g., water color or turbidity, presence of oil sheen, odors, and land disturbances).

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Manual Sampling

While automatic samplers are now more used in urban water work, they are much more expensive than manual samplers, still require substantial operator attention, and cannot be used in all situations. Manual samplers are still the necessary or better choice for sampling lakes and rivers that are relatively wide, deep, or both. They also give the flexibility to cover more locations than automatic samplers, which require a considerable installation effort.

Most manual samplers are one of two types: simple dipper pails (Figure 6-5) or cylinders with open ends that are shut with a remotely operated messenger tripping closure lids. Several designs of the second type have long been on the market, two common ones being the Van Dorn (Figure 6-5) and the Kemmerer bottles. Samplers of this type are typically cylinders lowered into the water with both end closures held open. When the sampler reaches the desired depth (determined from a marked line attached to it), a messenger is dropped down the line to trip the closure mechanism. The sampler is then drained through a spigot into sample bottles. Sample bottle rinsing can be accomplished by overflowing two or three bottle volumes. In recent years, these standbys have been redesigned, using materials that will not contaminate samples intended for analysis of metals and organic chemicals. Manual pump samplers are also available, generally for use in fast currents from a bridge.

In the case of streams, rivers, ditches, and other channels, it usually must be assumed for practicality that relatively homogeneous conditions prevail over the width and depth dimensions of the water. Small systems are generally more homogeneous than large ones. As a result of this assumption, samples for water quality in flowing channels are usually collected in midstream and at one depth. In the absence of any special considerations, collection at half of full depth is recommended. Environmental conditions in channels can differ longitudinally and with changing flows. These conditions especially affect particle transport (see 'Special Considerations for Sampling Solids' below). Therefore, sampling programs often require multiple stations and sample collection in a range of flow conditions in dry and wet weather.

Most channel sampling is conducted on foot in shallow flows. When wading, the individual collecting samples should face upstream. This orientation minimizes contamination of the sampled water that would be caused by the sampler's presence. The container should enter the water with the opening down to minimize collection of material from the surface layer. Unless a preservative has been added to the sample bottle before collection, it should be rinsed with two or three volumes of water by filling and totally emptying the sample bottle several times before capping. Several dip samples should be collected and composited. If the protocol for for the intended analyte(s) calls for adding a preservative to the sample bottle, it should be tilted down just slightly from the horizontal and should not be rinsed.

When sampling on foot is impossible or unsafe, some device must be lowered from overhead to reach the water. If a bridge spans a large channel, a Van Dorn

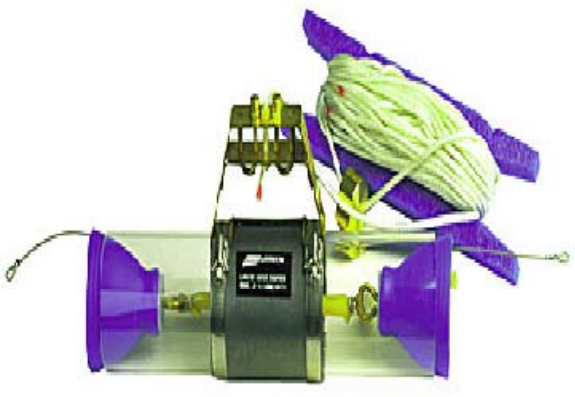
Figure 6-5: Polyethylene Dip Sampler, Swing Sampler, and Van Dorn Bottle



Polyethylene Dip Sampler



Swing Sampler



Van Dorn Bottle

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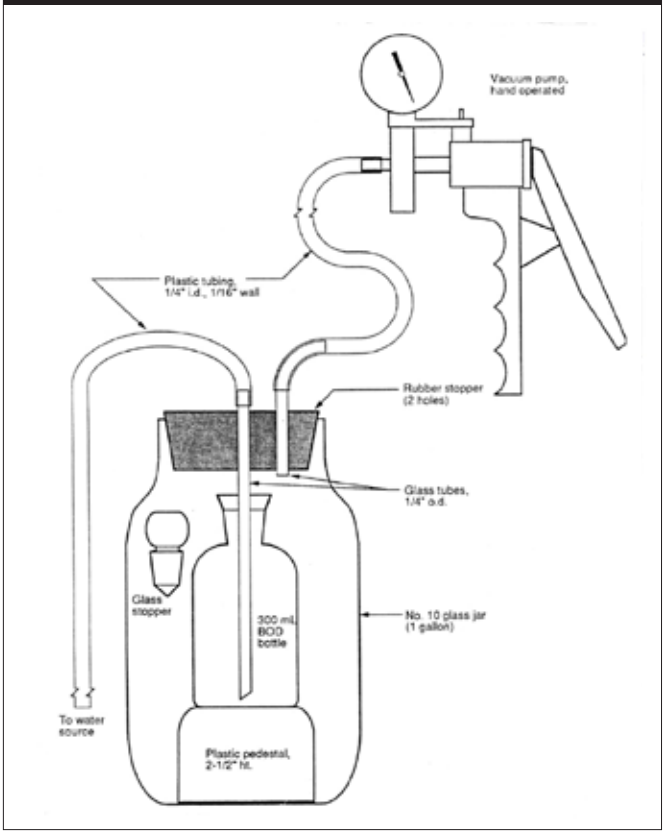
or similar sampler can be used if the current is not too great. In higher currents, a weighted, stainless steel bucket can be lowered on a line to a depth of 30 cm (1 ft) below the surface and then raised.

Other considerations prevail when sampling standing or tidal waters. When sampling a freshwater reservoir (e.g., a lake or wastewater lagoon) or relatively static estuary deeper than about 2 meters (6 ft), it is necessary to take into account the possibility of thermal stratification and the consequent variation in environmental conditions with depth. Depending on the program's objectives, samples might be drawn from the relatively uniform surface (epilimnion) or deep (hypolimnion) zones, in the transition area between them, or some combination of these. Sample locations will generally be accessed by boat, from which the sample can be taken with a Van Dorn or similar sampler.

Sampling in wetlands, shallow channels, and sheet flows is often complicated by shallow depth and patchy physical and vegetation structure. Sampling for dissolved oxygen analysis in shallow water without entraining atmospheric oxygen is especially difficult. The problem can be overcome by placing the sample bottle inside a larger stoppered bottle that is evacuated with a hand pump and then drawing the sample through a tube from the source to the sample bottle (Figure 6-6). In extremely shallow locations, it is best to use equipment like this for all water column sampling in order to avoid collecting sediments and organic debris from the bottom. Whether just one sample or several spatially distributed ones are collected, depends on the program's objectives and the water body's structure.

Any time the variable to be measured can easily exchange with the atmosphere, the sample bottle must be filled to overflowing, capped without trapping any air, and double-checked visually to be sure there are no air bubbles. The leading examples are dissolved oxygen and volatile organic compounds. The best practice, which should be followed whenever possible, is to cap the sample bottle under water. When this is impossible because of accessibility, it is acceptable to drain from a Van Dorn or similar sampler into the bottle that will be used for analysis, overflow it, and cap while water flows. It is never acceptable to pour from a sampler into a sample bottle for these analyses. In inaccessible locations where a messenger-activated sampler will not work, a special grab sampler allowing bottle opening and closure under water must be used.

Figure 6-6: Shallow Water Sampling Apparatus



Automatic Samplers: General Description

Automatic samplers offer a number of advantages over manual methods, as well as drawbacks associated with the expense of purchasing and installing them and the occasional unreliability of any electromechanical equipment. In any event, they are a necessity for many urban water monitoring programs. It is usually infeasible for human sampling personnel to function over extended flow events and produce a representative, flow-related composite sample or series of discrete samples. Attempting to do so still requires a flow meter, as well as expenditure of a significant portion of the capital and effort needed for a coordinated flow meter and automatic sampler setup.

While automatic samplers are indispensable in modern urban water monitoring programs, they must be installed and operated with care to produce data reliably. In most settings, they should be in secure housing to minimize the risk of damage and vandalism. Success usually requires experienced personnel for installation

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and maintenance when needed. Less experienced staff can be trained to program and attend the sampler and flow meter routinely. These operators must be at the sampling site frequently to check equipment operating condition, prepare for events, reprogram settings depending on expected flow conditions, change containers, and, of course, remove and handle samples.

Several manufacturers produce automatic samplers and compatible flow meters (Figure 6-7). While there is some variability in features, the most commonly used samplers have similar standard elements and capabilities. As mentioned above, modern samplers use materials for water-contacting parts that will not contaminate samples with metals or organics that may be subject to analysis. They can generally either deposit samples in a composite chamber or in multiple bottles arranged circularly in a base. Sampler base designs typically allow preserving samples by placing ice around them, and some manufacturers offer refrigerated units as an option. Samplers usually offer the hardware and software for flexible programming capability, allowing monitoring over a fairly wide range of conditions as well as data logging. They can be powered by line current with voltage step-down, 12-volt batteries, or, in many cases, solar panels. Many can utilize telemetry to reduce the need for human intervention and conveniently download data.

Automatic samplers employ vacuum suction to pull samples and have limitations on both the horizontal and vertical distances from which they can draw. While there is some difference among models, these limits are approximately 30 meters (100 ft) and 7 meters (23 ft), respectively. Beyond these distances, a submerged pump can be used to discharge samples into a container from which the automatic sampler draws.

There are a number of precautions in placing sampler intakes to avoid problems and unrepresentative samples. Both these risks can be reduced by situating intake so as to avoid sediments being scoured from the bottom and drawn into the line. The end of a flume for flow measurement, which will often be present, is an excellent spot for the sampler intake. If there is no flume, a good way to avoid sediment entrainment is by locating intakes on top of a small anchored piece of concrete. Water velocity should be above 100 cm/s (0.3 ft/s) to avoid the accumulation of particulates and ensure that all sediments are sampled (Burton and Pitt, 2002). Sampler intakes should not be located downstream of any treated wood structures whenever heavy metals or organic compounds are subject to analysis. Intakes in pipes should generally be elevated and in a turbulent zone to reduce blockage by debris. Pipe flow is often vertically stratified, and elevation tends to produce a more representative sample (Burton and Pitt, 2002).

A water level actuator, depth sensor, or rain gage can initiate sampling. Most commonly used is the flow meter's depth sensor, generally located just upstream of the sampling point in a control section (e.g., in a flume or behind a weir). The calibrated stage-discharge relationship provides flow measurements that determine, in conjunction with the programming, when collection should take place to provide a representative sample.

Automatic compositing can be done either on a time- or a flow-proportional basis. Time-based samples are drawn in equal volumes at equally spaced intervals, regardless of flow conditions. They do not closely rep-

Figure 6-7: Examples of Automatic Samplers



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resent the flow hydrograph and pollutant mass loading delivery, unless the time interval is relatively short. In its most common configuration, flow-proportional sampling weights the volume of a sample taken in proportion to the flow volume that has passed since the preceding sample. This method is the most convenient way of obtaining a sample representative of the overall event. In operation, the flow meter sends a signal to the sampler after a predetermined increment of flow to draw a predetermined volume of water.

Automatic samplers are now sometimes being used in conjunction with datasondes for continuous measurement of basic water quality variables (see listing above). For examples of using this combination of instruments, refer to Wilcock et al. (1995), St. Croix Watershed Research Station (1999), Baxter (2003,) Hall et al. (2004), and Buchanan (2006). Portable autoanalyzers are now coming on the market for potential use in association with automatic samplers for measuring other variables in the field. These instruments have long measured nutrients in the laboratory and are now coming into field service, especially in seawater monitoring applications. A portable incubator and microbial autoanalyzer is also available and could help in getting more representative bacteria data, given the problems in avoiding contamination with composite sampling and the consequent need to rely on grab samples.

Automatic Samplers: Programming Considerations

Thoughtful attention to programming will yield better data from automatic samplers. There will be less wasted effort in taking, and possibly expensively analyzing, samples that are not representative in terms of the monitoring program's objectives. The sampler must be programmed with: (1) the volume to collect each time an individual sample is drawn, and (2) the total number of samples to collect. The flow meter must be programmed with the flow pace, or flow quantity increment, i.e., the additional flow volume registered by the meter that will signal the samplers to draw water. The volume, number of samples, and flow pace must be balanced according to three considerations: (1) obtaining adequate quantity for laboratory analyses; (2) avoiding overfilling the sample containers, which results in unusable samples; and (3) sampling at points spaced sufficiently close to represent the runoff hydrograph relatively well. With faulty programming, small flow events can fail to produce enough quantity, and the hydrograph of large ones may not be well represented.

The more closely spaced in time the sampling points are, the more representative the sample will be. However, this consideration must be balanced with overfilling risk and, in case of battery power supply, the charge life relative to anticipated sampling duration. There is no certain way of specifying volume, number of samples, and flow pace at the outset of a new monitoring effort, but programming can be improved as experience with the site accrues. The best strategy, at least initially, is to use the smallest sample volume found to work well and, in case of compositing, the largest available container to add assurance against overfilling. Specifying flow pace and number of samples is usually hindered at the beginning by lack of information on flow volumes produced at the site by typical runoff events.

Common recommendation for the individual sample volume is in the vicinity of 100 mL. This quantity might be decreased to as little as perhaps 50 mL, if the list of analyses is relatively short, if there seems to be substantial overfilling risk, if there is a desire to sample at quite closely spaced points, or in case of some combination of these circumstances. It might be increased to perhaps 150 mL or even higher if there is concern about obtaining sufficient sample volume for analyses, and overfilling is not risky, so long as enough samples can be taken to represent the hydrograph well.

Deciding on the number of samples is best done with some analysis of expected flow patterns and the resulting hydrographs. The first thing to consider is how many samples the container can hold. For example, the commonly used 20-liter (5-gallon) carboy can hold 400 50-mL or 200 100-mL aliquots, which is not much of a limitation. Deep-cycle marine batteries are capable of drawing at least 300 samples before they need a recharge, which also does not pose much limitation in most cases. If the sampler were programmed to collect 200 samples for compositing over an anticipated 24-hour flow period, a sample could be collected every 7.2 minutes, offering excellent hydrograph coverage. However, a somewhat longer interval between samples would still give good coverage and at the same time leave carboy volume available for more insurance against overfilling. With experience, the setting can always be reconsidered for possible adjustment.

Flow pace is the total flow volume expected over a sampling period, divided by the number of samples. Obviously, volume will differ with conditions. Performing this programming step is easier if there is an existing flow record. The next best foundation is a good hydrologic model to forecast potential volume. In the absence

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of either of these assets, even a simple hydrologic model like the Rational Method can provide some basis. For example, the total runoff volume from a rainstorm can be approximated by multiplying the expected precipitation quantity, the area of the contributing catchment, and a runoff coefficient representing the catchment, along with appropriate conversion factors.

While good, strategic programming is the best way to balance the various considerations, there are some options if the circumstances create problems that make a balance impossible, or if the programming fails because of an unexpected occurrence. If somebody is at the sampling site or in touch by telemetry or anticipates a problem (e.g., overfilling), that person can either reprogram or change bottles or both. If the conflict between small flow event sample volume and large event hydrograph coverage cannot be resolved by programming alone, a possibility raised by Burton and Pitt (2002) is to substitute an enlarged container such as a Teflon-lined or stainless steel drum for the standard sample base. A smaller glass jar can then be suspended inside the large container to collect samples during relatively small events, while the overflow during bigger ones is collected in the large container.

Special Considerations for Sampling Solids

Solid particles are constituents of urban waters that are of interest both in their own right and as transport media for other pollutants. In aquatic monitoring programs, they are almost always represented by total suspended solids (TSS) analysis on a bulk sample intended for analyzing all constituents, dissolved or particulate. Dissolved substances are uniformly distributed in flowing and standing waters, but particles are often stratified vertically, horizontally, or both. Ideally, sampling would represent the actual distribution of particles. However, achieving this is likely to be complex and labor-intensive, making true representation infeasible in many routine monitoring programs. Still, with recognition of the issue, those designing and performing monitoring programs may often be able to avoid patently unrepresentative solids sampling and institute improvements whenever possible.

A number of factors are responsible for spatial stratification of particles (URS Greiner Woodward-Clyde, 1999). To start with, particles in water vary substantially in shape, size, and mass. These differences stem from watershed characteristics such as soils and topography, as well as from meteorological and hydraulic conditions like antecedent dry period, rainfall intensity, and flow rate and velocity. The conveyance (e.g., stream, pipe, ditch) represents another class of influences. The point in time of measurement (early in the flow event, during first flush, if there is one, versus later) also has a bearing.

Sediments larger than 60 μm in diameter are particularly susceptible to gravity and are not distributed evenly throughout the water column. In sinuous streams, particles can be distributed differently horizontally based on size, because of the differential velocity at the outside versus the inside of meanders. However, lighter particles, such as clays and silts, tend to be distributed more uniformly than larger ones (Burton and Pitt, 2002). Solids in these size fractions also generally have more environmental significance than the heavier particles, since they travel farther, affect more aquatic organisms, and collectively have much greater surface area for transporting other pollutants. Therefore, they are the implicit emphasis of many urban water monitoring programs, and the frequent stratification of larger particles is not such a large issue.

Even so, there are some sampling strategies that can reduce what stratification impact there may be on the program's representativeness. The easiest one is to orient the automatic sampler intake in the downstream direction. Neither manual nor automatic samples should be taken in conditions promoting solids stratification (e.g., at a tight bend in a stream or where there is a strong velocity differential with depth).

Several more burdensome strategies exist for consideration when either stratifying conditions cannot be avoided or the program's objectives depend on representing the relatively large solids well. One is to take multiple samples spatially distributed to cover the anticipated variability (vertical, horizontal, or both) and then composite them. This strategy is effectively limited to manual sampling, and it is difficult to get enough information on flow at multiple points to composite the samples proportionately. Isokinetic samplers (Figure 6-8) overcome the fundamental problem causing poor representation of large solids (namely, that sample intake is usually at lower velocity than the flow from which the sample is drawn) by pumping the sample at the same velocity as the flow. The higher the flow velocity, the more representative an isokinetic sample is likely to be. If the stratification is vertical, manual depth-integrating samplers (Figure 6-8) exist to represent the distribution. These samplers point directly into the flow; thus, the sample enters approximately isokinetically. Raising

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the sampler from the invert to the surface produces an integrated sample.

Water Sample Handling

The principal problem in any monitoring program is obtaining a sample that represents the conditions being investigated. When samples are taken from the field, they are removed from their original context and can undergo significant changes. Some of the key variables of common interest are particularly prone to alteration, including dissolved oxygen, metals and nutrient speciation and solubility, pathogens, and volatile organic compounds. The key to avoiding modification following sampling is to practice proper sample handling procedures. These procedures involve careful sample labeling and tracking, preserving samples as recommended, and beginning analytical processing within maximum holding times established for the respective water quality variables.

To avoid mistakes, label a sample bottle with an indelible marker before going into the field. The label should include:

- Sampling station;
- Date of collection (day/month/year);
- Time of collection (24-hour format, added in field);
- Name of person(s) performing sampling;
- Preservative added (if any); and
- Analyses to be performed.

Once the sample is collected, it should be capped with a lid also labeled with the station and date, as well as with the time if samples are taken over time. The bottle should then be sealed and the seal also marked with matching sample information. The seal should remain unbroken until the sample is ready to be opened for laboratory processing.

A tracking record for each sample registers possession as the sample travels from collection through analysis, making misplaced samples easier to find. Samples involved in litigation, especially, require formal chain-of-custody records. Analytical laboratories typically develop these forms appropriate to their services and supply them to customers.

Appendix B gives recommended preservation techniques and maximum holding times for common analytes. The specified maximum intervals between the time a sample is taken and the time it is analyzed vary widely for the different variables and constituents. Some key parameters must be determined in the field immediately after collection, including temperature, pH, dissolved oxygen, and chlorine residual. Other field determinations are, however, often less precise than laboratory analysis. Properly preserved samples can be carried back to the laboratory for replication of field analyses within 24 hours to add reliability. Once a sample reaches the laboratory, filtering for those analyses requiring it should be done within 24 hours. Samples should then be preserved at a temperature of 4°C, unless they are preserved with nitric acid for

Figure 6-8: Isokinetic Sampler and Depth-Integrating Sampler



Isokinetic Sampler



Depth-Integrating Sampler

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metals analysis. The principal references for more detail on sample handling as well as analysis are the American Public Health Association's (1998) *Standard Methods* (available by subscription on-line as of 2004) and the U.S. Environmental Protection Agency's (1983) methods manual.

Sample Analysis

Appendix C classifies into physical and chemical groups the many substances and characteristics that can be measured in water and sediments. The list represents hundreds of quantities, most among the organic chemicals, that could be analyzed. Clearly, judicious choice among all of these possibilities demands reliance on carefully developed objectives representing what one is trying to accomplish with the monitoring program. Among the information in Appendix B are the recommended analytical techniques for common analytes from the larger list. Excepting those few analyses that must be performed immediately in the field, most are laboratory procedures.

A leading issue in sample analysis is the ability to detect and numerically measure within defined bounds of certainty the quantities of interest. Relative to waste streams like industrial and municipal effluents, constituents of natural waters and even urban runoff are often present in low concentrations. These amounts could still be biologically significant, though, and thus the focus of monitoring program objectives.

There are a number of ways in which detection levels can be specified. But however the laboratory itself quantifies detectability, it should be capable of reliably giving results down to the reporting limits (RLs), the lowest concentration of a variable that can be reliably quantified within specified limits of precision and accuracy. Another approach to estimating limits is to use method detection limits (MDLs), the minimum that can be measured with 99 percent confidence that the concentration is above zero. Reliable RLs are often higher than MDLs. Laboratories frequently report values between MDL and RL but flag them to indicate uncertainty in the quantification. Appendix B gives RLs for common analytes as well as methods typically used for their measurement.

A key to achieving detectability in line with program objectives and overall good service is to select a laboratory carefully. Check a candidate laboratory's accreditation, if an accrediting program exists, and seek recommendations from past customers. Most importantly, write detailed specifications on sample handling procedures, methods, detection limits, and QA/QC requirements, using this chapter's recommendations. It is best to establish a contract with the laboratory spelling out all terms.

Simple field test kits have been marketed for years to perform many of the routine analyses. While these kits are easy to use, they have disadvantages for most urban water monitoring. For most analyses, their detection sensitivity is too low relative to concentrations usually encountered in natural waters and urban runoff, and they are subject to interferences that can be removed in more sophisticated laboratory analyses. They also pose the problem of distracting field workers with the time needed to perform analyses and properly handling reagents that may be toxic. Miniaturized laboratory instruments and multi-parameter testers, such as spectrophotometers and titration kits, represent improvements at least in detectability; but these instruments are quite expensive.

Quality Assurance/Quality Control

General Considerations

The effectiveness of any monitoring effort depends on a QA/QC program. This program provides quantitative measurements of the "goodness" of the data. For some variables, QA/QC involves calibration of instruments with known standards. To obtain measures of accuracy and precision, QA/QC may further involve analyses of blanks, replicate samples, control samples, and spiked samples. QA/QC also embraces cleaning and handling, as well as assessment measures taken with sampling equipment and containers to avoid contamination and validate the success of that endeavor.

Two of the most basic considerations in QA/QC were defined in Chapter 5: accuracy – agreement between the measurement of a variable in a sample and the true value; and precision – agreement among replicate analyses of a sample or among analyses performed on replicate samples. Other terms commonly used in both field and laboratory QA/QC programs are:

- Calibration samples – Samples prepared from distilled-deionized water that contain a known concentration of a specific substance or will

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produce a known instrument response; used for all instrumental analyses. Calibration samples are typically run at the beginning of an analytical series to set up the instrument and, often, during the course of the series, when they are often referred to as control samples or check standards.

- Blanks – Samples prepared from distilled water, perhaps with reagents added, to represent zero concentration of a specific substance, or to produce an instrument response that indicates zero concentration; used for nutrients, metals, and organics to check contamination.

Blank samples are taken from distilled, reagent grade, analyte-free, deionized water that is used to rinse sample bottles and sampler apparatus. There are a number of types of blanks: (1) instrument blanks – passed through measurement instruments; (2) calibration blanks – tested to discover contamination in auxiliary chemicals used to prepare calibration samples; (3) reagent or method blanks – checked with all analytical reagents added to detect contamination from these sources; (4) transport or field blanks – transported to the sampling location and treated like a sample thereafter to check for contamination introduced in the field; and (5) equipment blanks – pumped through sampling equipment.

QA/QC involves steps at various times in the process: prior to sampling, in the field, during laboratory analyses, and following up to evaluate and properly report results. The next several sections give general QA/QC guidelines for these steps. More detailed information is available in U.S. Environmental Protection Agency (1979).

Preliminary and Field QA/QC

Avoiding sample contamination requires careful cleaning of samplers, sample bottles, and laboratory equipment. Some general guidelines for cleaning are presented here. Analytical procedures for certain variables specify additional requirements. The recommended procedures should be applied to samplers, sample containers, and all laboratory glassware and implements that will come into direct contact with samples during collection, storage, or analysis.

To avoid the contamination of samples by residues or materials commonly found in sampling equipment, sampler apparatus and containers, including automatic sampler tubing and strainer, should be washed first with phosphorus-free detergent, followed by a tap water rinse. Tubing and containers should be treated with 10 percent hydrochloric acid, ultra-pure deionized water, and methanol rinses (omit acid for strainer). Follow cleaning with air drying. After the decontamination procedures have been completed, cap containers and seal other apparatus with aluminum foil. Keep all equipment in a clean, protected area.

Laboratory equipment should always be washed with detergent (generally phosphorus-free), rinsed with tap water, and rinsed an additional three times with ultra-pure deionized water. An ultrasonic cleaner can minimize the need for hand scrubbing. Following the water rinses, perform acid washing with high-purity acids as appropriate (sulfuric acid for nutrient analyses or nitric acid for metals testing). After acid washing, rinse equipment completely at least six times with ultra-pure deionized water and air dry.

If QA/QC criteria given later are not met, thoroughly review the cleaning operation to determine if inadequate cleaning procedures could be causing contamination.

The field QA/QC program consists of instrument calibration, field sample replication, and transport and equipment blanks. It is important to calibrate field instruments like pH and dissolved oxygen meters exactly as specified by the manufacturer. In many cases, the calibration should occur either once with each batch (up to 20) of samples, every few hours when the meter is stationary and continuously powered, each time the meter is turned on or the range is changed, or each time it is moved from one place to another. It is recommended that pH meters be calibrated with two buffers (e.g., pH 4.0 and 7.0) and checked with a third.

Field replicates are repeated samples, collected simultaneously or nearly so at the same location to provide an evaluation of total sample variability (i.e., field plus analytical variability). Generally, duplicates are sufficient for field replication, requiring one extra set of sample containers. As a rule, 5 to 10 percent of sample collections should be duplicated, allocated randomly. This frequency is not burdensome in manual sampling but can be when using automatic samplers. The most careful programs rotate a separate sampler and associated tubing among sites to obtain the requisite number of field duplicates. In addition, equipment blank samples should be collected on 5 percent of occasions and transport blanks carried along on at least 10 percent of site visits, randomly allocated in both cases.

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Laboratory QA/QC

Laboratory QA/QC begins with properly registering sample receipt, using a tracking form or custody-transfer record appropriate for the monitoring program. While the layout of these forms varies considerably, they generally include:

- Sampling and laboratory personnel (delivering and receiving sample and perhaps others);
- Delivery date and time;
- Sample identifiers;
- Sampling date and time;
- Sample matrix (e.g., water, sediment);
- Sample container type;
- Sample condition (e.g., preserved, on ice, warm, etc.); and
- Requested analyses.

Performing the remaining laboratory QA/QC procedures is generally the responsibility of the laboratory staff and not directly the province of urban water monitoring personnel. However, these personnel must specify and contract for sufficient QA/QC to meet the monitoring program's objectives as well as assess if it is carried out properly. Therefore, this section outlines typical laboratory QA/QC procedures. A monitoring program may not use all of the procedures mentioned, but all should be considered at the outset and dispensed with only if there is a good reason for doing so.

The next consideration is proper calibration of laboratory instruments. Specialized instruments (e.g., conductivity meters, turbidimeters) should be calibrated at least once with each batch of samples and whenever the instrument range is changed. A batch is considered to be up to 20 samples. Other constituents are analyzed on multiple-purpose instruments like spectrophotometers (nutrients), inductively coupled plasma-mass spectrometers (metals), and gas chromatograph-mass spectrometers (organics). These instruments should be calibrated at the outset of analyses with a calibration blank and a range of at least three concentrations spanning the complete anticipated range in the samples (e.g., 20, 50, and 100 percent of expected upper limit). Control samples should be run at two concentrations (e.g., 20 and 90 percent of the upper limit) with every sample batch.

Following is a list of other laboratory QA/QC procedures. In general, every monitoring program should strongly consider specifying at least the first four, as appropriate for the analyses to be performed. The latter two are often routine with laboratories. Those operating urban water monitoring programs should request the results if available, if they do not choose to write them into the specifications.

- Laboratory replicates – Replicate analyses should be performed on randomly selected sample bottles, generally at the rate of 5 to 10 percent for each analyte, to assess analytical precision. Usually, duplicate analyses are sufficient for procedures that are well proven in the laboratory.
- Method blanks – A method blank should be run with each batch of samples for each analyte requiring reagent addition, passage through an instrument, or both. A result exceeding the reporting limit is an indication of possible contamination. An investigation of contamination might include running an instrument blank, which can distinguish contamination originating in the instrument from a source in the reagents.
- Spiked samples – Spiked samples are prepared by adding known concentrations of a specific substance to an environmental sample. One set of spiked sample analyses should be performed on each batch for analytes subject to interferences from other substances in the water, often termed matrix interferences. Generally, nutrients, metals, and organics are candidates for this procedure. To perform it, a sample is first split into three portions. One part is analyzed for the constituent of interest as usual. The others are spiked with this constituent at a particular concentration, producing a pair of matrix spikes (MSs), together known as matrix-spike duplicates (MSDs). MSD analysis provides measures of both spike recovery and replicability (see *Data Quality Assessment* below).
- Surrogate samples – A surrogate is a type of spiked sample for checking extraction efficiency applied to samples from which organics (e.g., total petroleum hydrocarbons, volatile organic chemicals, pesticides) are extracted and analyzed. Surrogate standards are "non-target" compounds that behave similarly to the constituents of interest when analyzed. A thorough program applies the procedure to every sample, including calibration samples, blanks, and spiked samples, and evaluates recovery.

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- External samples (also known as standard reference materials, SRMs) – External samples are prepared by a source outside of the monitoring program to known concentrations of the analytes of interest. To evaluate accuracy, the laboratory should have a set schedule to submit these reference samples to analysts without divulging the concentrations.
- Split samples – Splits are samples divided for independent analysis between two or more parties as a measure of precision. Laboratories should establish arrangements with each other for periodic sample trading.

Data Quality Assessment

Data quality assessment involves steps at the laboratory level and, after receipt of the data, by monitoring program personnel. The laboratory should assess compliance with specific data quality objectives related to the various QA/QC procedures and undertake designated corrective actions if necessary and if at all possible. Monitoring program personnel should review the laboratory's performance in this regard and evaluate field QA/QC results and the completeness and representativeness of the overall program.

The various QA/QC results are assessed quantitatively as follows. Table 6-1 gives suggested data quality objectives as criteria to judge results, as well as actions to take if they are not met.

- Laboratory duplicates – Express precision as the relative percent difference (RPD):
  $RPD = 100(C_1 - C_2)/(C_{avg})$
  where: C_1 = Larger of two values;
  C_2 = Smaller of two values; and
  C_{avg} = Average of two values = $C_1 + C_2/2$
- Method blanks – Compare to RLs, MDLs, and measured sample values. Elevated readings signal probable contamination and reduce ability

Table 6-1: Suggested Data Quality Objectives and Actions to Take

QA/QC Procedure	Data Quality Objective[a]	Action[b]
Laboratory duplicates	Total suspended solids – RPD ≤ 20 Particle size distribution – RPD ≤ 30 Nutrients – RPD ≤ 20 Total hardness – RPD ≤ 10 Metals – RPD ≤ 20	
Pesticides – RPD ≤ 20	Reject batch results if RPD > 2 times objective. Flag batch results as estimates if RPD = 1-2 times objective.	
Method blanks	Maximum detected blank value ≤ 2 times RL	Reject batch results if blank value > 2 times RL. Flag as an estimate if sample measurement < 5 times a detected blank value. Investigate possible contamination sources in the field and laboratory. As needed, make use of equipment and instrument blanks and review all cleaning procedures.
Spiked samples	%R = 75-125	Reject batch results if %R < 50 or > 150. Flag batch results as estimates if %R = 50-75 or 125-150 (except do not flag if measurement < RL and %R = 125-150).
Surrogate samples	%R = 50-150	Reject batch results if %R < 50 or > 150.
External samples	%R within control limits established by the laboratory based on historical performance	Review and correct all relevant procedures if %R outside control limits and reanalyze control samples until objective met.

Notes: [a] RPD – Relative percent difference; RL – Reporting limit; %R – Percent recovery
[b] When data quality objectives are not achieved, reanalyze the affected batch, beginning with preliminary processing steps like filtering, if possible.

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to quantify concentrations with confidence, particularly low values.

- Spiked and surrogate samples – Express percent recovery (percent R) as:

  percent R = 100(S – U)/C

  where: S = Measured concentration in spiked or surrogate sample;

  U = Measured concentration in untreated sample (zero if not detected); and

  C = Actual concentration of spike or surrogate added.

The precision of spiked or surrogate sample analysis can also be assessed as RPD using the two MSD results.

- External samples – Express accuracy as percent recovery (percent R) using the formula:

  percent R = 100(M – T)/T

  where: M = Measured value; and

  T = True value of external standard.

In addition to tracking the laboratory's QA/QC performance and treating the data accordingly, monitoring program personnel should make assessments of:

- Field replicates – Poor replication could result from problems in the field or in the laboratory. If laboratory QA/QC shows that the laboratory is not the source, field notes and field procedures should be reviewed and corrected as necessary. Data from the sampling occasion are suspect, and judgment must be rendered on whether or not those data should be used or, if they are, flagged as estimates. Use the same RPD criteria as applied to laboratory duplicates to assist judgment.
- Sample holding times – Exceedence of designated holding times is cause for evaluating the acceptability of results, with judgment and overall QA/QC performance determining if and how the data will be used.
- Completeness – There should be evaluation and reporting of how completely the monitoring program fulfilled the coverage anticipated by the original objectives. One rather arbitrary criterion is that the program should produce as valid samples at least 95 percent of the targeted numbers; i.e., that analyzed data be reported for a minimum of 95 percent of the collected samples.
- Representativeness – It should be evaluated and reported how well the monitoring program reflected the scope of coverage anticipated by the original objectives. Criteria set during the monitoring program design should be brought into this evaluation (e.g., hydrograph coverage, rainfall quantities, antecedent dry period length, etc.).

How to Analyze Data

Handling Data Below Reporting Limits

Data sets from urban water monitoring programs frequently exhibit values below reporting limits, termed non-detected (ND) or censored data. This situation is particularly prevalent with dissolved metals and organic chemicals. The initial task in data analysis is to decide how to handle such values quantitatively in conjunction with higher numbers. Statisticians and others have debated numerous philosophies and techniques for handling censored data. The choice of method can substantially affect calculations performed on the data, particularly when ND values are proportionately numerous in the data set.

Kayhanian, Singh, and Meyer (2002) outlined and applied five methods to calculate the multi-event averages of event mean concentrations (EMCs) for 16 pollutants in highway runoff and used the averages to estimate mass loadings. Non-detected values among the pollutants ranged from 2 to 88 percent of the total measurements. Mass loading estimates produced by the five methods differed by less than 1 to more than 70 percent. The lower the reporting limit and the percent not detected, the lower the disagreement was. There was little consistency in the tendency of any method to give relatively high or low estimates. The authors did not recommend any one method. It appears from their results that a simple conventional technique like assigning a value of half the reporting limit to non-detected data gives results very similar to more sophisticated methods if the percentage not detected is relatively small (< 5 to 10 percent). With a larger proportion of censored data, a statistician's assistance should be enlisted to apply one of the other methods.

Graphing

The variety of possible objectives for urban water monitoring programs and the many different statistical and

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numerical data analysis methods available mean that any extensive treatment of these topics is beyond the scope of this book. The reader interested in references relevant to urban water resources should consult a statistical text like Zar (1998) or, for exploring the relationships among variables, a multivariate data analysis reference like Everitt and Dunn (2001). It can be said that, before any of these methods are applied to most cases, the data should be explored graphically.

Graphing too can take many different forms. The most basic is probably the scatter plot, in which a water quality variable is graphed against an independent variable like time, distance, or some condition thought to have a possible influence on it (e.g., a land use characteristic or another water quality variable). The scatter plot can be studied for the existence of a trend, which might suggest a follow-up statistical or numerical analysis (e.g., linear regression with an apparent linear trend).

Another very useful graph is the box plot (Figure 6-9). The box embraces relatively high and low values (e.g., upper quartile or decile [75th or 90th percentile] and lower quartile or decile [25th or 10th percentile]), with a bar to signify the median value (50th percentile). "Whiskers" extend from the box to indicate maximum and minimum values that are not outliers. Outliers are defined in various ways (e.g., more than 1.5 box lengths or 3 standard deviations above or below the box) and are shown individually.

Probability plots also find considerable use in analyzing urban water resources data. A probability plot graphs the cumulative probability of measurements falling above or below given values. A special form much used in this work is the log-probability plot to investigate if the data have a log-normal distribution (Figure 6-10).

Figure 6-9: Box Plot Structure

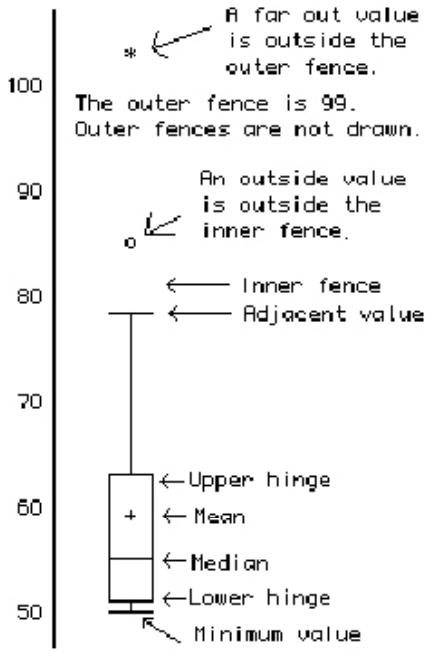
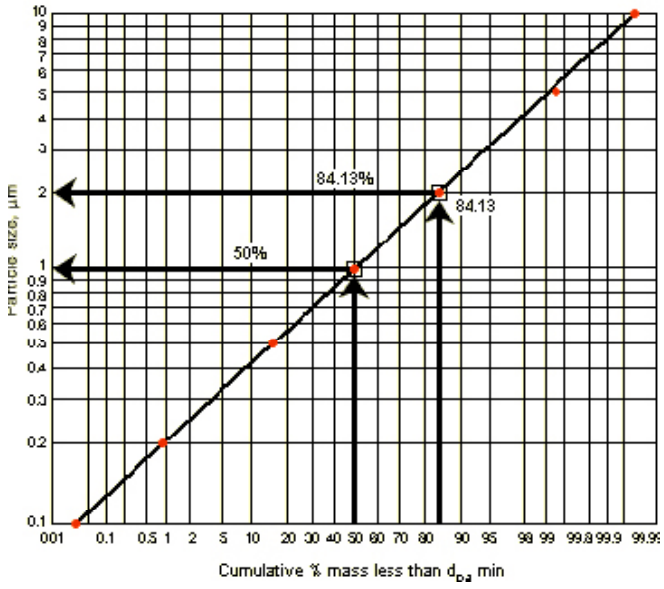


Figure 6-10: Lognormal Probability Plot Example



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If the probability plot of logarithmically transformed data is linear or nearly so, the log-normal distribution can be safely concluded. Water quality data are often found to have this distribution, and it is therefore frequently assumed without testing; but performing the simple graphical exercise even without formal statistical assessment adds assurance to data analysis.

Pollutant Mass Loading Estimation

Mass loading is the product of water volume times pollutant concentration. It is usually computed over a period of time, commonly a year. It is ideal and feasible to have a continuous flow record over the entire period to establish volume. However, there is almost never anywhere near complete coverage of concentration for a period of any length. Therefore, mass loading estimates must be made with only a partial record of events, usually made up of a series of EMCs from sampled events. To obtain a good loading estimate, it is obligatory that the sampled events be representative of the period of interest. As discussed earlier, representativeness is an important aspect of monitoring program design at the outset, and of data quality assessment at the conclusion of monitoring. Charbeneau and Barrett (1998) made the case that averaging EMCs is appropriate for estimating long-term mass loadings, which are affected more by volume than concentration. This advice reinforces the advisability of obtaining a continuous and complete flow record.

If the EMCs have a log-normal probability distribution, as they usually do in water quality data sets, they cannot be simply averaged. In that case, the appropriate expression for the mean EMC (a) is (Marsalek, 1990):

$$a = \mathrm{Exp}(\mu + s^2/2)$$

where: Exp signifies exponentiation on the base of the natural logarithms, e;

μ = Mean of natural logarithms of EMCs; and

s^2 = Variance of natural logarithms of EMCs.

The confidence interval (CI) surrounding the estimate can also be calculated by (Marsalek, 1990):

$$CI = a\ \mathrm{Exp}\{\pm \varphi\ [s^2/n + 2\ (s^2)3/(n-1)]^{0.5}\}$$

where: + is used for the upper confidence limit;

- is used for the lower confidence limit;

φ = 1.96 for 95 percent confidence interval or 1.69 for 90 percent confidence interval; and

n = Number of EMC values used to estimate mean.

Assessment of BMP Performance

BMP performance is a frequent subject of urban water monitoring programs. Most often, performance has been expressed in terms of efficiency as a percentage of entering pollutants captured by the device. Efficiency can be computed according to pollutant concentrations or loadings and in several ways. A cooperative project of the U.S. Environmental Protection Agency and the American Society of Civil Engineers established a National Stormwater Pollutant Database and prescribed methods for analyzing efficiency, pointing out six different ways to compute it (URS Greiner Woodward-Clyde et al., 1999). In a comparative example calculation, efficiencies ranged widely, depending on the computation method, in some cases by more than an order of magnitude.

Reliance on efficiency as the chief performance measure stems from wastewater practices that preceded the development of the stormwater management field. This measure generally provides a reasonably good picture of effectiveness in treating municipal and industrial effluents. However, stormwater and its management differ from these effluents in important respects: (1) flow is intermittent instead of, usually, continuous; (2) both flow rates and pollutant concentrations are generally more variable in stormwater; (3) long storage periods in some stormwater BMPs separate influent and effluent hydrologic characteristics widely in time; and (4) extended exposure to the soil and atmosphere in many stormwater BMPs subtracts water through infiltration and evapotranspiration. Therefore, calculating efficiency from point-in-time inlet and outlet concentration measurements, which is a common practice in wastewater work, is generally not valid in stormwater BMP monitoring.

The best way of setting up the efficiency calculation to recognize these realities of stormwater dynamics is as a comparison of the summation of inlet and outlet mass loadings:

Efficiency = (Sum of inlet loadings – Sum of outlet loadings)/ Sum of inlet loadings

Obtaining a good estimate of efficiency depends on having continuous flow records at the inlet and outlet and sufficient event mean concentration measurements to estimate loading within acceptable error bounds. If these data are adequate, estimating efficiency in this way will account for the effects of intermittent flow, variability, lag between inflow and outflow, and water

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loss. The resulting efficiency will reflect interdiction of pollutant transport through physical, chemical, and biological treatment mechanisms, as well as from flow quantity reduction through water loss. As URS Greiner Woodward-Clyde et al. (1999) pointed out, though, this and other similar methods they reviewed still will not tell if pollutant removal from inlet to outlet is statistically significant. To make that judgment, they put forth the method they called log-normal statistical efficiency, which uses an analysis of variance procedure. The interested reader should consult the original source for details.

Beyond the issue of how to calculate efficiency lies the matter of its adequacy as the only performance measure for stormwater BMPs. The relative variability of pollutant concentrations that can be found in stormwater affects efficiency. It has frequently been noted that efficiency of a given BMP tends to drop as the influent pollutant concentrations decline. The reason for this phenomenon is probably that it is relatively easy to achieve a large initial reduction by capturing the most treatable flow components (e.g., the largest solids making up the TSS) but increasingly harder to gain additional efficiency operating on the less treatable components (e.g., the smaller solids). While a relatively "clean" influent is often associated with low efficiencies, though, the effluent concentration often tends to be similar to that discharged by the same BMP treating a "dirtier" influent at a higher efficiency. Therefore, BMP performance should be judged by both efficiency of mass loading reduction and effluent quality.

The California Department of Transportation (2004) analyzed by linear regression effluent concentrations as functions of influent concentrations for a range of pollutants and various types of ponds, biofilters, and media filters. In some cases, the regressions were not statistically significant and the effluent concentrations were fairly uniform regardless of influent quality, whereas in others, significant regression equations were derived to forecast effluent (C_{eff}) in relation to influent (C_{inf}) concentrations:

$$C_{eff} = m\, C_{inf} + b$$

where: m = Slope of the regression line; and

b = Vertical-axis intercept of regression line.

The intercept b represents the irreducible minimum C_{eff}, the best quality effluent the BMP is capable of.

Sediment Monitoring

Introduction

Urban runoff and other diffuse sources of pollution are highly variable from place to place, and even in one place over time, in effluent quality and environmental effects. Therefore, these sources and their effects are difficult to characterize. They are often more dilute in contamination than industrial and municipal wastewater sources, and their negative impacts may be more the result of cumulative, chronic effects than of short-term, acute ones. Sediment monitoring offers the opportunity both to perform measurements on a component of the environment that does not vary so rapidly and to assess the potential for cumulative effects as well. Because of these advantages, sediment monitoring deserves more attention in urban water resource monitoring programs than it currently receives.

Sediments influence the environmental fate of many toxic and bioaccumulative substances in aquatic ecosystems. Specifically, sediment quality is important because many toxic contaminants found only in trace amounts in water can accumulate to elevated levels in sediments. As such, sediments serve both as reservoirs and as potential contaminant sources to the water column. Sediments tend to integrate contaminant concentrations over time and can represent long-term sources of contamination. Sediment-associated contaminants can also directly affect benthic full-time residents and other organisms that utilize bottom habitats for essential biological processes (e.g., spawning, incubation, rearing). Sediments, therefore, provide an essential link between chemical and biological processes. By understanding this link, environmental scientists can develop assessment tools and conduct monitoring programs to evaluate the health of aquatic systems more accurately.

Sediment monitoring has a great deal in common with water quality monitoring, particularly in the areas of objectives, the determination process for sample numbers, sample handling, commonly performed laboratory analyses, QA/QC, and data quality assessment. In these areas, provisions similar to those for water quality apply, except where supplemented or modified by special considerations given here. This section emphasizes subjects where the two types of monitoring differ, particularly locations, timing, and collection of samples and data analysis and interpretation. On the

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latter subject, an important issue in using sediment data is whether contaminants, especially metals, found in sediments are natural or from human activity. Research in Florida pioneered interpretive techniques to assist in making this judgment and design watershed management strategies accordingly. This section will highlight these methods after covering the basics of sediment monitoring.

Sample Collection

What and Where to Sample

As with all monitoring, sediment monitoring programs should be designed with respect to clear, comprehensive, specific objectives. One common general objective for sediment monitoring programs is to determine the level of sediment contamination existing, perhaps for comparison with quality criteria, dredging, or targeting sediment capping. In this case, it will probably be appropriate to composite a number of samples from the area of interest. Other common purposes for sediment monitoring are to determine the spatial variability of contamination, or to compare two or more areas or different situations. The best sampling design in this case would be to collect replicate samples from each area for separate analyses, with a composite from each as the fallback strategy if budget is limited. In all of these situations, the number depends on the areas' sizes, pollutant variability, acceptable uncertainty, and the cost of sampling. Three samples from an area, analyzed separately or composited, are a minimum for statistical purposes.

Another consideration in locating sampling stations concerns the variability of contaminant levels as a function of sediment grain sizes. The finer solids tend to concentrate pollutants more than the larger particles because of their greater surface area per unit volume available for surface processes of attachment (e.g., adsorption). The relative distribution of particles by size depends on hydrodynamic conditions, with the finer ones tending to deposit in slower flowing areas and the larger ones in faster moving locations. How to decide what flow regimes to sample depends, once again, on objectives and should be carefully considered.

Concerning sediment depth to sample, most monitoring is intended to document recent contamination and relatively short-term trends; hence, samples are most frequently collected from the surficial sediments (typically, the top 5 to 15 cm). Deeper sampling should probably be considered only when the objectives are directed at longer-term or historical trends.

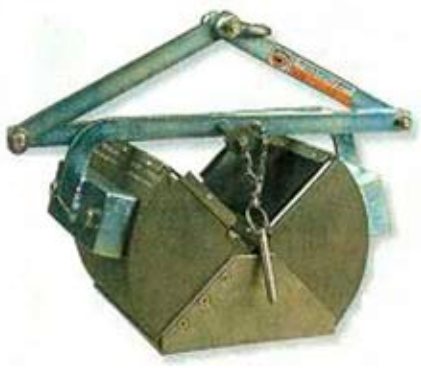
When to Sample

Sediment monitoring has the considerable advantages over water column monitoring of integrating pollutants over time and being much less transient. Still, currents do redistribute sediments, and this phenomenon must be considered in monitoring program design. With reference to the program's objectives, the designer can decide how important this factor is and, if it matters, how to structure sampling seasonally. Obviously, if very short-term trends in a stream are the focus of objec-

Figure 6-11: Ekman Dredge and Ponar Dredge



Ekman Dredge



Ponar Dredge

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tives, sediment monitoring must occur when sediments are being deposited during the storm season. If the overall potential effect of a winter's deposition on fish spawning in the early fall is the issue, monitoring must occur after the cessation of winter runoff and before spawning starts. If comparisons are to be made based on samples taken once a year for several years, monitoring should take place at the same time each year. If sediment monitoring is to occur in a relatively stable lake or wetland system, seasonal timing probably matters less. A clear statement of objectives should make these decisions quite easy to make.

How to Sample

Samplers available for sediment monitoring include scoops, corers, and dredges. The basic type to choose and the particular selection among the alternatives depend on the water body, the conditions, and the program objectives. Scoops can be ordinary shovels or fashioned from common materials for use in shallow water while wading. Some corers are meant for hand use, while others are for deep water. They are usually not appropriate for sediment sampling in streams unless they are being used for frozen core samples (Burton and Pitt, 2002). Dredges are usually most appropriate for dropping from a boat or bridge.

Samplers should be cleansed in the same way as containers used for water samples for analyses of nutrients, bacteria, metals, and organic chemicals. When the objective is to analyze certain quantities without contamination, the collector must be made from special materials. Again, the same guidelines prevail as presented for analyses of the same quantities in water; e.g., sediments to be subjected to volatile organic compound analysis must contact only Teflon.

- One of the most commonly used sediment samplers is the Ekman dredge (Figure 6-11). It is small and light and the easiest among the options to set. Because of its light weight, the Ekman dredge can collect samples only from soft mud, silt, or sand. However, for the same reason, it is the best choice where fine particles are likely to be disturbed by the force produced by objects moving through water. Depending on the required amount of sediment that must be collected, its relatively small size can necessitate collecting replicates to obtain sufficient quantity. Setting the dredge with a pole in shallow water increases the depth and success of sample collection. The Ekman dredge must be tripped with a messenger, similar to a Van Dorn water sampler. If the depth is not known, it is a good idea to touch the bottom with the dredge, pick it up a few feet, and move over a few feet before slowly lowering it back down to the bottom. If the sediment is compacted, or if there is a lot of gravel, rocks, or large debris, the heavier Peterson or Ponar (Figure 6-11) dredges must be used for sampling.
- Both the Peterson and Ponar dredges are large enough (14 to 32 kg, 30 to 70 lbs) to usually require winches for raising and lowering, although models small enough to be raised and lowered by hand are available. Small sticks that can prevent the Ekman dredge from closing will be crushed by these two dredges. Because of their larger sizes, much more water is displaced, and thus fine sediment is easily swept away before the jaws close. Gently lowering these dredges the last few feet can reduce the problem. These larger dredges can collect a larger surface area, but still only sample the top few centimeters of sediment. Attaching weights to them is one way to increase the depth of their bite. The Peterson and Ponar dredges are held open by their own weight and tripped by letting the line go slack.
- Whatever the type of dredge, a smooth retrieval is desirable to avoid losing some of the sample. It is a good idea to place a bucket under the dredge and haul it out of the water within the bucket to avoid letting some of the sample escape with the dripping water.

Less common in general urban water resources work are bedload samplers, which collect the sediments that travel along the stream bed. These samplers are box or basket traps located on the bed with open ends facing into the current. Some bedload samplers are embedded in the stream bottom with a slot opening even with the sediment surface.

Special Considerations for Sample Handling

Sediment samples should generally be passed through a 2-mm sieve to remove twigs, leaves, and other debris larger than any of the sediment particles. For some objectives, it is appropriate to separate the sample further by particle size. If the analysts wish to distinguish

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contaminant levels in fine sediments versus larger ones or versus an overall bulk sample, a subsample of fines should be separated out by sieving through a sieve of appropriate opening size (e.g., 63 mm).

Special Considerations for Sample Analysis

As with water samples, the variables to specify for laboratory analysis depend on the program's objectives, required certainty, costs, and available budget. With sediments, in comparison to water, there is a much higher potential to detect trace substances like the less prevalent metals, pesticides, polynuclear aromatic hydrocarbons, PCBs, etc.; and these measurements are often the principal subjects for analysis.

In addition to contaminants, sediment samples should generally be analyzed for:

- Grain size distribution;
- Moisture content;
- PH; and
- Organic content (as loss on ignition, also termed volatile organic solids, or total organic carbon).

Grain size distribution is important information in interpreting the relative ability of the sample to concentrate contaminants depending on the relative surface area of its makeup. Knowing the moisture content permits expressing results in terms of dry weight of bulk sample, which is superior to expression in terms of wet weight, which is variable. The pH is a key factor in the relative solubility of metals. A relatively acidic pH can mean that metals have dissolved in the water instead of adsorbed to solids; it does not necessarily indicate that they are low in the overall environment. Physicochemical processes by which contaminants associate with solids are related to the amount of organics present. For example, organics provide small pores for adsorption of synthetic organic chemicals.

Special Considerations on How to Analyze Data

General Guidelines

Sediment contaminant concentrations should be expressed in mass of pollutant per unit dry weight of sediment (e.g., mg zinc/dry kg of sediment, which is equivalent to parts per million). Quantities that occur in smaller amounts can be expressed in μg/kg, which is equivalent to parts per billion.

A useful way of expressing sediment contamination is the enrichment ratio, which is the ratio of the pollutant concentration in a sample to the concentration in a reference sample. The reference should be a sample that is equivalent in every way possible but stems from a location considered to be unaffected or minimally affected by the contamination sources influencing the sample being quantified.

Assessing Sediment Contamination Source

In the past, determining whether aquatic sediments were anthropogenically enriched with metals was a difficult process requiring comprehensive site-specific assessments. In recent years, Florida researchers have developed a practical approach for judging the likelihood of human versus natural sources, relying on normalization of metal concentrations to a reference element (Florida Department of Environmental Protection 1988). In Florida, normalization of metal concentrations to aluminum concentrations in estuarine sediments proved the most promising method of comparing metal levels regionally. Further research in Florida, Canada, and Washington State indicated that other crustal metals little influenced by anthropogenic sources (e.g., lithium) can also be appropriate reference elements for assessing sediments. Lithium is sometimes a better basis in areas whose geology is strongly influenced by glacial erosion. The Washington work extended application of the technique from estuarine to freshwater wetland sediments.

To understand this assessment tool, it is helpful to know the geochemical processes that govern the behavior and fate of metals in water. Natural sediments are predominantly composed of debris from weathering of rocks. Acids formed in the atmosphere or from the breakdown of organic matter (e.g., carbonic, humic, fulvic acids) mix with water and form leaching solutions. These leaching solutions break down rocks and carry away the products in solution or as solid debris. This debris is chiefly composed of chemically resistant minerals, such as quartz and clay minerals, which are the alteration products of other aluminosilicate minerals. Naturally occurring metals can substitute for aluminum in the aluminosilicate structure, where they

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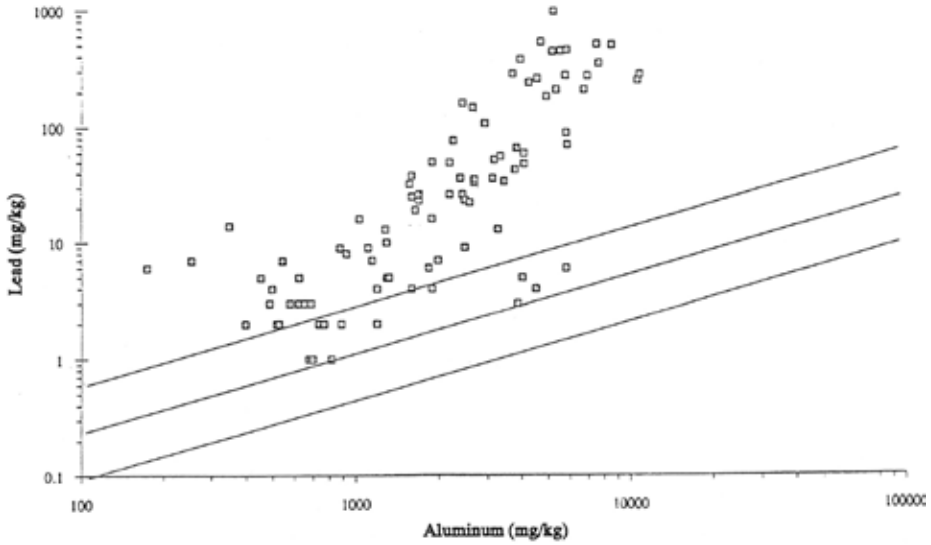
are tightly bound and not prone to being released in water. In contrast, dissolved metals from natural and anthropogenic sources adsorb to particulate matter, a more loosely bound configuration. These metals are generally more subject to release back into the dissolved form by physical or chemical changes in the water.

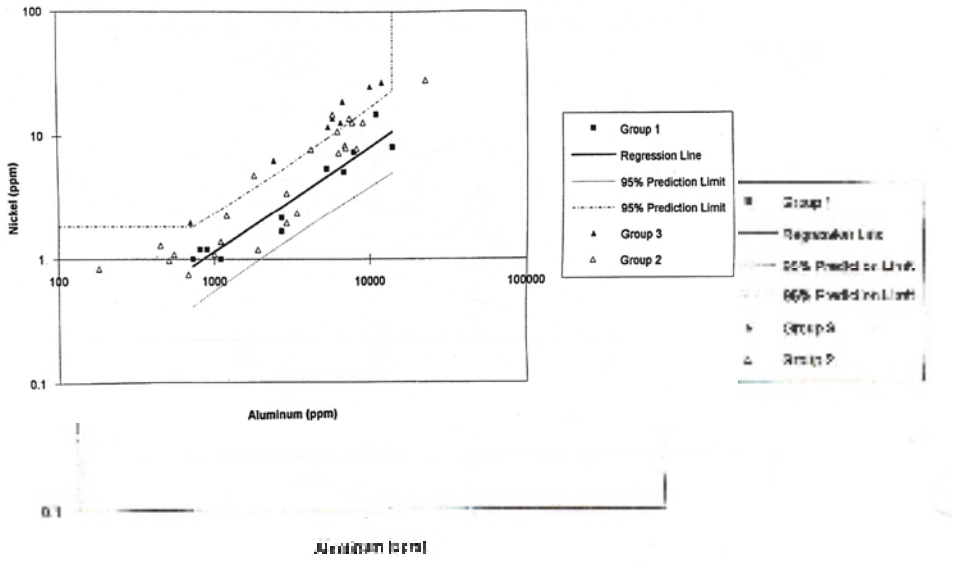
The tool for interpreting metal concentrations in sediments is based on demonstrated, naturally occurring relationships between metals and aluminum (or an alternative like lithium). These natural relationships were used to develop guidelines to distinguish natural sediment deposits from anthropogenically contaminated sediments. This tool is based on a statistical linear regression analysis with aluminum (or lithium) as the independent variable and another metal of interest as the dependent variable. A plot of the regression line

Figure 6-12: Lead Versus Aluminum in Biscayne Bay Sediments



Source: Adapted from Florida Department of Environmental Protection, 1993

Figure 6-13: Nickel Versus Aluminum in Puget Sound Area Freshwater Wetland Sediments



Source: Adapted from Valentine 1994, Azous and Horner 2001

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and 95 percent confidence lines on either side brackets the region expected to contain sediments with the metal primarily originating from natural sources. Figure 6-12 shows the relationship for lead versus aluminum in Biscayne Bay (Florida) sediments. All points lying above the upper confidence limit are regarded as anthropogenically contaminated.

For Puget Sound area (Washington) freshwater wetlands, the regression was first performed using data from a set of wetlands whose watersheds had relatively little urbanization (Group 1 in Figure 6-13 for nickel versus aluminum; Valentine, 1994; Azous and Horner, 2001). Then data were plotted from moderately and heavily urbanized sets (Groups 2 and 3, respectively, in Figure 6-13). The figure shows that, for nickel, all of the Group 3 samples fall above the 95 percent confidence line, as do a majority of the Group 2 samples. While aluminum as the reference yielded the better regression in the example, for other metals, lithium as the reference resulted in a superior regression for this glaciated region.

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Measurement Procedure Using a Current Meter

1. Extend a measuring tape at right angles to the direction of flow and measure the width of the cross section. Record measurements on a data sheet. Leave the tape strung across the stream.
2. Divide the width into segments using at least 20 points of measurement. If previous flow measurements have shown uniform depth and velocity, fewer points may be used; smaller streams may also require fewer points. Measuring points should be closer together where depths or velocities are more variable. Cross sections with uniform depth and velocity can have equal spacing.
3. Record the distance from the initial starting bank and the depth.
4. Record the current velocity at each measuring point. Horizontal (from left to right bank) and vertical (top to bottom) variation of stream velocity may influence streamflow measurements. To correct for vertical differences, measuring at certain depths can yield acceptable estimates of the mean velocity over a vertical profile. If the depth exceeds 0.8 m (2.5 ft), velocities should be measured at 20 percent and 80 percent of full depth and averaged to estimate mean velocity. In the depth range 0.1 to 0.8 m (0.3 to 2.5 ft), take the velocity at 60 percent of the full depth (measured from the surface) as an estimate of the mean over the profile. Measuring velocity in water shallower than 0.1 m (0.3 ft) is difficult with conventional current meters. If much of the reach of interest is very shallow, or flow is too slow for current meter measurement, consider installing a control section and V-notch weir.
5. Calculate flow as a summation of flows in partial areas (Figure 6-A-1) using the following equation:

$$q_n = v_n d_n (b_{n+1} - b_{n-1})/2$$

where: b_{n-l} = Distance from initial point n to the preceding point n-1 (m [ft]);

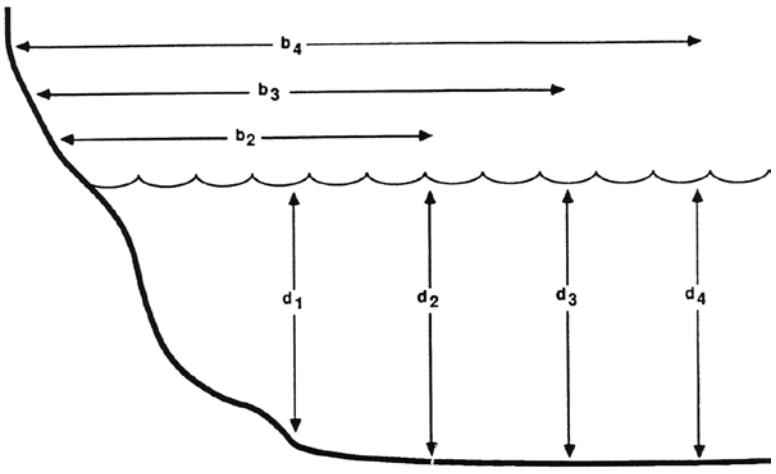
b_{n+l} = Distance from initial point n to the following point n+1 (m [ft]);

d = Mean depth of partial area n (m [ft]);

v = Average current velocity in partial area n (m/sec [ft/sec]); and

q = Discharge in partial area n (m^3/sec [ft^3/sec]).

Figure 6-A-1: Variables Used to Calculate Stream Discharge Using the Current Meter Method



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Recommended Sampling and Analysis Procedures for Water Quality Variables						
Variable	Container[a]	Preservation[b]	Maximum Holding Time	Analytical Methods[c]	Reporting Limit	Unit
Miscellaneous						
pH	P, G	None (field)	None	EPA 150.1; SM 4500-H^+	0.1	pH
Dissolved oxygen	Gd[d]	None (field)[e]	None[e]	EPA 360.1, 360.2; SM 4500-O	0.1	mg/L
Conductivity	P, G		28 days	EPA 120.1; SM 2510	1	μS
Total hardness	P, G	HNO_3 to pH < 2	6 months	EPA 130.1, 130.2; SM 2340B	0.5	mg/L
Alkalinity	P, G		24 hours	EPA 310.1, 310.2; SM 2320	0.1	mg/L
Biochemical oxygen demand	Gd[d]		24 hours (6 preferred)	EPA 405.1; SM 5210	3	mg/L
Chemical oxygen demand	P, G	H_2SO_4 to pH < 2	28 days	EPA 410.1; SM 5220	10	mg/L
Residual chlorine	P, G	None (field)	None	EPA 330.5; SM 4500-Cl	0.1	mg/L
Cyanide	P, G	NaOH to pH > 12	14 days	EPA 335.2; SM 4500-CN^-	3	μg/L
Solids						
Total suspended solids	P, G		7 days	EPA 160.2; SM 2540D	1	mg/L
Total dissolved solids			7 days	EPA 160.1; SM 2540C	1	mg/L
Turbidity			48 hours	EPA 180.1; SM 2130	0.05	NTU
Particle size distribution				SM 2560	1	μL/L
Nutrients						
Total phosphorus	P, G	H_2SO_4 to pH < 2	28 days	EPA 365.1; SM 4500-P F	5	μg/L
Soluble reactive phosphorus			48 hours	EPA 365.1; SM 4500-P F	2	μg/L
Ammonia-nitrogen			28 days	EPA 350.1; SM 4500-NH_3	10	μg/L
Nitrate + nitrite-nitrogen			28 days	EPA 353.1; SM 4500-NO_2, NO_3	10	μg/L
Total nitrogen			28 days	SM 4500-N	10	μg/L
Total Kjeldahl nitrogen			28 days	EPA 351.1; SM 4500-N_{org}	100	μg/L

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Recommended Sampling and Analysis Procedures for Water Quality Variables *continued*						
Variable	**Container[a]**	**Preservation[b]**	**Maximum Holding Time**	**Analytical Methods[c]**	**Reporting Limit**	**Unit**
Metals						
Silver	P, Teflon, or borosilicate glass	HNO_3 to pH < 2	48 hours to filter for dissolved, 6 months to analyze	EPA 200.8; SM 3125	0.2	µg/L
Aluminum					25	µg/L
Arsenic					0.5	µg/L
Cadmium					0.2	µg/L
Chromium (total)					1	µg/L
Copper					1	µg/L
Nickel					2	µg/L
Lead					1	µg/L
Zinc					1	µg/L
Chromium (Cr^{+6})				EPA 218.4; SM 3500-Cr	50	µg/L
Selenium				EPA 270.2, 270.3; SM 3500-Se	2	µg/L
Mercury	G or Teflon	5 mL/L of 12 N HCl or BrCl[f]	48 hours to filter for dissolved, 28 days to analyze	EPA 245.2; SM 3112	0.5	µg/L
Pathogens						
Fecal coliforms	Sterile P, G	None[g]	8 hours	SM 9221, 9222	1	cfu/100 mL or MPN/100 mL
Escherichia coli				SM 9221, 9222	1	cfu/100 mL or MPN/100 mL
Total coliforms				SM 9221, 9222	1	cfu/100 mL or MPN/100 mL
Enterococci				SM 9230	1	col/100 mL
Total petroleum hydrocarbons						
TPH-gasoline	G		14 days	EPA SW 8015	50	µg/L
TPH-Diesel			7 days to extract, 40 days to analyze	EPA SW 8015	50	µg/L
TPH-motor oil			7 days to extract, 40 days to analyze	EPA SW 8015	50	µg/L
Oil and grease		HCl or H_2SO_4 to pH < 2	28 days	SM 5520	5	µg/L

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Recommended Sampling and Analysis Procedures for Water Quality Variables *continued*						
Variable	**Container[a]**	**Preservation[b]**	**Maximum Holding Time**	**Analytical Methods[c]**	**Reporting Limit**	**Unit**
Pesticides						
Organochlorines	Amber glass		7 days to extract, 40 days to analyze	EPA SW 8081. 8085; SM 6630	0.01-0.1	µg/L
Organophosphorus				EPA SW 8085	0.01-0.1	µg/L
Nitrogen				EPA SW 8085	0.01-0.1	µg/L
Carbamates				EPA SW 8321	0.07-3.5	µg/L
Herbicides				EPA SW 8085; SM 6640	0.1-1.0	µg/L
Miscellaneous organics						
Polynuclear aromatic hydrocarbons	Amber glass	None[g]	7 days to extract, 40 days to analyze	EPA SW 8270, 8310; SM 6440	0.05	µg/L

[a] P – plastic (polyethylene); G – glass.
[b] Hold all samples on ice in the field and at 4°C in the laboratory, in addition to any preservation listed. HNO_3 – nitric acid; H_2SO_4 – sulfuric acid; HCl – hydrochloric acid.
[c] EPA – from U.S. Environmental Protection Agency (1983); SM – from American Public Health Association (1998); EPA SW – from U.S. Environmental Protection Agency (1986).
[d] Biochemical oxygen demand bottle.
[e] Can be chemically fixed in the field and titrated in the laboratory.
[f] Filter for dissolved sample analysis before preservation.
[g] Normally none except holding at 4°C but add sodium thiosulfate in the presence of chlorine.

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Types of Water and Sediment Quality Variables

Note: Abbreviations and customary units of measurement are in parentheses; mL – milliliters; L – liters; mg – milligrams; µg – micrograms; µL – microliters.

- Measures of solids – Impacts include light and visibility reduction, abrasion of sensitive aquatic animal tissues, transport of other pollutants, and sediment deposition.
  - Settleable solids (mL/L).
  - Total suspended solids (TSS, mg/L) – Trapped by 0.45-micrometer filter.
  - Total dissolved solids (TDS, mg/L) – Passed through 0.45 micrometer filter and measured gravimetrically after sample evaporation.
  - Turbidity (Nephelometric Turbidity Units, NTUs) – Represents light-scattering ability of suspended particles.
  - Particle size distribution (PSD, % by volume larger than or smaller than given sizes; diameters at which selected % occur [e.g., d_{10}, d_{50}]; µL particle volume/L water volume) – Determined by an electronic particle counter.
- Nutrients – Increases cause eutrophication, excessive nuisance algal growth accompanied by change in algae types (tendency toward filamentous); oxygen depletion upon death and decay.
  - Phosphorus (µg/L in natural waters, sometimes mg/L in effluents) – Most often responsible for eutrophication in fresh waters.
    - Total phosphorus (TP).
    - Soluble reactive phosphorus (SRP), sometimes orthophosphate-phosphorus, which makes up most of SRP.
  - Nitrogen (µg/L in natural waters, sometimes mg/L in effluents) – Most often responsible for eutrophication in salt waters.
    - Ammonia nitrogen (NH_3-N or NH_4^+-N) – Also toxic in high concentrations.
    - Nitrate- (NO_3^-), nitrite- (NO_2^-), and nitrate+nitrite-nitrogen.
    - Total Kjeldahl nitrogen (TKN) – Ammonia plus organic nitrogen.
    - Total nitrogen (TN).
- Metals (µg/L in natural waters, sometimes mg/L in effluents) – Many are toxic to aquatic life, and some bioaccumulate and biomagnify; the first three are most often detected in stormwater runoff and natural waters.

  Copper (Cu)
  Lead (Pb)
  Zinc (Zn)
  Antimony (Sb)
  Arsenic (As)
  Beryllium (Be)
  Cadmium (Cd)
  Chromium (Cr), +3 and +6 valences, total
  Mercury (Hg)
  Nickel (Ni)
  Selenium (Se)
  Silver (Ag)
  Thallium (Th)

Metals can be measured as dissolved, "total recoverable," or both. Dissolved metals have the most immediate toxic effects, but those in solid state can dissolve and also accumulate in sediments and affect life there.

Calcium (Ca) and magnesium (Mg) are non-toxic metals that reduce solubility and therefore harmful effects of other metals and together produce what we call "water hardness." Water quality criteria are based on hardness. Whenever the objective is to determine if natural water metals criteria are met, hardness should be determined and expressed as "mg/L calcium carbonate, $CaCO_3$."

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- Pathogens (no. colonies/100 mL, with no. colonies often expressed as most probable no. [MPN]) – Criteria and limits are in terms of "indicators" that may not be disease-causing themselves but are intended to indicate the presence of fellow-traveling direct pathogens. Analysis of specific pathogens is almost never done in routine environmental work, indicators are extremely variable, and pathogen methods are arguably the least satisfactory in aquatic science.
    - Fecal coliforms – Present in the bodies of all warm-blooded animals.
    - Total coliforms – Some have natural sources, especially soils.
    - Enterococci – Closer indicator of human disease potential than fecal coliforms but not much advantage in environmental variability.
- General measures of organics:
    - Biochemical oxygen demand (BOD, mg/L) – Commonly used to monitor sewage and other effluents high in rapidly decomposable organics.
    - Total organic carbon (TOC, mg/L).
    - Chemical oxygen demand (COD, mg/L).
- Petroleum and its products:
    - Oil and grease (mg/L).
    - Total petroleum hydrocarbons (TPH, mg/L) – Often divided into fractions such as Diesel and gasoline.
- Specific organic chemicals (µg/L) – Many are toxic to aquatic life, and some bioaccumulate and biomagnify.
    - Only pentachlorophenol, certain pesticides, and polychlorinated biphenyls (PCBs) have water criteria for natural waters.
    - Other groups may be represented in effluent limitations and are sometimes detected in natural waters; examples:
        - Volatile organic chemicals (VOCs) – Components of solvents and fuels, most but not all containing chlorine or bromine (benzene and its relatives are exceptions); many are carcinogenic; easily lost from samples to atmosphere and very reactive with other substances.
        - Organophosphorus pesticides (e.g., the commonly used diazanon).
        - Polynuclear aromatic hydrocarbons (PAHs) – Combustion by-products often found in stormwater runoff and sometimes in natural waters.
        - Numerous other industrial and commercial chemicals with various formulations.
- Miscellaneous quantities.
    - Temperature (° Celsius).
    - pH – On 0-14 scale, with 0-6.99 signifying acidic, 7.00 neutral, and 7.01-14 alkaline.
    - Dissolved oxygen (DO, mg/L).
    - Conductivity (microsiemens/centimeter, µS/cm) – Measures ability of water to conduct an electric current because of presence of all dissolved substances, most of which are of natural mineral origin and are not pollutants.
    - Total residual chlorine (mg/L) – Toxic to aquatic life.
    - Cyanide (µg/L) – Toxic to aquatic life.

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CHAPTER 7

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CHAPTER 7

Biological Monitoring and Assessment

Introduction

Scope of Biological Monitoring and Assessment

Traditionally, monitoring surface waters to assess their ecological health and the effects of pollution discharges has relied upon physical and chemical measurements of samples from the water column. This approach originated when the emphasis was on the effects of discharges such as wastewater treatment plants and industrial effluents. These discharges are continuous and generally have a lower degree of variability in flow and water quality than intermittent sources like urban stormwater runoff. Judgment of the effects of relatively uniform discharges on aquatic organisms is based to a large extent on bioassays exposing test species to concentration ranges of pollutants. While these standard procedures deviate from the reality of stresses in natural systems in many respects, they do reflect uniform effluents better than intermittent, more variable ones. When attention turned to these latter discharges, the need for a more direct means of assessing actual ecological effects became apparent. This chapter outlines techniques of biological community assessment to detect the effect of diffuse sources of pollution on aquatic life.

Intermittent discharges create shock loadings to a water body, and the ecological effects depend on many variables and complex interactions. Moreover, many runoff pollutants become attached to sediment particles and settle quickly, exerting detrimental effects over a long period. Furthermore, the high peak flow rates and volumes of urban runoff degrade habitat (e.g., channel and bank erosion) and elevate sediment deposition, the effects of which are not detected by water quality monitoring.

Monitoring biological communities is the most integrated approach to surface water quality assessment and management. While water quality data reflect short-term conditions that exist when a particular sample is collected, biological communities accurately indicate overall environmental health because they continuously inhabit receiving waters and react to various long-term physical and chemical influences. Aquatic organisms also integrate a variety of environmental influences, hydrologic and other physical aspects, chemical effects, and interactions among the biota themselves.

Biological assessment involves integrated analyses of structural and functional components of the aquatic communities. Bioassessments are best used to detect aquatic life impairments and assess their relative severity. Once impairment is detected, additional chemical and biological toxicity testing can identify the causative agent(s) and the source. Both biological and chemical methods are critical in successful pollution control and environmental management programs. They are complementary, not mutually exclusive, ways to enhance overall program effectiveness.

In summary, key advantages of bioassessments are (after Barbour et al., 1999):

- Biological communities reflect the overall ecological integrity of all elements of complex systems.
- Over time, biological communities integrate the effects of various stressors operating at different levels, providing a measure of response to fluctuating environmental conditions.

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- By assessing the integrated response to highly variable pollutant inputs, biological communities provide a practical approach for monitoring runoff source impacts and the effectiveness of best management practices.
- Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to the cost of assessing toxic substances.
- The public is highly interested in the status of biological communities as a measure of environmental health.

In the broadest sense, biological community assessment embraces monitoring of both habitat features and biota in both the plant and animal kingdoms. Habitat features of importance to aquatic life are very numerous and even extend outside of the aquatic environment itself to the riparian zone. Primary producers are found among the macrophytic rooted plants and the periphyton attached to surfaces in the water. Benthic macroinvertebrates are both consumers of aquatic and terrestrial primary production and food sources for fish. Clearly, the potential subjects for monitoring biological communities are so numerous and diverse that designing a feasible monitoring program that will give needed answers highly depends on formulating carefully considered, comprehensive objectives as covered in Chapter 5.

There has been much progress in aquatic bioassessment through benthic macroinvertebrate monitoring. This segment of the community directly represents the ability of the resource to sustain life, which habitat assessment does not. Relative to fish, the invertebrates are much less mobile. They therefore register conditions in a particular location better and are considerably easier to monitor. Progress accelerated when researchers developed indices representing overall benthic macroinvertebrate communities instead of attempting to interpret the significance of measures on individual species or genera.

Beginning in the 1980s, researchers, agencies in some states, and the U.S. Environmental Protection Agency began to develop and codify procedures to guide biological monitoring and assessment. The early developments culminated in issuance of Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish (Plafkin et al., 1989), updated as Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish (Barbour et al., 1999). The Rapid Bioassessment Protocols (RBPs) give complete coverage of monitoring the three biotic communities named in the title, as well as habitat. Burton and Pitt (2002) summarized key provisions of the habitat, benthic macroinvertebrate, and fish protocols, as well as related methods from the state of Ohio, in their Appendices A to C. This chapter does not repeat the extensive material in these references but helps guide potential users to the resources they can find within the protocols, with specific attention to habitat and invertebrate monitoring. It also exemplifies some of the subject matter with case studies representing individual approaches found to work well. The chapter also briefly covers aquatic toxicity assessment, which is not a part of the RBPs.

Reference Conditions for Biological Monitoring

The issue of reference conditions is critical to the interpretation of biological surveys. The term "reference" is more appropriate when applied to a foundation for comparison in studies within the natural environment than "control," which is commonly used in laboratory experimentation. A reference site is a location unaffected by the variable(s) whose effects are to be measured at a "treatment" or "test" site according to the objectives adopted for the monitoring program. In this context, the term "treatment" refers to the influence created by the variable(s) of interest. If the reference site is carefully chosen, equivalent measurements of conditions there and at the test location should elucidate the type and extent of effects created by the test variable(s). As with so much else in monitoring program design, selecting a good reference site depends strongly on clear, complete objective statements. In practice, test variables in urban water resources work are often measures of impact, such as the quantity and water quality of a discharge, or of BMP performance.

Barbour et al. (1996a) described two general types of references, site-specific and regional. The first type represents measurements of conditions either upstream of an intervention, such as a discharge or BMP installation, or from a "paired" watershed. The appendix to Chapter 5 explores paired watershed monitoring program design in some detail. Site-specific references are established at the outset of a monitoring program, in relation to its

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specific objectives. Regional references, on the other hand, consist of measurements from a population of sites relatively unaffected by the usual influences being studied within a fairly homogeneous region and habitat type. These sites usually serve as bases for comparison for various monitoring programs within the region for which they are suited.

Two major concerns always attend the designation of reference sites. One regards the similarity in all conditions except the test variables between the reference and treatment sites. Dissimilarity introduces potential alternative explanations for any observed effect. The second question is the degree that influences to be tested could still have on a reference site. This latter question is particularly evident in urban water work, where the urban influences could be so all-pervasive that there are no true references. In reality, this matter must often be resolved by settling for the "best attainable" conditions (Horner et al., 2002), locations that are not "pristine" but where human presence is sufficiently muted to offer the ability to distinguish clearly what are the effects of stronger influences.

Barbour et al. (1996a) noted the advantages of site-specific upstream references: (1) if carefully selected, the habitat quality is often similar to that measured downstream, thereby reducing complications in interpretation arising from habitat differences; and (2) impairments due to upstream influences from other sources are already factored into the reference conditions. Where feasible, effects should be bracketed by establishing a series or network of sampling stations at points of increasing distance from the test location, although this strategy can greatly raise costs. These stations will provide a basis for delineating impact and recovery zones. In significantly altered systems (e.g., channelized or heavily urbanized streams), suitable reference sites are usually not available. In these cases, historical data or simple ecological models can be used to establish reference conditions, although with less confidence than afforded by direct measurement.

While site-specific reference conditions represented by the upstream-downstream, or paired-site approach are desirable, Hughes (1995) pointed out three problems associated with their use: (1) they provide limited capacity for extrapolation beyond the site-specific; (2) they hence involve a substantial assessment effort that is likely to have little value in future monitoring; and (3) in many cases there are too few reference sites, often only one, for statistical assessment of measurement uncertainties.

Regional reference sites can overcome these disadvantages of site-specific references. The concept of systematically regionalizing reference site establishment got a major boost with Omernik's (1987) ecoregional framework for interpreting spatial patterns in state and national data. The geographical framework is based on regional patterns in land-surface form, soil, potential natural vegetation, and land use. Geographic patterns of similarity among ecosystems can be grouped into ecoregions and sub-ecoregions. Naturally occurring biotic assemblages, as components of the ecosystem, would be expected to differ among ecoregions but be relatively similar within a given ecoregion.

Establishing and characterizing a set of reference locations represents a substantial investment for a region. But this investment can pay off over time in more revealing and certain interpretations of monitoring findings than those that are possible with complete reliance on site-specific referencing. Nevertheless, site-specific references will still be required to meet certain objectives.

Habitat Monitoring

Introduction

An evaluation of habitat quality is crucial to achieving many objectives in the assessment of ecological integrity. Raven et al. (1998) pointed out that habitat and biological diversity are closely linked. In the most general sense, "habitat" incorporates all aspects of the physical and chemical environment, along with the interactions among living organisms. This broad spectrum makes the number of possible monitoring subjects a very long list, which for feasibility must be pared in relation to the objectives being pursued. Usually, the definition of habitat is narrowed to the quality of the internal (to the water body) and external riparian environments that influence the structure and function of the aquatic community. The RBPs adhere to this definition. This more restricted definition still leaves many possible conditions for consideration as monitoring subjects, and the attendant need to apply objectives to focus on the most crucial ones.

The presence of an altered habitat structure is one of the major potential stressors of aquatic systems (Karr

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et al., 1986). A degraded habitat, often from hydrologic modification, can sometimes obscure investigations of the biological effects of contaminated water, sediments, or both. Habitat monitoring should be strongly considered, along with physical, chemical, and biological monitoring, when the objective is to distinguish such effects. Habitat knowledge is essential to pairing stations for study (i.e., upstream and downstream or in paired watersheds). Because conditions are usually not identical from site to site, some habitat data can help in interpreting measurements from paired sites. Where physical habitat quality at a test site is similar to that of a reference, detected impacts can be attributed to water quality factors or other stressors. In the opposite situation of dissimilar habitats, the location with more degraded habitat could be limited more by that condition than other stressors. With all its potential value, though, habitat monitoring cannot replace or be a surrogate for biological measurements when the objective is to discern the condition of biotic populations or communities. Biological quality cannot be safely deduced from habitat conditions and must be measured directly, if that is the focus of objectives.

The following subsections on monitoring program elements preserve the same terminology with regard to "sampling" that was used in preceding monitoring chapters. Of course, tasks in habitat monitoring frequently do not involve sampling in the same context as collecting a parcel of water or sediment. Instead, habitat monitoring usually involves tasks like measuring dimensions and observing and then describing (and also perhaps scoring) environmental attributes. Nevertheless, this chapter maintains the terminology, both for consistency in language and to emphasize that the same set of decisions must be made in properly designing habitat monitoring programs as in any other monitoring effort.

What to Sample

As pointed out in the introduction, potential variables for habitat monitoring are very numerous. Researchers and agency staff based at local, state, and federal levels have collectively devised many standard variable lists and protocols for guiding habitat monitoring. Locally and regionally derived lists typically represent the concerns of the area (e.g., anadromous fish spawning and rearing habitat features in the Pacific Northwest, conditions for resident warm-water and cold-water fish species in the Upper Midwest) and usually should not be transferred in whole to other places.

The RBPs prescribe a series of descriptive, measured, and scored variables in their habitat monitoring protocol. The descriptive set consists of:

- Stream characterization;
- Watershed characterization;
- Riparian vegetation;
- Aquatic vegetation; and
- Sediment and substrate.

Measured quantities are:

- Instream features (measured or estimated dimensional characteristics, mostly);
- Large woody debris; and
- Basic water quality variables (temperature, conductivity, dissolved oxygen, pH, and turbidity).

The RBPs recommend scoring the following variables in four categories from optimal to poor quality for organism support, with five numerical scores to represent distinctions within each category. In some cases, variables do not apply to both high- and low-gradient streams but only one.

- Epifaunal substrate and available cover – Includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks available as refugia, feeding areas, or sites for spawning and nursery functions of aquatic macrofauna.
- Embeddedness – Refers to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, the surface area available for macroinvertebrate and fish shelter, spawning, and egg incubation decreases.
- Pool substrate characterization – Evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (e.g., gravel, sand) and rooted aquatic plants support a wider variety of organisms.
- Velocity/depth combinations – Patterns of velocity and depth are included for high-gradient streams under this parameter as an important feature of habitat diversity. The best streams in most high-gradient regions will have all four

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patterns present: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow.

- Pool variability – Rates the overall mixture of pool types found in streams according to size and depth. The four basic types of pools are large-shallow, large-deep, small-shallow, and small-deep.
- Sediment deposition – Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition.
- Channel flow status – The degree to which the channel is filled with water.
- Channel alteration – A measure of large-scale changes in the shape of the stream channel.
- Frequency of riffles or bends – A way to measure the sequence of riffles and thus the heterogeneity occurring in a stream. Riffles are a source of high-quality habitat and diverse fauna.
- Channel sinuosity – Evaluates the meandering of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when it fluctuates as a result of storms.
- Bank stability – Measures bank erosion or the potential for erosion.
- Bank vegetative protection – Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone.
- Riparian vegetative zone width – Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone.

For example, categories and scores for embeddedness are shown in Table 7-1.

As mentioned earlier, work in various places has identified habitat variables providing the most crucial information for regional biota. A systematic, objective process of singling out, from the multitude of possibilities, those variables giving the best return of important information permits streamlining habitat monitoring. For example, May (1996) used a partial least-squares correlation analysis to identify the most effective physical habitat measures of Puget Sound area lowland stream quality, in relation to the ability to support benthic macroinvertebrate communities. The resulting variables are:

- Large woody debris frequency;
- Large woody debris volume;
- Glide habitat (as percent of wetted area);
- Pool habitat (as percent of wetted area);
- Pool frequency;
- Cover on pools (vegetation cover as percent of total pool area);
- Stream bank stability; and
- Embeddedness.

Several investigators have developed regional indices representing habitat quality based on multiple variables. An index is useful to express relative habitat quality among different locations in the same or different streams. The indices have generally been composed of scores assigned to observations (and in some cases measurements) in categories, usually a simplified version of the RBP scoring illustrated above. Since these indices are not a mathematical combination of measurements themselves, they have customarily been labeled "qualitative." The Ohio Environmental Protection Agency's (1989) Qualitative Habitat Evaluation Index (QHEI) incorporates substrata, instream cover, channel morphology, riparian width and cover, and pool, glide, and riffle characteristics. May's Qualitative Habitat

Table 7-1: Embededness Categories and Scores

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Source: Barbour et al., 1999

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Index (QHI) is made up of 15 variables scored in four quality categories and combined additively.

Where to Sample

The usual variability of habitat and impossibility of monitoring throughout the ecosystem inevitably raises the question of where it is best to monitor. Barbour et al. (1999) advised in the RBPs that, when sampling water bodies with complex habitats, a complete inventory of the entire reach is not necessary. They add, however, that the sampling area should be representative of the reach, incorporating riffles, runs, and pools if these habitats are typical of the stream in question. Mid-channel and wetland areas of large rivers, which are difficult to sample effectively, can be avoided. Sampling effort should be concentrated in near-bank habitats where most species occur.

When to Sample

If habitat knowledge is essential to the objectives, it should be monitored simultaneously with biological sampling. Simultaneous monitoring saves effort and therefore costs. While habitat is not invariable over time, it is likely to vary less, and more slowly, than the biota of interest. Therefore, it is appropriate for the biological monitoring schedule to control timing of habitat work.

How Many Samples to Take

Overall, the same representativeness and statistical considerations covered in Chapter 5 and (for water quality and sediment monitoring) in Chapter 6 also apply to habitat monitoring. When true sampling is required, composite sampling, as opposed to individual small replicates, is the norm for RBP investigations to characterize stream reaches. However, taking too few samples for a composite can be a major source of variance. Replication is strongly encouraged for precision evaluation of the methods.

How to Sample

As with guidance on what to sample in habitat monitoring, there are numerous guides on performing the various monitoring tasks. The RBPs contain field data sheets and associated text guidance. Prior to formulating his own system, May (1996) assessed more than 10 general purpose protocol documents, most from the Pacific Northwest, and a number of additional special purpose procedures. He incorporated the most appropriate features from these resources to arrive at a comprehensive procedure applicable to wadeable streams supporting or potentially supporting anadromous salmon in and near urban areas. The reader launching a habitat monitoring program has the choice of proceeding with the national RBPs, at least at first, or seeking out already developed regional methods. Such methods may already have adapted the RBPs for regional circumstances. These methods should be evaluated for the intended purposes, and either used if applicable or adapted with guidance by the objectives and the modifications made by others when they needed different techniques.

Chapter 6 emphasized the importance of careful, complete field notes while taking water quality samples. Field notes are, if anything, even more important for habitat monitoring, since they constitute the only record of many measurements and observations of habitat attributes. Any reader contemplating or performing habitat monitoring should consult the Chapter 6 discussion of field notes. The safety of the record should be ensured in all cases, but particularly for habitat monitoring, by keeping more than one copy of field notes in different locations.

Quality Assurance/Quality Control

Habitat monitoring QA/QC is less developed and formalized than for water quality and sediment monitoring. The RBPs recommend the following steps:

- Train field personnel in the assessment techniques being used.
- Calibrate the judgment criteria for each habitat variable and for the stream settings in which they will be assessed. Calibration involves determining if generally recommended scoring systems apply in these settings by employing them, as a preliminary step, across a representative range

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of conditions and then adjusting them if warranted.

- Make periodic checks of assessment results using pictures of monitoring reaches and discussions among the personnel involved. A more advanced form of this step would be independent assessments by participants, a form of replication for precision evaluation.

How to Analyze Data

To a large extent, routine data analysis in habitat monitoring accompanies or is a nearly immediate outgrowth of monitoring itself. The scoring systems and indices described above represent straightforward means of analyzing raw data. The Snohomish County [Washington State] Public Works Department (2002) took a somewhat more advanced approach to index formulation, using the procedure for developing indices of biological integrity (IBIs) to derive an index of habitat integrity (IHI). The following section on Benthic Macroinvertebrate Monitoring covers the IBI procedure. The variables identified by Snohomish County as being most instrumental were:

- Fine sediment ratio – Bed surface ratio of fine sediment (< 6.3 mm) to larger particles;
- Unstable banks ratio – Ratio of unstable to stable bank length;
- Hydrologically modified banks ratio – Ratio of hydrologically modified to unmodified bank length;
- Pool functional area ratio – Ratio of pool areas to non-pool areas;
- Pools per unit bankfull width; and
- Large woody debris and stumps per unit bankfull width.

Benthic Macroinvertebrate Monitoring

Introduction

Benthic macroinvertebrates live in close association with the bed (benthic area) of a water body, are visible to the human eye, and do not possess an internal skeleton. They include the juvenile forms of insects, which typically emerge to the terrestrial world as adults; mollusks (e.g., snails, clams); crustaceans (e.g., crayfish, shrimps, amphipods); and various worms. They have some but not a high degree of mobility. As biological monitoring subjects, benthic macroinvertebrates have a number of advantages (Barbour et al., 1999):

- Macroinvertebrate assemblages are good indicators of localized conditions. Because many have limited migration patterns or a sessile mode of life, they are particularly well suited for assessing site-specific impacts (e.g., in upstream versus downstream studies).
- Macroinvertebrates integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages respond quickly to stress; the overall community responds more slowly.
- An experienced biologist can often detect degraded conditions with only a cursory examination of the benthic macroinvertebrate assemblage. Macroinvertebrates are relatively easy to identify to family; many taxa intolerant of human-induced stresses can be identified to lower taxonomic levels with relative ease.
- Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects.
- Sampling is relatively easy, requires few people and inexpensive gear, and has minimal detrimental effect on the resident biota.
- Benthic macroinvertebrates serve as a primary food source for fish, including many recreationally and commercially important species.
- Benthic macroinvertebrates are abundant in most streams. Many small streams (first and second or-

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ders), which can have a diverse macroinvertebrate fauna, only support a limited fish fauna.

- Most public agencies that routinely collect biosurvey data focus on macroinvertebrates. Many regions already have background macroinvertebrate data.

Where to Sample and How Many Samples to Take

As with all other monitoring, allocation of sampling effort should be based on the set objectives and weighing of variability and costs to acquire the desired information with a sufficient level of assurance. Benthic macroinvertebrates generally vary greatly in spatial dimensions in response to the substrata, depth, velocity, overhanging and aquatic vegetation, and other conditions. Therefore, a statistical analysis will often dictate a very large number of samples to arrive at a reliable estimate of population sizes. There has been a definite trend away from population estimates and the diversity indices that were applied in analysis of population data, except for basic research purposes. The environmental management field has moved instead toward benthic indices of biotic integrity (B-IBIs). The section *How to Analyze Data* below covers the concepts and methods associated with B-IBIs.

If the objective is to develop a B-IBI or use an existing one, the first question is whether to sample a single habitat type (e.g., a stream riffle) or multiple habitats (e.g., beneath overhanging vegetation, in addition to a riffle). The RBPs present protocols for both options. The original RBPs (Plafkin et al., 1989) emphasized the sampling of a single habitat, a riffle or run, as a means to standardize assessments among streams having those habitats. The revised RBPs (Barbour et al., 1999) still considered this approach to be valid, because macroinvertebrate diversity and abundance are usually highest in cobble substrate (riffle/run) habitats. Where cobble substrate is the predominant habitat, this sampling approach provides a representative sample of the stream reach. However, some streams naturally lack much of that substrate. In cases where the cobble substrate represents less than 30 percent of the sampling reach in reference streams, one or more other habitats should be sampled. Habitats to sample should be selected based on the habitat availability in the reference state, and not in potentially impaired streams. Absence in an impaired stream of a habitat that occurs in the reference will, of course, influence the results, which is appropriate in comparing conditions.

The RBPs define five habitat types that support benthic macroinvertebrates (Barbour et al., 1999):

- Cobble (hard substrate) – Prevalent in riffles (and runs), which are a common feature throughout most mountain and piedmont streams; dominant in many high-gradient streams;
- Snags – Accumulated woody debris that has been submerged for a relatively long period (not recent deadfall and not large logs, which are generally difficult to sample adequately);
- Vegetated banks – Submerged lower banks having roots and emergent plants associated with them;
- Submerged macrophytes – Aquatic plants rooted on the bottom of the stream; and
- Sand (and other fine sediment) – Usually the least productive macroinvertebrate habitat in streams, although the most prevalent in some streams.

The RBPs recommend using a kick net for single-habitat sampling and a D-frame net for multiple-habitat work (refer to *How to Sample* below). The protocols prescribe the types and numbers of locations each net type should be used in. They specify compositing all samples to represent the habitat.

B-IBIs have been developed principally through single-habitat (riffle) monitoring programs using Surber samplers (refer to *How to Sample* below). Using a statistical bootstrap algorithm, Fore and Karr (unpublished manuscript cited by Karr and Chu, 1997) analyzed how many samples taken in this way are needed for a relatively precise quantification of metrics making up the B-IBI. They concluded that using the mean of three replicates taken within the riffle habitat is sufficient and that using five replicates yields little additional precision.

Another consideration is sufficient sampling to obtain an adequate number of invertebrates to be representative. There is disagreement on this point, with Karr and Chu (1997) recommending the collection, identification, and counting of at least 500 individuals per habitat for B-IBI metrics computations, a larger number than that cited in the RBPs. These authors believe that sampling sufficient organisms is far more important than the way in which sampling is organized. It is certainly true that larger numbers give more preci-

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sion but also that taxonomic work is time-consuming and therefore expensive. Like all other decisions in monitoring program design, this one ultimately comes down to the objectives, environmental variability, and available budget. The dilemma illustrates once more the importance of considering and defining these factors at the outset of the program and then relying on them in making decisions.

With most objectives aimed at impact or BMP assessment, ideal sampling locations for the three replicates consist of rocks 5 to 10 cm (2 to 4 inches) in diameter resting on pebbles in a water depth of 10 to 40 cm (4 to 16 inches) within the main flow of the stream (Karr and Chu, 1997). The three locations should be selected through a random process. On grid paper, map a fairly homogeneous reach approximately 50 to 100 meters (164 to 328 ft) in length, if the riffle is at least this extensive. Each square represents a potential Surber sampling spot of 1 ft square. Eliminate any grids that lie beneath undercut banks, overhanging vegetation, or other bank influences. Number the remaining grids. Use a random number generator to select three grids for sampling.

Upon occasion, urban water resources monitoring programs may have objectives more far-reaching than the routine ones. In these cases, a more sophisticated sampling program design could be warranted. For example, variability within a habitat type could be explored by sampling along several transects within it. These transects could be placed randomly or purposely in locations representing different substrata. A sample allocation strategy more sophisticated than the simple random approach outlined above (e.g., stratified random sampling, systematic sampling) could better apply in these cases.

When to Sample

Many invertebrates are found in aquatic systems throughout the year. Still, seasonal factors cause shifts in numbers and relative dominance. Insects emerge in response to temperature and light. Large flows can wash out organisms and deplete the community for a time. Therefore, timing should be considered relative to objectives. If the objective is to determine the maximum production capability of the system, sampling should occur when conditions are stable and elevated temperature and light are stimulating biological activity, but before there is substantial emergence (i.e., spring or early summer). If the objective is to compare conditions among streams, sampling should occur in all of them over a short time span. If the intention is to make comparisons over a period of years, monitoring must be scheduled for the same time each year.

As an example, monitoring of human development effects in the Pacific Northwest has concentrated on sampling each September for several good reasons (Karr and Chu, 1997): water flows are generally fairly stable and safe for field work then, before the fall and winter rains, and invertebrates tend to be abundant. Sampling in September also minimizes disturbance of the spawning redds of anadromous salmonids.

How to Sample

In the RBPs, Barbour et al. (1999) described five sampling devices commonly used in macroinvertebrate assessment work (all with the standard 500-μm mesh size nytex screen):

- Kick net – 1 x 1 meter (3.3 x 3.3 ft) net attached to two poles; most efficient for sampling cobble substrate where velocity of water will transport dislodged organisms into net; designed to sample 1 m^2 of substrate at a time; can be used in any depth from a few centimeters to just below 1 meter;
- D-frame dip net – Frame 0.3 meter (1 ft) wide x 0.3 meter (1 ft) high and shaped like the letter "D" attached to long pole; net is cone- or bag-shaped for capture of organisms; can be used in a variety of habitat types, either as a kick net or for "jabbing," "dipping," or "sweeping";
- Rectangular dip net – Frame the same size as a D-frame net and also attached to a long pole; net is cone- or bag-shaped; sampling is conducted similarly to the D-frame device;
- Surber sampler – Frame 0.3 x 0.3 meter (1 x 1 ft) placed horizontally on cobble substrate to delineate a 0.09 m^2 (1 ft^2) area; vertical section of frame has the net attached and captures the dislodged organisms from the sampling area; restricted to depths of less than 0.3 m (1 ft); and
- Hess sampler – Cylindrical metal frame approximately 0.5 m (1.6 ft) in diameter sampling

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an area of 0.8 m^2 (8.6 ft^2); an advanced design of the Surber sampler intended to prevent escape of organisms and contamination from drift; restricted to depths of less than 0.5 m (1.6 ft).

The RBPs give complete advice on using the kick net and D-frame dip net samplers recommended for single- and multiple-habitat work, respectively. Important techniques in using a Surber sampler are:

1. Sample from downstream to upstream to avoid early disturbance of later sampling spots.
2. Stand downstream of the sampling point, place the sampler with the net opening facing upstream, and brace the sampler's frame in place firmly.
3. Starting with rocks closest to the net opening, rub rocks by hand to dislodge invertebrates into the net; place rocks in a bucket of water for later inspection and hand picking of any remaining animals.
4. Thoroughly disturb the pebble layer with a small rake or large spike to a depth of at least 10 cm (4 inches) for at least 1 minute; collect any rocks appearing and save them in the bucket.
5. Lift the frame off the bottom slowly and tilt the net up and out of the water while keeping the open end upstream.
6. Invert the net (and removable receptacle, if the net has one) into a white wash pan; repeatedly dip the net in the stream to concentrate debris in the bottom and empty into the pan each time.
7. Take great care to capture all individuals in the net, using a magnifying glass and forceps to spot and remove animals as necessary.
8. With a small amount of water in the pan, pick through the collection to find all invertebrates and place them in a sample jar about half full of ethyl alcohol preservative and sitting in the pan to avoid spillage; again take great care to capture all individuals, using a magnifying glass and forceps as necessary.
9. Pick invertebrates from the rocks and bucket using the same care and place them in the sample jar.
10. Properly label the sample jar (see *Quality Assurance/Quality Control* below).

How to Handle Samples

Once preserved in 100-proof ethyl alcohol, invertebrate samples are stable for a reasonable period until identification. Because they do deteriorate, the taxonomic work should occur as soon as possible and certainly within months of collection.

The main issue in sample handling is whether or not to subsample to reduce the burden of sorting and identification. Authorities are divided on the wisdom of subsampling. As pointed out earlier, Karr and Chu (1997) believe in the necessity of a sample of 500 animals minimum, which removes subsampling as a consideration unless the collection is particularly rich. Courtemanch (1996) argued against subsampling but recommended a volume-based procedure if it must be done. The RBPs (Barbour et al., 1999) embrace subsampling and cite justification for it. They present a fixed-count approach based on a 200-organism subsample but applicable to any size (e.g., 100, 300, 500). The subsample must be sorted and preserved separately from the remaining sample for quality control checks.

Quality Assurance/Quality Control

QA/QC procedures are less developed for biological than for water quality and sediment monitoring but more complete than for habitat monitoring. The following recommendations are primarily derived from and based on the RBPs (Barbour et al., 1999).

For QA/QC of field work:

1. Prepare sample labels on a medium resistant to deterioration in alcohol with the sample identification code, date, stream name, sampling location, and collector's name. Place labels inside sample containers. Label the outside of the container with the same information. Also, include this information on chain-of-custody forms.
2. After sampling has been completed at a given site, all nets, pans, etc. that have come in contact with the sample should be rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found should be placed into the sample containers. The equipment should be examined again prior to use at the next sampling site.

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3. Duplicate sampling at 10 percent of the sites, minimum, to evaluate precision and repeatability of results for the sampling technique and collection personnel.

Recommended laboratory QA/QC procedures are:

1. Laboratory QA/QC personnel or a qualified co-worker should examine at least 10 percent of the sorted samples in each lot. (A lot is defined as a special study, basin study, entire index period, or individual sorter.) The worker will examine the grids chosen and the tray used for sorting and look for organisms missed by the sorter. Organisms found will be added to the sample vials. If the QA/QC worker finds fewer than 10 organisms (or 10 percent in larger subsamples) remaining in the grids or sorting tray, the sample passes; if more than 10 (or 10 percent) are found, the sample fails. If the first 10 percent of the sample lot fails, the worker will check a second 10 percent of the lot. Sorters in training will have their samples 100 percent checked until the trainer decides that training is complete.
2. After laboratory processing is complete for a given sample, all sieves, pans, trays, etc., that have come in contact with the sample should be rinsed thoroughly, examined carefully, and picked free of organisms or debris. Add organisms found to the sample residue.
3. Maintain a voucher collection of all samples and subsamples. These specimens should be properly labeled, preserved, and stored in the laboratory for future reference. A taxonomist (the reviewer) not responsible for the original identifications should spot check samples corresponding to the identifications on the bench sheet.
4. A reference collection of each identified taxon should be maintained and verified by a second taxonomist. The word "val." and the first initial and last name of the person validating the identification should be added to the vial label. Specimens sent out for taxonomic validations should be recorded in a "taxonomy validation notebook" showing the label information and the date sent out. Upon return of the specimens, the date received and the finding should also be recorded in the notebook, along with the name of the person who performed the validation.
5. Record information on samples completed through the identification process in the "sample log" notebook to track the progress of each sample within the sample lot. Update tracking of each sample as each step is completed (i.e., subsampling and sorting, mounting of specimens, taxonomy).
6. Maintain a library of basic taxonomic literature to aid identification of specimens, and update it as needed. Taxonomists should participate in periodic training on specific taxonomic groups to ensure accurate identifications.

How to Analyze Data

There has been a certain loss of confidence in diversity indices for interpretation of trends responding to impacts of human actions and management strategies. As a result, several different kinds of community indices have been introduced. These indices more fully exploit the data resulting from community monitoring and relate more closely to community structure and processes than do diversity indices. Terms applied to the indices include invertebrate community index (ICI) and benthic index of biotic integrity (B-IBI). Indices of these types are composed of metrics representing aspects of both elements and processes within the macroinvertebrate assemblage. Although these indices have been regionally developed, they are typically appropriate over wide geographic areas, usually with some modification of metrics for regional circumstances (Barbour et al., 1995).

Fore and Karr (1994) outlined the general procedure for B-IBI development as follows:

1. Develop metrics appropriate for the geographic area that respond to known sources of human influence.
2. Test the metrics developed in Step 1 with a second, independent data set.
3. Develop an index based on proven metrics; test the index on a third, independent data set.
4. Fine-tune the index.

The key to successful B-IBI development is selection of metrics. The most effective metrics are those having ecological relevance, exhibiting response across a range of human influence, and distinguishing well between relatively pristine and degraded sites. Four

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studies published from 1995 through 1997 that tested potential metrics in detail serve as a basis for general recommendations, presented in Table 7-2 (DeShon, 1995; Barbour et al., 1996b; Fore et al., 1996; Smith and Voshell, 1997). While these metrics were found to have wide applicability, their utility should be checked regionally and replaced by others if they are found to be superior.

Some basic statistical and graphing procedures are useful in the initial identification of potential metrics. If an index is being constructed to study biological response to increasing urbanization, for example, bivariate correlation analyses relating all potential metrics to an urbanization measure can show the strongest associations. The seven to ten metrics with the highest correlations should be reviewed to judge if any represent very similar attributes and might be dropped. Also, metrics in the next tier of correlation coefficients should be reviewed to see if they represent different attributes that might be an asset to index development. Based on these reviews, decide on the composition of metrics that should be used for an initial trial B-IBI.

The next step in index development is scoring metrics. Continuing with the example, plot each of the tentatively selected metrics versus the urbanization measure. Through visual assessment of the graphs, assign ranges of the urbanization variable representing relatively high to low development, typically in five steps, although there may be situations where one less step or one or two more are appropriate. Again working visually, determine what range of each biological metric is consistent with each urbanization range. Assign scores

Table 7-2: Definitions of Best Candidate Benthic Metrics and Predicted Direction of Metric Response to Increasing Perturbation

Category	Metric	Definition	Expected Reaction to Impairment
Richness	Total # Taxa	Measure of richness of macroinvertebrate Taxa	Decrease
	# EPT Taxa	# of taxa in the EPT insect orders	Decrease
	# Ephemeroptera Taxa	# of mayfly taxa	Decrease
	# Plecoptera Taxa	# of stonefly taxa	Decrease
	# Trichoptera Taxa	# of caddisfly taxa	Decrease
Composition	% EPT	% mayfly, stonefly, and caddisfly larvae	Decrease
	% Ephemeroptera	% mayfly nymphs	Decrease
Tolerance/Intolerance	# Pollution Intolerant Taxa	Richness of perturbation-sensitive species	Decrease
	% Tolerant Taxa	% macrobenthos tolerant of perturbation	Increase
	% Dominant Taxa	Measure of the dominance of the most numerous taxon. Can also be calculated for 2nd, 3rd, 4th and 5th most dominant taxa.	Increase
Feeding	% Filterers	% macrobenthos which filter water or sediment for FPOM	Variable
	% Grazers and Scrapers	% macrobenthos that scrape or graze at periphyton	Decrease
Habit	# of Clinger Taxa	# insect taxa	Decrease
	% Clingers	% insects with fixed retreats or adaptations to attach to surface in moving water	Decrease

Source: Barbour et al. 1999, as compiled from DeShon 1995, Barbour et al. 1996b, Fore et al. 1996, Smith and Voshell 1997

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to each metric range from 1 for the lowest interval to 5 for the highest. The B-IBI is the sum of all metric scores, with the maximum possible B-IBI being the product of the number of metrics and the maximum score (5). The tasks outlined here complete Step 1 in the general procedure. Steps 2 and 3 should follow.

In fine-tuning the index (Step 4), it is advisable to perform some statistical and numerical tests to evaluate the index's performance for its intended purpose. These tests can involve linear regressions and multivariate techniques like discriminant function analysis and logistic regression to create models relating B-IBI and independent variables like the urbanization measure. During these analyses, metrics can be removed and added to the index (e.g., R^2, the coefficient of determination for regressions) to see if these alterations result in improvement in measures of model effectiveness.

Toxicity Assessment

Introduction

Toxicity assessment is not a routine activity in urban water monitoring. Many assessment procedures exist, although some have limited usefulness in the usually variable environment of waters affected by runoff from diffuse landscape sources. Therefore, this coverage will just summarize the field in a general manner. Burton and Pitt (2002) provide considerable detail in their Chapter 6 and Appendix D.

Toxicity assessment options can be classified as:

- Toxicity screening procedures – An instrumental analysis to express toxicity to a microorganism of an environmental sample relative to a control sample;
- Whole-effluent toxicity (WET) tests – Controlled laboratory exposure of a test species to various strengths of a natural or wastewater sample;
- Sediment toxicity tests – Controlled laboratory exposure of a test species in vessels containing sediments as well as water, generally over a somewhat extended period;
- In situ toxicity tests – Confined exposure of a test species in the natural environment; and
- Tissue analysis – Measurement of substances in organism tissues to determine their bioaccumulation.

Toxicity Screening Procedures

The most common screening procedure is the Microtox test. Microtox is a trademark of AZUR Environmental. The Microtox Acute Toxicity Test is a 15-minute exposure, metabolic inhibition test that uses freeze-dried luminescent bacteria (Vibrio fischeri NRRL B-11177) to assess the acute toxicity of water, soil, or sediment samples. The test system is comprised of the Model 500 Analyzer, Microtox reagent and test solutions, a personal computer, and MicrotoxOmni™ Software for capturing and analyzing test data. Toxicity is expressed in terms of reduction in light output with exposure to the sample relative to a control. If a series of dilutions of the sample has been tested, which is the standard protocol, and if light reduction exceeds 50 percent, EC50 (the 50 percent effective concentration) can be calculated to express the sample dilution that reduces light output by half compared to the control.

Microtox is a convenient and relatively inexpensive way of identifying the potential for generalized toxicity to aquatic biota of interest. However, it does not provide evidence of the source(s) of toxicity or of actual toxicity to those organisms. To achieve this, more probing analyses must be performed with more specific objectives. Still, the procedure provides urban water resource managers with a tool to identify the need for and plan additional work.

Whole-Effluent Toxicity (WET) Tests

WET tests are bioassays most commonly performed on species long considered to be good laboratory test specimens. The species most often used are the alga Selenastrum capricornutum; the invertebrates (zooplanton) Daphnia magna, Daphnia pulex, and Ceriodaphnia dubia; and the fish Pimephales promelas (fathead minnow). Juvenile rainbow trout (Salmo gairdneri) have also been used quite frequently. The U.S. Environmental Protection Agency (1991) recommended simultaneous WET tests on a fish, an invertebrate, and an alga. National Pollutant Discharge Elimination System (NPDES) permits sometimes require at least fathead minnow and zooplankton bioassays.

WET tests are performed in laboratory containers, most commonly with acute exposures to a number of test organisms over 48 or 96 hours, although longer,

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chronic tests certainly can be and often have been conducted. A series of dilutions of the sample from 100 percent to 0 (control) strength elucidates a range of effects. In acute tests, the effects are normally simply lethality or non-lethality. Their results are usually expressed in terms of the LC50, the sample concentration lethal to 50 percent of the organisms present, often with the length of the testing period also indicated (e.g., LC50-48 h, LC50-96 h). Chronic assays reveal degrees of sublethal effects, such as effects on mobility, growth, or reproduction.

WET tests have the advantage of being guided by well-standardized procedures under a high degree of control. However, they represent a very artificial environment that makes it difficult to extrapolate results to natural systems. They use organisms that are rarely inhabitants of the ecosystem of interest and omit inter-species interactions (e.g., competition, predation) present in the natural environment. WET tests reflect only one type of stressor, contaminants dissolved in water, and omit the effects of other key stressors, like hydrology-driven phenomena and sediment contamination. Very importantly for urban water resources investigations, they miss the pulse exposures of stormwater runoff.

Some work has been done to address these shortcomings but has not advanced far. For example, Herricks and colleagues experimented with time-scale toxicity testing (Herricks, Milne, and Johnson, 1994, 1998; Brent and Herricks, 1998, 1999). This research was designed to assess the effects of brief exposures, such as would occur in storm runoff episodes, based on sublethal responses during a post-exposure observation period. The results exhibited both delayed effects and, sometimes, organism recovery, which suggests that toxicity tests used to monitor brief exposures should use environmentally relevant exposure durations and post-exposure observations.

Sediment Toxicity Tests

Methods for long-term, chronic testing of sediment toxicity are relatively new (U.S. Environmental Protection Agency, 2000). Using invertebrates as test specimens, these procedures require 42 days or longer to run and are thus relatively expensive. They are mentioned here just to alert urban water resources managers, who may encounter more attention to sediment contamination in the future.

In Situ Toxicity Tests

The basic approach to in situ toxicity testing is to confine test species in a container, expose them to the environment being studied, and observe their lethal or sublethal responses. A number of media exist for in situ toxicity testing, including instream artificial substrates, baskets containing rock or mesh, glass slides, side-stream chambers, and cages. All of these devices require protection from high flows, and they must be secured to the bed of the water body (Burton and Pitt, 2002).

In situ testing has a number of advantages. Like other types of field analysis, this type of testing avoids the extensive artificiality of laboratory conditions and the difficulties of extrapolating laboratory results to the field. Naturally, it also incorporates environmental conditions that are difficult or impossible to produce in the laboratory, such as sunlight; suspended solids; diurnal effects of oxygen and temperature; spatial and temporal variation of physicochemical constituents; stressor magnitudes, frequencies, and durations; presence of natural substrata; and other factors (Burton and Pitt, 2002). Of particular importance in urban water resources investigations, the test organisms are subject to the multiple stresses and actual exposure patterns of episodic stormwater runoff events.

There are also some disadvantages associated with in situ toxicity testing. Test species can be affected by transportation stress and starvation in enclosures. Protecting test media from high flow can artificially alter the effects of flow on organisms. They may not experience the same sediment transport patterns as free-living individuals. Containment removes interactions with other species and other members of the same species. Unprotected devices are also subject to disturbance by humans and animals.

In situ tests provide the best information about toxicity when used in conjunction with the results of other monitoring. In accordance with program objectives, these additional assessments might include monitoring of water quality, sediment quality, or both; habitat conditions; and benthic macroinvertebrates.

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Tissue Analysis

Inorganic and organic chemicals accumulate in the tissue of organisms through chronic exposure to polluted waters and sediments as well as through the ingestion of food. The goal of any evaluation of bioaccumulation is to relate body-residue concentrations of toxins to effects in aquatic species. Accomplishing this goal allows the response to toxins to be linked directly to sources of contamination. While many factors affect the bioavailability of toxins in the environment, it is the amount of exposure in the receiving species that causes the toxic response. Despite the potential usefulness of this approach, it has not been pursued much through development of standard test procedures and long-term studies (Burton and Pitt, 2002).

An alternative to the use of test species are semipermeable membrane devices (SPMDs). SPMDs are polymeric tube bags containing a lipid compound, which mimics uptake and concentration of contaminants in living tissue. Comparisons of concentrations of target compounds in SPMDs and test species have shown that they often provide similar results (Burton and Pitt, 2002).

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CHAPTER 8

Impact Avoidance

Avoiding impacts to aquatic ecosystems can only be achieved through careful site design and implementation of source control and management practices. However, any one stormwater management tool is unlikely to achieve the stormwater management objectives for a given development on its own. It is therefore necessary to consider the objectives early in the design process, when competing demands can be carefully balanced and an integrated approach achieved. This approach reduces both the need for and the size of treatment devices, as well as their construction and maintenance costs and obligations. Achieving an overall stormwater management objective by using a treatment train approach that combines a number of different tools or practices is essential to successful program implementation.

It is important to recognize that limiting hydrological modification is just as important as water quality treatment if aquatic resource protection is to be achieved. Hydrologic change also influences the whole range of environmental features that affect aquatic biota – flow regime, aquatic habitat physical structure, water quality, biotic interactions, and food sources. In addition to the hydrological change resulting from urban development, there are changes to the runoff delivery system. Soil compaction or impervious surfaces convert what was once subsurface groundwater flow to overland surface water flow. Thus the precipitation over a small watershed reaches the stream with a typical delay of just a few minutes, instead of what once was a lag of hours, days, or even weeks. The result is a dramatic change in flow patterns in the downstream channel, with the largest flood peaks doubled or more and the more frequent storm discharges increased as much as tenfold.

Many of the effects of stormwater are, by themselves, relatively small. When considered on a watershed basis, however, their cumulative effect is substantial, such as in the case of flooding due to gradual increases in upstream impervious areas. To manage these effects, we need to understand them on a watershed basis, where the effects are discernible, but prevent them on an individual site basis, where the physical changes to the hydrological cycle are made. This is the role of watershed management plans: as a range of approaches to achieve overall watershed objectives, they are a key tool for integrated stormwater management.

This chapter is divided into two major components: site (and watershed) resource protection and enhancement, and source control. The section on site resource protection and enhancement includes discussion of riparian buffers, upland forests, wetlands, steep slopes, and the importance of soils. The section on source control provides discussion of site practices, including low impact design to avoid adverse impacts from residential and commercial areas.

It is important to reiterate that both components can and should be applied on a site-by-site basis as well as on a watershed basis to provide maximum downstream aquatic system protection.

The final section of this chapter sets out information on various new approaches.

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Site Resource Protection and Enhancement

The site resources referred to here are those natural features or site characteristics that, to a large extent, provide a benefit to receiving systems just by existing. They serve the general public by continuously reducing peak rates and volumes of stormwater runoff, provide water quality treatment, and prevent damage to improved or natural lands either on site, where the site resources exist, or downstream of those resources.

Site resources have intrinsic and other values for habitat and biodiversity beyond their stormwater functions. These include a wide variety of items, but those discussed here are considered primary resources that should be recognized and considered in site development and use. The following site resources (some of which are less obvious than others) are considered important primarily for their stormwater management benefits. They will be discussed in further detail in the following sections.

- Terrestrial ecology and landscape form;
- Headwater streams;
- Wetlands;
- Floodplains;
- Riparian buffers;
- Vegetation;
- Soils;
- Slopes/topography;
- Other natural features; and
- Linkage with site development.

Site resources often overlap. For example, a riparian buffer may lie within a floodplain, or, conversely, a forested area may form part of a riparian buffer. In this chapter, they are discussed individually, although their benefits may be, and generally are, overlapping and cumulative.

Most readers are probably already familiar with the following terms and discussion. Recognition of their values cannot be overemphasized, but they are often overlooked during the site development phase. Too often, we consider "low impact" approaches such as swales, bioretention, infiltration, or rain gardens to be stormwater management practices. Those practices impact the natural environment less than more traditional practices such as ponds, but they are only part of the solution. There has to be a fundamental shift in how we use land if we are to protect aquatic resources. Too often, we shape the land to fit a style of development. We have to start thinking about how to shape our use to fit the land. Any approach is only as strong as its weakest component. Doing half of what is needed is good from an evolutionary context, but resource protection may not result.

Terrestrial Ecology and Landscape Form

Where natural features are located on a site is just as important as the characteristics of the natural features themselves. There are several basic principles of ecology that can be used to improve the quality of receiving environments. These principles, detailed below, apply to all site resources:

- Retain and protect native vegetation (forest, regenerating forest, wetlands) – these ecosystem types have important intrinsic values and provide different habitats for native flora and fauna as well as different ecological functions.
- Allow natural regeneration processes to occur (e.g., pasture => scrub => forest; wet pasture => wetland).
- Undertake weed and pest control of invasive, non-native species to improve the natural succession potential of native vegetation. Allow natural processes and seed dispersal mechanisms to occur.
- Replant and restore with native plants to provide vegetation cover that is characteristic of what would once have been there and/or that reflects other local remnants in the area.
- Restore linkages with other natural areas or ecosystems (e.g., by using waterways and riparian areas, linking fragmented forest remnants, linking wetland ecosystems and freshwater ecosystems to terrestrial forest/scrub remnants).
- Our knowledge is limited, and we do not know what we are doing yet. When we design a bridge or a building, we include a factor of safety. We do not normally include a factor of safety for

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the environment, and that lack of additional protection is reflected in the continuing decline of aquatic resources.

It is important to retain natural areas (including scrub, forest, and wetlands) on a site for their biological diversity and intrinsic values, which include the following:

- They are important as characteristic examples of biodiversity in a region or district.
- They contain a diversity of species or ecosystem types.
- They may contain rare or special features or unusual ecosystem types.
- They are valuable as habitats for native species.
- They have the ability to sustain themselves over time (e.g., through available seed sources, active regeneration, the level of weeds and pests and outside influences controlled).
- They are of adequate size and shape to be viable.
- They provide a buffer to habitats or natural areas from outside influences. These may include scrub on edges of native wooded areas or intact sequences from estuarine to terrestrial, from freshwater to terrestrial, from valley bottom to ridge top. They also provide linkages with other natural areas (corridors for birds or invertebrates).

Long-term ecological viability is the ability of natural areas to retain their inherent natural values over time. This includes the ability of a natural area to resist disturbance and other adverse effects, as well as the ability of its component plant and animal species to regenerate and reproduce successfully. Complex ecosystems often have a messy or "wild" appearance to them as their complexity increases. A mature forest can take hundreds of years to develop, so seeing one indicates a lack of recent disturbance.

Headwater Streams

A stream is a natural body of water that includes a free-flowing area of concentrated flow, an area having pools of water, a spring outfall, and/or a wetland. In the context of a stream, the area of concentrated flow has defined banks and bottom, not including areas of sheet or shallow concentrated flow such as swales.

Nationwide, as shown in Table 8-1, 73 percent of the total length of all streams in the U.S. are first- and second-order streams. These streams tend to be filled



Example of wetlands and native wood areas.

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in, enclosed, and developed over. If one of our goals is to protect third-order and larger streams, that goal cannot be attained if first- and second-order streams are destroyed. Imagine, if you will, that 73 percent of your arteries were clogged or significantly impaired: your state of health could certainly never be considered good. Unless first- and second-order streams are protected, expectations for larger streams have to be reduced. This thought could have a substantial impact on how we develop land and on our normal practice of enclosing first-order streams to allow development to proceed on top of what was once a natural system. Once we enclose a stream and build on top of it, that stream is gone. How many times have all of us remembered a stream that we played in as children and found that stream now gone? It is a sad but recurring story.

Wetlands

Wetlands include permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals adapted to wet conditions. They occur on water margins or on land that is temporarily or permanently wet. Wetlands are a major habitat for freshwater fish as well as for frogs, birds, and invertebrates. Almost half (42 percent) of the total U.S. threatened and endangered species depend upon wetlands for survival. Wetlands have unique hydrological characteristics that can be irreversibly modified by activities such as drainage.

There can be few other vegetation classes that have suffered as severely during human times as wetlands have. There are many reasons for this, mainly related to the fact that wetlands are on flat land, suited to agriculture, and generally display a vegetation that is held in low esteem by the average person. These changes have occurred despite the value of wetlands as wildlife habitats, regulators of flooding, their intrinsic values, and their benefits for recreation and scientific research. Nevertheless, a far larger area than that remaining today has been lost through drainage or filling.

The vast majority of wetlands are less than 10 acres in size. It is also reasonable to assume that there are many more in the less than two-acre category, but they are generally not reported. This is especially true in headwater areas of watersheds, where very small wetlands may be present.

It is important to recognize that even without the presence of humans, wetland systems are being modified and eliminated by a natural ecological ageing process: succession. The filling and conversion of wetlands into more terrestrial types of ecosystems occurs naturally, but at a relatively slow rate. The intervention of humans into the process accelerates this conversion process from a period of hundreds of years to a very short time frame that can be measured in years.

In addition to the beneficial values shown in Table 8-2, the above list can be expanded to incorporate stormwater quality treatment. Natural systems have

Table 8-1: Relationship Between Stream Order and Other Stream and Floodplain Measures for Nontidal Streams of the United States; Meters (m), Kilometers (km)

	Stream				Floodplain	
Order	Number	Length (km)	%	Cum %	Width (m)	Area (km^2)
1	1570000	2526130	48.4	48.4	3	7578
2	350000	1295245	24.8	73.2	6	7771
3	80000	682216	13.1	86.3	12	8187
4	18000	347544	6.7	92.9	24	8341
5	4200	189218	3.6	96.5	48	9082
6	950	97827	1.9	98.4	96	9391
7	200	47305	0.9	99.3	192	9083
8	41	22298	0.4	99.7	384	8562
9	8	10002	0.2	99.9	768	7682
10	1	2896	0.1	100.0	1536	4448

Source: Brinson, 1993

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complex mechanisms, and the following list describes the major processes occurring in wetlands that allow them to provide water quality enhancement functions. These mechanisms include:

- Settling/burial in sediments;
- Uptake of contaminants in plant biomass;
- Filtration through vegetation;
- Adsorption on organic material;
- Bacterial decomposition;
- Temperature benefits; and
- Volatilisation.

Floodplains

Floodplains occupy those areas adjacent to stream channels that become inundated with stormwater during large rainfall/runoff events. For the most part, rainfall is the main cause of flooding, although surges by wind-driven currents can exacerbate the problem or (in unique situations) actually cause the flooding problem. Flooding problems result from two main components of precipitation: the intensity and duration of rainfall, and its areal extent and distribution.

The form of the stream channel and its associated floodplain in part determine the size of the flood, particularly its depth and areal extent. A small watershed and wide floodplain will result in a shallow, but widespread flood. A deep channel and steep slopes, on the other hand, will result in deeper flooding, but on a small areal extent.

The many benefits that floodplains provide are partly a function of their size and lack of disturbance. But what makes them particularly valuable ecologically is their connection to water and the natural drainage systems of wetlands, streams, and estuaries. The water quality and water quantity functions they provide overlap with the landscape functions of tract size and ecosystem complexity to make them exceptionally valuable natural resources.

Table 8-2: Summary of Wetland Functions and Values

Function/Value	Description
Flood control	Attenuation of peak flows
	Storage of water
	Absorption by organic soils
	Infiltration to groundwater
Flow augmentation	Maintenance of streamflow during drought
Erosion control	Increased channel friction
	Reduction in stream velocity
	Reduction in stream scour
	Channel stability through vegetative roots
Water quality	Sedimentation
	Burial of pollutants in sediments
	Adsorption of pollutants to solids
	Uptake by plants
	Aerobic decomposition by bacteria
	Anaerobic decomposition by bacteria
Habitat for wildlife	Food
	Shelter/protection from predators
	Nursery area for early life stages
Fisheries habitat	Freshwater mussels, crayfish, fish
Food chain support	Food production (primary production)
Recreation/aesthetics	Enjoyment of nature
Education	Teaching, research

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Floodplains provide flood storage and conveyance during periods when flow exceeds channel boundaries. In their natural state, they reduce flood velocities and peak flow rates by out of stream bank flow of stormwater through dense vegetation. They also promote sedimentation and filter pollutants from runoff. In addition, having a good shade cover for streams provides temperature moderation of streamflow. Maintaining natural floodplains also promotes infiltration and groundwater recharge while increasing or maintaining the duration of low surface streamflow. Another function of floodplains is the temporary storage of floodwaters. If floodplains were not protected, development would, through placement of structures and fill material in the floodplain, reduce their ability to store and convey stormwater when necessary. This, in turn, would increase flood elevations upstream of the filled area and increase the velocity of water traveling past the flow area that has been reduced by fill material. Either of these conditions could cause safety problems or significant damage to private property.

Natural floodplains are fertile and support a high rate of plant growth that in turn supports and maintains biological diversity. They provide breeding and feeding grounds for fish and wildlife and habitat for rare and endangered species.

Ground cover in natural wooded floodplains tends to be composed of leaf and dense organic matter. Organic soils have a lower density and higher water-holding capacity than mineral soils, due to their high porosity or the percentage of pore spaces. This porosity allows floodplain soils generally to store more water than mineral soils would in upland areas.

Riparian Buffers

Although reduction of pollutants can be a function of riparian buffers, they also contribute significantly to other aspects of water quality and physical habitat. Habitat alterations, especially channel straightening and removal of riparian vegetation, continue to impair the ecological health of streams more often and for longer time periods than do pollutants.

When considering riparian buffer systems, it is helpful to examine the variety of benefits that are gained by their protection or implementation.



Example of a Small Headwater Wetland

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Temperature and Light

The daily and seasonal patterns of water temperature are critical habitat features that directly and indirectly affect the ability of a given stream to maintain viable populations of most aquatic species. Considerable evidence shows that the absence of riparian cover along many streams has a profound effect on the distribution of a large number of species of macroinvertebrates and fish.

In the absence of shading by a forest canopy, direct sunlight can increase stream temperatures significantly (up to 12° C), especially during periods of low streamflow in summer. Riparian buffers have been shown to prevent the disruption of natural temperature patterns as well as to mitigate the increases in temperature following upstream deforestation.

Habitat Diversity and Channel Morphology

The biological diversity of streams depends on the diversity of habitats available. Woody debris is one of the major factors in aquatic habitat diversity. It can benefit a stream by:

- Stabilizing the stream environment by reducing the severity of the erosive influence of streamflow;
- Increasing the diversity and amount of habitat for aquatic organisms;
- Providing a source of organic carbon; and
- Forming debris dams and slowing stream velocities.

Loss of the riparian zone can lead to loss of habitat through stream widening, where forest is not replaced by permanent vegetation, or through stream narrowing, where forest is replaced by grass. In the absence of woody vegetation, bank erosion and channel straightening can occur. The accelerated streamflow velocity allowed by straight channels promotes channel erosion that may exceed the overland sediment load entering the stream. This process can eventually lead to the development of wide, shallow streams that support fewer species.

Food Webs and Species Diversity

The two primary sources of natural food energy input to streams are litterfall from streamside vegetation and algal production within the stream. Total annual food energy inputs are similar under shaded and open canopies, but the presence or absence of a tree canopy has a major influence on the balance between litter input and primary production of algae in the stream.



Example of a wooded floodplain in a local park

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Having a stream exposed to sunlight for most of the day promotes algal growth and proliferation of algal grazing species. This proliferation reduces species diversity. The diversity of the macroinvertebrate community in a stream protected by a riparian buffer is much greater than the diversity of a stream that does not have a riparian canopy. This diversity is important, because it occurs in a very small area that goes from lowland wetter soil conditions to upland fairly rapidly and thus promotes very different vegetative types. Also, riparian buffer areas are adjacent to streams and therefore to floodplains. Through periodic out-of-bank flow, floodplains are depositional zones for fertile sediments, which is why areas adjacent to streams have always been considered so productive from an agricultural perspective.

Pollutant Removal

Riparian vegetation removes, sequesters, or transforms nutrients, sediments, and other pollutants. The removal function depends on two key factors:

- The capability of a particular area to intercept surface and/or groundwater-borne pollutants; and
- The activity of specific pollutant removal processes (filtration, adsorption, biological uptake, etc.).

Sediment trapping in riparian forest buffers is facilitated by physical interception of surface runoff that causes flow to slow and sediment particles to be deposited. Channelized flow is not conducive to sediment deposition and can, because of its higher velocities, cause erosion in the riparian buffer.

Channel Stability and Flood Flow Protection

Streams are dynamic systems that are characterized by change. In-stream stability and stream bank erosion at a given point are heavily influenced by the land use and condition in the upstream watershed. However, vegetation – especially woody vegetation – is essential for stabilizing stream banks. Forested buffer strips have a direct effect on stream bank stability by providing not only deep root systems that hold the soil in place more effectively than grasses, but also a degree of roughness capable of slowing runoff velocities and spreading flows during large storm events. While slowing flood velocities may increase flood elevations upstream and in the buffer, downstream flood crest and damage may be significantly reduced. These processes are also critical for building floodplain soils.



Example of a small stream with riparian cover

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Vegetation

Vegetation cover has changed considerably as man's influence on his environment has expanded, with the most dramatic changes occurring in the past century. Almost every kind of vegetation imaginable exists in the U.S., and each of them has suffered from our use of the land. As we have already discussed wetlands, it would be of value here to discuss forest land, which has a number of components whose characteristics determine its effectiveness in terms of water quantity and quality.

Stormwater Runoff Reduction

Woody vegetation and forest floor litter have a significant impact on the total volume of rainfall converted to runoff. Runoff volumes from forested areas are much lower than volumes from other land uses. This lesser volume in runoff acts to minimize downstream erosion and instability problems. This can clearly be shown by some of the runoff curve numbers listed in Table 8-3 that are provided in the Natural Resources Conservation Service (NRCS) Technical Release No. 55 for various land uses. Some of those curve numbers are provided here to demonstrate the differences that vegetation variety has, in conjunction with soil conditions, on curve numbers. The higher the curve number the greater the runoff.

Using the curve number approach, relationships can be drawn (hypothetically) regarding the amount of forest that would have to be planted to compensate for imperviousness. That ratio, depending on soils and slopes, can be approximately 6:1, meaning that it takes six times as much wooded area to compensate for a given amount of impervious surface. This considers only volume, but prevention of concentrated flow, absence of soil compaction due to development, etc. also need to be considered.

Soil Structure

Forest soils are generally regarded as effective nutrient traps. Most nutrients are retained (and recycled) in the leaf litter and shallow soil layers. The ability of a forest soil to remove nutrients in surface and groundwater is partially dependent on soil depth, ground slope, density of vegetation, permeability, extent and duration of any shallow water table, and its function as a groundwater discharge zone.

Organic Litter Layer

The organic litter layer in a forest buffer provides a physical barrier to sediment movement. It also maintains surface porosity, higher infiltration rates, increased populations of soil mycorrhizae (a symbiotic relationship of plant roots and the mycelium of fungi that aids in decomposition of litter and translocation of nutrients from the soil into the root tissue), and provides a rich source of carbon essential for denitrification. The organic soil provides a reservoir for storage of nutrients to be later converted to woody biomass.

A mature forest can absorb as much as 14 times more water than an equivalent area of grass. The absorptive ability of the forest floor develops and improves over time. Trees release stored moisture to the atmosphere through transpiration, while soluble nutrients are used for growth.

Table 8-3: Curve Numbers for Various Land Covers

Cover type/land use	Hydrological condition	A	B	C	D
Impervious areas		98	98	98	98
Woods	poor – no forest litter	45	66	77	83
	good – litter and brush	30	55	70	77
Pasture	good	39	61	74	80
Lawns/open space	good – full grass cover	39	61	74	80

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Forested Areas

Trees have several advantages over other vegetation in improving water quality. They aggressively convert nutrients into biomass. They are not easily smothered by sediment deposition or inundation during periods of high water level. Their spreading root mats resist the development of gullies and stimulate biological and chemical soil processes. They produce high amounts of carbon needed as an energy source for bacteria involved in the denitrification process. A forest's effectiveness in pollution control will vary with the age, structural attributes and species diversity of its trees, shrubs and understory vegetation.

To consider the involvement of a forested area in water quality treatment, there are a number of functions that define that performance. These functions can be broadly defined as physical and biological functions and include the following:

Physical Function

The forest floor is composed of decaying leaves, twigs, and branches that form highly permeable layers of organic material. Large pore spaces in these layers catch, absorb, and store large volumes of water. Flow of stormwater through the forest is slowed down by many obstructions. Suspended sediment is further removed as runoff flows into the vegetation and litter of the forest floor. This sediment is readily incorporated into the forest soil. With a well-developed litter layer, infiltration capacities of forest soils generally exceed rainfall and can also absorb overland flows from adjacent lands.

Biological Function

Forest ecosystems serve as filters, sinks, and transformers of suspended and dissolved nutrients. The forest retains or removes nutrients in a variety of ways. It rapidly incorporates biomass, stores it long term, improves soil nutrient holding capacity by adding organic matter to the soil, reduces leaching of dissolved nutrients in subsurface flow from uplands by evapotranspiration, provides bacterial denitrification in soils and groundwater, and prevents erosion during heavy rains.

Soils

Soils possess several outstanding characteristics as a medium for life. They are relatively stable structurally and chemically. The underground climate is far less variable than above-surface conditions. The atmosphere remains saturated or nearly so, until soil moisture drops below a critical point. Soil affords a refuge from high and low extremes in temperature, wind, evaporation, light, and dryness. These conditions allow soil fauna to make easy adjustments to the development of unfavorable conditions. On the other hand, soil hampers movement. Except for organisms such as worms, space is important. It determines living space, humidity, and gases.

A wide diversity of life is found in the soil. The number of species of bacteria, fungi, protists, and representatives of nearly every invertebrate phylum found in soil is enormous. It has been estimated that approximately 50 percent of the earth's biodiversity occurs in soil. Dominant among the soil organisms are bacteria, fungi, protozoans, and nematodes.

As detailed by the NRCS soil classification systems, all soils are contained within the following four categories:

- Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.3"/hour).
- Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep/moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 – 0.3"/hour).
- Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 – 0.15"/hour).
- Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils

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over nearly impervious material. These soils have a very low rate of water transmission (0 – 0.05"/hour).

Soils having greater infiltration rates also have reduced runoff potential. From a groundwater recharge and stormwater runoff perspective, prioritizing development on Group C and Group D soils would be more desirable than allowing development on Group A or Group B soils. If the overall development density was set at a given level, clustering that development on poorer soils would result in less of an increase in stormwater runoff than development on soils with greater infiltration rates. This would also have significant beneficial effects on groundwater recharge that could help maintain stream baseflows as a watershed develops. Maintaining highly permeable soils in open space areas would provide a better approach to baseflow maintenance than artificial infiltration in smaller selected areas that would come with long-term maintenance concerns.

Slopes/Topography

Steeper slopes also increase the erosion potential of the soil. Looking at the Universal Soil Loss Equation (USLE) (now the Revised Universal Soil Loss Equation – RUSLE), you can gain an understanding of the importance of slope in the calculation of soil loss. The slope length factor (LS) demonstrates that there is a direct relationship between slope and calculated soil loss. The Universal Soil Loss Equation (USLE) is a simple empirical formula that was developed approximately 30 years ago and derived from the theory of erosion processes. The general form of the equation is:

A = (R)(K)(LS)(C)(P)

where:

A = Calculated soil loss (tons/ha)

R = Rainfall energy factor

K = Soil erodibility factor

LS = Slope-length factor

C = Cropping management (vegetative cover) factor

P = Erosion practice factor.

The greater the slope, the greater the soil loss. In calculating the LS term, LS is based upon the length and steepness of a given slope. If the slope length is kept constant, its doubling (log-log relationship) causes the LS factor to approximately double. This means that a slope of 2 percent (100 m length) has an LS factor of 0.29, where a slope of 4 percent has an LS factor of 0.6. A slope of 16 percent has an LS factor of 5. A slope of 16 percent has 17 times the soil loss of a 2 percent slope, all other factors being equal. In other words, disturbance of steep slopes has a dramatic impact on site soil loss.

By identifying steeper slope areas in the initial stages of project planning for a new development, portions of a site that have increased potential for erosion can be identified. This process would allow for site development to occur in a less destructive manner or for more stringent erosion and sediment control practices to be implemented during site development.

Other Natural Features

Every site has natural features that would have substantial stormwater management benefits if they were integrated into the development approach. The previously discussed ones are important individually, but there are others that are important as well and should be integrated to provide a better site management approach.

Depression Storage and Evapotranspiration

Of the rainfall that strikes roofs, roads, and pervious surfaces, some is trapped in the many shallow depressions of varying size and depth present on practically all ground surfaces. The specific magnitude of depression storage varies from site to site. Depression storage commonly ranges from 1/8 to 3/4 inches for flat areas and from 1/2 to 1-1/2 inches on grasslands of forests. Significant depression storage can also exist on moderate or gentle slopes with some estimation for pervious surfaces being between 1/4" to 1/2" of water and even more on meadows and forest land. Steeper slopes would obviously have smaller values.

When using traditional hydrologic procedures, depression storage is contained in an initial abstraction term. This term includes all losses before runoff begins. It includes water retained by vegetation, evaporation,

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and infiltration. It is highly variable but generally correlated with soil and cover parameters.

Prior to urbanization, watersheds have a significant depressional storage factor. The urbanization process generally reduces that storage in addition to significantly modifying the land's surface. The combination of site compaction, site imperviousness, and reduced depression storage causes dramatic increases in downstream flood potential and channel erosion.

Information from one watershed study indicated that long-term average annual predicted runoff varied from less than 12" (18 percent of rainfall) to greater than 24" (greater than 35 percent of rainfall). The 12" coincided with subwatersheds under permanent forest cover, while the 24" coincided with subwatersheds in predominantly agricultural land use and on low infiltration soils. There is a clear statement in these statistics that significant volume reductions in runoff exist in forested watersheds compared to volumes of runoff from agricultural land cover.

The infiltration of water into the surface soil is responsible for the large abstraction (loss) of rainwater in natural areas. The infiltration capacity of most soils allows low-intensity rainfall to totally infiltrate, unless the soil voids become saturated or the underlain soil is much more compact than the top layer. High-intensity rainfalls generate substantial runoff because the infiltration capacity at the upper soil surface is surpassed, even though the underdrain soil might still be dry.

Natural Drainage Systems

Natural site drainage features exist on every site. The most common of these features is an already existing flow path for stormwater runoff. Water doesn't travel down a hill in a straight line. Straight channels or pipes are something that humans have developed to accelerate the passage of water downstream as quickly as possible. During site development, the tendency is to place water in conveyance systems, open or enclosed, which follow the shortest distance to site outfalls.

Shortening the flow distance effectively increases the slope that water travels on, accelerates the flow of water, and increases the ability of water to scour downstream receiving systems. When water travels over a meandering flow path, energy is dissipated, which reduces the erosion potential. Shortening flow lengths reduces energy expended and increases the available erosion-producing energy. Stream channels will meander regardless of the degree of human alteration. Replicating existing flow paths and lengths to the extent possible promotes channel stability and increases function and value.

The additional functions provided by meandering channels in comparison to straight channels are also simply related to the length of the aquatic resource and the time that the water is in contact with the various biotic and abiotic processing mechanisms: the additional length of meandering channels provides a greater total quantity of aquatic resource and its associated functions and values.

Soil Compaction

Areas have increased runoff after development for a number of reasons. The most important cause is usually the increased amount of pavement and roof areas. However, urban soils also undergo major modifications that result in increased runoff. These soil modifications may mostly affect infiltration, but other soil changes also occur. Specifically, reductions in the organic content of the surface soil layers and removal of plants will reduce the evapotranspiration losses and contribute to increases in runoff. This is especially important in areas where surface soils are relatively shallow and located above impermeable layers.

The soil compaction during construction and use likely causes most of the reduced infiltration capacity of urban soils. In addition, many more subtle changes will also occur. Many of these changes contribute to the reduction of measured infiltration, such as the replacement of native plants that typically have much deeper root systems with shallow-rooted grasses. The removal of the native soils results in the removal of organic matter, mature and deep-rooted plants, and the soils themselves, often exposing a deeper soil material that is much less able to allow infiltration or evapotranspiration. There are a number of options to address this concern:

- In areas of significant site disturbance, and where there is less than three feet of cut or where cuts or fills of at least three feet are intended to facilitate site development, the expected permeability of the soil may be reduced. Stormwater management calculations, which

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detail post-construction hydrology, should use a modified approach to soil classifications.

- In areas of significant soil disturbance, and where there is less than two feet of cut or fill, soil classifications are not modified, but the approved permit should contain a construction requirement to the effect that significantly disturbed soils in areas where those soils remain pervious should be chisel-plowed. Chisel-plowing will break the surface crust of the disturbed soil and allow for a greater infiltration rate. This would provide a good foundation for the placement of topsoil and prevent topsoil slippage on slopes that become saturated.
- Avoid compaction altogether by keeping equipment out of areas preserved for open space.
- Making soil amendments, or otherwise modifying soil structure and chemical characteristics, is becoming an increasingly popular stormwater management practice. However, little information is available to quantify benefits and problems associated with their use.

Linkage with Site Development

The above natural site features all provide stormwater management benefits if considered and integrated into the initial site development plan. They cannot be considered an afterthought of the site planning stage. If stormwater considerations are neglected until the overall site plan has been developed, there are too many site conflicts to provide an effective site management plan that protects aquatic resources. At this point, issues related to levels of imperviousness, location of utilities, and lot layouts prevent integration of site features into a development approach, and it is too late for aquatic resource protection.

It is vital that a pre-development site inventory plan be drafted and submitted with the site development and stormwater management plan. It would also be advantageous to have a narrative submitted that details what steps have been taken to incorporate natural site features into the site development plan. This approach will require a rethink away from the traditional site development approach that has existed for many years.

Source Control

Source control is often considered in a traditional context such as industrial site source control. At the same time, there are now other source control components that aim to eliminate the source of a pollutant from potentially entering the receiving system and control impacts on any kind of land use. This approach constitutes a considerable expansion of the traditional use of the term.

Traditional Source Control

Source control and management procedures attempt to reduce or avoid pollutants getting entrained in stormwater runoff. These practices assume that the pollutant source is necessary for the successful operation of the business or activity, and seek to control the release of pollutants or remove them before they come into contact with stormwater. For example, service stations inherently use trade oils and gasoline as their main business activity, but they are required to cover the service area and shut off stormwater pipes during tanker deliveries to prevent the discharge of petroleum products to the environment via stormwater drains.

The EPA advocates that businesses that handle chemicals or produce wastewater carry out an environmental audit to identify actual and potential pollutant sources. An action plan should then be developed to eliminate any actual pollution and minimize the risk of potential pollution.

Source control practices identify pollutant sources and construct physical works to prevent them from coming into contact with stormwater. The classic example is the above ground storage tank with a berm constructed around it. The berm volume is greater than the volume of the storage tank.

Other examples include:

- Physical control structures such as berming, spill containment;
- Covering stockpiles of soil, waste products;
- Directing washwater to sanitary sewers; and
- Covering "dirty" work areas such as truck washes or oil changing bays.

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Numerous procedures can be designated as management practices, from local government initiatives to regularly removing gutter dusts before they get entrained in stormwater to industrial protocols for handling chemicals. The common factor is that there is a process to be followed that minimizes the risk of pollutant transfer to stormwater.

Local government initiatives include:

- Street vacuuming;
- Education initiatives; and
- Recycling.

Industry initiatives include:

- Refueling procedures;
- Chemical handling procedures;
- Staff training regarding proper disposal areas for wastes, chemicals, etc.; and
- Proper storage of chemicals, fuel etc.

Significant information on traditional source control is available from the EPA website, so further detail is not being provided here.

Eliminating the Pollutant Source

When considering a given pollutant, it is becoming more recognized that treatment represents the "ambulance at the bottom of the cliff." Treatment cannot be expected to remove all pollutants of concern nor to totally eliminate a particular one. Questions are increasingly being asked as to where specifically a pollutant found in a watershed is coming from. It may be that removing the pollutant source is more economical than attempting to remove the pollutant once it is in the water column.

A good example of a source control was the removal of lead from gasoline in the 1980s, a source control activity that has led to the reduction of lead levels in receiving environments. In the same regard, older roofs were recognized in the Baltimore NURP study as being a significant source of copper. Painting those roofs, using a different material if the roof has to be replaced, or preventing new copper roofs would be an effective approach to copper reduction. The Chesapeake Bay Program has been addressing nutrients and has targeted phosphorus for years. An effective approach to phosphorus reduction has been the elimination of phosphorus from detergents.

More and more we have to ask ourselves why a certain pollutant is being found. It may be that we can't eliminate it from a local context and must consider either regional or national initiatives to eliminate the source, but changes can only be made if we understand cause and effect. It is expected that significant efforts will be expended to consider more benign materials from a water quality perspective.

Source Control in the Broader Context

Sir Isaac Newton (1643-1727) theorized in one of his laws that "for every action there is an equal and opposite reaction." This law is very true, and the only way to reduce or eliminate reactions is to reduce or eliminate actions. The whole premise behind source control in the broader context is to reduce actions and thereby reduce the inevitable reactions. Using or disturbing less of a site results in less potential downstream impact. There are a number of names given to this approach, including low impact design, conservation design, water sensitive urban design, or sustainable urban drainage systems. These will be discussed in more detail later in the chapter.

Each proponent of a given approach will claim that theirs is the most encompassing of all essential elements, but the argument revolves more around details than around concepts. There are, however, a number of essential components that are needed in all of the approaches. They include the following:

- Reducing site disturbance;
- Reducing impervious surfaces;
- Distributing flow and reducing efficiency of flow conveyance;
- Implementing integrated stormwater management;
- Creating or protecting natural areas;
- Clustering development; and
- Reusing water (where possible).

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Each of these items will be discussed individually with regard to their importance in the overall context. Having only one or several of these elements in place will provide a benefit, but overall resource protection will need to incorporate all of them to maximize benefits. Even with all of these elements, it is necessary to consider those items listed earlier in the chapter relating to site resource protection and enhancement. In addition, there may still be a need to provide structural stormwater management.

Reducing Site Disturbance

There are two contexts to consider in a discussion of overall site disturbance:

- Construction-generated sediment loads; and
- Permanent stormwater issues related to quantity and quality of runoff.

Erosion and Sediment Control

Any discussion of erosion and sediment control has to break the term down into its two basic components, "erosion" and "sediment control." When land is disturbed at a construction site, the erosion rate increases with removal of ground cover, normally vegetative, which protects soils from erosion. The major problem with erosion is the movement of soil off-site and the subsequent impact of sedimentation on the receiving environment.

The high yield from the urbanizing catchment stems from the considerable portion of its ground area that is bared for construction (in one watershed, for example, approximately 28 percent at the time of the study). The yield from the sub-watersheds undergoing 100 percent construction was estimated to be approximately 16,800 t/km^2/yr, or hundreds of times the yield from undisturbed or stable areas of the watershed.

Reducing the limits of site disturbance by leaving steeper areas natural, not exposing erodible soils, and maintaining a vegetative cover can all reduce the amount of work that sediment control practices must do and reduce downstream sedimentation. A simple way to consider how site development can affect sediment yield is to once again look at the Revised Universal Soil Loss Equation.

$$A = R \times K \times (L\,S) \times C \times P$$

where:

A = Soil loss (tonnes/hectare/year)

R = Rainfall erosion index (J/hectare)

K = Soil erodibility factor (tonnes/unit of R)

LS = Slope length and steepness factor (dimensionless)

C = Vegetation cover factor (dimensionless)

P = Erosion control practice factor (dimensionless).

Clearly, changing the vegetative cover, or reducing area of disturbance or slope being disturbed all have a significant effect on soil loss.

By clustering development on a portion of a site while protecting critical areas, overall site disturbance is reduced, which in turn reduces sediment yield.

In addition to sediment as a pollutant, site disturbance will also affect the quantity of water that leaves a construction site. A clear example of this are again the NRCS runoff curve numbers for average antecedent runoff conditions shown in Table 8-4.

Table 8-4: Runoff Curve Numbers Compared to Construction Curve Numbers

Cover type/land use	Hydrological condition	A	B	C	D
Woods	poor – no forest litter	45	66	77	83
	good – litter and brush	30	55	70	77
Meadow	-	30	58	71	78
Lawns/open space	good – full grass cover	39	61	74	80
Bare soil	-	77	86	91	94

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A simple TR-55 analysis can show that runoff is dramatically increased during the construction phase of site development. Sediment control practices are very seldom designed to provide water quantity control, especially for channel erosion. Thus, as can be seen, the greater the area of disturbance, the greater the peak discharge and total volume of runoff. If stream channel protection is a program goal, the erosion that the permanent stormwater system is intended to reduce or prevent (even if using permanent source controls) may occur prior to implementation of those permanent controls.

Permanent Stormwater Management

The effects of urbanization on soil structure can be significant. A common approach to site development is to clear most, if not all, of the site being developed. Existing vegetated areas are often cleared even when in non-essential locations. The clearing and grading of areas that will remain pervious results in significant compaction of those areas. This compaction reduces expected infiltration rates and increases overland flow.

In addition to soil structure, forested areas and wetlands should be seriously considered for retention if aquatic resource protection is a program goal.

Reducing Impervious Surfaces

There have been many studies relating impervious surfaces to aquatic system impact. We are seeing now (as mentioned in the introduction) that impervious surface considerations alone are an imperfect barometer of ecosystem health. But even so impervious surfaces have a profound impact on the generation of stormwater runoff, the conveyance of that runoff to drainage systems, and the subsequent problems that result from a water quantity and quality standpoint.

Stormwater considerations have to be an integral component of site development if impervious surface coverage is to be addressed at all. Items such as road widths, amounts of off-street parking spaces, driveway lengths, roof areas, and sidewalks must all be given careful consideration if impervious surfaces are to be reduced.

Another problem related to impervious surfaces is the creeping increase of impervious surfaces once land has been developed. Residential properties designed to have a maximum impervious surface of 50 percent may find subsequent levels of 70 percent or more as people increase driveway widths, patios, etc. This impervious surface area creep can have a significant effect on local drainage design if storm drain pipes are sized for a level of imperviousness that is exceeded.



Example of a very wide street

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Distributing Flow and Reducing Efficiency of Flow Conveyance

The construction of efficient conveyance systems accelerates the flow of water from the top of a watershed to streams, estuaries, and coastlines. The traditional approach of catch pits draining into piped systems and rapid delivery to the receiving system accelerates flow dramatically beyond natural drainage conveyance and prevents potential water loss through infiltration.

Efficient conveyance was a drainage goal of the 1960s and early 1970s, when water was considered the common enemy. A common pattern of watershed development has been for development to occur from the mouth of the watershed upwards over time. This generally resulted from initial development depending on travel by water. This historical approach meant that upstream landuse was generally pasture, agriculture or forest having natural flow of drainage across the land and into streams. As the upstream watershed developed, downstream flows were increased and the delivery of stormwater downstream was accelerated.

That approach has evolved over the past 30 years, first to on-line ponds and later to off-line ponds. As we have looked closer at cause and effect, we are now realizing that "inefficiency" at the top of the watershed will provide significant benefits over the traditional approach. There is greater recognition that disconnecting drainage systems from their outlet can provide downstream benefits.

An example of possible disconnection is the consideration of curbing on streets. With a local requirement for curbing, flow is immediately concentrated adjacent to the curb and travels along the curb until it must enter a catch basin. As a result, stormwater flows are concentrated at the top of the watershed, delivered to a catch pit, and placed into a stormwater pipe whose outfall is into a receiving system or, hopefully, into a stormwater management structure. The net effect is an increase in peaks, volumes, and pollutant delivery downstream. We need to look for opportunities to disconnect drainage systems to provide better resource protection.

Implementing Integrated Stormwater Management

Stormwater management has historically been considered an afterthought and has to be integrated into the overall site development planning process. There are two key components of stormwater design: prevention and mitigation.

Prevention

Prevention includes land-use planning, not only on a site basis but taking into account the relationship between the individual site and the sub-watershed. This is an important context when considering wildlife corridors or riparian buffers. In all cases, the goal should be to use the simplest approach possible. This relies on the use of natural site features (wetlands, forested areas, meadows) in conjunction with source control practices such as green roofs, rain gardens, swales, filter strips,



Example of an "ancient" approach to drainage

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revegetation, and water reuse. The key element of these source control practices is to reduce the total volume of runoff while providing water quality treatment. While initial efforts in stormwater design were directed at centralizing runoff for control and treatment, newer concepts aim to disperse the runoff as much as possible. An example of this would be the elimination of curbing in a subdivision, which would tend to disperse flows rather than concentrating them. This is a significant shift in thinking.

Mitigation

Mitigation has clearly been the focus of program implementation over the past 20 years. Practices that fit into this category include ponds, wetlands, filter systems, and hydrodynamic separators. The use of these practices assumes that water quantity and water quality cannot be addressed through prevention. They tend to represent the "ambulance at the bottom of the cliff."

While prevention is the most desirable outcome, some mitigation will always be necessary. The key point with mitigation is to reduce to the extent possible the amount of work that must be performed. In addition, not all mitigation practices are created equal. A given development may primarily have suspended solids issues, and a pond may prove effective here, while nutrients, metals, or organics may be a primary consideration elsewhere. Mitigation needs to be considered in the context of the problem that it is addressing.

Having a good understanding of prevention and mitigation allows us to consider aspects of prevention that would reduce downstream effects of stormwater runoff.

Creating or Protecting Natural Areas

In many site development situations, the creation of a meadow as open space would have significant stormwater management benefits for both water quantity and water quality. If well designed and constructed, the area could become an attractive amenity to a community and enhance the value of the properties.

In a similar fashion, reforesting of steep slopes or protection of natural woody vegetation elsewhere on a site would have long-term benefits in a stormwater context. Whereas traditional stormwater practices clog or fill in over time, thus reducing their effectiveness, areas that have been revegetated become more effective over time and bring with them a reduced maintenance responsibility. Forested areas intercept rainfall and have an organic leaf and branch ground cover that acts to retain water. In addition, trees use and store nutrients for



Subdivision without curbing or catch pits

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long periods of time and, as discussed above, moderate temperatures during the summer.

As wildlife corridors could be re-established as well, there could be significant wildlife benefits.

Wetlands are also very valuable and productive ecosystems whose maintenance or enhancement would have significant benefits. These benefits, as discussed above, include flood control, low streamflow augmentation, erosion control, water quality, and habitat.

Clustering Development

As a source control tool, clustering is very important and may be considered, in conjunction with protection or enhancement of site resources, a keystone of the overall source control. Without clustering, protection of important site features is impossible. From a stormwater management standpoint, clustering minimizes stormwater and pollutant load generation and is clearly preventive in nature.

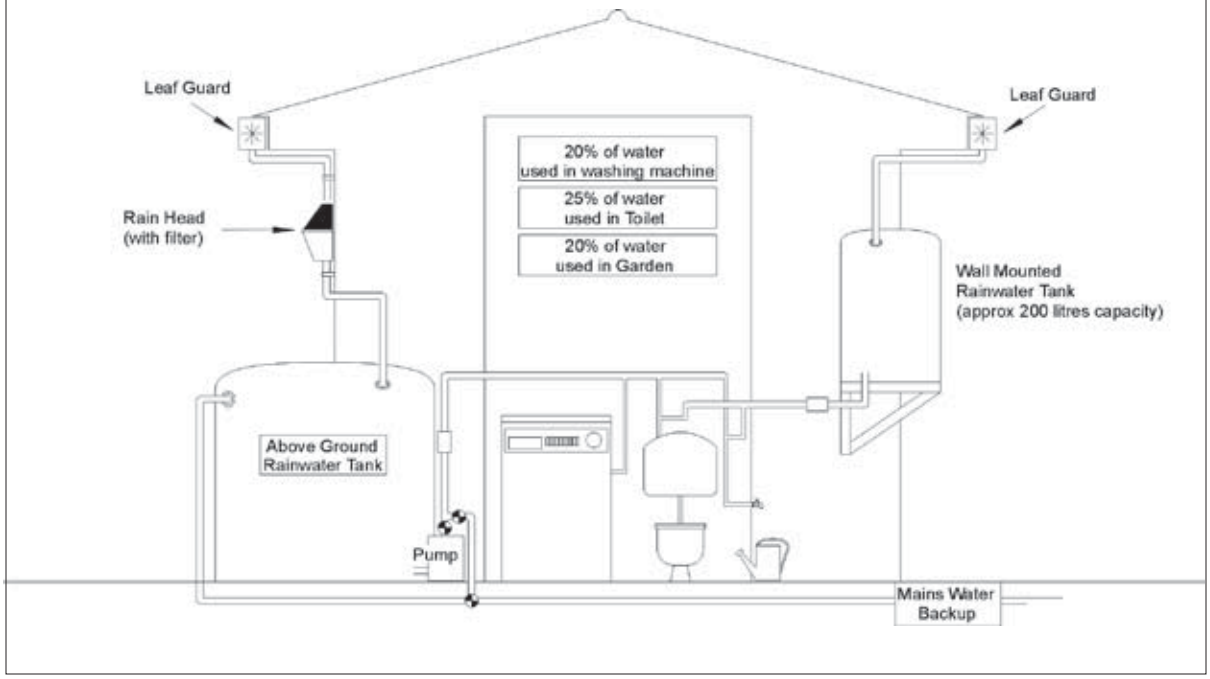
Although some density bonuses may be considered to encourage use of clustering, clustering in a strict sense usually begins after the decision on overall site density has been made. In some cases, clustering may provide different types of development, including single- and multi-family development. Clustering may involve lot design and arrangement only, or it may involve changing the types of residences. The challenge is to maximize benefits such as open space in conjunction with developer-desired outcomes.

Clustering benefits include:

- Reduced imperviousness;
- Reduced pollutant generation;
- Preservation of natural site values;
- Habitat and wildlife values;
- Passive recreation and open space amenities; and
- Cost reduction.

In consideration of clustering, it is important to overcome barriers to its use. These barriers may include minimum lot sizes, inflexibility by local jurisdictions, the time that the permitting process may take and uncertainty by developers that the proposal would be acceptable. Local government needs to revisit code requirements to facilitate implementation of innovative approaches.

Commonly used components of a water tank



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Reusing Water

At this point, it would be beneficial to discuss the use of rainwater tanks as a stormwater management source control practice. They are primarily water quantity management devices but do have minor water quality benefits, depending on the amount of atmospheric deposition in a given area or the pollutant load that may result from the roof itself (zinc, copper, etc.). They have been used for centuries for supplying household and agricultural water.

Approximately 60 percent of domestic water use goes to toilet flushing, laundry, and garden watering. If roof runoff could be stored and used for those purposes, it would not contribute runoff during storm events and represent a reduced volume downstream. This could be part of an overall strategy for stormwater management in which roof areas do not contribute runoff. Benefits could be even greater for industrial sites that use water in their daily operations.

Rainwater tanks are not a stand-alone solution for quality and quantity issues in a watershed, but they can be implemented as a part of an integrated approach toward:

- Reducing stormwater volumes entering the receiving waters through the use of stormwater captured and used on site;
- Reducing flows into downstream stormwater treatment practices;
- Reducing peak stormwater flows from the sub-watershed by providing permanent or temporary storage;
- Reducing sanitary sewer overflows by reducing the rates and volumes of stormwater that enters directly or indirectly into sanitary sewers;
- Reducing roof-generated pollutants entering water bodies; and
- Reducing demand for potable water, which leads to more effective use of water resources.

Rainwater tanks can be used in residential, commercial and industrial developments. The applications include the following:

- Treating roof runoff and accordingly reducing the size of the downstream treatment devices. In this case, the roof runoff, after storage in the tank system, would enter the receiving waters separately, while the ground runoff would be routed via the downstream treatment practice. An example of this would be industrial or commercial sites, where the roofs are treated by tanks while parking areas are treated by rain gardens or swales. Another example are high-density subdivisions, where tanks address roofs and the rest of the area is treated by wetlands.
- Managing stormwater in infill developments where the existing drainage system capacity is already exceeded for the design storm (generally 1 in 10 year capacity). There are different types of rainwater tanks to suit the available space and required volume.
- In conjunction with other practices, working toward hydrological neutrality in order to mitigate adverse effects of a development.
- Providing treatment, peak attenuation, and non-potable water supply benefits as multi-purpose devices. When coupled with adequate roof areas, they become financially self-supporting for reasonably large non-potable water demands.



Water tank capturing roof runoff

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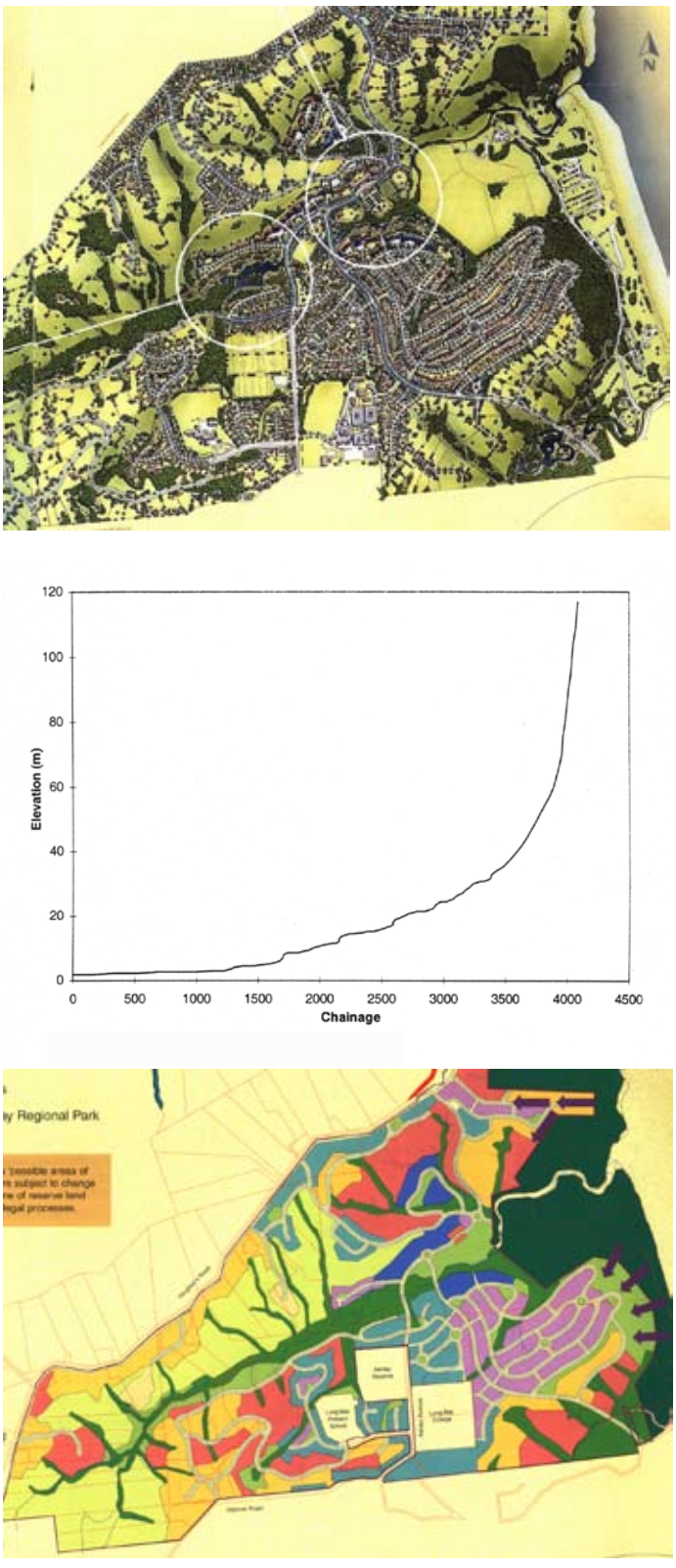
Figure 8-1: Watershed Information – Intended Growth, Stream Slope, Sensitive Areas



An Example from a Watershed-Wide Context

While implementation of source controls on a site-by-site basis is essential, the optimum level for consideration of source control is on a watershed basis. If clustering is valuable on an individual site basis, its consideration on a watershed scale could have huge benefits in terms of existing resource protection and enhancement, while the desired level of development could still be accounted for. The following example shown in Figure 8-1 is put forth to demonstrate the value of source control from a watershed perspective. Expected development of this watershed will accommodate 8,000 new residents.

The headwaters of the watershed are on steeper land, and the intention is to protect first-order streams and avoid mass earth movement during the developing phase. As a result, density is approximately one house per acre. In other words, those areas have a lot yield based on an average density of one house per acre, but clustering is encouraged. Average lot sizes are expected to be approximately 20,000 ft^2, which means that overall site development will disturb about half of each site. The gullies and first-order streams are protected and revegetated where necessary. Site stormwater controls will be rain gardens, swales, filter strips, and water reuse for each house. Using this approach, traditional stormwater practices such as ponds or wetlands are not necessary.

Downstream of the headwaters, the land flattens out. All perennial streams are

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protected and riparian corridors re-established. Lots are approximately 10,000 ft^2, and development will take a more conventional approach, although rain gardens and water tanks will still be used on individual lots. Due to increasing imperviousness, stormwater management will take the form of constructed wetlands located on ephemeral watercourses that provide water quality and quantity control.

The lower area of the watershed will be intense development, including commercial, institutional, high-density residential, and town development. Again, all of the perennial streams are protected and riparian corridors established. Stormwater management in this portion of the watershed will use constructed wetlands as the primary stormwater practice. Upon completion of the development approach, there will be pedestrian movement adjacent to the riparian corridors throughout the watershed.

A major focus of this approach is the protection and enhancement of aquatic resources. The watershed has historically been pasture with significant stock access to streams that has severely impacted on aquatic resources. Through substantial revegetation throughout the watershed, especially in the headwaters, removal of fish blockages where they currently exist, and implementation of stormwater management throughout the watershed while accommodating significant urban growth, it is hoped that aquatic resource values can improve as urbanization occurs.

Various New Approaches

There are a variety of approaches around the world that have a similar foundation in minimizing our impact on receiving systems. They all differ in certain aspects that would make them interesting to investigate further.

Low Impact Design (LID)

LID's basic tenet is to create a hydrologically functional landscape that mimics the natural hydrologic regime. This objective is accomplished by:

- Mimimizing stormwater impacts to the extent practicable. Techniques include reducing imperviousness, conserving natural resources and ecosystems, maintaining natural drainage courses, reducing the use of pipes, and minimizing clearing and grading.
- Providing runoff storage measures dispersed uniformly throughout a site's landscape with the use of a variety of detention, retention, and runoff practices.
- Maintaining pre-development time of concentration by strategically routing flows to maintain travel time and control the discharge.



University of Maryland rain garden monitoring site

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- Implementing effective public education programs to encourage property owners to use pollution prevention measures and maintain the on-lot hydrologically functional landscape management practices.

LID does not rely on the conventional end-of-pipe or in-the-pipe structural methods but instead uniformly or strategically integrates stormwater controls throughout the urban landscape.

Conservation Design

Conservation design is a design approach to site development that protects and incorporates natural site features into the stormwater management program. There is a subtle difference between conservation design and LID in that a primary emphasis of conservation design is to incorporate natural site features into the site development process and thereby reduce or eliminate the need for structural stormwater management. As a central tenet, maintenance of natural site features plays a greater role in conservation design than it does in LID. Clustering development on a smaller portion of a site provides greater retention of natural site features that assist in stormwater management. This is a small difference, though, that can be incorporated into LID, but it is more clearly stated in the conservation design approach.

The site features to be protected and incorporated are similar to those discussed earlier in the chapter and include the following items:

- Wetlands;
- Floodplains;
- Forested areas;
- Meadows;
- Riparian buffers;
- Soils; and
- Other natural features.

In short, the point of conservation design is to do more with less. Design principles (which are identical to the ones used in LID) include:

- Achieving multiple objectives;
- Integrating stormwater management and design early into the site planning and design process;
- Prevention rather than mitigation;
- Managing stormwater as close to the point of origin as possible, minimizing collection and conveyance; and
- Relying to the maximum on natural processes within the soil mantle and the plant community.

Water Sensitive Urban Design (WSUD)

WSUD is similar to LID and conservation design and has been developed in Australia to address issues there. WSUD is a philosophical approach to urban planning and design that aims to minimize the hydrological impacts of urban development on the surrounding environment. Stormwater management is a subset of WSUD directed at providing flood control, flow management, water quality improvements, and opportunities to harvest stormwater to supplement potable water



Bioretention in Sydney



Rain garden in Auckland

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for non-potable uses (that is, toilet flushing, garden irrigation, etc.).

Key planning and design objectives of WSUD are:

- Protecting and enhancing natural water systems in urban developments;
- Integrating stormwater treatment into the landscape by incorporating multiple-use corridors that maximize the visual and recreational amenity of developments;
- Protecting water quality draining from urban development;
- Reducing runoff and peak flows from urban developments by employing local detention measures and minimizing impervious areas;
- Adding value while minimizing drainage infrastructure development costs.

WSUD recognizes that opportunities for urban design, landscape architecture, and stormwater management infrastructure are intrinsically linked. The practices that promote long-term success of a stormwater management scheme are called Best Planning Practices (BPPs) and Best Management Practices (BMPs). They can apply to greenfield land development sites, redevelopment sites in built-up areas, and, in some instances, to retrofits in fully urbanized watersheds. The scale of application can range from individual houses, streetscapes and precincts, to whole watersheds.

Sustainable Urban Drainage Systems (SUDS)

SUDS is a design approach for urban drainage in England and Wales that includes long-term environmental and social factors in decisions about drainage. It takes account of the quantity and quality of runoff and of the amenity value of surface water in the urban environment. Many existing urban drainage systems can cause problems of flooding, pollution or damage to the environment and are not proving to be sustainable.

Drainage systems can be developed in line with the ideals of sustainable development by balancing the different issues that should be influencing the design. Surface water drainage methods that take account of quantity, quality, and amenity issues are collectively referred to as SUDS. These systems are more sustainable than conventional drainage methods because they:

- Manage runoff flowrates, reducing the impact of urbanization on flooding;
- Protect or enhance water quality;
- Are sympathetic to the environmental setting and the needs of the local community;
- Provide a habitat for wildlife in urban watercourses; and
- Encourage natural groundwater recharge (where appropriate).

They do this by:

- Dealing with runoff close to where the rain falls;
- Managing potential pollution at its source now and in the future; and
- Protecting water resources from point pollution (such as accidental spills) and diffuse sources.

Low Impact Urban Design and Development (LIUDD)

Low impact urban design and development is a design approach used in Auckland, New Zealand whose concepts and approach are similar to all of the above-mentioned ones. LIUDD presents an alternative approach to site and watershed development from a stormwater management perspective. Its basis lies in the recognition that the volume of stormwater discharged from a site may be of equal importance to limiting pollution discharge. The low impact urban design and development approach is another stormwater management tool for reducing the adverse impacts of stormwater runoff. There are two primary areas of interest addressed in this design approach:

- Erosion and sediment control during construction, and
- Permanent stormwater management.

The Auckland approach recognizes that much of the technical information for LIUDD has been developed from a design perspective but is doing considerable work to address the institutional barriers to successful implementation of LIUDD. Local land use plans tend to have enough flexibility to allow for case-by-case implementation of the approach; the major problem regards codes of practice or engineering standards. These can include minimum street width, requirements for curbing, side walks, and other criteria that prevent LIUDD

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from being implemented. Significant efforts have gone into removing these barriers where they exist.

In addition, there are several case studies of LIUDD approaches on a watershed basis. Monitoring of watercourses for quantity, quality, and biology has been done prior to development initiation. It will take approximately 10 years for ultimate development to occur in these watersheds, and monitoring will be done both during and post-construction to evaluate the benefits of LIUDD on a watershed basis.

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CHAPTER 9

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CHAPTER 9

Erosion and Sediment Control

Erosion and sediment management practices have not evolved to the extent that stormwater management practices have over the past 10 years. There are, however, other components that have more recently begun to emerge. These components include considering temporary and permanent revegetation, phasing work to limit open areas, using chemical flocculation of sediment traps to provide enhanced sediment discharge reduction (especially of clay soils), and also looking at innovative ways of offsetting the residual impacts that result from sediment yields. If improved treatment is to be provided, however, more attention needs to be given to advancing erosion and sediment control practices. It is also important to note that erosion and sediment control is increasingly being looked at as an essential component of the overall site development package. The linkages between this early stage of site development and the longer-term approach to stormwater management can not be separated if we are to protect our downstream aquatic environments.

For erosion and sediment control programs, technology must continue to improve and approaches must be further refined if aquatic resource protection is to be realized. An effective stormwater management program is not going to achieve its goals if the receiving systems are severely impacted during the construction phase of a project. In addition to significant sediment loads, the construction phase of site development can increase the total volume and peak rates of stormwater exiting a site and cause downstream channel instability concerns. It is a positive step, therefore, that the Phase II program is also emphasizing erosion and sediment control on smaller sites as an essential permit component.

While this chapter can be read alone, it should be considered in conjunction with the rest of the manual to achieve a full appreciation of the development cycle and all the aspects that contribute to it.

Regulatory Nature of Erosion and Sediment Control

Phase II of the National Pollutant Discharge Elimination System (NPDES) specifies that a program to reduce pollutants has to be developed, implemented, and enforced in any stormwater runoff from construction activities that result in a land disturbance of greater than or equal to one acre. Reduction of stormwater discharges from construction activity disturbing less than one acre must be included in your program if that construction is part of a larger common plan of development or sale that would disturb one acre or more.

The program must include the development and implementation of, at a minimum:

- A regulatory mechanism to require erosion and sediment controls, as well as sanctions to ensure compliance, to the extent allowable under state, tribal or local law;
- Requirements for construction site operators to implement appropriate erosion and sediment control best management practices;
- Requirements for construction site operators to control waste such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste at the construction site that may have adverse impacts on water quality;

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- Procedures for site plan review that incorporate consideration of potential water quality impacts;
- Procedures for receipt and consideration of information submitted by the public; and
- Procedures for site inspection and enforcement of control measures.

It is important to note that examples of sanctions to ensure compliance include non-monetary penalties, fines, bonding requirements, and/or permit denials for non-compliance. The EPA recommends that procedures for site plan review include the review of individual pre-construction site plans to ensure consistency with local erosion and sediment control requirements.

Procedures for site inspections and enforcement of control measures could include steps to identify priority sites for inspection and enforcement based on the nature of the construction activity, topography, and the characteristics of soils and receiving water quality. Additional educational and training measures for construction site operators should also be considered. Phase II of the NPDES program provides for regulatory flexibility that would require pollution prevention plans for non-sediment generated pollutants.

Phase II of the NPDES municipal requirements provides an excellent platform from which erosion and sediment control can be more effectively managed.

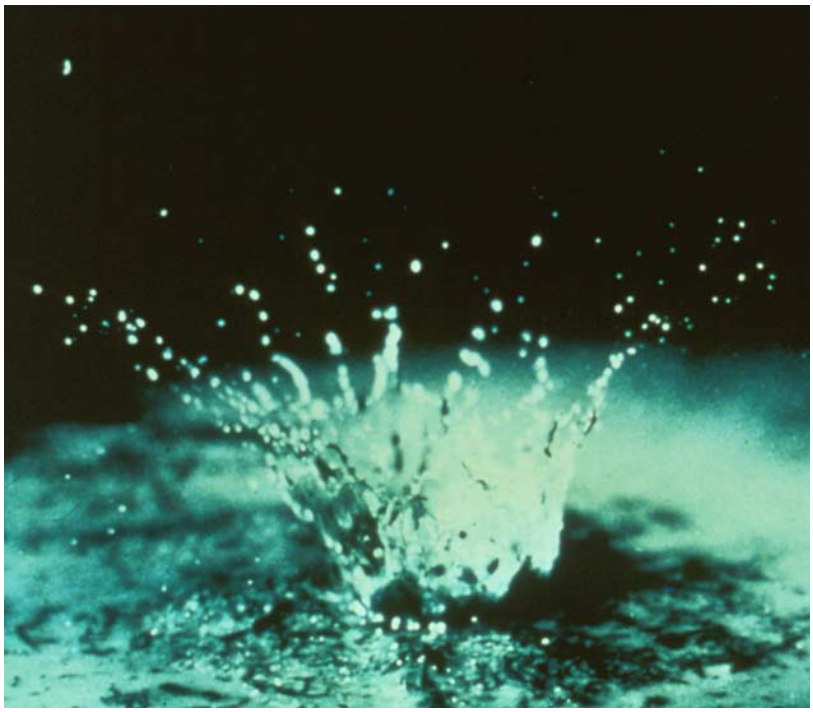
Principles of Erosion and Sediment Control

Erosion and sediment management must always be thought of as two separate components, erosion control and sediment control.

Erosion is the process whereby the land surface is worn away by the action of water, wind, ice, or other geological processes. The resultant displaced material is known as sediment, with sedimentation being the deposition of this eroded material. Accelerated erosion is primarily caused by human activities and is a much more rapid process than natural erosion.

The basic erosion process consists of detachment, transport, and sedimentation, with water often being the key eroding agent and transport medium. When considering erosion, the following seven main types need to be looked at:

- Splash erosion is commonly caused by raindrop impact. This impact can break up the soil surface with a net effect of moving soil particles down the slope.
- Sheet erosion occurs when intensity of rainfall exceeds the infiltration rate. Sheet erosion refers to the uniform removal of soil in thin layers by the forces of raindrops and overland flow.



Raindrop impact

- Rill erosion is the removal of soil by runoff moving in concentrated flows. The velocity and the turbulence of the flow increase in these concentrated flow paths, with the resultant energy detaching and transporting soil particles.
- Gully erosion is the next step from rill erosion, where gullies form that are usually distinguished by being greater than 300 mm in depth. The potential for gullies to transport significant amounts of sediment is large, and from an erosion control standpoint, they should be avoided.
- Tunnel erosion is the removal of subsurface soil by subsurface water, while the surface soil

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remains intact. This produces large cavities beneath the ground surface that can eventually lead to collapse of the surface material.

- Channel erosion occurs once the water in concentrated flow reaches the stream system. This erosion is essentially caused when the water velocity increases such that scouring or undercutting of the stream banks occurs. Channel erosion is noted to have a direct relationship with watershed urbanization, with increased flows and increased erosion occurring once a watershed is urbanized.
- Mass movement is the erosion of soil or rock by gravity-induced collapse. It can be triggered by heavy rainfall and increased groundwater pressure, or by streams undercutting the base of a slope where works are occurring.

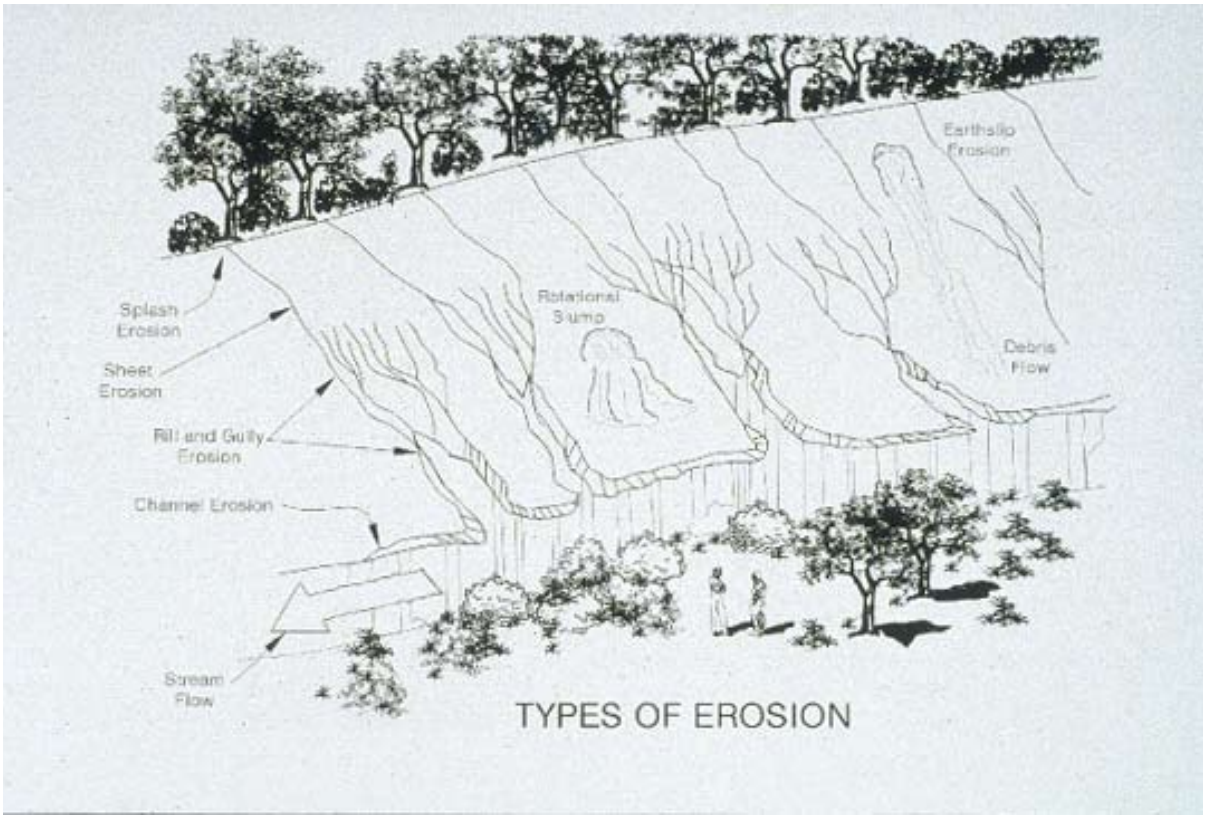
It is also important to understand the factors that influence the erosion process. These four factors (discussed below) are climate, soil characteristics, topography, and ground cover. They also form the basis of the Universal Soil Loss Equation, which will be discussed in detail later in the chapter.

Climate

Climate is a key factor, with rain being the driving force of erosion. The erosive power of rain is determined by rainfall intensity and the droplet size. The annual pattern of rainfall and temperature change is also critical in that it determines the extent and growth rate of vegetative cover, the key tool in prevention of erosion.

Soil characteristics

All soil characteristics, including texture, organic matter content, structure, and permeability are important. Sand, silts, and clays are the major soil particle classes, and it is critical to understand the soils you are working with to be able to assess the erodibilty of these different particles. Organic matter is critical in improving soil structure and increasing the permeability and water-holding capacity of the soil. Soil permeability in itself is important, with soils with higher permeability producing less runoff than soils with a low permeability. Soil structure is also important in that compacted soil will result in runoff as opposed to infiltration.



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In this context it should be noted that soil compaction is also a major issue that needs to be considered. Soil compaction during construction and use is likely to cause most of the reduced infiltration capacity of urban soils. This aspect of construction activities is often not given due attention, in spite of the fact that the reduced infiltration is known to result in increased runoff and associated effects (Pitt et al., 2002).

Topography

Topography is important primarily from a slope length and angle perspective. The shape of the slope also plays an important part, with the base typically being more susceptible to erosion than the top due to runoff arriving at the base at a faster, more concentrated rate. Reference should be made to section 8.9 of this chapter for an illustration of slope versus sediment yields.

Ground Cover

Ground Cover includes vegetation and surface treatment such as mulches and geotextiles. This aspect is the most important and effective form of long-term erosion control. Good ground cover provides direct instant protection, slows runoff, and maintains the soil's ability to absorb water.

Evapotranspiration

Evapotranspiration is a further factor often not considered. In some areas, however, it is critical in that minimal rainfall and high evapotranspiration in the summer period can lead to soil moisture deficit. This becomes a critical factor when the question of establishing vegetative cover for erosion control arises, because it can lead to the necessity of considering alternative methodologies to establish a vegetative cover.

Once the principles of erosion and sedimentation are understood, it is much easier to also understand the importance of erosion control and sediment control. Erosion control is based on prevention of erosion in the first instance and includes controls such as revegetation, contour slope drains, project phasing, and time frame limitations. The specific designs of some erosion control mechanisms are discussed later in this chapter.

Sediment Control is based on prevention of sedimentation and of sediment leaving the site in question. Sediment control is never 100 percent effective, but with effective erosion control, it can go a long way toward minimizing downstream effects of sediment discharge.

When assessing construction operations, the emphasis must always be on the prevention of erosion in the first instance. Only after this has been fully assessed should the operation consider the sediment control options for the site. These options may have numerous components, but they will always include perimeter controls. It is important, however, to recognize that sediment control can also include controls such as sediment traps and ponds within a site that may reduce reliance on the perimeter controls installed.

Assessing Sediment Generation of Construction Sites

The most important physical property of a soil particle is its size. The size of the particle can be determined in a number of ways. The nominal diameter refers to the diameter of a sphere of the same volume as the particle, and the sieve diameter is the minimum length of the square sieve opening through which a particle will fall. Recognizing the size of material on an earthworks site can increase the awareness of how easy or difficult it can be to remove sediment once it is in suspension. This helps target the erosion and sediment controls. Clay is considered to be less than 0.002 mm in diameter, silt between 0.002 and 0.063 mm, and sands greater than 0.063 mm. While sands and silts are more erodible than clays, they settle easier, whereas clays, a cohesive material that can form quite strong bonds once in suspension, are very difficult to trap with sediment control mechanisms. This places the emphasis on sites with clay soil dominance on erosion control methodologies.

The Universal Soil Loss Equation (USLE) is a simple model that was originally developed for agricultural practices and is now recognized as a suitable sediment yield estimation tool for activities such as earthworking operations. Rather than providing an accurate estimate of actual total sediment yield, the most beneficial use

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of the USLE has proven to be the identification of variations of sediment yields across a particular site. To achieve this, it is critical that a site is divided up into logical sectors, based on gradient, slope length, and surface cover. Other factors to consider are the proximity and nature of the receiving environment. Once completed, the USLE will allow the erosion and sediment control methodology to be tailored to suit the variations across the site.

The USLE is based on the following factors:

Rainfall Erosion Index (R)

This factor is a measure of the erosive force and intensity of the rain in a normal year. It is based on the energy and the maximum 30-minute intensity for all major storms in an area during an average year. It is derived from probability statistics resulting from analyzing rainfall records of individual storms.

Soil Erodibility Factor (K)

This represents the ability of the surface to resist the erosive energy of rain. Texture is the principle factor affecting K, but structure, organic matter, and permeability also contribute. Adjustments are made to the K factor as the site works progress, reflecting the percentage of clay, silts and sands within a soil structure. In calculating the K factor, an allowance is also made for the percentage of organic matter that is contained within the soil.

Length-Slope Factor (LS)

This is a numeric representation of the length and slope angle of a site. It is the ratio of soil loss per unit area on a site to the corresponding loss from a 22.1-meter-long experimental site with a 9 percent slope. Representative slope length and gradients are assessed for the separate sediment sources and depicted in a table. It should be noted that the potential sediment generation on a site increases geometrically with an increase in gradient. It is therefore essential that bare area and slope length are minimized on steeper gradients. This may be achieved by staging works, progressively stabilizing completed areas and installing contour drains to reduce slope lengths.

Ground Cover Factor (C)

This is the ratio of soil loss under specified conditions to that of a bare site. Where the soil is protected against erosion, the C Factor will reduce the soil loss estimate. This factor also takes into account the effectiveness of the vegetation and mulch in preventing the detachment and transport of soil particles.

Erosion Control Factor (P)

This factor reflects the roughness or smoothness of the earthworks surface with the rougher surface having a lesser value. As examples, bare soil that is compacted and smooth would have a P factor of 1.3 while a rough irregular surface such as contour plowing would have a value of 0.8. The lower value results in reduced erosion.

Once the values for R, K, LS, C, and P have been derived, the value for estimated sediment generated can be calculated. To estimate the quantity of sediment likely to be discharged to the receiving environment, it is necessary to multiply this result by the areas of exposure, the sediment delivery ratio, the sediment control measure efficiency, and the duration of exposure. Areas of the site, or the entire site, that are demonstrated to exhibit high sediment yields can then be managed accordingly.

It is important to also be aware that the sediment that is generated will be mobilized as either bedload or as suspended sediment. Bedload is moved at or near the bottom of the stream, while suspended sediment is mixed with the waters of the receiving environment.

Impacts of Sediment Discharge on Receiving Environments

Irrespective of the erosion and sediment controls employed, construction activities lead to sediment generation and to a subsequent sediment discharge with, among others, visual, recreational, and ecological impacts. These activities can be appropriately managed by the respective authorities through a range of tools inclusive of both regulatory and educational initiatives. One of the key tools in the educational component is a specific guideline for erosion and sediment control.

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The range of guidelines available typically provide a comprehensive guide for erosion and sediment control, detail the specific policies and rules applying to the site in question, and essentially work toward minimization of adverse environmental effects of sediment discharge through appropriate use and design of specific measures.

The guidelines should detail both principles and practices emphasizing the importance of both non-structural and structural measures to be implemented on sites.

In terms of the regulatory component, permits are key tools that are utilized to minimize impacts from sediment discharge. It is also recognized that compliance inspections of these permits are an important aspect of ensuring that environmental objectives are achieved. Associated with this key tool is an enforcement role which, when combined with all other relevant program aspects, will provide a suitable implementation mix.

There are many effects associated with sediment discharge. Runoff from construction sites is by far the largest source of sediment in urban areas under development. Soil erosion removes over 90 percent of sediment by tonnage in urbanizing areas where construction activities occur. The following values illustrate some of the measured sediment loads associated with construction activities found across the United States.

- York County Soil and Water Conservation District 1990 – Sediment loading rates vary from 36.5 to 1000 tons/acre/year, which is 5 to 500 times greater than those from undeveloped land.
- Franklin County, Florida – Sediment Yields
    - Forest: less than 0.5 ton/acre/year
    - Rangeland: less than 0.5 ton/acre/year
    - Construction Site: 30 tons/acre/year
    - Established Urban: less than 0.5 ton/acre/year
- Washington Department of Ecology, 1989 – Erosion rates range from 50 to 500 tons/acre/year for construction activities. Natural erosion rates from forest are 0.01 to 1.0 ton/acre/year.
- Wisconsin Legislative Council, 1991 – Erosion rates range from 30 to 200 tons/acre/year, which is noted to be 10 to 20 times those of croplands.

As summarized above, the huge potential for sediment to be generated from land bared through construction activities is significantly greater than for many other land uses.

A study undertaken in Auckland, New Zealand measured sediment yields from various land uses over time and predicted the average annual soil loss for these land uses. Construction sites were shown to have a predicted average annual soil loss of up to 400 times that of a pastoral site. The study also demonstrated that sediment yields would increase markedly with larger storm events. The significantly higher levels of sediment that occur as a result of land disturbance activities need to be identified within the specific program and to have the appropriate policy backing to ensure that these issues can be addressed.

The following effects can result from sediment discharges.

Biological Effects

Large amounts of sediment in a waterway are harmful to fish and other aquatic life. Aquatic life can be physically smothered by a build-up of sediment in the stream bed. Aquatic life not actually covered by deposits of silt can sustain damage to their gill and mouthparts due to the abrasive nature of the silt. The juvenile stages of many species are particularly vulnerable. Sedimentation may also significantly alter habitats, for example by destroying spawning grounds.

Algae, the major food supply for stream life, can be scoured off the rocks in the stream bed by sediment. Other links in the food chain may also be affected and the surviving animals forced to migrate elsewhere if they can.

Turbidity (cloudiness of the water) from suspended solids in the water may stop animals feeding because they cannot see their prey. It can also affect aquatic life by increasing heat absorption and therefore the temperature of the water. It also stops light penetrating the water, slowing down photosynthetic activity and subsequent plant and algae growth.

Other Pollutants

Sediment transports other pollutants such as lead, hydrocarbons, agricultural nutrients, and toxic substances into streams and harbors. There they can accumulate and affect aquatic life. Control of the pollutants transported by sediment is simply achieved by controlling the generation and movement of sediment itself.

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Stream Blockage

Sediment deposition can lead to the infilling of affected water bodies. This in turn can lead to a reduction in their hydraulic efficiency, an increase in susceptibility to flooding, and restrictions to access. While such sediment deposition has environmental impacts, the removal works also have potential for serious environmental effects.

Effects on Consumable Water Resources

High loadings of suspended solids affect the use of water for irrigation, stock, and domestic water supplies. Sediment in irrigation water clogs pump filters and sprinkler nozzles. In domestic and stock water supplies, it can lead to unacceptable drinking quality. Removing sediment from drinking water can be an expensive operation. Furthermore, sediment can form a threat to the useful life of dams.

Aesthetic Values

Sediment discharges into streams, lakes, or coastal waters detract from their aesthetic qualities. Clean, clear water is perceived as being much more conducive to recreation than "dirty," sediment-laden water. The purely scenic value of water bodies such as key harbor areas is enhanced by their degree of clarity.

Damage to Property and Public Utilities

Construction activities can inundate lower-lying properties or roadways with sediment if adequate control measures are not in place.

Effect of Sediment on Matters of Cultural Significance

Construction activities often disturb items and matters of cultural and archaeological importance. The effects can vary from a direct effect on these matters, such as significant destruction or alteration of a physical site, through more indirect effects such as impacts on cultural values.

Erosion Control Measures

Erosion control mechanisms typically include the following measures.

Earth Dike

A temporary berm or ridge of compacted soil, located in such a manner as to channel water to a desired location.

Its purpose is to direct runoff to a sediment trapping device, thereby reducing the potential for erosion and off-site sedimentation. Earth dikes can also be used for diverting clean water away from disturbed areas.

Earth dikes are often constructed across disturbed areas and around construction sites such as graded parking lots and subdivisions. The dikes shall remain in place until the disturbed areas are permanently stabilized.

Runoff Diversion Channel/Berm

A non-erodible channel or berm for the conveyance of runoff constructed to a site-specific cross section and grade design. To either protect work areas from upslope runoff (clean water diversion), or to divert sediment-laden water to an appropriate sediment retention structure.

Contour Drain

A temporary ridge or excavated channel, or a combination of ridge and channel, constructed to convey water across sloping land on a minimal gradient. To



Example of an earth dike flow diversion

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periodically break overland flow across disturbed areas in order to limit slope length and thus the erosive power of runoff, and to divert sediment-laden water to appropriate controls or stable outlets.

Benched Slope

Modification of a slope by reverse sloping to divert runoff to an appropriate conveyance system. The purpose is to limit the velocity and volume, and hence the erosive power of water moving down a slope and therefore minimize erosion of the slope face.



Contour drain



Slope benches

Rock Check Dam

Small temporary dam constructed across a channel (excluding perennial watercourses), usually in series, to reduce flow velocity. May also help retain sediment. The primary purpose of a rock check dam is to reduce the velocity of concentrated flows, thereby reducing erosion of the channel. While trapping some sediment, they are not specifically designed to be utilized as a sediment retention measure.

Top Soiling

The placement of topsoil over a prepared subsoil prior to the establishment of vegetation. This serves to provide a suitable soil medium for vegetative growth for erosion control while providing some limited short-term erosion control capability.

Temporary and Permanent Seeding

The planting and establishment of quick-growing and/or perennial vegetation to provide temporary and/or permanent stabilization on exposed areas. Temporary seeding is designed to stabilize the soil and to protect disturbed areas until permanent vegetation or other erosion control measures can be established. It may be used where the area to be stabilized needs temporary stabilization but is not yet up to final grade and requires further earthworks.

Hydroseeding

The application of seed, fertilizer, and a paper or wood pulp with water in the form of a slurry which is sprayed over the area to be revegetated. To establish vegetation quickly while providing a degree of instant protection from rain drop impact.





Examples of rock check dams

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This form of revegetation facilitates the establishment of vegetation on steep slopes and also allows a mixture of appropriate seeds to be utilized dependent upon the site conditions. It is, however, dependent upon the availability of appropriate hydroseeding contractors with suitable machinery.

Mulching

The application of a protective layer of straw or other suitable material to the soil surface to protect it from the erosive forces of raindrop impact and overland flow.



Straw mulch being applied



Turf being applied to topsoil

Mulching also helps to conserve moisture, reduce runoff and erosion, control weeds, prevent soil crusting, and promote the establishment of desirable vegetation.

Turfing

The establishment and permanent stabilization of disturbed areas by laying a continuous cover of grass turf. Provides immediate vegetative cover in order to stabilize soil on disturbed areas.

Geosynthetic Erosion Control Systems

The artificial protection of channels and erodible slopes utilizing artificial erosion control material such as geosynthetic matting, geotextiles or erosion matting. Immediately reduces the erosion potential of disturbed areas and/or reduces or eliminates erosion on critical sites during the period necessary to establish protective vegetation. Some forms of artificial protection may also help to establish protective vegetation.

Stabilized Construction Entrance

A stabilized pad of aggregate on a filter cloth base located at any point where traffic will be entering or leaving a construction site. To assist in minimizing dust generation and disturbance of areas adjacent to the road frontage by giving a defined entry/exit point.

Pipe Drop Structure/Flume

A temporary pipe structure or constructed flume running from the top to the bottom of a slope. A pipe drop structure or a flume structure is installed to convey surface runoff down the face of unstabilized slopes in order to minimize erosion on the slope face.





Stabilized construction entrance

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Level Spreader

A non-erosive outlet for concentrated runoff constructed so as to disperse flow uniformly across a slope. To convert concentrated flow to sheet flow and release it uniformly over a stabilized area to prevent erosion.

Surface Roughening

Roughening a bare earth surface with horizontal grooves running across the slope or tracking with construction equipment. To aid in the establishment of vegetative cover from seed, to reduce runoff velocity and increase infiltration, and to reduce erosion and assist in sediment trapping.

Rock Outlet Protection

A section of rock protection placed at the outlet end of culverts, conduits, and channels.

Its purpose is to reduce the velocity and energy of water such that the flow will not erode the receiving downstream reach.

This practice applies where discharge velocities and energies at the outlets of culverts, conduits, and channels are sufficient to erode the next downstream reach.

Sediment Control Measures

Sediment control mechanisms typically include the following measures.

Temporary Swale

A temporary excavated drainageway.

Its purpose is to prevent runoff from entering disturbed areas by intercepting and diverting it to a stabilized outlet or to intercept sediment-laden water and divert it to a sediment trapping device.

Conditions where this practice applies:

- To divert flows away from a disturbed area and to a stabilized area;
- To shorten overland flow distances intermediately across disturbed areas;
- To direct sediment-laden water along the base of slopes to a trapping device; or
- To transport off-site flows across disturbed areas such as rights-of-ways.



Flow spreading



Surface roughening





Examples of pipe and flume downdrains

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Sediment Retention Trap and Pond

A temporary device formed by excavation and/or embankment construction in order to intercept sediment-laden runoff and provide an impoundment for suspended sediment to settle out. To treat sediment-laden runoff and reduce the volume of sediment leaving a site in order to protect downstream environments from excessive sedimentation and water quality degradation.



Sediment ponds and traps



Sediment ponds and traps

Silt Fence

A temporary barrier of woven geotextile fabric used to intercept runoff, reduce its velocity, and impound sediment-laden runoff from small areas of disturbed soil. To detain flows from runoff so that deposition of transported sediment can occur through settlement. Silt fences can only be used to intercept sheet flow. They cannot be used as velocity checks in channels or placed where they will intercept concentrated flow.

Super Silt Fence

A temporary barrier of geotextile fabric over chain link fence used to intercept flows, reduce their velocity, and impound sediment-laden runoff from small catchment areas. To reduce runoff velocity and allow the deposition of transported sediment to occur.



Silt fence



Super silt fence

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Straw Bale Barrier

Temporary barrier of hay bales used to intercept and direct sediment-laden surface runoff from small areas to a sediment retention facility so that deposition of transported sediment can occur.

Stormwater Inlet Protection

A barrier across or around a cesspit (stormwater inlet) that is designed to intercept and filter sediment-laden runoff before it enters a reticulated stormwater system via a cesspit.

Earth Dike

A temporary berm or ridge of compacted soil (inclusive of topsoil) to create impoundment areas where ponding of runoff can occur and suspended material can settle before runoff is discharged.

Sump/Sediment Pit

A temporary pit constructed to trap and filter water for pumping to a suitable discharge area. The design is based on a perforated vertical standpipe placed in the center of a pit that is then backfilled with aggregate.

Perimeter Dike/Swale

A temporary ridge of soil excavated from an adjoining swale located along the perimeter of the site or disturbed area.

Its purpose is to prevent off-site storm runoff from entering a disturbed area as well as prevent sediment-laden storm runoff from leaving the construction site or disturbed area.

A perimeter dike/swale is constructed to divert flows from entering a disturbed area, along tops of slopes to prevent flows from eroding a slope, or along the base of slopes to direct sediment-laden flows to a trapping device. The perimeter dike/swale shall remain in place until the disturbed areas are permanently stabilized.

Non-Sediment-Related Pollutants from Construction Sites

Concrete washings, water blasting, equipment washing, concrete and tile cutting are all works occurring at construction sites that can pollute waterways unless care is taken. These pollutants are known to cause problems due to their highly alkaline nature. They contain oxides, heavy metals, or, possibly, petroleum products.

There are, however, practices that can be followed to ensure that the effects from these activities do not create adverse effects. These can include the following:

- When washing operations generate fine sediments (silts or clays), make sure the wash water is confined, filtered or diverted across to a soak area. If discharge is necessary, it should go into a sanitary sewer, not the stormwater system.
- Do not wash equipment on site unless there is a designated washout area where wash water soaks into the ground or is treated.
- When waterblasting, contain dirty waste runoff. Chemical additives should not be discharged to the stormwater system. Utilize filter cloth to filter out paint flakes and sediment prior to discharge.
- Slurry from directional drilling must be allowed to settle, with the water soaking to ground or taken off-site to an appropriate disposal location.



Inlet protection



Sediment dewatering pit

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Innovative Practices

While the previously detailed erosion and sediment controls are typical traditional controls and will be reasonably effective for most sites, there are many circumstances where more specific innovative practices should be employed. Erosion and sediment controls need to be significantly advanced in this area to ensure protection of the receiving environment.

Innovative practices should be considered on all sites, particularly those that show high sediment yields, and include the following structural and nonstructural measures.

Mulching

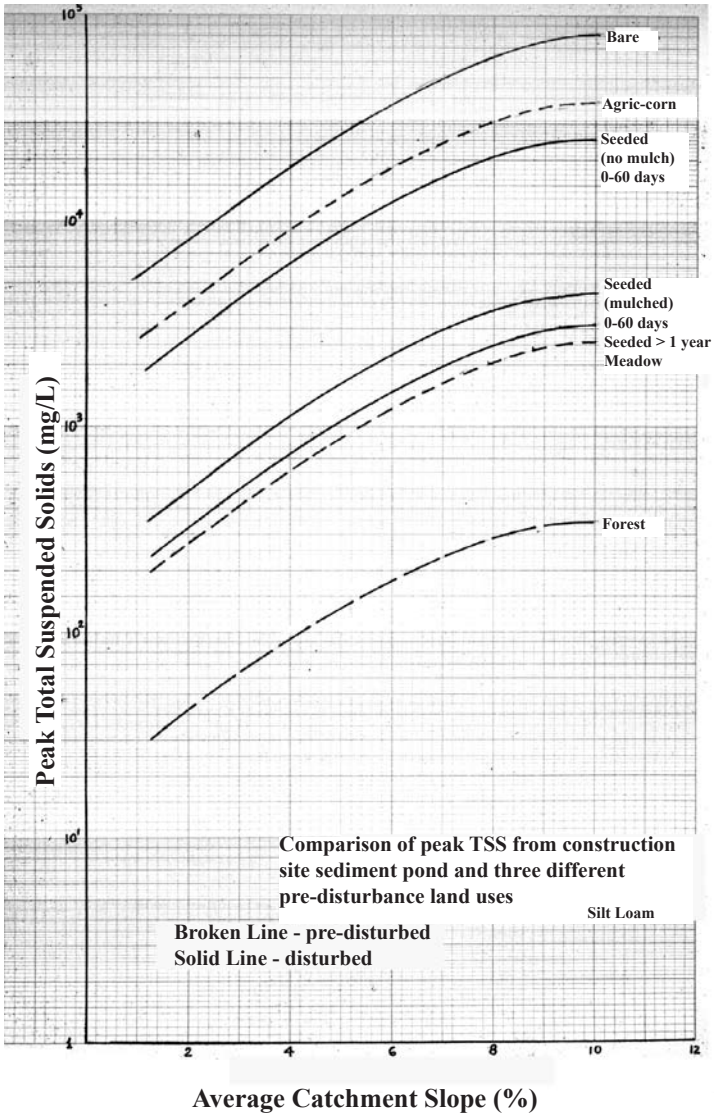
It is acknowledged that when land is disturbed for construction and other activities, the rate of erosion increases as unvegetated surfaces are subjected to raindrop impact and overland flow. While the benefits of stabilization of soils to minimize erosion have been supported by research for some time, it is important to recognize that the application of mulch has been somewhat inconsistent. It is critical that mulching becomes an integral part of any earthworks site and forms a part of all erosion and sediment control plans.

Investigation results demonstrate that:

- Established grass cover and mulching topsoil surfaces are the most effective way of reducing sediment discharge.
- Clay- and silt-size particles typically form the greatest proportion of sediments discharged from construction sites that have effective sediment controls, and the discharge of these particles is minimized through mulching the surface in question.
- Mulched topsoil areas produce up to 95 percent less sediment discharge than bare subsoil surfaces.

A study done in the U.S. in the mid-1980s (Maryland Department of Natural Resources) looked at a number of parameters that could affect the discharge of sediments from a construction site. One component of the study was to look at the benefits of temporary stabilization techniques as an erosion control tool. The results of this project demonstrated the various stabilization techniques and the impact of slope on sediment loadings. They are illustrated in Figure 9-1. It is important to note that there is a clear trend not only for sediment loading to increase with slope angle, but also for it to decrease as vegetative cover increases.

Figure 9-1: Relationship Between Vegetative Cover and Slope Versus Sediment Yield



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Chemical Treatment of Runoff

One method of enhancing the retention of suspended sediment in earthworks runoff is the use of flocculant. In recent advancements, liquid flocculant can be added directly to sediment retention pond inflows via a rainfall-activated system. The flocculant causes individual particles to be destabilized (neutralizing electrical charges that cause particles to repel each other), accelerating the coagulation and settlement of particles that may otherwise be discharged from the pond.

The key purpose of using flocculation is to treat sediment-laden runoff to an extent greater than standard sediment control practices and to reduce the volume of sediment leaving a site.

Flocculation may be used to enhance the retention of sediment on earthworks sites where there are concerns about the scale of works, potential effects on sensitive receiving environments, or cumulative discharges, or where it may not be feasible to construct standard sediment control practices.

Flocculation using the system illustrated below is simply incorporated into the design of a sediment retention pond. The catchment draining into the pond needs to be considered carefully throughout the period of flocculation, as the components making up the flocculation system are sized on the catchment characteristics, including area and soil type. The rainfall-activated flocculation system outlined in this section is based on the use of polyaluminum chloride (PAC). Other aluminum coagulants, including alum (aluminum sulphate), may be suitable for use; however, methodologies may need to be adapted to produce appropriate outcomes.

The general components of the flocculation system include a rainfall catchment tray, header tank, displacement tank, and flocculant reservoir tank, as detailed below.

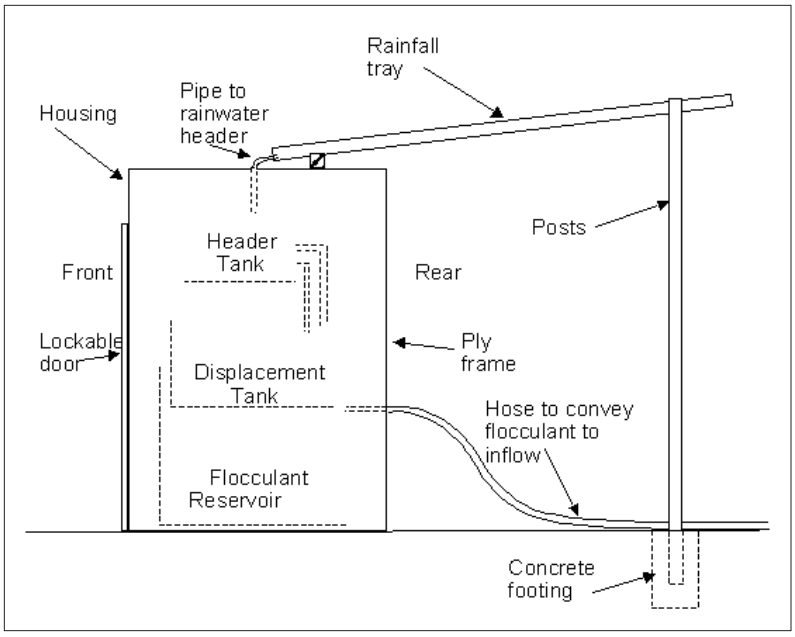
Rainfall from the watershed-sized rainfall tray drains to a header tank. The header tank provides storage capacity to avoid dosing during initial rainfall following a dry period and to attenuate dosing at the beginning and end of a rainstorm (to simulate the runoff hydrograph). The header tank provides:

- Zero flocculant discharge until a pre-selected quantity of rain has fallen, to allow for initial infiltration and saturation of dry ground before runoff commences;
- A slow start to the dosing rate to allow for the response time of runoff flowing off the site at the beginning of a storm; and
- An extension of the dosing period beyond the rainfall period to provide treatment of runoff that occurs following cessation of rainfall.

From the header tank, the rainwater discharges by gravity into a displacement tank which floats in the flocculant reservoir. As the displacement tank fills with rainwater, flocculant is displaced through the outlet in the reservoir tank and then flows by gravity to the



Example of an on-site chemical flocculation system



Schematic of a chemical flocculation system

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dosing point. The dosing point should be selected in an area of high turbulence in the pond inflow channel.

The zero (flocculant) discharge rainfall volume can be adjusted manually for site characteristics by adding or removing water from the header tank.

It is important that the pH of the soils in the area in question is understood. The pH of soils should be tested prior to and during construction, as the exposure of different soil horizons may alter the runoff pH. Dosing with aluminum-based flocculant should cease where the pH drops below 5.5, as the toxicity of the aluminum fraction of the flocculant increases below this level, potentially placing at risk receiving environment organisms.

The use of flocculation will lead to more frequent sediment retention pond maintenance. The sediment containing the flocculant is not considered to be toxic, as the aluminum is bound up with the soil particles. It is common practice for the accumulated sediment to be dried on site and incorporated into fills.

Flocculants can provide an alternative to traditional sediment control practices. Dependent upon the nature of the site, they can ensure that adequate controls are implemented when site conditions restrict options.

Performance of flocculants for sediment removal has proved the approach to be very effective at removal of pond sediments, especially for finer silt and clay particles. Monitoring of 21 sediment ponds demonstrated that efficiencies ranged between 90 and 99 percent removal of suspended sediments. In circumstances where flows exceeded pond design criteria, efficiencies were also notably enhanced.



Roof area of flocculation unit

The key features of this approach are the following:

- They are simple to install and maintain.
- They do not require electrical power.
- They are rainfall-activated.
- They dose the critical storm.
- They are easily transportable and reusable.
- They are cost-effective (around $1,500 plus maintenance and operational costs).
- They require no dedicated staff.

Low Impact Design (LID)

The principles behind LID are based upon using an analysis of existing site conditions as a baseline from which to commence site planning. The site conditions provide an inventory of the full range of natural systems such as soils, geology, vegetation, habitat, and the cultural and archaeological factors associated with the site. The more the complex and integrated nature of the conditions is understood, the better the earthworks and building program can be fitted on the site with reduced impact. LID is similar to erosion control in that it is a preventative approach reducing the amount of sediment generated by practicing the principles through planning processes.

Only after a full site analysis and inventory has been undertaken can the erosion and sediment control plan be developed and full control mechanisms considered.

While considered innovative, LID should be built into all erosion and sediment control methodologies. It needs to be the first step considered in the management of a site.

In addition to the LID principles detailed above, a further innovative consideration is one associated with limiting the season within which construction activities can occur. A policy of this nature is utilized in Auckland, New Zealand, where construction activities over a certain size require specific approval to continue work over the winter

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months. The rationale behind this practice is the increase in rainfall which is expected over the winter period in addition to lower ground temperatures and reduced evapotranspiration, which creates some difficulties in establishment of vegetative cover for stabilization. Dependent upon the site vicinity to receiving environments, many construction activities can not continue under these conditions due to the increased sediment yields and the difficulties that will be experienced.

While the practice of not working over this high-risk period is one that needs to be considered on a site-by-site basis, it does provide a further tool in the erosion control tool box and can go a long way toward prevention of sediment discharge and the associated problems.

Watershed-Wide Considerations

While this chapter focuses primarily on development activities, it is important that the issue of sediment discharge from development activities is not considered in isolation. Pollution (sediment) budgets on a watershed-wide basis may assist in determination of the prime sources of pollution within the watersheds of concern. This concept is one that needs further consideration, and while it would provide good generic information, it is recognized as being a difficult study to undertake.

The above demonstrates some of the innovative practices that currently exist and can be employed as part of an erosion and sediment control plan. There are many more practices in this category, and programs need to consider them in association with the traditional measures available.

Ten Commandments of Erosion and Sediment Control

It is important that all the principles and practices that apply be put into the context of a program and site development. To assist in this process, a set of "commandments" can be considered on all development sites. These "commandments" have been adopted by many programs and are utilized on a regular basis when erosion and sediment control are considered. They provide a checklist and also demonstrate the key aspects that should always be considered.

1. Minimize Disturbance

Some parts of sites should not be opened up, and where construction is required, ensure this is undertaken carefully to avoid sensitive areas. These sensitive areas include wetlands, streams, and steep slopes. This component is clearly linked to the planning phase of all developments, and if you can plan to only undertake earthworks on land that is suitable for this activity, you will go a long way toward reducing accelerated erosion. LID also



Minimal disturbance for earthmoving

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attempts to limit total site disturbance. Working with existing site contours, as opposed to mass earthworking, will reduce overall site sediment discharge.

2. Stage Construction

Where possible, stage construction such that it is undertaken in manageable segments that can include revegetation and therefore limit the erosion potential. Sites that expose the whole area at one time constitute a considerable risk with a significant potential for erosion of large sediment yields.

3. Protect Steep Slopes

Associated with minimization of disturbance, steep slopes should always be avoided. This is clearly demonstrated by the Universal Soil Loss Equation, according to which these slopes can generate the biggest percentages of sediment yields. Runoff should also be diverted away from these slopes. Where slopes will be disturbed and revegetation is required, techniques over and above those traditionally utilized will need to be considered.

4. Protect Watercourses

Again associated with the minimization of disturbance, existing streams and drainage patterns need to be identified and protected as part of the planning phase of the development cycle. These systems are critical components of our receiving environments. If work is required that disturbs these areas, specific careful management is required.

5. Stabilize Exposed Areas Rapidly

The best way to prevent erosion is to fully stabilize the soils to prevent raindrop impact and scour. This may require stabilization during the development as well as stabilization at the completion of the earthworking phase. To provide the vegetative cover required, it may be necessary to look further than tradition conventional grass sowing and move toward methodologies such as straw mulching as a standard practice.

6. Install Perimeter Controls

The key behind effective sediment control is to treat only the runoff that is required to be treated. Essentially, treat only dirty water and keep clean water clean. The best way of achieving this is to employ perimeter controls that divert clean water safely to a point of discharge. Perimeter controls can also act to ensure that dirty water does not leave the site, as well as direct sediment-laden water to the necessary controls within the site.

7. Employ Detention Devices

A further critical feature associated with erosion control measures is the use of sediment traps and ponds. These work on the principle of detaining sediment-laden runoff, and while never 100 percent effective, they are a critical component. These measures need to be designed to local standards and must be able to withstand the rainfall conditions for the area while not overtopping.

8. Register and Attend Local Contractor or Designer Education Courses

9. Make Sure the Erosion and Sediment Control Plan Evolves as Site Development Proceeds

10. Assess and Adjust

These last three commandments refer to ensuring that you have appropriately trained personnel on site, that your erosion and sediment control plan adjusts as the site evolves, and that continual monitoring and assessment of the site occurs.

These "ten commandments" can be easily transferred to any program. It is important to note the emphasis they place on nonstructural techniques. Since these principles focus on the prevention of erosion in the first instance, they take pressure off the sediment control measures. This does not mean that the sediment control measures are not necessary, but that maintenance and overloading of these structures is not as frequent if there is less sediment entering.

Essential Program Elements

For the erosion and sediment program to be successful, it is critical that its institutional aspects evolve along with its technical aspects.

The ultimate goal of any erosion and sediment control program is to minimize or reduce adverse

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water quantity and quality impacts. This cannot be accomplished without an effective, efficient, and comprehensive institutional foundation. There must be adequate legal authority, performance standards, design assistance and guidance, program funding and staffing, commitment to enforcement, comprehensive approaches to research, and program evaluation and evolution. All of these program elements must have a solid institutional foundation that exists prior to any practices being constructed. In addition, regardless of the best of intentions, the program must have political support, which is translated into funding and other necessary program support components.

Essential program elements include:

- Basic goals;
- Authority and implementation structure (relationship and linkage to other local government programs);
- Performance standards;
- Exempted and waived activities;
- Design guidelines and assistance;
- Inspection procedures;
- Funding;
- Staffing;
- Educational activities;
- Compliance and enforcement;
- Maintenance; and
- Evaluation and evolution.

Design Plans

Detailed plans should be submitted and reviewed for larger site disturbances. The threshold size of the site in question should relate to the use of practices that require engineered design. If sediment traps are used, detailed designs should be submitted for review, and formal local agency approval should be obtained prior to works commencing. This threshold could also relate to areas where watershed size exceeds the ability of a particular practice to treat the runoff. An example of this is a silt fence, where concentrated flow would exceed design criteria.

Inspection Documentation and Frequency

An integral part of the inspection process is the question of how often inspections are considered necessary. During the construction process, site conditions can change rapidly, and assurance of adequate site control may necessitate frequent site visits by the inspector. Inspection frequency needs to be flexible, corresponding to shifts in the intensity of activity going on at construction sites.

When active construction is occurring, erosion and sediment control inspections should be conducted on a specified, appropriate frequency. This frequency will depend on the level of activity and may be developed during the construction period. When work on the site stops temporarily, inspections should still occur periodically to ensure that work has not resumed and that erosion and sediment controls are being maintained and still working. That inspection can be a 'windscreen inspection' to verify that construction has not initiated. It would be good to conduct a walk-around inspection at least once a month or after significant rainfall events to ensure that site controls are still functioning as required.

After completing the inspection, the inspector should leave an inspection report with the contractor, sending a copy to the developer and possibly the property owner. The report should serve as a site report card, clearly documenting proper installation and maintenance of site controls as well as any deficiencies in site control implementation. If there are areas of non-compliance, the inspection report initiates a "paper trail," which is integral to successful enforcement actions. To improve the effectiveness of inspections, it is important to establish standard, well-documented inspection procedures. These procedures should specify in detail the actions an inspector conducts at a site, set out options and list steps to be taken when site compliance is inadequate, and establish a process to be initiated if there is a disagreement on site.

Clarification of Roles on Site

A clear, formal statement of individual responsibility always benefits program implementation. The agreement should clearly define roles and levels of responsibility. When setting out these roles, it is important to be cognizant of the legal responsibilities of each authority.

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Adequacy and Use of Guidelines

Program implementation will only be effective if there is a 'level playing field' where everyone has an equal responsibility to implement erosion and sediment control practices. There are several approaches that need to be jointly considered:

- Educational activities;
- Mandatory requirements where the regulated community recognizes their obligations; and
- Inspection and enforcement. A site presence will demonstrate to contractors and developers that program implementation is important. Enforcement procedures are also important in public recognition of program responsibility and obligation.

Adequacy of Erosion and Sediment Control Implementation

The purpose of program implementation is to ensure good site control to minimize sediment discharge into receiving waters. Program structure can take many forms, but it is the end result of resource protection that is the reason for program implementation.

Erosion and sediment control practices can be considered individual components of an environmental treatment train. Site control cannot rely upon one single practice to provide effective control. It will take a number of practices working in conjunction with one another to achieve that goal.

Permit Processing

Permits are a key tool utilized to enable erosion and sediment control objectives to be transferred and implemented on specific sites. Therefore, processing of permits is a very important first step in ensuring that these objectives are reflected on the ground and that all relevant parties understand the key issues and solutions associated with the development of a site.

The Erosion and Sediment Control Law is the key to minimizing adverse effects from construction and therefore needs to be considered "up front" by the developer and appropriately approved by the respective local authorities. This will ensure that controls required are documented and form a condition of the permit, thus making compliance and enforcement an easier task. In terms of the type and level of information required, this should include: contour plan, measures proposed, design criteria and justification, construction sequence, staging details, and maintenance. By including all this information on one plan, the contractor can also access the detail without second-guessing.

An environmental effects analysis is a second area of information that could be supplied as part of the permit application. This enables the developer to gain an understanding of the values of the receiving environment and adjust the erosion and sediment control plan accordingly to reflect this. The process of the developer undertaking this task also has a significant educational effect. Not only will it eventually change the attitude of developers toward erosion and sediment control, but it will also ultimately lead to significant improvements to site implementation. It also needs to be mentioned that the immediate receiving environment, such as on-site stream systems, needs careful consideration.

It is important that the development cycle is considered as a whole and sight is not lost of other key areas. The obvious area in this regard is the long-term stormwater discharge that is detailed in other parts of this document. There is little value in implementing a satisfactory erosion and sediment control program only to find all the benefits compromised by ineffective stormwater management over the long term.

Environmental Goals and Clear Guidance

Development and documentation of clear goals for the various receiving environments is critical. This should also include detail of the steps that can be taken to achieve these goals. This information could be included within an updated Erosion and Sediment Control Guideline.

Permit Inspection and Enforcement

Ensuring compliance with program requirements makes for a level playing field where all the players have the same responsibilities. Failure to take enforcement action can lead to widespread problems on other sites.

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Enforcement is made more difficult by the fact that no one wants to be considered a "bad guy." Inspectors and program administrators need to recognize that, at times, they will have to act as "policemen." To facilitate these actions, the programs framework should specify the procedures, options, and remedies to be followed by staff when conducting compliance and enforcement activities.

As-built Requirements/ Pre-construction Meetings

As-built plans, especially for sediment ponds or traps, are extremely helpful in assessing the adequacy of implementation. Sediment ponds or traps are structural practices, and their performance depends to a large extent on adequacy of construction. Will there be leakage around the outfall pipe, has compaction been adequately done, and are design elevations reflected in construction? Sometimes these questions cannot be answered by an inspector, and having as-built requirements will provide further assurance that construction was adequately done.

Pre-construction meetings between the inspector, developer, designer, and contractor can provide an excellent starting point, where any questions regarding site implementation, timing, and phasing can be resolved. Important elements of erosion and sediment control implementation can be emphasized. Pre-construction meetings are important in getting a project off to a good start. Too often, site construction gets quickly out of control, and getting effective erosion and sediment control implementation becomes extremely difficult.

Mandatory or Voluntary Educational Programs

Generally, educational programs should be voluntary. However, there are certain program elements that can benefit from, or even depend on, mandated educational programs. An example of this would be a requirement that a responsible person from an individual contracting company attend an erosion and sediment control training program. This program could last one day and explain why implementation of erosion and sediment control is important and how to construct individual practices. The States of Delaware and Maryland, for example, have a mandatory contractor certification program that requires every site contractor to have at least one individual responsible for site controls attend a course in erosion and sediment control. To date, thousands of people have attended these programs, and they have proven popular with attendees.

Individuals attending these programs generally enjoy outdoor, water-related activities, and relating these activities to the program's goals leads to a more personal commitment by attendees. This greatly enhances program effectiveness.

If an educational program is mandatory, it must be available on a regular basis. This allows individuals who need this training to attend sessions and carry out their function under the program. Educational activities for the general public generally cannot be offered on a regular basis but rather when opportunities become available.

Educational programs aimed at the construction industry present a special challenge because of the constant turnover of employees. This implies a need for courses to be held on a more frequent basis. A contractors' course can last from a half day to one day. It needs to stress general information about erosion and sediment control as well as problems and solutions, along with information about the contractors' specific responsibilities and obligations.

While design guidance manuals or guidelines are extremely important, consultants can benefit greatly from periodic workshops on design aspects. These workshops can explain the rationale behind practice selection and design criteria, provide supplementary, up-to-date information on designing practices, and include case studies that illustrate good and bad examples of design and use of practices. Having a good relationship with the design community reduces potential problems in all aspects of program implementation.

Workshops conducted on a periodic basis could be used not only to disseminate information, but also to obtain feedback regarding program implementation, conduct case studies, bring in experts to discuss a specific issue, and demonstrate new strategies or products.

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Program Requirements

It has been emphasized throughout this chapter that erosion and sediment control is an important part of the development cycle. It needs to be undertaken with consideration of all the aspects previously mentioned.

There are, however, the big "Cs" of an erosion and sediment control program that, similar to the ten commandments, should always be considered. They are:

- COMPREHENSIVE management of land use, water resources, and infrastructure throughout a catchment is necessary.
- CONTINUITY of erosion and sediment control and stormwater management programs over a long period of time will be required to address these problems.
- COOPERATION between all statutory bodies, the public sector and the private sector is essential to prevent and solve problems.
- COMMON SENSE in our institutional approach is essential.
- COMMUNICATION is crucial: between entities involved in program implementation; between implementing agencies and those being regulated; with politicians to gain their support; and with the general public to convey how normal activities can cause pollution and how to become part of the solution.
- COORDINATION of efforts for cost-effective implementation to maximize benefits is indispensable.
- CREATIVITY in technology and in our approach to solving this complex problem is critical.
- CASH in terms of program support and implementation of necessary controls is essential.
- COMMITMENT to solving these problems is of the utmost importance. Whether our children will have clean water, a high quality of life, and a vibrant economy will depend on our sincerity of effort.

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CHAPTER 10

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CHAPTER 10

Structural Stormwater Management Facilities

The full range of stormwater best management practices (BMPs) currently available to manage urban runoff includes both nonstructural measures and structural facilities. Nonstructural stormwater management measures, which can influence the amount of runoff and associated pollutants that are produced from a storm event, are discussed in detail in Chapter 7. This chapter presents technical information on the wide range of structural stormwater management facilities that are presently available to the developers and administrators of urban runoff management programs.

Unlike their nonstructural counterparts, structural stormwater management facilities generally do not influence the quantity and quality of stormwater runoff initially produced by rainfall. Instead, they respond to that initial runoff in a variety of ways, depending upon their basic operating principles and structural characteristics. These principles and characteristics include the relative ability of each to control runoff quantity and improve runoff quality, the mechanisms and materials they use to do so, the means by which they discharge their outflows, and their method of construction. As a result, these basic principles and characteristics can also be used to group the numerous types of structural facilities into broader categories as well as identify key design, construction, operation, and maintenance needs of each.

Compared to the 1994 *Fundamentals of Urban Runoff Management* that was the forerunner of this book, presenting a detailed chapter on structural stormwater management facilities is more difficult today. This is due to a number of reasons. In the intervening decade, the range of available types of structural facilities and the number of design variations have grown considerably. In addition, research into structural facility components, performance, operation, cost, construction, and ancillary impacts has also grown by a similar amount. These two factors have, in turn, increased the amount of available information that could be included in such a chapter. In addition, this knowledge growth rate is expected to continue in the future, increasing the likelihood that any information included in the chapter will quickly become obsolete. Finally, unlike 1994, there are many excellent structural facility design manuals that are readily available today from other public and private sources.

Therefore, rather than providing detailed design, construction, and maintenance specifications for each of the many structural stormwater management facilities currently available, this chapter will assist readers in selecting the most appropriate facilities, whether its for a particular development site or an entire urban runoff management program. It will do so by reviewing the basic operating principles and associated component and site needs of each facility type. It will then use this information to organize the large number of individual types into more general categories that should make it easier to both understand and select the optimum

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structural facilities. Finally, the chapter will provide an overview of key planning considerations and design requirements for each type of facility. This information will be supplemented by references to specific structural facility design manuals prepared by others that can be used to obtain for more detailed information.

Providing assistance in selecting the most appropriate structural stormwater management facility or facilities is important for several reasons. In addition to addressing the specific requirements of a development site or the overall needs of an urban runoff management program, it should be noted that the EPA's Stormwater Phase II Final Rule requires operators of small municipal separate storm sewer systems (or MS4s), which include municipalities and highway agencies, to develop and implement a runoff management program that utilizes best management practices (BMPs) to address post-construction runoff from land development and redevelopment sites. These BMPs are to include a combination of nonstructural measures and structural facilities, which the MS4 program developers are required to identify. NPDES permitting authorities, typically comprised of state governments and tribes, are also encouraged to develop a menu of BMPs to assist MS4 program developers in this process. As such, it can be seen that selecting the most appropriate structural BMPs for a runoff management program is an important component of the program's overall success.

Prior to the presentations on BMP selection, however, the chapter will begin with a discussion of two key design parameters that pertain to all structural stormwater management facilities:

1. The maximum rainfall for which runoff must be treated.
2. The minimum level of runoff treatment that must be provided.

In the past, the maximum rainfall amount, often referred to as the facility's design storm, has at times been the source of confusion and misunderstanding, which has affected the performance of both specific structural facilities and the overall urban runoff management program that created them. Similar confusion over required or attainable treatment levels during that design storm (and smaller events) has also adversely impacted both facility and program performance, albeit for somewhat different reasons. The discussions will attempt to reduce some of this confusion and promote better understanding of these two fundamental program parameters.

Design Storms

As described in the EPA's Stormwater Phase II Final Rule, urbanization can adversely impact streams, ponds, lakes, and other water bodies in two general ways. The first is caused by an increase in the type and amount of pollutants in stormwater runoff, which can harm aquatic life through both direct physical contact and their food chain. These impacts are described in detail in Chapter 3. The second cause is the increase in the volume of runoff that is delivered to and must be conveyed by water bodies. As described in Chapter 2, excessive increases in runoff volume can cause erosion and scour which, in turn, can harm aquatic life through a loss of both habitat and food sources, even without an increase in pollutant loading. In addition, excessive volume increases can cause flooding that can damage property and threaten human safety.

As a result, an effective urban runoff management program must address the impacts of land development and redevelopment on both runoff quality and quantity. However, while these requirements are easily stated and understood in general terms, there are some specific program requirements that must be determined in order to achieve them. One of these requirements is the exact amounts of rainfall and/or runoff that the program must address, both for runoff quality and quantity purposes. However, in attempting to do so, some complications arise. First, as discussed in Chapter 2, the amount of rain produced by a given storm event can range from a trace amount to a foot or more, depending upon location, season, and other meteorological factors. The amount of resultant runoff from these rainfalls can also vary, depending not only upon the specific rain depth but a number of other factors unassociated with the rainfall. The fact that rain events generally vary in a random way from storm to storm further complicates our efforts to select appropriate rainfall or runoff amounts.

One could turn to the EPA's Stormwater Phase II Final Rule for guidance. However, a review of the requirements for post-construction stormwater management reveals only general language regarding the need to develop a stormwater program that will reduce runoff pollution from land development and redevelopment projects to the maximum extent practicable. There is no mention of maximum or design storm depths, durations, or frequencies upon which to base specific program requirements, other than some discussion of controlling pollutant impacts on an average

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annual basis. As stated elsewhere in the final Rule, this lack of specificity on EPA's part is, in fact, deliberate, since it allows states and other regulated entities to develop program requirements and design parameters that specifically address their unique stormwater needs and problems. It also allows the EPA to improve and expand their stormwater regulations in an iterative manner, with greater specificity included in future versions of the Rule based upon the knowledge gained from previous ones. Unfortunately, while such customization and ongoing improvement of a nationwide rule is commendable, it also complicates the present task facing local program developers.

We can begin to find some answers by dividing up the urban runoff management program into the two major components described above: runoff quantity and runoff quality control. These are addressed separately below.

Runoff Quantity Control

From a risk perspective, increases in runoff quantity in the form of flooding can have direct impacts on all forms of life, including human. Therefore, while the potential for a loss of human life due to development-induced flooding may be relatively small, the effect or cost of such a loss is unquestionably large. As a result, the maximum design storm level for runoff quantity control must also be large in order to reduce the risk to an acceptably small amount. For that reason, many urban runoff management programs typically select large maximum design storm levels to address the quantitative runoff effects of land development and redevelopment. In keeping with the requirements of the National Flood Insurance Program (and many associated state floodplain management programs), the 100-year storm has typically been used as the maximum design storm for the control of runoff quantity increases.

However, to effectively manage runoff quantity increases caused by land development and redevelopment, it is not sufficient to simply exercise control over the maximum design storm. That is because runoff quantity increases caused by land development can also be expected to occur during smaller storms, and such increases, combined with their increased frequency of occurrence, can also cause significant flood and, in particular, erosion damage. In fact, on a percentage basis, the runoff volume increase experienced during smaller storms is typically greater than that which occurs during the maximum design storm. As a result, runoff quantity control must extend over a range of storm events up to and including the maximum design storm, which should be seen only as the upper limit of a range of necessary control.

For these reasons, it is common for an urban runoff management program to require runoff quantity control for a number of specific storm frequencies. For example, the New Jersey Stormwater Management Rules promulgated by the state's Department of Environmental Protection require runoff quantity control for the 2-, 10-, and 100-year storm events. In Maryland, the state's Department of the Environment requires runoff quantity control for the 1-, 10-, and 100-year storms in certain areas of the state to provide channel, overbank, and extreme flood protection. Many other states, counties, and municipalities have similar quantity control requirements.

However, although an appropriate range of design storms have been identified for runoff quantity control, the necessary level or degree of control must still be determined. To do so, we must first consider what runoff quantities are actually increased by land development and what can be done to either prevent or mitigate them. As discussed in detail in Chapter 2, land development and redevelopment projects that increase site imperviousness and drainage system efficiency will cause increases in both the site's total runoff volume and the peak runoff rate. As described in Chapter 2, both research and analysis have shown that increases in either of these quantities can cause downstream flooding, erosion, and habitat damage. As such, to be effective, it will be necessary for an urban runoff management program to address the increases in both runoff volume and peak runoff rate. And since increases in peak runoff rate are caused, at least in part, by runoff volume increases, it should be possible with a single set of controls to affect both quantity parameters.

Which returns us to the question of what level or degree of quantity control is necessary. An obvious first choice would be to require no increases in total runoff volume or peak runoff rate between pre- and post-developed site conditions, applied to a range of storm events up to a maximum 100-year storm. And as discussed in Chapter 8, Impact Avoidance, this is perhaps the most effective way to prevent the environmental damage and safety threats posed by runoff quantity increases. However, while limiting post-development peak runoff rates to pre-developed levels has proven

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to be readily achievable at most development sites regardless of site characteristics, similar control of post-development runoff volumes has proven to be more difficult. This is due, in part, to the different processes needed to control runoff rate and volume and, in part, to the very nature of land development itself. Regarding the different processes, reduction of post-development peak runoff rates can be accomplished through the temporary storage and slow release of the developed site's runoff. This can be accomplished through the construction of stormwater detention basins and related facilities that typically do not require any special site conditions other than sufficient space for construction and a downstream discharge point that can safely accept the basin's outflow. Both of these can usually be provided at most development sites with, at worst, a limited loss of developable land.

Reducing post-development runoff volumes to pre-developed rates, however, can be significantly more difficult if not impossible to achieve at many development sites. For unlike peak rate reductions that only require temporary storage of runoff, runoff volume reductions require what could be described as permanent runoff reductions. That is to say, reducing post-developed runoff volumes to pre-developed amounts requires the increased volume caused by the development to be infiltrated into the site's soils and not to be allowed to leave the site. While such infiltration can be possible at sites with granular, highly permeable soils with deep groundwater and bedrock levels, it can be difficult or impossible to achieve on sites with relatively impermeable soils and/or shallow depths to groundwater or bedrock. Even at permeable soil sites, achieving the required infiltration rates and volumes may be difficult due to the fact that the development has increased impervious coverage of the site, consequently reducing the area of pervious cover over which the infiltration can occur. Therefore, while the total volume of infiltration required under post-development conditions is essentially equal to pre-developed conditions, it must be achieved over a smaller area. This effectively increases the required soil infiltration rates, sometimes to unachievable levels. This problem can be compounded by excessive groundwater mounding, which can affect the infiltration facility itself and/or adjacent structures or systems such as basements and septic system disposal fields. Finally, the potential for groundwater contamination by the stormwater-borne pollutants infiltrated with the site's runoff may also prevent the use of infiltration.

As a result, the goal of maintaining pre-developed site runoff volumes, however desirable, has proven elusive in many areas. As a consequence, alternative quantity control measures have been sought. The most popular to date appears to be simply requiring post-developed peak runoff rates to not exceed pre-developed ones for a range of storm events through the use of on-site stormwater detention. However, despite both its popularity and apparent logic, research conducted in New Jersey and elsewhere has shown that, in addition to ignoring runoff volume increases, such a requirement can be, at best, ineffective and, in certain instances, actually detrimental: in a number of cases, downstream peak runoff rates turned out to be greater than those that would have occurred if the requirement (and associated on-site detention) had not been imposed. The results of one key research effort are summarized below.

The South Branch Rockaway Creek Stormwater Management Study was conducted by the Natural Resources Conservation Service (NRCS) and the New Jersey Department of Environmental Protection (NJDEP) in 1986. Among its many findings, the study demonstrated how ineffectual and, at certain locations, harmful a policy of maintaining post-development runoff rates at pre-developed levels can be. The study analyzed the 12.3 square mile watershed in west-central New Jersey under present (i.e., 1986) and ultimate development conditions. It then simulated the effects of a runoff quantity control policy that simply required no increase in predeveloped peak runoff rates for a land development site.

The results of that simulation are summarized in Tables 10-1, 10-2, and 10-3. Shown in the tables are the estimated peak 2-, 10-, and 100-year discharges at three of the study's eight points of analysis for both present and ultimate levels of development. The three points of analysis are located at the upper, central, and lower portions of the watershed as shown in Figure 10-1. The upper location (Point 1) has a total drainage area of approximately 0.6 square miles and has only a single subarea discharging to it, while the central and lower locations (Points 4 and 8, respectively) have increasingly larger drainage areas and, as such, receive the outflows from increasingly greater numbers of subareas. Point 4 has a total drainage area of approximately 7.3 square miles and receives runoff from 16 watershed subareas, while Point 8, which is located near the mouth of the South Branch, has a total drainage area of 12.3 square miles and receives runoff from all 23 subareas delineated for the study.

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The tables contain three sets of peak discharges at each location for each storm frequency. The first set of peak discharges represents existing development levels at the time of the 1986 study, while the second set represents ultimate development of the watershed in accordance with current zoning but without any runoff rate controls. The third set of peak discharges also represents ultimate development conditions but with the requirement that peak runoff rates from future developments could not exceed those under existing development levels. These requirements, which were contained in the current land development ordinances of the watershed's municipalities, were achieved in the study by allowing each watershed subarea to represent a future development site, each with its own on-site detention basin that achieved the required peak rate reduction for the 2-, 10-, and 100-year storms.

As can be seen in all three tables, ultimate development of the South Branch Rockaway Creek watershed will cause increases in existing 2-, 10-, and 100-year peak runoff rates at all three points of analysis summarized in the tables. For example, Table 10-1 indicates that the existing 2-year peak runoff rate at Point 1 is estimated to increase from 136 CFS to 186 CFS under ultimate development conditions. Similarly, Table 10-3 indicates that the existing 100-year peak runoff rate at Point 8 is estimated to increase from 3840 CFS to 4660 CFS under ultimate development conditions. Similar increases can be seen in the tables for all points of analysis and storm events.

Further review of the tables also indicates how effective the watershed's 1986 peak runoff rate controls will be. As described above, these runoff quantity controls required peak developed site outflows not to exceed those under existing development for the 2-, 10-, and 100-year storms. At Point 1 (which is located in the upper portion of the watershed at the outlet of a single development site), this requirement will effectively control the peak increases caused by that development at that location for all three storm events. For example,

Table 10-1: Summary of Peak 2-Year Discharges, South Branch Rockaway Creek Stormwater Management Study

Point of analysis	Existing peak discharge (CFS)	Ultimate development without peak controls		Ultimate development with peak controls	
		Peak (CFS)	% of existing peak	Peak (CFS)	% of existing peak
1	136	186	136%	132	97%
4	594	901	152%	726	122%
8	419	690	165%	665	159%

Table 10-2: Summary of Peak 10-Year Discharges, South Branch Rockaway Creek Stormwater Management Study

Point of analysis	Existing peak discharge (CFS)	Ultimate development without peak controls		Ultimate development with peak controls	
		Peak (CFS)	% of existing peak	Peak (CFS)	% of existing peak
1	472	558	118%	464	98%
4	2100	2660	127%	2350	112%
8	1770	2280	129%	2250	127%

Table 10-3: Summary of Peak 100-Year Discharges, South Branch Rockaway Creek Stormwater Management Study

Point of analysis	Existing peak discharge (CFS)	Ultimate development without peak controls		Ultimate development with peak controls	
		Peak (CFS)	% of existing peak	Peak (CFS)	% of existing peak
1	896	1020	114%	882	98%
4	4320	5330	123%	4750	110%
8	3840	4660	121%	4710	123%

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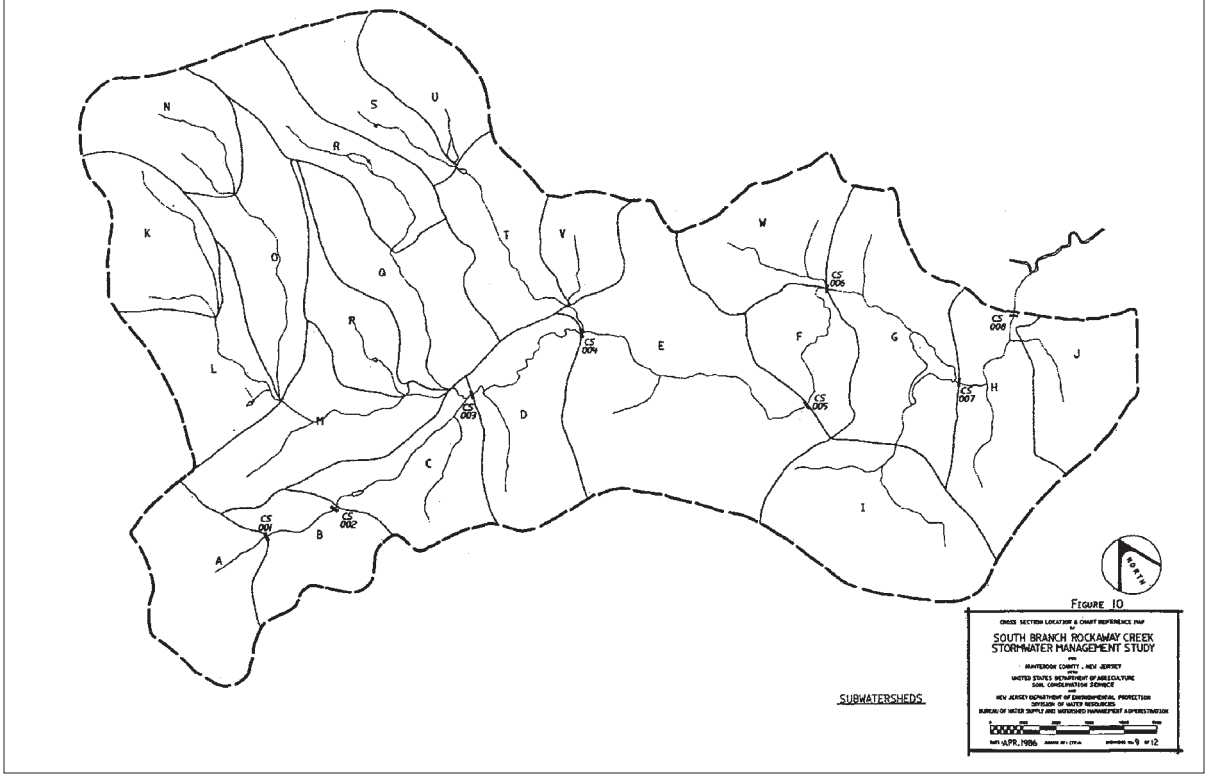
as shown in Table 10-1, the 2-year peak runoff rate at Point 1 following development in accordance with the peak rate controls described above would be 98 percent of the existing 2-year peak rate. Similar peak rates are achieved at Point 1 for the 10- and 100-year storms as shown in Tables 10-2 and 10-3, respectively.

However, further review of the tables indicates that the effectiveness of the peak rate requirement will decrease as the South Branch continues downstream through the watershed, receiving runoff from more development sites and their on-site detention basins. For example, Table 10-1 indicates that the developed 2-year peak runoff rate with peak rate controls at Point 4, which is located in the central portion of the watershed, will be 726 CFS or approximately 22 percent greater than the existing 2-year peak rate of 594 CFS. Continuing downstream, the developed 2-year peak runoff rate with peak rate controls at Point 8, which is located at the lower end of the watershed, will be 665 CFS or approximately 59 percent greater than the existing 2-year peak rate of 419 CFS.

Similar results can be seen in Tables 10-2 and 10-3 for the 10- and 100-year storms. As with the 2-year storm, the peak rate controls for both events are fully effective at Point 1 which is immediately downstream of a single development site and on-site detention basin. However, at lower locations in the watershed with multiple development site and on-site basins contributing flow, the developed peak rates begin to exceed the existing rates and approach those for developed conditions without peak rate controls. For example, as shown in Table 10-2, the developed 10-year peak runoff rate at Point 8 with peak rate controls will be 2250 CFS, which is not only 27 percent greater than the existing 2-year peak rate but only 30 CFS or 2 percent less than the estimated 10-year peak rate at this location without any peak rate controls. This loss of effectiveness is greatest for the 100-year storm at Point 8 where, as shown in Table 10-3, the peak developed runoff rate with peak rate controls of 4710 CFS will not only exceed the existing peak rate of 3840 CFS but also the developed peak rate without controls of 4660 CFS. In other words, not only have the peak rate controls failed to maintain existing peak runoff rates throughout the watershed following ultimate development, they have actually caused developed peak rates to exceed those that would have occurred if no controls had been imposed.

Figure 10-1: South Branch Rockaway Creek Watershed Points of Analysis



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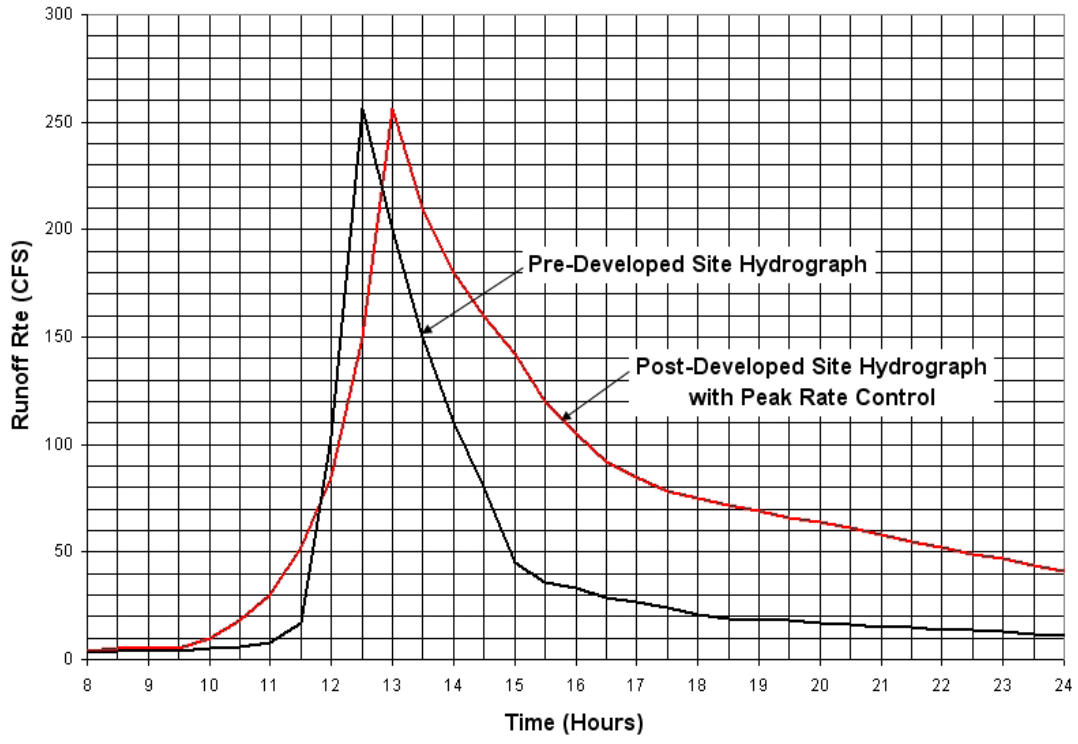
From the above, it can be seen that selecting a runoff quantity control that simply requires peak developed site runoff rates not to exceed those under existing or pre-developed conditions may prove ineffective. This ineffectiveness may even reach levels where the peak runoff rates produced by the controls, which were intended to prevent the adverse runoff quantity impacts of land development, actually exceed those that would have occurred if the controls had not been imposed. As a result, instead of preventing the adverse runoff quantity impacts of land development, the peak rate controls actually made them worse.

Based on an analysis of the South Branch Rockaway Creek study and the development of similar studies, several reasons can be found for these unfortunate results. They include alterations in the timing of runoff from land development sites caused by both the site's more efficient drainage systems and its on-site detention facility that achieves the required peak rate reductions. An additional and perhaps more significant reason for the ineffectiveness of the peak runoff rate controls is a failure to recognize and address the runoff volume increases that are also typically caused by land development. A simplified explanation of this complicated effect is illustrated in Figure 10-2. The figure depicts the runoff hydrograph from a development site under both pre-developed and developed conditions. The developed condition hydrograph is based on reducing the peak rate of runoff created by the development to a rate equal to the pre-developed peak. This is the same peak rate control used in the South Branch Rockaway Creek Stormwater Management Study discussed above and has been achieved by temporarily storing and slowly releasing the runoff hydrograph from the developed site similar to the South Branch study.

As can be seen in Figure 10-2, the pre- and post-developed peak runoff rates from the development site are indeed equal. However, further examination of the hydrograph shows several key dissimilarities. First, the two peak runoff rates occur at different times, with the pre-developed hydrograph peaking at Hour 12.5, approximately 0.5 hours before the post-developed one. This is due, at least in part, to the timing effects of the site's new drainage system and on-site detention basin. Second, due in part to this peak time difference, there is a period of approximately 0.9 hours (between approximately Hours 11.9 and 12.8) when the post-developed runoff rates are less than those for

Figure 10-2: Comparison of Pre- and Post-Developed Site Hydrographs with Peak Rate Control



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pre-developed conditions. However, starting at Hour 12.8 and continuing beyond the end of the x-axis at Hour 24.0, the post-developed condition runoff rates exceed the pre-developed ones by amounts that range from approximately 25 percent to over 200 percent. From the detailed discussion in Chapter 2 regarding the quantitative impacts of urbanization, it can be seen that these increased runoff rates are the result of the increased runoff volume caused by the site development. This increased runoff volume (represented by the area beneath the hydrograph plot) requires the non-peak post-developed runoff rates to generally exceed those for pre-developed conditions.

In addition, these higher non-peak runoff rates are the primary reason why the developed peak rates with peak rate controls at Points 4 and 8 in the South Branch Rockaway Creek Stormwater Management Study exceeded those for existing or pre-developed conditions. Looking again at Figure 10-2 and assuming that it represents the runoff at Point 1, the following can be seen: if the peak runoff rates downstream at Points 4 and 8 were produced, in part, by the runoff at Hour 12.8 or later at Point 1, then the post-developed peak rates at these locations would exceed the pre-developed peak. That is because, as described above, the post-developed flows at Point 1 starting at Hour 12.8 will be greater than the pre-developed rates, even though the peak rate controls produced the same peak rate at Point 1. For example, if the pre-developed peak runoff rate at Point 4 is produced, in part, by the pre-developed rate at Point 1 at Hour 14, then the post-developed rate at Point 4 can be expected to increase (despite the same peak rate at Point 1) because, as shown on Figure 10-2, the post-developed rate at Point 1 will be approximately 70 percent greater than the pre-developed one.

The above findings further highlight the value of maintaining both existing runoff peaks and runoff volumes following land development or redevelopment. However, recognizing how difficult it may be to achieve the site infiltration rates required to do this, how else may the problem of peak runoff rate increases downstream of development sites be addressed? Fortunately, additional watershed-level studies similar to the South Branch Rockaway Creek Stormwater Management Study offer some answers. These answers are illustrated below in a discussion of two such studies performed in New Jersey during the same time period as the South Branch study.

The two studies in question were performed to both confirm the peak runoff rate increase problem highlighted by the South Branch study and to develop answers to it. The studies were based in the Middle Brook watershed in Somerset County and the Devils Brook watershed in neighboring Middlesex County. Details of both studies are presented in the reference section of this chapter. Both watersheds are located in the central portion of New Jersey. The 16 square mile Middle Brook watershed is characterized by forest cover and steep ground slopes formed by the Watchung Mountains, while the 22 square mile Devils Brook watershed has significantly flatter ground slopes and a combination of forest cover along with existing residential and agricultural land uses.

In the Middle Brook Watershed study, the pre-developed land use was assumed to be entirely forest, while the Devils Brook Watershed study was based upon existing development levels at the time of the study. As a result of these factors, the two studies taken together are felt to be generally representative of the range of potential topographic, geologic, and land development conditions that may be encountered in an urban runoff management program. Finally, it should be noted that, due to generally fair to poor soil permeability in both watersheds and, in the case of the Middle Brook, shallow depth to bedrock due to the mountainous terrain, maintaining pre-developed runoff volumes was not considered feasible. This was particularly the case for the large runoff increases created during the 10- and 100-year storms whose control was vital to preventing existing erosion and flooding problems in both watersheds from worsening with future development.

Included in each study's scope was the investigation of an idea developed through the analysis of pre- and post-developed runoff hydrographs similar to those in Figure 10-2. The idea was this: Could the downstream runoff increases described above be avoided by reducing the post-developed peak runoff rate from a land development site to less than the existing rates? While such a control would not decrease the post-developed runoff volume, could a reduction in post-developed peak runoff to rates less than pre-developed conditions cause sufficient flattening of the post-developed hydrograph to maintain pre-developed peak rate not only at but downstream of land developments? The results of these two studies are summarized below.

First, both studies confirmed the problem of increased post-developed peak runoff rates highlighted by the South Branch Rockaway Creek Stormwater Management Study. For example, the Devils Brook watershed study demonstrated an increase in down-

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stream peak runoff rates despite a peak rate control that maintained pre-developed peaks at each development site in the watershed. These results are illustrated in Figures 10-3 through 10-5. They depict for the 2-, 10-, and 100-year storms, respectively, the post-developed peak rates with the peak rate control described above at various points of analysis in the watershed expressed as a percentage of the pre-developed peaks at those locations. The points of analysis used in the study are numbered consecutively and increase in value in a downstream direction. As can be seen in Figure 10-3, the 2-year peak post-developed rates generally increase

Figure 10-3: Comparison of 2-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Devils Brook Watershed

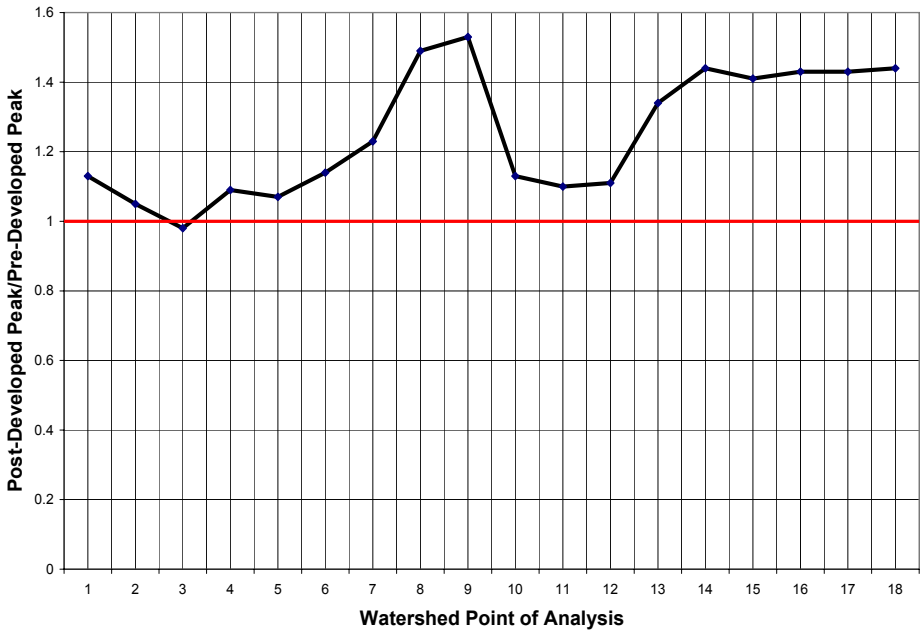
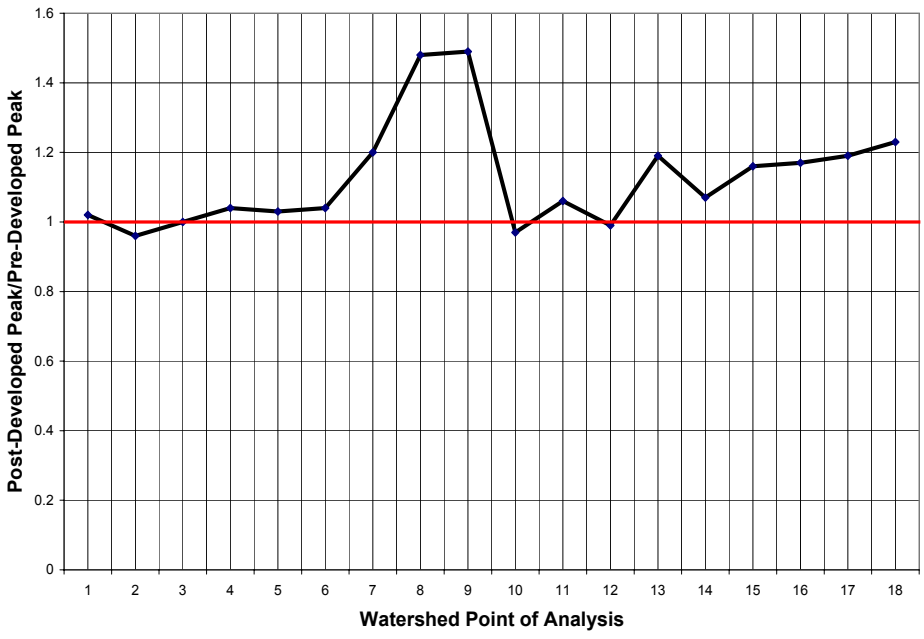


Figure 10-4: Comparison of 10-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Devils Brook Watershed



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in a downstream direction from the upper to lower portions of the watershed (i.e., the displayed values exceed 1.0) despite the peak post-developed runoff from each watershed subarea (again assumed to represent a future development site) being equal to the pre-developed rate. At Point of Analysis 18 at the mouth of the watershed, the post-developed peak runoff rate is approximately 42 percent greater than the pre-developed rate. Similar results are shown for the 10- and 100-year storms in Figures 10-4 and 10-5, with post-developed peak rates ranging as high as 20 percent to 45 percent greater than pre-developed. It should be noted that qualitatively similar results were also encountered in the Middle Brook Watershed study.

Having confirmed the peak rate increase problem caused by setting post-developed peak runoff rates equal to pre-developed rates, both studies then investigated the effectiveness of reducing post-developed peak runoff rates from land development sites to rates less than, rather than equal to, predeveloped peak rates. As noted above, existing erosion and flooding problems in both watersheds made effective runoff quantity control a vital requirement in both watersheds. Because of this need and the inability to control runoff volume increases through infiltration, it was necessary to develop effective peak rate controls that avoided the peak rate increase problems highlighted by the South Branch Rockaway Creek study. After several iterations, the peak runoff rate control criteria presented in Table 10-4 were selected for each development site in the watersheds. As shown in the table, the Middle Brook Watershed study investigated the downstream effectiveness of reducing the post-developed peak runoff rates from development sites for the 2-, 10-, and 100-year storms to 50 percent, 65 percent, and 80 percent, respectively, of the pre-developed peak site rates. In the Devils Brook Watershed study, the percentages of the pre-developed 2-, 10-, and 100-year peak runoff rates were 40 percent, 65 percent, and 65 percent, respectively.

The results of applying the Devils Brook peak rate reduction factors shown in Table 10-4 are illustrated in Figures 10-6 to 10-8. As shown in Figure 10-6,

Figure 10-5: Comparison of 100-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Devils Brook Watershed

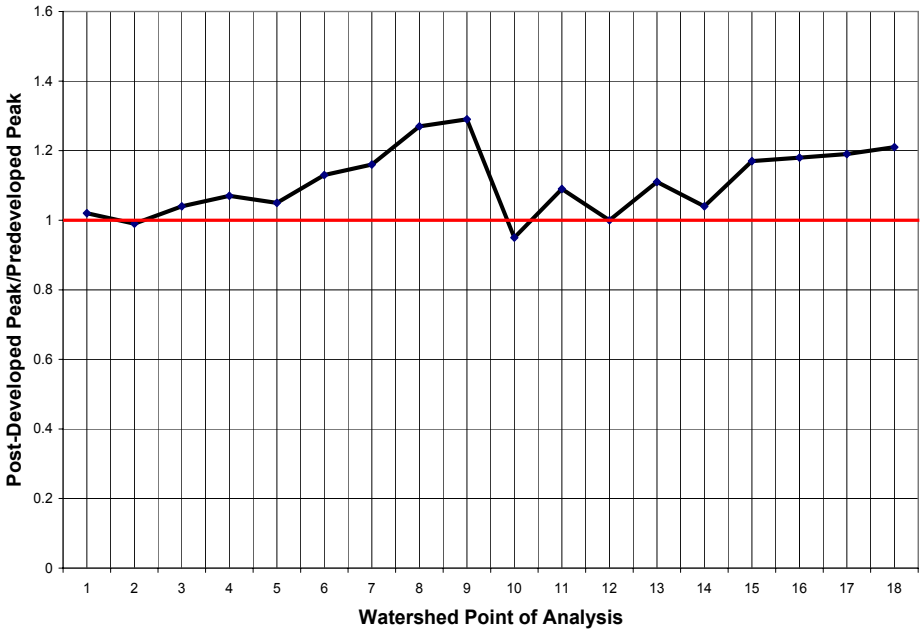

Table 10-4: Final Peak Runoff Rate Reduction Factors, Middle Brook and Devils Brook Watershed Studies

Watershed	Required Post-Developed Peak Site Outflow Rates Expressed as Percentage of Pre-Developed Peak Rate		
	2-Year Storm	10-Year Storm	100-Year Storm
Middle Brook	50%	65%	80%
Devils Brook	40%	65%	65%

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requiring future development sites in the Devils Brook watershed to reduce their post-developed 2-year peak runoff rates to 40 percent of their pre-developed rates achieved the desired goal, namely, to not allow ultimate watershed development to increase pre-developed 2-year runoff rates anywhere in the watershed. Unlike the 2-year storm results shown in Figure 10-3, where post-developed peak site rates were allowed to equal pre-developed ones, Figure 10-6 shows that, by reducing peak site rates to 40 percent of pre-developed peaks, the post-developed 2-year peak runoff rates throughout Devils Brook remain at or below pre-developed levels.

Figure 10-6: Comparison of 2-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Devils Brook Watershed

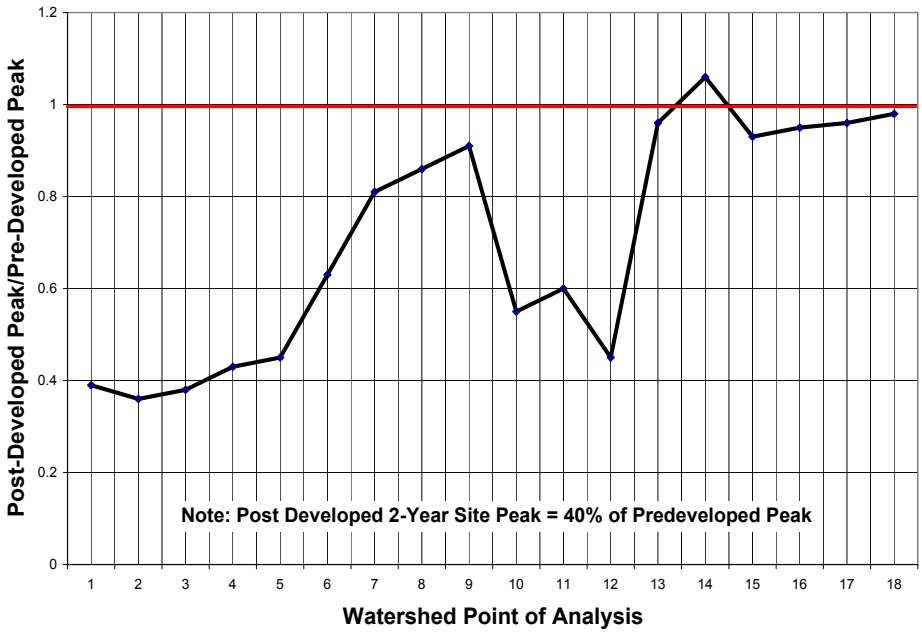
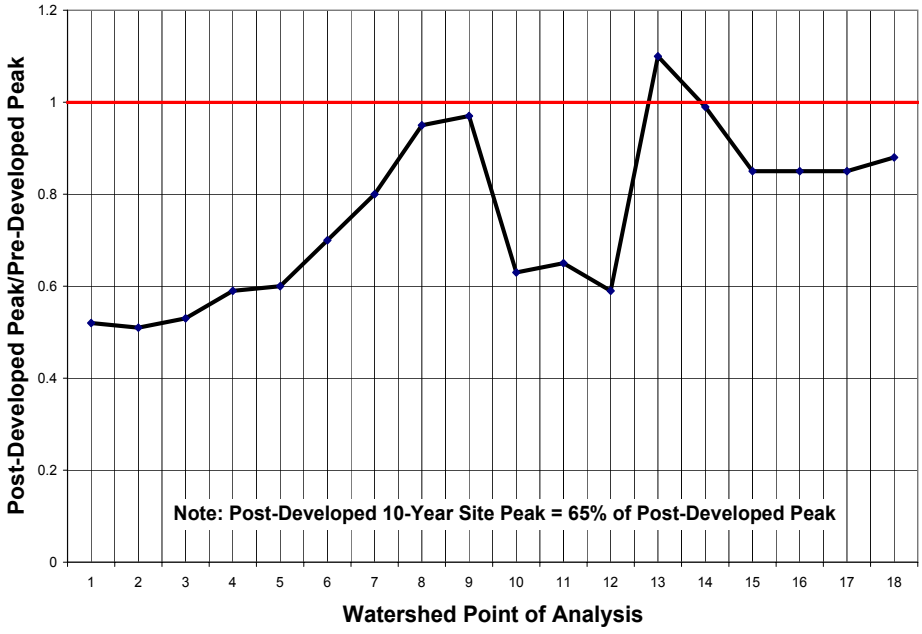


Figure 10-7: Comparison of 10-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Devils Brook Watershed



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A single exception to these results occurs at Point of Analysis 14 where the post-developed peak 2-year rate exceeds the pre-developed one by approximately 5 percent. Similar results are shown for the 10-year rates in Figure 10-7 with, again, a small exceedance at Point of Analysis 13. For the 100-year storm, Figure 10-8 shows that the post-developed 100-year peak runoff rates remain without exception at or below pre-developed levels throughout Devils Brook. This contrasts with the results shown in Figure 10-5, where allowing post-developed peak site runoff rates to equal pre-developed conditions resulted in post-developed peak increases

Figure 10-8: Comparison of 100-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Devils Brook Watershed

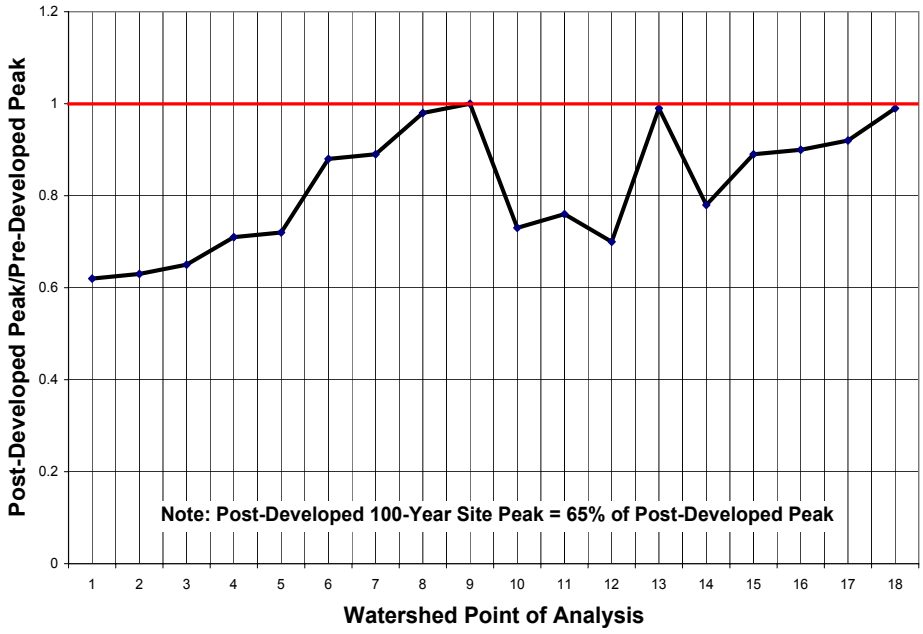
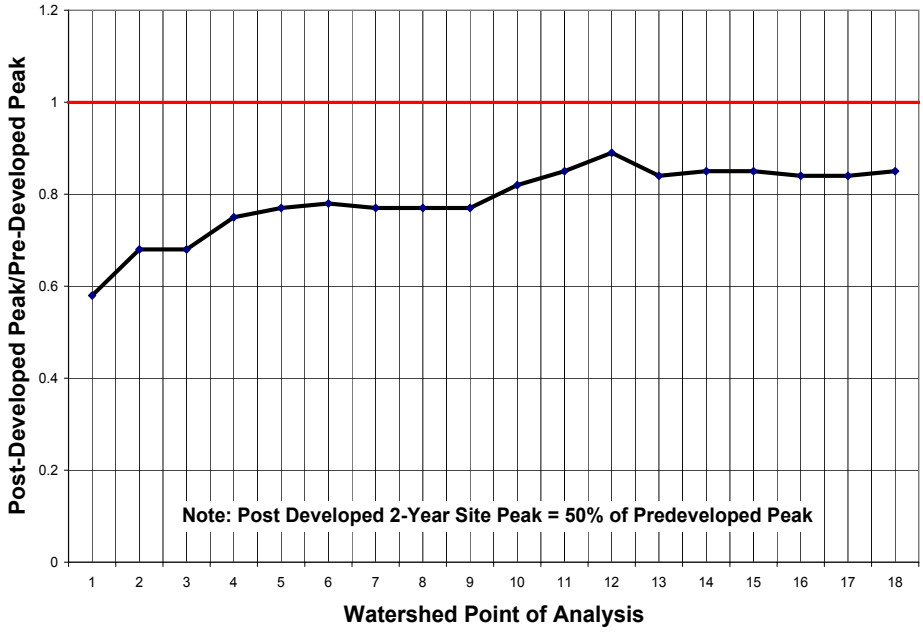


Figure 10-9: Comparison of 2-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Middle Brook Watershed



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throughout most of the waterway, ranging as high as 30 percent at Point of Analysis 9.

The results of applying the Middle Brook peak rate reduction factors shown in Table 10-4 are illustrated in Figures 10-9 to 10-11. As shown in Figure 10-9, requiring future development sites in the Middle Brook watershed to reduce their post-developed 2-year peak runoff rates to 50 percent of their pre-developed rates also achieved the goal of not increasing pre-developed 2-year peak runoff rates anywhere in the watershed following ultimate development. Figure 10-6 shows that the post-developed 2-year peak runoff rates throughout

Figure 10-10: Comparison of 10-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Middle Brook Watershed

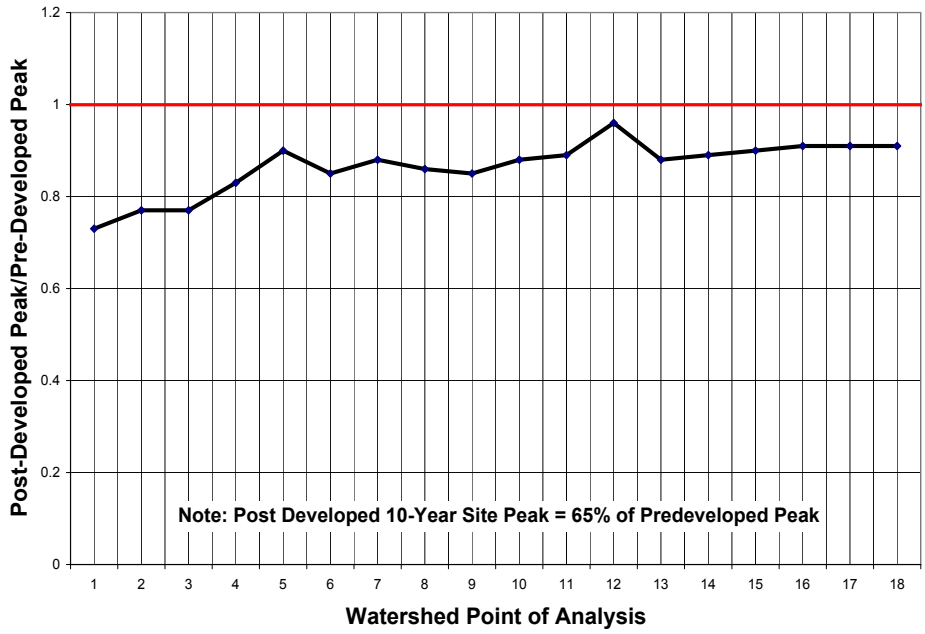
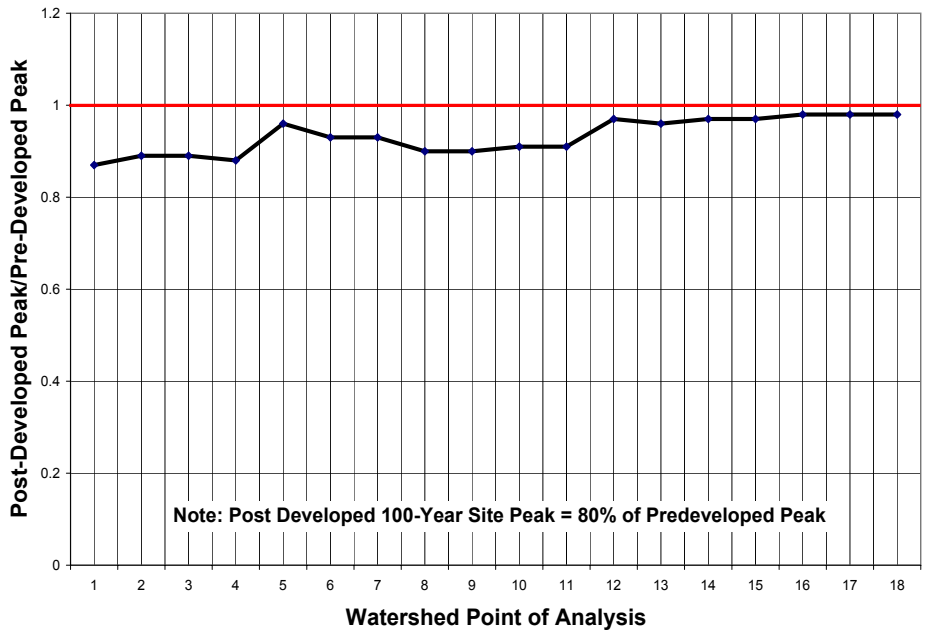


Figure 10-11: Comparison of 100-Year Pre- and Post-Developed Peak Rates with Peak Rate Controls, Middle Brook Watershed



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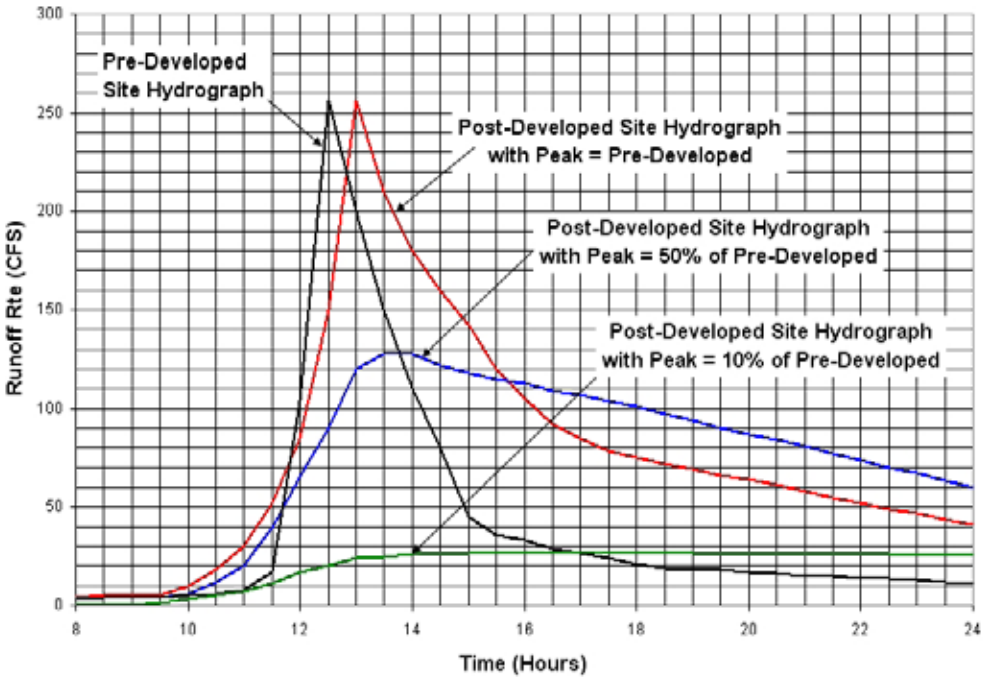
Middle Brook remain at or below pre-developed levels. Similar results are shown for the 10- and 100-year storms in Figures 10-10 and 10-11, where post-developed 10- and 100-year peak site runoff rates are required to be 65 percent and 80 percent, respectively, of the pre-developed peak site rates.

A simplified explanation of the reasons why the peak rate reduction factors used in the Middle Brook and Devils Brook watershed studies were effective in preventing downstream peak runoff rate increases is presented in Figure 10-12. The figure once again depicts the pre- and post-developed site hydrographs shown in Figure 10-2, with the peak of the post-developed hydrograph equal to the pre-developed peak. As noted in the discussion of Figure 10-2, the post-developed runoff rates for this level of peak rate control are less than pre-developed for only approximately 0.9 hours or from Hour 11.9 to 12.8. However, also shown in Figure 10-12 is a post-developed site hydrograph with a peak runoff rate equal to 50 percent of the pre-developed rate as analyzed in the Middle Brook study. An examination of this hydrograph shows that, under this level of peak rate control, post-developed runoff rates are less than pre-developed for approximately 2 hours (from approximately Hour 11.8 to 13.8), or more than twice as long as the post-developed site hydrograph with a peak equal to pre-developed. This increased time period offers greater opportunity for this and other post-developed site hydrographs with similar levels of control to combine downstream in such a way as to produce a total downstream peak that is no greater than the pre-developed peak at that location.

From the above, it becomes apparent that, at least for the study watersheds described above, simply requiring land development and redevelopment sites to match their pre-developed peak runoff rates will not prevent increases in peak downstream runoff rates. As such, the development-induced runoff quantity impacts of flooding, erosion, and habitat damage described in detail in Chapter 2 will not be avoided even with the imposition of runoff quantity requirements in the watersheds' runoff management programs. Based upon the results of the studies described above, the State of New Jersey has adopted statewide 2-, 10-, and 100-year peak rate reduction factors of 50 percent, 75 percent, and 80 percent, respectively, for all land development and redevelopment projects that disturb at least an acre of ground surface. These requirements are contained in the state's Stormwater Management Rules (N.J.A.C 7:8) promulgated by the New Jersey Department of Environmental Protection (NJDEP).

Figure 10-12: Comparison of Pre- and Post-Developed Site Hydrographs with Various Peak Rate Controls



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At this point, it is important to note more recent research into the effectiveness of peak reduction factors to control runoff volume increases. From a flood prevention standpoint, limiting downstream post-developed peak discharge rates on a waterway to levels no greater than pre-developed (as achieved through the use of development site peak rate reduction factors described above) should be effective in preventing increases in existing waterway flood depths and limits. However, research conducted since the Middle Brook and Devils Brook studies, including McRae in 1997 and Bledsoe in 2002, indicates that limiting downstream waterway discharges to pre-developed levels may not be sufficient to prevent development-induced erosion damage along the waterway. This is due, once again, to the increase in total site runoff volume caused by the development (and highlights once again the desirability of preventing runoff volume increases where possible through site design and post-development runoff infiltration).

As shown in Figure 10-12, the two post-development site hydrographs with peaks equal to 100 percent and 50 percent of predeveloped will both have runoff rates that exceed pre-developed rates for an extended period of time. As noted above, this is due to the greater runoff volume under post-developed conditions, represented by the area under the hydrographs, that causes a longer overall duration of runoff than under pre-developed conditions. This longer runoff duration means a similarly longer period when the runoff will create shear and other forces along the downstream waterway's bed and banks. If these forces are greater at times than certain critical levels, which are based upon various waterway properties, erosion will occur even if the runoff rate is less than pre-developed. In fact, it can be seen that, as the peak post-developed site runoff rate becomes a smaller percentage of the pre-developed rate, the duration of post-developed runoff can be expected to increase. If this increased time includes longer periods of excessive channel forces, reducing post-developed site peak runoff rates may actually cause greater erosion than higher post-developed peaks.

In response to this research, some jurisdictions, including the State of Maryland, have adopted significantly lower peak rate reduction factors for erosion control than the 2-year 50 percent reduction factor required by New Jersey. As described in Chapter 2 of the October 2000 Maryland Stormwater Design Manual, the rationale for this greatly increased control of frequent storm events typically associated with waterway erosion is that "runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels." Or, as one might add, at least not exceeded for durations longer than under pre-developed conditions.

This rationale is illustrated with the final post-developed site hydrograph shown in Figure 10-12. With a peak runoff rate equal to only 10 percent of the pre-developed peak, it can be seen that there is not only a considerably longer period when post-developed runoff rates are less than pre-developed (between approximately Hours 10 and 17 in Figure 10-12) but that, even beyond Hour 17, the post-developed runoff rates only exceed the pre-developed rates by a small percentage and have absolute values considerably less than the pre-developed peak.

In conclusion, it is important to note that all of the studies and research discussed above are highly complex and that their specific findings pertain to particular watersheds and water bodies. Nevertheless, while conducting similar studies of the watersheds and water bodies under the jurisdiction of a new urban runoff management program would be the most accurate way of determining appropriate runoff volume controls for that program, the results discussed above can be (and have been) used effectively to formulate general quantity requirements.

In summary, the above subsection on runoff quantity control design storms presented the following ideas and information:

- Runoff quantity controls are necessary in order to prevent the adverse flooding, erosion, and habitat impacts that can be caused by land development and redevelopment.
- In order to prevent this wide range of impacts, the maximum design storm for runoff quantity control is typically set at the 100-year storm frequency.
- The most effective runoff quantity controls are those that limit both post-developed site runoff volumes and peak rates to levels no greater than pre-developed site conditions.
- Limiting post-developed runoff volumes to pre-developed amounts may be difficult or impossible to achieve at certain development sites due to insufficient soil permeability, soil thickness, and other site factors.
- Where post-developed runoff volumes cannot be maintained at pre-developed amounts, requiring

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post-developed peak site runoff rates to be less than pre-developed rates has been shown to be more effective than allowing post-developed peaks to equal pre-developed peaks.

- The required percent reduction below pre-developed peak rates can range from approximately 10 percent to 50 percent for frequent storm events such as the 1- or 2-year storm to 60 percent to 80 percent of the 100-year storm.
- Exact determination of required peak rate reduction factors requires detailed watershed and water body data and analyses.

Runoff Quality Control

As noted at the start of this section on design events, it is necessary for an effective urban runoff management program to address both the quantitative and qualitative impacts of urbanization. That is because the land development and redevelopment activities associated with urbanization can have adverse safety and environmental impacts due to changes in both stormwater runoff quantity and quality. And similar to runoff quantity controls, the establishment of effective runoff quality controls includes the determination of a maximum rainfall or runoff amount that such controls will apply.

In seeking information on appropriate runoff quality design event limits, one encounters problems similar to those described above for runoff quantity design events. A review of the EPA's Stormwater Phase II Final Rule once again does not yield any specific requirements (for reasons explained in the final Rule text). Therefore, a review of the requirements of established urban runoff management programs is the next logical avenue of pursuit. However, a review of these programs shows that the concept of a runoff quality design event has been the source of some confusion and misunderstanding, which has diminished the success of certain programs. As a result, this section will attempt to address these misunderstandings and promote the selection of effective and understandable design event levels.

As with runoff quantity, a runoff quality design event represents the maximum event depth, measured either by rainfall or runoff, that must be met by a runoff management program's stormwater quality requirements. As such, it represents an upper limit on the performance of structural facilities designed and constructed to prevent the adverse runoff quality impacts of land development. This immediately raises three questions regarding the maximum runoff quality design event:

1. Should the maximum design event be based upon rainfall or runoff?
2. What should the maximum design event depth be?
3. Is a total event depth sufficient, or is a temporal distribution also required?

Each of these questions is addressed below.

Rainfall or Runoff

In addressing the first question, some additional and intriguing questions are raised. First, since the goal of the urban runoff management program is to prevent adverse impacts to stormwater runoff, shouldn't the runoff quality design event be based upon the runoff from a development, rather than the rainfall that produces it? At first look, an affirmative answer to this question would appear logical. And in fact, many existing urban runoff management programs have chosen to do that. In simplified form, these programs require that a certain level of quality treatment be provided to a fixed amount of runoff. And while the level of treatment may vary, depending on the type of development or pollutant and/or the proximity and value of a downstream water body or other resource, the amount of runoff to be treated, typically expressed as a depth over the development site's area, usually remains the same.

For example, many municipal, county, and state runoff management programs currently require treatment of the first inch of runoff, averaged over the total site area, from a proposed development site. This requirement is imposed regardless of the type of development. In some programs, this is done to simplify the computations needed to meet the requirement, while in others, it is considered the best or at least a suitable maximum runoff quality design event.

However, the use of runoff in general and a constant or fixed amount in particular as the runoff quality design event can cause significant disparities in the levels of water quality control provided by different types of developments. In addition, these disparities unfortunately result in certain development types normally associated with greater pollutant loadings than others being allowed to provide lower overall levels of quality

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treatment. The example presented below illustrates this problem.

For example, let's apply the 1 inch runoff requirement to both a single family residential and a commercial development site, each one acre in area. The development characteristics of each site are summarized in Table 10-5. Both sites are assumed to have soils belonging to Hydrologic Group C as defined by the Natural Resource Conservation Service's (NRCS) Technical Release 55 – Urban Hydrology for Small Watersheds (TR-55), which has become something of a standard for computing runoff volumes and rates from land development sites. As shown in Table 10-5, 20 percent of the proposed residential site and 85 percent of the proposed commercial site will be covered with impervious surfaces. The remainder of both sites will be turf grass that will be assumed to be in good hydrologic condition as defined in TR-55. According to the parameters defined by the TR-55 methodology, the impervious surfaces at both sites will have a Runoff Curve Number (CN), which is a measure of a surface's runoff potential, of 98, while the turf grass surfaces will have a CN of 74. (See Table 2-2a in TR-55 for more details of these various CNs.) It should be noted that the proposed impervious coverages for each development type in Table 10-5 are identical to those specified for these land uses in Table 2-2a. As such, they can be considered typical of these two types of development.

Utilizing the runoff volume computation methodology contained in TR-55, which is based upon the NRCS Runoff Equation, for an average runoff depth of 1 inch from both the proposed residential and commercial sites, we can compute the rainfall depths that would be required at each site. These results are summarized in Table 10-6. As shown in the table, it will be necessary for approximately 2.6 inches of rain to fall on the proposed residential site to produce the required 1 inch of runoff that must receive runoff quality treatment. However, at the proposed commercial site, only 1.4 inches of rain will be necessary to produce the same 1 inch runoff treatment volume. When we remember from Chapter 2 that different rainfall depths of equal duration, which we must assume are occurring at our two proposed development sites, are associated with different probabilities or recurrence intervals, we can see that this disparity in required rainfall depth means that the two sites are not provided equal levels of runoff quality treatment.

This disparity can be illustrated by analyzing the recurrence interval of each required rainfall depth. To do so, we will need to locate our proposed sites somewhere in the country, since the recurrence interval of a certain rainfall will depend upon its geographic location. We will also need to assume a duration of the rainfall that produced the 1-inch design event volume (although it is interesting to note that many programs do not specify a duration, an omission that prevents any determination of design event probability). Assuming that both sites are located in central New Jersey and assuming that both rainfalls have a 24-hour duration, we can quickly perform a simplified statistical analysis of 24-hour rainfall records for this part of the state in order to produce estimates of each rainfall's recurrence intervals. The results of our simplified analysis, based upon rainfall data developed by the Hydrometeorological Design Studies Center of the National Weather Service, are shown in Table 10-6 and illustrated in Figure 10-13.

From the above results, it can be seen that by requiring both the proposed residential and commercial sites to treat up to an equal runoff depth of 1 inch, the residential site will provide the required treatment for all storms up to a 2.6 inch rainfall, which for a 24-hour storm duration will have a recurrence interval of approximately 0.8 years or 10 months. However, the same

Table 10-5: Residential and Commercial Site Characteristics, Runoff Quality Design Event Example

Development Type	Area (Acres)	% Impervious Cover	% Pervious Cover	Pervious Cover Type	Impervious Cover CN	Pervious Cover CN
Residential	1.0	20%	80%	Grass	98	74
Commercial	1.0	85%	15%	Grass	98	74

Table 10-6: Required Rainfall Depths and Recurrence Intervals, Runoff Quality Design Event Example

Development Type	Average Site Runoff (Inches)	Required Site Rainfall (Inches)	Rainfall Recurrence Interval (Months)
Residential	1.0	2.6	10
Commercial	1.0	1.4	2

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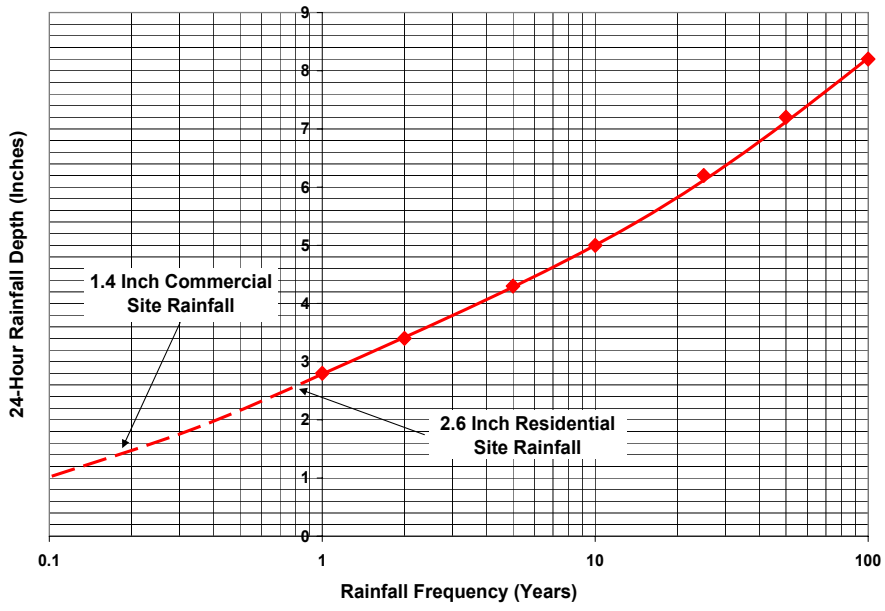
size commercial site will only be required to treat the runoff from all storms up to a 1.4 inch rainfall, which will have a recurrence interval of approximately 0.2 years or 2 months. Stated another way, the proposed commercial site will only be required to provide one fifth the level of runoff quality protection of the residential site, measured on a recurrence interval or probability basis. And when the higher expected pollutant loadings from the commercial site are taken into consideration, this disparity in treatment or protection levels becomes even more detrimental to the goals of the urban runoff management program.

The above illustrates that rainfall and not runoff should be used to specify the maximum water quality design storm. That is because, unlike runoff, a rainfall depth is independent of development type, surface cover, and other site features. And as a series of random events with sufficient records of past occurrences, rainfall can be statistically analyzed to produce depth-probability or depth-recurrence interval relationships. These relationships can be used, in turn, to select the correct rainfall depth for a desired or required level of protection that can be applied uniformly to all developments, regardless of type. However, as shown in the above example, using a fixed runoff depth instead of rainfall allows the probability or recurrence interval of the design event to vary with the development site's rainfall-runoff characteristics. And since each type of development will generally have different characteristics, the resultant runoff depth and, more importantly, level of water quality protection will vary with the development type, and in a direction that allows those levels to decrease with increasing imperviousness.

One additional point should be noted. Many programs that have adopted a runoff depth as the basis of their quality design storm have done so on the assumption that only the impervious surfaces at a proposed development site will produce runoff under such storm conditions. As a result, there will be a relatively constant relationship between rainfall and runoff that will avoid the variable recurrence interval or level of protection problem discussed above. Other programs do use a rainfall depth, but then only compute the resultant runoff from the site's impervious surfaces. However, a review of the runoff computations for both the residential and commercial sites in the above example shows that this will only be true at sites with highly permeable soils with large initial abstractions or surface storage volumes. In the above example, the pervious portions of the residential site that were assumed to have grass cover were the source of more than half the total average 1-inch site runoff depth that required runoff quality treatment. Even the grass areas at the largely impervious commercial site in the example contributed approximately to the total 1 inch of runoff from the site. Therefore, those programs that

Figure 10-13: Estimated Design Event Rainfall Depths and Recurrence Intervals



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do not include pervious surface runoff must consider whether such runoff can be safely ignored in the design of structural runoff quality treatment facilities.

Maximum Event Depth

Regarding the question of maximum design storm depth, one must consider the overall level of runoff quality protection that is being sought by the urban runoff management program. Since nonpoint source pollutant loadings and associated runoff quality impacts are discussed or otherwise addressed on an annual basis in many research studies and most stormwater regulations, including the EPA's Stormwater Phase II Final Rule, most existing urban runoff management programs use the same one-year period as the time basis for their runoff quality requirements. For example, many programs require specified levels of pollutant removal or treatment measured on an average annual basis. Therefore, if the time basis of the runoff quality requirement is one year, the largest likely storm that may occur in that one-year period would be the logical choice for a maximum design storm. As a result, many runoff management programs either use or formerly used a maximum annual rainfall as the maximum runoff quality design storm depth.

However, it should be noted that for most, if not all, structural stormwater facilities, some degree of runoff quality treatment is provided even for rain events that exceed the maximum design storm. This will occur primarily during those storm periods when the actual runoff volume and/or rate is less than the maximum design level, although some degree of treatment (albeit at a reduced rate) may occur during periods of overflow when the actual volume and/or rate exceeds the maximum design level. This is true for both online and offline structural facilities. As a result, the use of a maximum design storm depth less than the maximum annual storm appears justifiable.

Presently, the use of a rainfall depth that, in combination with all smaller storms, will on average produce 90 percent of the average annual rainfall (or impervious surface runoff) at a land development site appears to be a standard technique for selecting a maximum runoff quality control design storm depth in many current urban runoff management programs. Other programs use a variation of this technique by specifying some percentage of the 1- or 2-year rainfall as the maximum design storm depth, again based upon the finding that the resultant rainfall will represent approximately 80 to 90 percent of annual average rainfall or impervious surface runoff at the development site. Determination of the required depth typically requires a suitably long rainfall record with adequate areal coverage that can then be statistically analyzed to determine average annual rainfall patterns and depths. Depending upon the variation in average annual rainfall throughout a program's jurisdiction, one or more design depths may need to be specified. Examples of various maximum runoff quality design storm depths in current state stormwater management programs are summarized in Table 10-7.

Design Storm Distribution

The decision of whether a maximum design storm depth alone is sufficient or whether a temporal distribution of that design depth is also needed will depend in large measure on the types of structural facilities that might be used to meet the urban runoff management programs' runoff quality control requirements. If all of the potential structural facilities will provide the required level of runoff quality control primarily through some form of storage and slow, regulated release that results in the peak outflow rate being a small percentage of the peak inflow rate, then a maximum design storm depth may be sufficient. This is due to the fact that in such facilities, the total volume of inflow is the domi-

Table 10-7: Maximum Runoff Quality Design Storm Depths Examples

State Program	Maximum Quality Storm Depth
Connecticut	1.00 Inches
New Jersey	1.25 Inches in 2 Hours
New York	0.8 to 1.3 Inches Depending Upon Location
Maryland	0.9 to 1.0 Inches Depending Upon Location
Washington	72% of 2-Year, 24-Hour Storm

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nant design factor, and the various rates at which the inflow may occur have little influence on overall facility size or details. Typical examples of such volume-based structural facilities include infiltration basins, retention basins (also known as wet ponds), wetlands, and even extended detention basins where the peak outflow is a small percentage of peak inflow.

However, if the potential structural facility types include those that do not rely to any great extent on runoff storage but instead treat runoff at flow rates essentially unchanged from their inflow rates, then it will be necessary to specify both a maximum design storm depth and the manner in which that depth will occur over time. This is because the dominant design factor for such facilities is the maximum inflow rate, not the total inflow volume, and it will therefore be necessary to determine that maximum runoff rate. This will require knowledge of the total duration of the design storm and the manner in which the rain fell during that time period. A design storm distribution will also be required for volume-based facilities if the peak outflow rate is sensitive not only to total inflow volume but also to inflow rates. This can generally be assessed by comparing the peak inflow and resultant outflow rates. If the peak outflow rate is greater than approximately 10 percent of the peak inflow rate, then such inflow rate sensitivity probably exists, or at the least needs to be checked, and a design storm distribution will also be required. Typical examples of peak rate-based structural facilities include swales, filter strips, and hydro-mechanical devices including the growing number of manufactured runoff treatment devices.

Having determined the need for a design storm distribution to accompany a program's maximum design storm depth, the logical next question is: what type of distribution? And the answer can be found in the same discussion of recurrence interval or level of runoff quality protection that was presented in the section above on design storm depths. Presumably, a runoff management program's design storm depth, which, when converted to runoff over a drainage area, will determine the total runoff volume of the design storm, will be based upon some measure of probability or recurrence interval, such as a 1- or 2-year, 24-hour storm or a 90 percent rainfall depth. As such, this probability or recurrence interval will establish the level of runoff quality protection or control that will be provided by volume-based structural stormwater management facilities designed to treat the associated runoff volume. However, as noted above, there are certain types of structural facilities such as swales, filter strips, and especially hydro-dynamic devices that do not provide volume-based treatment and whose designs are not based upon a total runoff volume but upon a peak design storm runoff rate. To ensure that these peak rate-based facilities provide the same level of runoff quality control or treatment as volume-based ones, it will be necessary to use a design storm distribution that produces peak runoff rates that have the same probability or recurrence interval as the design storm's total rainfall depth.

To do so, this design storm distribution must have certain important characteristics. First, since it will be used to design stormwater management facilities for a range of development sites and Times of Concentration (see Chapter 2), the design storm distribution must be able to produce peak runoff rates with the same recurrence interval for all of them. As a result, the design storm distribution must consist of varying rainfall rates throughout its duration, with the maximum rainfall intensities for each time period up to the total design storm duration all having the same probability or recurrence interval; namely, the recurrence interval of the storm's total rainfall depth. For an urban runoff management program that utilizes a 24-hour design storm depth, an appropriate design storm distribution could be one of the dimensionless rainfall distributions developed by the Natural Resources Conservation Service (NRCS) for Technical Release 55 – Urban Hydrology for Small Watersheds (TR-55). Each of these distributions meets the maximum rainfall intensity criteria described above; namely, each contains a range of intensities and durations with the same probability or recurrence interval and, as such, can be used to produce the peak runoff rates for a range of Times of Concentrations.

However, it is important to emphasize at this point that the use of any of the NRCS design storm distributions in TR-55 requires the design storm depth to have been based upon 24-hour rainfall data and be assumed to fall over a 24-hour period. Using any of the TR-55 distributions to compute a peak runoff rate or entire hydrograph for a rainfall with a total duration other than 24 hours will result in incorrect runoff rates and inconsistent recurrence intervals between the total design storm runoff volume and peak runoff rate. As described above, this will lead to inconsistent levels of protection between volume-based and peak rate-based structural facilities. This also applies to the use of the NRCS design storm distributions for a design event runoff volume of unspecified duration.

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For these reasons, an urban runoff management program that uses a design storm duration other than 24 hours must also develop an appropriate design storm distribution. For example, New Jersey's Stormwater Management Rules specify the use of a 1.25-inch, 2-hour runoff quality design storm. Based upon a statistical analysis of New Jersey rainfall data, such a rainfall has a recurrence interval of approximately 0.8 years or 10 months. Therefore, to insure that peak rate-based runoff treatment facilities will provide the same level of protection as volume-based facilities, it was necessary to vary the intensity of the 1.25 inches of rain over the total 2-hour duration in such a way that the resultant peak runoff rate for any Time of Concentration up to 2 hours would have the same 10 month recurrence interval.

The resultant New Jersey stormwater quality design storm distribution is shown in Figure 10-14 and Table 10-8. Figure 10-14 depicts a nonlinear rainfall distribution with the maximum intensity (indicated by the slope of the line) occurring in the middle of the 2-hour storm duration. This general shape is similar to several other design storm distributions, including the various TR-55 design storms, with the centrally located maximum rainfall intensity and overall symmetric shape considered to have average runoff potential. In addition, a review of Table 10-8 shows how, for a range of rainfall periods up to the total 2-hour duration, the maximum rainfall intensities occurring in those periods have the same 10-month recurrence interval as the overall 1.25 inch, 2-hour design storm. These various intensities were determined from the same statistical analysis of New Jersey rainfall data used to determine the recurrence

Figure 10-14: New Jersey 1.25-Inch/2-Hour Stormwater Quality Design Storm Distribution

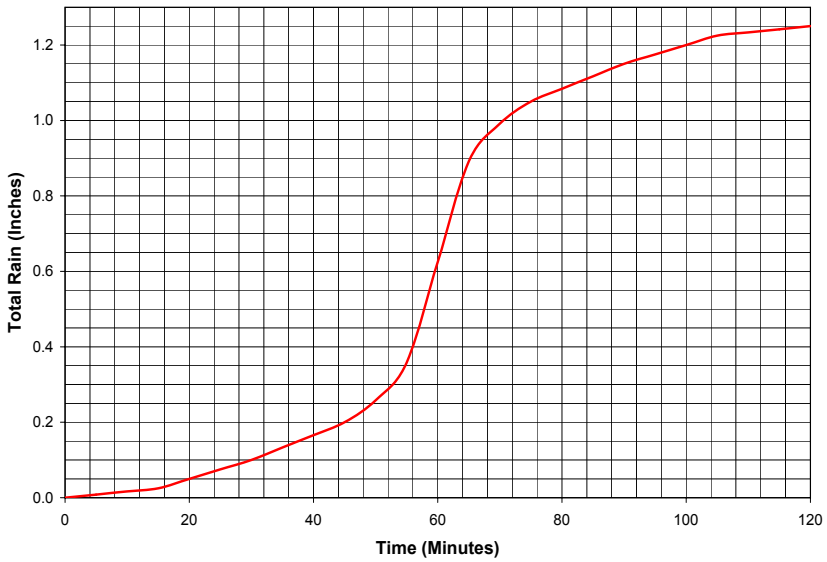

Table 10-8: New Jersey 1.25-Inch/2-Hour Stormwater Quality Design Storm, Maximum Rainfalls and Probabilities for Various Time Periods

Time Period (Minutes)	Maximum Rainfall (Inches)	Maximum Rainfall Intensity (Inches/Hour)	Average Recurrence Interval
10	0.53	3.2	10 Months
20	0.73	2.2	10 Months
30	0.85	1.7	10 Months
60	1.05	1.05	10 Months
90	1.20	0.80	10 Months
120	1.25	0.625	10 Months

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interval of the overall 1.25 inch, 2-hour design storm. As a result of these specific rainfall intensities and durations within the overall 2-hour duration, both volume- and peak rate-based structural stormwater management facilities design in accordance with this design storm will provide the same level of runoff quality protection and control.

In summary, the above subsection on runoff quality control design storms presented the following ideas and information:

- Runoff quality controls are necessary in order to prevent the adverse impacts on water quality, aquatic organisms, and habitat that can be caused by land development and redevelopment.
- In order to prevent these impacts, the maximum design event for runoff quality control is typically based upon a percentage of the maximum annual rainfall or runoff.
- The selection of a runoff quality design event depth should be based upon a standard rainfall depth and duration with an appropriate probability or average recurrence interval. This allows a consistent level of runoff quality treatment or control to be achieved for all land development and redevelopment sites.
- Use of a standard runoff depth instead of rainfall causes inconsistencies in the level of runoff quality treatment or control between different development types, with the sites with the greatest amount of impervious cover providing the lowest level of treatment.
- In order to achieve consistent levels of runoff quality treatment or control between volume-based structural facilities such as basins and wetlands and peak rate-based facilities such as swales and hydro-dynamic devices, it is necessary to also specify a temporal distribution of the design storm rainfall.
- This distribution must be capable of producing peak design storm runoff rates that are identical to the probability or average recurrence interval of the total design storm depth. As such, a nonlinear distribution based upon site- or area-specific rainfall intensity-duration-frequency data is required.

Long-Term Rainfall-Runoff Simulation

To complete our discussion of design events, it is important to revisit a topic discussed in detail in Chapter 2; namely, the use of continuous rainfall-runoff simulation based upon long-term rainfall records to determine suitable levels of runoff quantity and, in particular, quality control at a land development site. Depending upon the extent and detail of the available rainfall data and the suitability of the simulation techniques for the project in question, the use of such analytic tools and data can produce results that are superior to the single, maximum design approach described above. This is true for several reasons, most notably the increased accuracy or certainty of results achieved by analyzing the actual rainfall events that occurred at a land development site over an extended time period over the use of a single design storm that is presumed to represent that long-term rainfall. Other advantages include the ability of continuous simulation to include the variability of rainfall depths and occurrences and the interaction between sequential events into the analysis. Since the required rainfall record length should be several multiples of the desired design storm level, continuous simulation is currently more appropriate for runoff quality than quantity control due to the typically lower treatment or control levels required for quality control. Nevertheless, depending upon the rainfall record length and desired level of protection, runoff quantity control analysis and design based upon long-term simulation can also provide superior results to a single design storm approach.

As discussed in Chapter 2, factors that may complicate or even prevent the use of long-term simulation typically include the lack of adequate rainfall data, either in overall length, time increment, or proximity to the development site. Other factors include lack of adequate calibration and verification data, increased analysis time and costs, and the lack of an appropriate simulation model. Despite these complications, an urban runoff management program should always include provisions that allow such an approach to be utilized, particularly to address runoff quality impacts. Programs should also devote some portion of their overall runoff management efforts to developing such analytic tools for eventual future use. For example, the Washington Department of Ecology has sponsored the development of the Western Washington Hydrology Model (WWHM), a continuous runoff simulation model based upon the

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computer program HSPF (Hydrological Simulation Program – Fortran). According to the department, its plans for the WWHM include improving the model so that it can eventually provide users with the appropriate runoff quality flow rate for land development sites in the western portion of the state, rather than relying on the design storm approach currently utilized by the department. As rainfall data and continuous simulation models become more available, use of this approach is expected to increase.

In summary, the above section on design storms presented the following ideas and information:

- Effective urban runoff management requires control of both the runoff quantity and quality impacts of land development and redevelopment.
- Levels of quality and quantity control can be established through the selection of appropriate design events.
- In order to ensure uniform levels of control, design events should be based upon rainfall rather than runoff amounts and should also have a specified duration that will allow recurrence interval determination.
- A design storm will also require a rainfall distribution over its duration if both volume-based and peak rate-based structural stormwater management facilities are included in the urban runoff management program.
- Such distributions must produce peak runoff rates with the same probability or recurrence interval as the total design storm depth.
- Where available and feasible, continuous rainfall-runoff simulation using long-term rainfall records can produce superior results to a single design storm approach.
- Urban runoff management programs should both monitor and promote the development of continuous simulation techniques and data.

Treatment Levels

In developing a list of suitable structural stormwater management facilities to address the runoff quality requirements of an urban runoff management program, two questions are immediately raised:

1. What runoff pollutants should be treated?
2. What treatment levels should be provided?

These questions are both complex and inter-related. Their answers depend primarily on the conditions within the geographical boundaries of an urban runoff management program. These conditions include, among many others, present runoff quality and quantity levels; the presence, extent, and severity of any existing water body impairments; existing and future land uses, development levels, and water body uses; and related needs such as water supply, sewage treatment, and recreation. It can be seen that such issues pertain to the entire scope of an urban runoff management program and not just to its structural facility component.

A review of the EPA's Stormwater Phase II Final Rule illustrates both the area-dependent and complex nature of these two issues. As discussed above, the final Phase II Rule does not contain specific requirements for either the types of runoff pollutants that must be addressed or the levels of treatment that must be provided by the various owners of small municipal separate storm sewer systems (MS4s). According to the final Rule, this is intentional, for it allows the individual MS4 owner to evaluate and select the pollutants and treatment levels necessary to both achieve the program's goals and comply with NPDES requirements. In addition, the lack of specificity in the final Rule also affords the EPA, designated NPDES permitting authorities, and Phase II permittees the time and opportunity to further investigate stormwater runoff processes, pollutants, and impacts and to introduce more specific requirements into the Rule as problems require and future solutions allow. This process will be supplemented by the ongoing process of determining total maximum daily loads (TMDLs) of specific pollutants for impaired water bodies.

Nevertheless, before a comprehensive list of effective structural stormwater management facilities can be compiled for an urban runoff management program, or a specific facility selected for a land development proposal, both questions must be addressed. This is due to the fact that not all structural stormwater management

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facilities can effectively treat the same runoff pollutants or provide similar levels of treatment. Therefore, the program's runoff treatment and control goals must be understood before structural facility selection can begin. Information regarding the identification of pollutants of concern and the establishment of required treatment or control levels can be found in Chapters 3 through 6.

The remainder of this section will focus on a third question that logically follows from the first two discussed above; namely, once key runoff pollutants and required treatment or removal rates have been identified, how does an urban runoff management program go about specifying what structural facilities can be used to meet these treatment requirements? Without such information, the program's runoff treatment goals can obviously only be stated, but never met with any certainty.

However, analysis of this question raises more complex ones, including what runoff pollutants can each type of structural facility effectively treat and, more importantly, what specific level of treatment can each type provide. Specific answers to these questions, the second in particular, depend upon several highly variable factors, including the concentration and total load of the pollutant, the volume and various rates of the runoff that transports it, antecedent rainfall and runoff conditions, and even the season or time of year. The variability of both applicable pollutants and levels of treatment can be seen by reviewing the sampling results of actual structural facilities taken over a number of storm events. Depending upon the pollutant, the reduction in pollutant load or mean concentration achieved by the structural facility can vary considerably from event to event, with even negative reductions achieved at times, particularly for nutrients. Such variability makes it extremely difficult to determine a structural facility's exact pollutant removal rate and illustrates why pollutant removal criteria are typically based upon average annual conditions.

In light of these questions and complexities, a review of current urban runoff management programs indicates that there are two general approaches to the task of specifying an appropriate set of structural stormwater management facilities to meet a program's runoff quality goals. A discussion of each approach is provided below. Solely for the purposes of these discussions, the two approaches have been assigned the following names:

1. Specified Facility Approach
2. Specified Treatment Approach

The discussions presented below are intended to illustrate the distinguishing features of each approach and identify some of the advantages and disadvantages of each. Nothing presented in these discussions should be considered to favor one approach over the other.

Specified Facility Approach

Following the selection of the program's pollutants of concern and their required level of treatment or control, a list of structural stormwater management facilities considered capable of providing such treatment must be selected. The selection process is typically based upon both model studies and field sampling of each structure type over a range of conditions. Typically, such activities were previously conducted by others with the results taken from a literature search or from one of the growing number of pollutant removal performance databases. At times, this data is supplemented by research conducted or sponsored by the program itself. From this information, a list of structural facilities considered capable of providing the program's required level of runoff quality treatment can be developed using the specified facility approach.

In the specified facility approach, exact pollutant removal performance values for the structural facilities on the program list do not have to be determined. Instead, the list identifies those structural facilities considered capable of meeting the program's treatment requirements. As a result, the specific question "Exactly how much pollutant reduction can a facility achieve?" is replaced by the relative and, therefore, more easily answered question "Can the facility achieve enough?" In this approach, it is also not even necessary to assign a numerical value to the required level of treatment. The program only needs to match up a required level of treatment with a list of capable or acceptable structural facilities.

An example of the specified facility approach can be found in the Stormwater Management Manual for Western Washington, developed by the Washington State Department of Ecology. In Chapter 4 of Volume I of this manual, the department defines four levels of required treatment in the western portion of the state, depending upon a range of factors, including the type of proposed land development, the intensity of traffic or other site uses, and the presence of impacted water bodies downstream. However, quantitative values for these four levels of treatment, expressed either as

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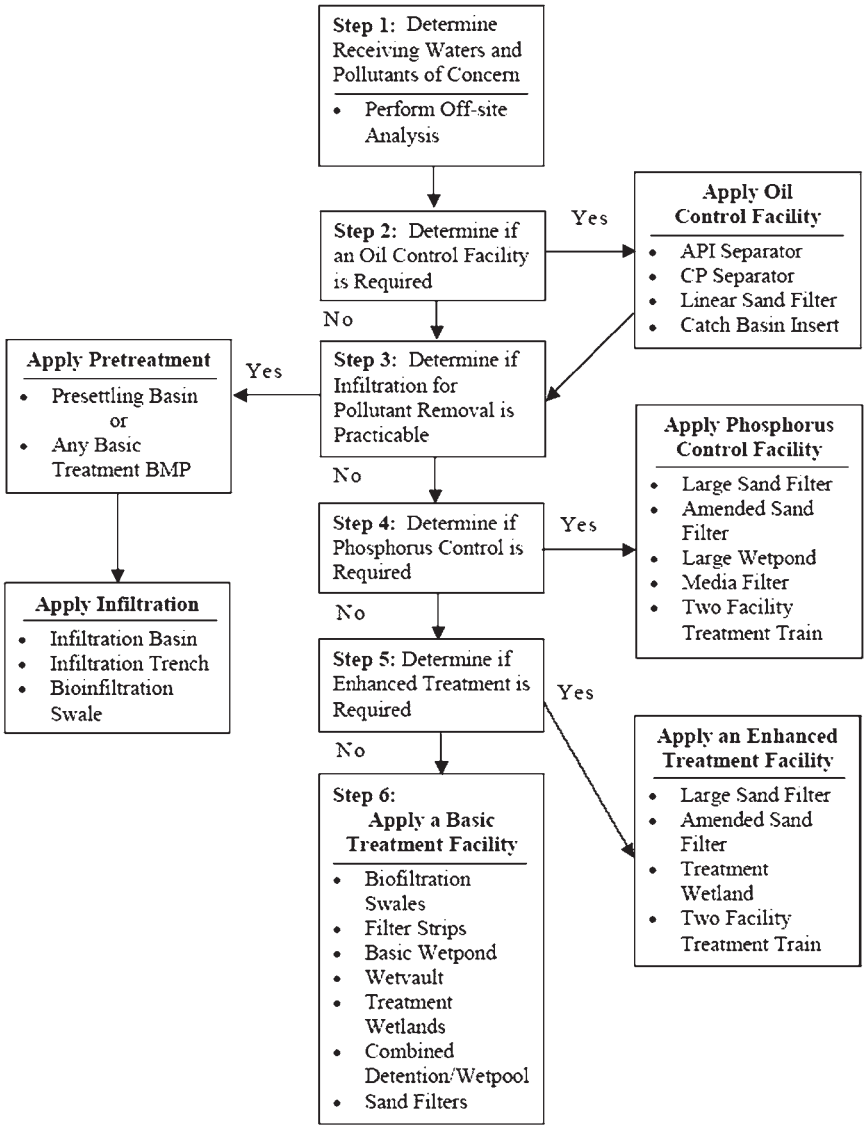
pollutant removal rates or other standard performance measures, are not specified. Next, the manual presents a list of structural facilities that are considered capable of providing each level of required treatment. Subsequent volumes of the manual then provide details on the hydrologic, hydraulic, and structural design of the various facilities.

The overall selection process is illustrated in the chart shown in Figure 10-15. In the figure, which is based upon Figure 4.1 in the Western Washington Manual, the various structural facilities considered acceptable for each required level of runoff treatment can be seen in various boxes around the chart's perimeter following the designation of each required treatment level. What should be noted is the lack of any specific treatment levels, either in the form of required program levels or actual facility performance values.

A variation of the specified facility approach can be found in the Maryland Stormwater Design Manual published by the state's Department of the Environment. In Chapter 1 of that manual, the required levels of post-development runoff treatment are stated. They include 80 percent removal of post-development total suspended solids (TSS) load and 40 percent of post-development total phosphorus load. In Chapter 2, the manual provides a detailed listing of acceptable

Figure 10-15: Structural Stormwater Management Facility Selection Chart from the Stormwater Management Manual for Western Washington



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structural facilities considered capable of meeting these required treatment levels. Detailed sizing and structural criteria for these facilities are provided in subsequent chapters and appendices. However, similar to the Western Washington Manual, the Maryland Manual does not provide specific pollutant removal performance values for the selected facilities. Instead, it states in Chapter 1 that any of the structural facilities can be assumed to meet the program's required TSS and phosphorus removal levels if it is sized to capture the required runoff quality control volume, designed in accordance with the specific structural criteria contained in the manual, and both constructed and maintained properly.

From the above examples, it can be seen that the specified facility approach is in keeping with the minimum requirements for post-construction stormwater management contained in the EPA's Stormwater Phase II Final Rule. As stated in the final Rule, owners of small municipal separate storm sewer systems (MS4s) are required to "develop and implement strategies which include a combination of structural and/or nonstructural best management practices (BMPs) appropriate for the community." Such BMPs should also "minimize water quality impacts and attempt to maintain pre-development runoff conditions." As in the two examples above, no structural facility performance values are specified, only the need to achieve suitable protection levels with acceptable structural facilities.

As noted above, the advantage of the specified facility approach is the avoidance of any need to provide specific performance data for structural stormwater management facilities. In light of the uncertainties regarding such data and the difficulties in selecting (and possibly defending) representative values, this advantage can be significant. However, there are certain disadvantages that urban runoff management program developers should be aware of. These include the need to identify all acceptable structural facilities for each level of runoff quality control. In the case of the Western Washington Manual, this required the development of four sets of acceptable structures, one for each of the state's required treatment levels. As the number of required treatment levels increases, this can become cumbersome to administer and use, particularly when different portions of a proposed development site fall under different treatment requirements. It should be noted that this problem is addressed very effectively in the Western Washington Manual by the structural facility selection chart shown in Figure 10-15.

A second disadvantage of the specified facility approach is that is promotes, to a certain degree, the site design philosophy that a single structural facility can be used to meet all of the program's runoff treatment requirements. In providing a list of equally acceptable facilities, it is left to the site designer to simply select a single one best suited to site conditions in order to meet program requirements. Providing such a list can, albeit unintentionally, limit site design creativity and lead to the repetitive use of one or a few structural facilities that can earn program approval. It should be noted that both the Western Washington and Maryland Manuals address this issue by continually promoting site design creativity and the incorporation of structural facilities and nonstructural measures. For example, the introduction to the Maryland Manual states:

> *It is hoped that the design standards and environmental incentives provided below will produce better methods and advance the science of managing stormwater by relying less on single BMPs for all development projects and more on mimicking existing hydrology through total site design policies.*

A final disadvantage may occur in programs with multiple pollutant removal requirements. Since not all structural facilities are equally effective at treating certain pollutants, it is not uncommon to provide a series of facilities in a treatment train approach in order to meet the removal requirements for all of the required pollutants. In such cases, one facility may be selected to provide the required levels of treatment for pollutant A, followed by a second facility for pollutant B. However, since there are no specific performance values for the selected facilities for each pollutant and, therefore, no way to incorporate these values into the facility designs, each must be designed to meet all of the requirements specified for that facility by the program. This can result in overdesign, which may not be detrimental from a runoff protection standpoint but from cost, land disturbance, safety, and/or maintenance standpoints. Programs may respond to this problem by preparing alternative design standards for structural facilities used in series or treatment trains. However, this can increase the effort needed to create, administer, and design under the program.

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Specified Treatment Approach

The specified treatment approach is the second method of determining acceptable structural stormwater management facilities for an urban runoff management program. Under this approach, both required treatment levels for each pollutant of concern and a list of structural facilities are developed and specified by the program. However, in contrast to the specified facility approach, the list of structural facilities includes specific pollutant removal rates or other performance measures for each facility type. This allows a site designer to select a single or combination of facilities that meet the program's treatment levels based upon their respective performance values.

An example of the specified treatment approach can be found in the New Jersey Stormwater Best Management Practices Manual published by the state's Department of Environmental Protection (NJDEP). In Chapter 4 of the manual, the NJDEP establishes a required TSS removal rate of 80 percent for land development and redevelopment projects, as well as the removal of nutrients to the maximum extent feasible. The chapter also provides a list of approved structural facilities that includes adopted TSS, total phosphorus, and total nitrogen removal rates for each. These removal rates can then be used to select appropriate facilities to meet the required treatment levels. Subsequent chapters in the manual provide design details for each facility type.

The various structural facilities and adopted removal rates are summarized in Table 10-9. It should be noted that the range of TSS removal rates shown for extended detention basins, vegetative filters, and wet ponds reflects varying facility designs. For example, for extended detention basins, the 40 percent to 60 percent TSS removal range pertains to extended detention times varying from 12 to 24 hours. For wet ponds, the 50 percent to 90 percent TSS removal range is based upon both the relative size of the pond's permanent pool and the use of extended detention above the permanent pool level. The 60 percent to 80 percent range of TSS removal rates for vegetative filters is based upon the type of vegetation used in the filter, which can range from turf grass to indigenous woods.

The above shows that one of the advantages of the specified treatment approach is that in providing designers and reviewers with quantitative measures of facility effectiveness, it also provides a demonstrable method of using structural stormwater management facilities either individually or in series to meet the program's pollutant treatment requirements. This allows designers a greater degree of freedom in selecting and locating structural facilities on a land development site. It also allows certain structural facilities such as extended detention basins or turf grass filters, that would not be sufficient by themselves, to be included in a site design. Under the specified facility approach, such facilities, which are relatively easy and inexpensive to design, construct, and maintain, may not be allowed. In addition, by providing a range of removal rates, the specified treatment approach allows designers to adjust a facilities design to optimize its size and features to meet the program's required treatment rates.

As stated above, the primary disadvantage of the specified treatment approach is the required development of appropriate removal rates for the program's pollutants of concern. This requires a considerable amount

Table 10-9: Approved Structural Facilities and Adopted Pollutant Removal Rates, New Jersey Stormwater Best Management Practices Manual

Structural Facility Type	Adopted TSS Removal Rate (%)	Adopted Total Phosphorous Removal Rate (%)	Adopted Total Nitrogen Removal Rate (%)
Bioretention Basin	90	60	30
Constructed Wetland	90	50	30
Extended Detention Basin	40 – 60	20	20
Infiltration Basin	80	60	50
Manufactured Treatment Device	Subject to NJDEP Verification		
Pervious Paving	80	60	50
Sand Filter	80	50	35
Vegetative Filter	60 – 80	30	30
Wet Pond	50 – 90	50	30

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of research and review in order to develop appropriate removal rates that are accurate not only for a specific facility type but also relative to other types. This must be done for each pollutant of concern in the program. Once this process is completed, the existence of specific, quantitative removal rates may inadvertently imply an accuracy that does not exist. The New Jersey Manual addresses this concern with the following text:

> *It is important to note that the TSS removal rates shown in [Chapter 4] have been based upon several sources of BMP research and monitoring data as well as consultation with numerous stormwater management experts. As demonstrated by that research, actual TSS removals at specific BMPs during specific storm events will depend upon a number of site factors and can be highly variable. As such, the TSS removal rates presented in Table 4-1 are considered representative values that recognize this variability and the state's need to develop and implement a statewide stormwater management program.*

Another disadvantage to the specified treatment approach is the need to address structural facilities in series or a treatment train. While this was also required with the specified facility approach, the specified treatment approach requires a methodology by which the total pollutant removal rate of the structure series can be determined. In the New Jersey Manual, a simplified equation is presented that allows the determination of the total pollutant removal rate of two separate structural facilities operating in series. The equation is presented below:

$$R = A + B - [(A \times B)/100]$$

where:

R = Total Pollutant Removal Rate

A = Pollutant Removal Rate of the Upstream BMP

B = Pollutant Removal Rate of the Downstream BMP

The equation assumes that the removal rates shown in Table 10-9 for a specific facility remain the same regardless of the facility's location in the series. Recognizing the limitations of this assumption, the manual also provides the following guidelines for arranging the various facilities in the most effective order:

1. Arrange the BMPs from upstream to downstream in ascending order of TSS removal rate. In this arrangement, the BMP with the lowest TSS removal rate would be located at the upstream end of the treatment train. Downstream BMPs should have progressively higher TSS removal rates.
2. Arrange the BMPs from upstream to downstream in ascending order of nutrient removal rate. Similar to 1 above, the BMP with the lowest nutrient removal rate would be located at the upstream end of the treatment train in this arrangement. Downstream BMPs should have progressively higher nutrient removal rates.
3. Arrange the BMPs from upstream to downstream by their relative ease of sediment and debris removal. In this arrangement, the BMP from which it is easiest to remove collected sediment and debris would be located at the upstream end of the treatment train. In downstream BMPs, it should be progressively more difficult to remove sediment and debris.
4. These guidelines should generally be applied in the order presented above. As such, a series of BMPs would be preliminarily arranged in accordance with their relative TSS removal rates (Guideline 1). This preliminary arrangement would then be refined by the BMPs' relative nutrient removal rate (Guideline 2) and then their ease of sediment and debris removal (Guideline 3). Two or more iterations may be necessary to select the optimum arrangement, which should also include consideration for site conditions and the abilities and equipment of the party responsible for the BMPs' maintenance.

The Future

In addition to the two general approaches discussed above, a third approach to designating acceptable structural stormwater management facilities for runoff quality control holds great promise for the future. Under this approach, loadings of a program's pollutants of concern would be estimated from a continuous rainfall-runoff simulation based upon long-term records for actual rain events. These loadings would then be introduced to one or a series of structural facilities that would achieve load reductions on an event-by-event basis based upon both the event and facility characteristics. Upon completion, a comparison could be made over a selected time period between pre- and post-development pollutant loadings.

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Utilizing this approach, an urban runoff management program could require specific pollutant treatment or removal levels based upon site location, development type, and/or type and condition of the downstream water body. Such treatment levels could range, for example, from no increase in existing pollutant loadings for low-intensity developments or unimpaired downstream water bodies to a specific decrease in existing loadings for high-intensity developments or impaired downstream water bodies. Reductions in existing loadings may also be appropriate for redevelopment projects in highly urbanized areas with highly impaired water bodies in order to restore such water bodies and address environmental justice issues in such areas.

While the data, models, and other analytical tools are already available and being used for specific development proposals, the application of this approach to a program-wide basis remains in the future. As noted above, the development to date of the Western Washington Hydrology Model (WWHM) by the Washington Department of Ecology represents an initial step toward such an approach. Further movement is expected with the continued development and application of TMDLs for impaired water bodies. A comparison of the two structural facility designation approaches discussed earlier in this section indicates that the specified treatment approach appears initially somewhat better suited to advance toward this more detailed program type.

In summary, the above section on pollutant treatment levels and structural facility performance presented the following ideas and information:

- After identifying pollutants of concern and determining appropriate treatment or removal levels, a list of acceptable structural stormwater management facilities capable of achieving these treatment levels needs to be specified.
- At present, there are two general approaches used to specify such a list.
- The specified facility approach is based upon specifying a list of acceptable structural facilities that will meet the program's runoff quality requirements without specifying facility pollutant treatment performance values.
- The specified treatment approach also specifies a list of acceptable structural facilities along with specific pollutant treatment performance values for each.
- Both approaches have advantages and disadvantages. In general, the specified facility approach requires less initial development. However, the specified treatment approach offers more options in the selection of structural facilities and appears more suited for future development.
- Future urban runoff management programs are expected to be based upon long-term, continuous simulation of runoff and both pollutant generation and treatment.

Structural Facility Selection and Design Criteria

Similar to the 1994 *Fundamentals of Urban Runoff Management*, this section of the structural stormwater management facilities chapter will present information on the selection, siting, and design of structural facilities. However, in the period between the 1994 edition and the present book, the amount of detailed, reliable, and readily available information on these topics has grown at what seems like an exponential rate. The 1994 *Fundamentals* book contained more than 35 pages of structural facility selection criteria, performance data, and design details for seven types of structural facilities, consisting of wet ponds, extended detention basins, oil separators, wetlands, infiltration practices, swales, and sand and leaf compost filters. Much of the information contained in those pages had previously received limited distribution or had been unpublished. However, at the time of this chapter's writing, a single internet search of "structural stormwater management facilities" yields 224,000 sites, while "best management practices manual" yields an additional 6,690,000.

In light of this almost incomprehensible wealth of structural stormwater management facility information, this chapter will take a different approach to providing structural facility selection, siting, and design information. Instead of adding to this vast body of information (and raising the number of structural facility sites to 224,001), it recommends in Table 10-10 those information sources, available through the internet, that it considers exceptional and worthy of note by urban runoff management program developers and administrators. It should be noted that there are many other outstanding sources not mentioned below and that the order of those that are should not be taken as an indication of relative quality or value.

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Table 10-10: Recommended Structural Stormwater Management Facility Selection, Siting, and Design Information Sources

Source:	The Stormwater Manager's Resource Center
By:	The Center for Watershed Protection
Site:	http://www.stormwatercenter.net/SMRC_home_test.htm)
Comments:	Outstanding internet site with slideshows, fact sheets, and even a stormwater manual builder.
Source:	NPDES Stormwater Home Page
By:	U.S. Environmental Protection Agency
Site:	http://cfpub.epa.gov/npdes/home.cfm?program_id=6
Comments:	Nothing like going to the Source for information. And there's plenty, including the Stormwater Phase II Final Rule, fact sheets, and outreach materials.
Source:	Guide for Best Management Practice Selection in Urban Developed Areas
By:	American Society of Civil Engineers
Site:	https://www.asce.org/bookstore/book.cfm?book=4058
Comments:	Concise guide that covers all of the pertinent facility selection criteria.
Source:	Stormwater Management Manual for Western Washington
By:	Washington Department of Ecology
Site:	http://www.ecy.wa.gov/programs/wq/stormwater/manual.html
Comments:	One of the most comprehensive stormwater management manuals available. Includes extensive structural facility design criteria and explanations.
Source:	Maryland Stormwater Design Manual
By:	Maryland Department of the Environment
Site:	http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp
Comments:	Outstanding stormwater management manual with numerous structural facility design examples and sample computations.
Source:	New Jersey Stormwater Best Management Practices Manual
By:	New Jersey Department of Environmental Protection
Site:	http://www.njstormwater.org/bmp_manual2.htm
Comment:	Comprehensive stormwater manual that includes extensive structural facility design, construction, and maintenance criteria, including adopted pollutant removal performance rates.
Source:	Wisconsin Stormwater Manual
By:	Wisconsin Department of Natural Resources
Site:	http://www.dnr.state.wi.us/org/water/wm/nps/stormwater/publications.htm#uwex
Comment:	Extensively researched stormwater management manual with concise presentation of structural facility design criteria.
Source:	Stormwater Treatment Devices: Design Guideline Manual
By:	Auckland Regional Council
Site:	http://www.arc.govt.nz/arc/environment/water/stormwater-tp10.cfm
Comment:	Includes well-researched chapters on numerous structural stormwater management facilities. Proves that both runoff and runoff management expertise know no borders.

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Washington Department of Ecology, "Stormwater Management Manual for Western Washington," September 2003.

Wisconsin Department of Natural Resources, "Wisconsin Stormwater Manual," 2000.

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CHAPTER 11

Low Streamflow Augmentation and Groundwater Recharge

This is a difficult chapter to write. There is considerable discussion about issues related to low streamflow and the impacts of imperviousness on streamflow, but reality is a bit more elusive. Some researchers have noted that urbanization decreases low flows, others have found that baseflows have increased as urbanization has occurred, and some studies have not been able to support a conclusion either way.

As a result, this chapter will attempt to discuss the issue objectively and make recommendations where appropriate. Clearly, it is a difficult issue to quantify, as very few studies have been conducted over a time scale that is long enough to assess trends or establish very basic issues such as flow change resulting from increased impervious surfaces. Several case studies will be presented that argue both sides from a trend perception.

Stormwater professionals are increasingly aware both of the impacts that stormwater volumes have on sizing of stormwater practices and the possible impacts of additional volumes on receiving system health. A number of practices are available to reduce total stormwater runoff, including water reuse and practices that increase retention of water in the soil mantle, but reducing surface runoff is not the same as maintaining groundwater recharge. There are many situations where both types of practice (volume reduction and recharge) must be used in conjunction if downstream receiving system protection is to be provided.

If an effective policy is to be developed, there must be an understanding of groundwater/surface water interaction, recharge/discharge zones, and hydrogeology. It is also important to be aware of the ambiguity that surrounds the issue so that an intelligent discussion and a better understanding of possible variables can result.

It is important to note that the following discussion does not address the impacts caused by the use of groundwater as a water supply source. While aquifer drawdown by water supply wells can result in the loss of groundwater resources, the issue is beyond the scope of this manual.

General Understanding

First, it is important to define what low streamflow is.

> *Low streamflow is that flow that occurs during periods of little rain, typically in mid-late summer and can be highly variable over time primarily due to watershed geology, climate, and topography. It can also be affected by many other factors.*

When it is not raining and runoff into streams through the drainage system has ended, the flow in the stream is derived from groundwater. If groundwater levels are reduced so that they decline below the stream bed invert, the stream loses its ability to have perennial flow. It then becomes an ephemeral stream and loses the potentially rich biologic atributes that a perennial stream can have.

Baseflow is influenced by groundwater gradient, hydrogeologic properties (eg. permeability) of the aquifer materials, and the properties of the materials at the surface water/groundwater interface. With urbanization,

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the main change is in groundwater gradient. Areas with steeper gradients are likely affected differently than areas of low hydraulic gradients. Recharge areas will be affected more than discharge areas. Examples of two types of aquifers are shown in Figure 11-1.

Our study of stormwater over the years has focused on imperviousness as an effects indicator. Impervious cover does significantly increase peak rates of discharge and volumes. The perception is that impervious cover will reduce groundwater recharge and cause water levels in urban streams to decline during dry periods. The groundwater table is not replenished, as surface runoff during storms will carry water away that would otherwise infiltrate into the ground.

From a stormwater management perspective, we initially controlled runoff by detention practices that might mitigate downstream flood increases, but detention ponds, and even retention ponds (due to bottom sealing) have not resupplied water to groundwater. Infiltration practices are among the few urban practices that provide groundwater recharge at least as a byproduct.

Attempts to detect the effect of impervious surfaces on stream baseflow are very difficult due to the need for long-term data from watersheds where the hydrological record has existed prior to watershed development and extended throughout the development period. Too often, gauging stations are discontinued or are on watersheds so large that development on a subwatershed level will not show significant change. In addition, groundwater supply may come from an area outside of a subwatershed or from an area that has not been developed.

As a result, most of our understanding stems from a rational expectation that imperviousness reduces groundwater recharge, which then translates into reduced stream baseflow.

Various Influences on Stream Base Flow

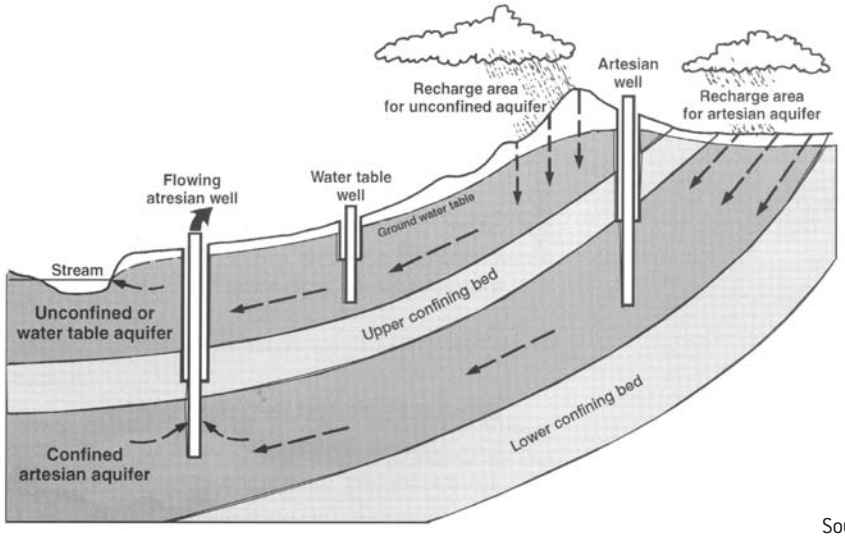
Transpiration, Evaporation, and Evapotranspiration

Transpiration, the process by which water from plants is discharged into the atmosphere as vapor, depends essentially on the same factors as those which control evaporation, namely air temperature, wind velocity, and solar radiation. Transpiration also varies with the species and density of plants and to a certain extent with the moisture content of the soil, in that a certain minimum amount of water must be available to the plant roots.

Evaporation is the process whereby liquid water becomes water vapor. It includes vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces.

Evapotranspiration, the combination of evaporation and transpiration, is the consumptive use of plants, or

Figure 11-1: Two Common Types of Aquifers



Source: Arc, 2003

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the total amount of water absorbed by vegetation for transpiration or building of plant tissue, plus evaporation from the soil. Evapotranspiration has a significant effect on water yield from a watershed. It has to be considered on a seasonal as well as an annual basis to allow a good understanding of fluctuation and total amounts.

Timing of Groundwater Response

The effect of land use change on watershed yield is not instantaneous. While the evaporated and runoff components may respond relatively quickly to a land use change, increased recharge to a groundwater system may not express itself as a corresponding increase in surface discharge for many years. The timing of effects of a large-scale land use change on watershed yield will be different throughout the range of groundwater systems within a watershed.

Timing is effected by both shape and profile of a groundwater system, and these two factors have significant impacts on where surface discharge may occur in different land use scenarios. Another timing factor is the depth of unsaturated zone above the aquifer. This does not affect the equilibrium discharge conditions, but it will affect the timing of the response to recharge change, since aquifer heads will need to increase to a higher level before surface discharge can occur.

Predictors of groundwater response times are an essential part of predicting likely effects of land use change on low streamflow.

Leakage

Storm drains and sanitary sewers can function in two different ways. On the one hand, they may intercept groundwater, convey it downstream, and thus reduce groundwater levels in the vicinity where the water was intercepted.

On the other hand, sanitary sewer pipes may augment groundwater by leaking into adjacent soil and elevating groundwater levels through continuous flow.

The same could occur if potable water lines leaked. Water supply systems may have significant influence on groundwater levels, because leakage from a pressurized water main would occur all of the time, not just during storm events.

Both of these situations are common in urban utilities and may to some degree offset impervious surface impacts.

Compaction

The issue of compaction is extremely important when considering infiltration and subsequent impact on base stream flow.

Infiltration of rainfall into pervious surfaces is controlled by three mechanisms:

- The rate of entry of water through the soil/plant surface;
- The rate of movement of water through the vadose (unsaturated) zone; and
- The rate of drainage from the vadose zone into the saturated zone.

During periods of rainfall excess, long-term infiltration is generally the least of these three rates. The runoff rate after depression storage is filled is the amount by which the rainfall intensity exceeds the infiltration rate. The infiltration rate typically decreases during periods of rainfall excess. Storage capacity is recovered when the drainage from the vadose zone is faster than the infiltration rate.

The surface entry rate of water may be affected by the presence of a thin layer of silts and clay particles at the surface of the soil and vegetation. These particles may cause a surface seal that would decrease a normally high infiltration rate. The movement of water through the soil depends on the characteristics of the underlying soil. Once the surface layer is saturated, water cannot enter soil faster than it is being transmitted away, so this transmission rate affects the infiltration rate during longer events. The depletion of available storage in the soil affects the transmission and drainage rates, and the storage capacity of soils depends in turn on the soil thickness, porosity, and the soil-water content. The effective porosity of the soil is again affected by many factors, such as soil texture, root development, soil insect and animal bore holes, structure, and presence of organic matter.

The infiltration of water into the surface soil is responsible for the largest abstraction of rainwater in natural areas. The infiltration capacity of most soils allows low-intensity rainfall to totally infiltrate, unless the soil voids become saturated or the underlain soil is much more compact than the top layer. High-intensity rainfalls generate substantial runoff because the infiltration capacity at the upper soil surface is surpassed, even though the underlain soil might still be very dry.]

Urban development increases runoff due to a number of reasons, including impervious surfaces, but urban soils may also be significantly compacted during the urban

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development phase of land conversion. Soil compaction due to construction significantly reduces infiltration capacity of urban soils. For one, it will reduce the organic content of the surface layers, generally seen as a reduction of topsoil depth in a post-, compared to a pre-development condition. Also, urban land development generally involves massive site clearance of vegetation and movement of dirt with large areas of cut and fill, all of which require heavy earth-moving equipment that compacts soils. These areas, even vegetated, have significantly reduced ability to infiltrate rain into the ground, which further reduces groundwater recharge. In addition, the use of exotic plants over native vegetation may result in roots being shallower. Urban soils are very shallow to begin with, and the lack of penetration into the ground reduces infiltration rates further. A pre-development condition for a site may be forest with deep-rooted woody vegetation or meadow with shrubby plants that also have deeper roots. Prairie grasses have exceptionally deep roots that improve soil infiltration rates.

Percentage of Baseflow Versus Streamflow

A number of studies have discussed percentages of baseflow versus total streamflow. In all studies reviewed, the percentage of baseflow versus stormflow decreases as watershed imperviousness increases. That is not a surprising result, as impervious surfaces have profound effects on overland flow rates and volumes. But at the same time, a reduction in percentage of baseflow versus total streamflow does not necessarily mean that baseflows in a given stream are decreasing as a result of watershed development. It only means that a greater percentage of flow is now "quickflow" or stormflow.

The Auckland Regional Council study on the Oteha stream found the baseflow ratio reduced from 0.79 to 0.4 between 1982 and 2002. But baseflow is highly variable and shows no real trend. Rainfall variation in this study had a bigger influence than urbanization. There may be a lag effect where effects may be more rapid in high permeable materials such as sands or gravels.

Recognizing that watershed hydrology is determined by rainfall, land cover (which also affects evapotranspiration), soils, slopes, and conveyance, a reduction in the percentage of flow that is baseflow may not necessarily mean that baseflow itself is decreasing at all. There may be a reduction in evapotranspiration that allows a percentage increase in total streamflow as less is sent back to the atmosphere.

Trends would indicate the potential for decreasing groundwater recharge, but the effect has not been clearly defined. We know what level of recharge is necessary to maintain stream baseflow. What we do not know are the compounding factors or sources of other influences on groundwater recharge. Studies around the U.S. and New Zealand would indicate that there are situations where post-development baseflows are higher than pre-development, which presents a problem with establishing recharge requirements.

Case Studies

There are a number of case studies that may provide a greater understanding of the baseflow issue.

North Carolina (Evett et al., 1994)

Baseflow and precipitation trends at U.S.G.S. gage sites were studied in four urban centers and surrounding rural areas. The flows in these areas decreased in recent years. While the results tend not to support the development/reduced baseflow discussion, they did show that trends in precipitation alone cannot account for the decreased flow in urban and rural streams. Regional land use effects could be exerting some negative effect on the rural streams as well.

Explanations given in the study were the following:

- The urbanization effect on baseflow exists but may be too small to show up in the statistics.
- Some substrate types are less vulnerable to reduced groundwater recharge than others.
- The streams studied were large and of mixed land use. Factors outside the station area may have exerted an effect at the measuring point.

It was concluded from the study that there is some support for the theory that urbanization causes a decrease in low streamflows over time, but statistically, the results are inconclusive. It appears more likely that most small streams, both urban and rural, are experiencing decreasing low flows over time to a greater degree than would result from decreasing trends in precipitation alone.

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Long Island, New York (Simmons and Reynolds, 1992)

This study and an earlier one (Simmons and Reynolds, 1982) attributed the alteration of flow components to the installation of sanitary sewers for the conveyance of treated wastewater to tidewater, the routing of stormwater directly to streams, and an increase in impervious surfaces throughout the watersheds. They reported as much as a 70 percent reduction in baseflow in streams draining Long Island between 1948 and 1985.

Upper Chattahoochee River Basin, Georgia (Calhoon, Frick, and Buell, 2003)

The baseflow component of total streamflow in Peachtree Creek has declined from approximately 50 to 30 percent since continuous streamflow measurements began in 1958. Equilibrium in the baseflow decline does not appear to have been reached in this watershed, and it can be extrapolated that without any additional increase in urbanization, further declines in baseflow will occur. Conversely, baseflow components of total streamflow in Snake Creek and the Chestatee River, watersheds that had little to no urban development, have been more consistent over time.

An extrapolation done in the study shows that for each percent increase in impervious area, there is a corresponding decrease in baseflow of approximately 2 percent.

It must be pointed out that the study did not actually look at baseflow level reduction but rather considered it as a percentage of total streamflow. The relative contribution of baseflow to total flow was reduced, but no conclusions can be stated regarding actual reductions in stream baseflow as a result of urbanization.

Upper River Rouge Watershed (Richards and Brabec, undated)

Analysis of discharge data from the Upper River Rouge at Detroit shows a gradual increase in baseflow and streamflow since 1932. The trend was consistent even in the late 1990s when the precipitation decreased over a three-year period. It is possible that changes in seasonal precipitation distribution account for some of this increase in baseflow. Most of the recharge in a watershed occurs in the dormant season, particularly in the late fall, when evapotranspiration fluxes are low. Climate changes that increase the proportion of precipitation falling in the dormant season could increase baseflow with no apparent increase in annual precipitation. Thus, if a drop in evapotranspiration is the cause of the trend, its decrease has to be related to either the presence of imperviousness or changes in the type and aerial extent of vegetation which are reducing the efficiency of evapotranspiration.

Another interesting possibility discussed is that climate changes have decreased the driving force for evapotranspiration over the study period. A decrease in evapotranspiration will increase the amount of water available for recharge. Annual potential evapotranspiration (estimated using the Thornwaite method) over the period of interest suggests that the driving force for evapotranspiration has not changed significantly. Total streamflow and surface runoff have increased significantly over the time period.

Australia (Zhang, L., et al., June 2003)

There have been a number of studies in Australia that estimate response of groundwater systems to changes in recharge that arise from land use changes. A primary emphasis of some of these studies is concern over expansion of saline land surfaces and rising river salinities that occur in many parts of Australia.

In addition, Australia is a very dry climate, and other studies have considered the effects that large-scale afforestation has on the volume of streamflow and the associated water allocations. The impact of afforestation on mean annual flow is well known, but efforts have been underway to better understand its impact on seasonal flow or flow regime. It was found that blue gum plantations would significantly reduce low flow and hence increase flow variability. Results indicated that the maximum reduction in mean annual flow would be 8 percent for Lake Eidon and 14 percent for Goulburn Weir if all suitable areas were planted.

New Zealand (Herald, 1989)

Monthly streamflow yields and flow duration curves for watersheds of pastoral, urban construction, and fully urbanized land covers were compared. Due to missing data, it was not possible to compare annual water budgets for the study watersheds. However, comparison of the area-specific yields for the periods for which data were available provided a useful index for the magnitudes of change likely to occur as urban development proceeds.

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Groundwater recharge was markedly reduced as a result of urban development. An index of monthly groundwater recharge showed substantial recharge in the pastoral watersheds during four months of the study period, but only limited recharge in the urban construction watershed during three months, and no recharge in the urban watershed. An intuitive assumption commonly suggested in the literature is that the reduced groundwater recharge subsequent to development leads to a reduction of low flows. However, although results of the study show an increase in total discharge and a decrease in groundwater recharge, low flows were also seen to increase in both frequency and magnitude. These findings may suggest that more sustained low flows result from the urban watershed responding more rapidly to lower-intensity and shorter-duration rainfall than pastoral watersheds.

General Discussion

There is probably truth in both the assumption that infiltration to groundwater is reduced by urban impervious surfaces and that evaporative losses may be reduced since both interception storage and depression storage are often reduced by urban development. The net effect of these changes is commonly an increase in total runoff. When considering low streamflow or baseflow, the issue is one of prediction from a trend perspective.

This is an important issue, as designing for infiltration on a watershed basis may result in groundwater levels potentially being higher than during the pre-urbanization period. At the same time, disregard for potential drop in groundwater levels due to urbanization may result in loss of perennial streams and their associated aquatic ecology.

The important point to recognize is that the two issues are not necessarily at the opposite ends of the "hydrological spectrum." Through watershed-wide approaches, we can consider the variables that have the greatest effect on stream baseflows.

The historical approach of predominantly using wet or dry stormwater management ponds cannot address the issue. Any analysis of extending pond outflow durations will not address overall changes to groundwater recharge or discharge, because no stormwater ponds, no matter how large, can delay wintertime rainfall sufficiently for it to become summertime runoff. Yet exactly this magnitude of delay does occur under pre-development conditions, because far more of the precipitation is stored as groundwater than can ever be stored in stormwater ponds. This stored precipitation is also released from the groundwater much more slowly than from a pond. Therefore, we have to rethink our traditional approaches to stormwater management if we consider stream baseflow protection an important program issue.

The specific issues that seem to relate to variations of stream baseflow are:

- Watershed imperviousness;
- Compaction of soils;
- Loss of watershed evapotranspiration;
- Existence of significant natural recharge areas; and
- Leakage of water and sewer pipes.

With all that said and done, we need to recognize that there are adverse impacts to the urbanization of previously undeveloped land. If we are going to continue with traditional development approaches, we will lose many of those resources that attract us to a given location. If we can implement a stormwater program that addresses these items, stream baseflow impacts can be better predicted and designed for.

Recommendations

When considering recommendations for an approach to low streamflow maintenance, we need to address the items mentioned in the *General Discussion* section of this chapter. In addition, there are obvious overlaps with other chapters, especially Chapter 8, Impact Avoidance. We have to recognize the value of natural site features, including existing vegetation, and protect those features.

Reduce the Impact of Watershed Imperviousness

Urban land use will continue to create and maintain impervious surfaces. Roads must shed water for safety reasons, and structures cannot leak. With that said, we can reduce the impact of those impervious surfaces through a number of different actions, including the following:

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Disconnection of Impervious Surfaces from the Historic Drainage System

This approach would mean disconnecting roof runoff from the historic drainage system. The basic approach here is to reduce the efficiency of the stormwater conveyance system by slowing the water down and allowing greater contact with vegetation and soil.

Green Roofs

Green roofs are being considered much more as a mainstream practice than they have been historically. In the early 1980s, rooftop storage was a measure considered for detention of stormwater to reduce potential increases in peak flow. At that time, it was eliminated as a practice because roof leakage was a problem. Using an impermeable membrane in conjunction with better site control will reduce leakage concerns. A good design approach for green roofs can provide significant hydrological benefits for smaller storms and improve evapotranspiration potential.

Water Reuse

Water reuse is a good practice even if stream baseflow is not an issue. Use of roof runoff for water reuse reduces not only the total volume of stormwater runoff but also demand for public supply. Unlike evapotranspiration, which is very seasonal in benefit, water reuse provides benefits all year, as long as there is water use in a residential, commercial, or industrial property. Water reuse can be very beneficial on industrial properties where water is essential for day-to-day operations.

Bioretention Practices

Bioretention practices include rain gardens, filtration systems that use organic materials, swales, and filter strips. Studies have detailed volume reductions for these types of practices in the range of 20 to 35 percent, and a recent study in Melbourne detailed a 54 percent annual reduction of total runoff. That is a significant reduction in runoff volume. Bioretention practices can be used in very urban environments such as parking areas, or along roads as swales.

Infiltration Practices

In an urban environment, putting water into infiltration will help maintain groundwater recharge and take out some of the stormflow and pollutants, which provides multiple benefits. Infiltration practices are especially appropriate on small sites where total drainage to the practice is fairly small. Having more practices serving smaller drainage areas, rather than fewer practices serving larger ones, is desirable, as clogging may reduce overall effectiveness and total clogging of one or more systems is not as critical if there are more practices serving the same property. In addition, when imple-



Melbourne bioretention practice where total volume study was done



Example of an infiltration practice used for groundwater recharge

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menting infiltration practices, it is important to put a greater effort into providing infiltration in recharge areas and less effort into discharge areas. There is still concern about long-term performance of infiltration practices, and an aggressive program of site inspection and maintenance is necessary to ensure that proper maintenance is accomplished.

It is important that all of the above practices be used in a "treatment train" approach to protecting stream baseflow. Possibilities for a reduction of "effective" imperviousness exist on any new development and can often be considered cost-effectively as a retrofit. In Auckland, a number of industrial sites have instituted water reuse on sites that are completely impervious, and benefits include reduced water charges for plant operation in addition to reduced stormwater quantity and quality concerns.



Revegetation of steep slopes and footprinting house locations in a development to minimize surface runoff



Example of a porous block parking area

Minimize the Impact of Soil Compaction

The easiest way to reduce soil compaction is to keep construction equipment off site areas that are to be left in a natural state. That is often not possible due to maximum development for profit margins. Still, there are a number of ways in which this concern can be addressed and soil permeability improved:

1. Where cuts or fills of at least two feet are intended to facilitate site development, the expected permeability of the soil may be reduced. Stormwater management computations that detail post-construction hydrology should use a modified approach to soil classifications.
2. In areas of significant site disturbance, and where there is less than two feet of cut or fill, soil classifications are not modified, but the approved site permit should contain a construction requirement that significantly disturbed soils in areas where those soils remain pervious should be chisel-plowed. Chisel-plowing will break the surface crust of the disturbed soil and allow for a greater infiltration rate. This would provide a good foundation for the placement of topsoil and prevent slippage of the topsoil on slopes that become saturated.
3. Use of soil amendments (compost, polyacrylamides) or otherwise modifying soil structure and chemical characteristics is becoming more popular. At present, there is little information to quantify benefits or problems with their application.
4. Rather than using a minimum depth of topsoil that is stockpiled and disposing of the rest off-site, the depth of topsoil that is retained on site should be maximized. This topsoil can act as a sponge during rainfall. One good requirement would be to maintain, to the extent possible, the same volume of topsoil on a property post-development that existed prior to development.
5. Woody vegetation should be planted in open space areas to improve root depth penetration. There will be a period of time when compacted soils reduce permeability, but long-term benefits will be obtained.

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Maintain Watershed Evapotranspiration

In a number of places in this manual the value of vegetation has been stressed. Maintaining evapotranspiration in a watershed is an effective balance to prevent increases in groundwater levels. For years, people have been planting willow trees in areas of high water table to reduce groundwater levels. Native vegetation, deeper roots, protection of existing woody vegetation, or planting more vegetation all provide a wealth of benefits, including seasonal drawdown of groundwater and maintaining a balance for groundwater recharge. The above-mentioned Australian study on afforestation shows that woody vegetation can have a significant impact on baseflow. Those study results can be considered in an urban context where woody vegetation has been removed and groundwater levels could increase.

Leave Areas of Significant Recharge Natural

In every watershed, there are areas where significant groundwater recharge occurs. In general, these areas are away from stream channels but not situated on steep slopes. They are sandy soils and sandy loam soils that have high infiltration rates. In existing wooded areas, these soils act as a sponge for any rainfall that lands on them. Before development occurs in a given watershed, watershed planning should detail environmentally sensitive areas that include areas of significant groundwater recharge. Those areas should be targeted for limited growth and site disturbance. Watershed areas with limited recharge capability would be more suitable for higher levels of site disturbance and development.

Prevent Water and Sewer Pipe Leakage

Older water supply and wastewater pipe systems certainly leak. Design criteria for both also have a factor of safety for pipe sizing that accounts for infiltration or exfiltration. Newer construction techniques can minimize that historic leakage problem, but this is only done on an emergency basis or where pipe systems must be upgraded to account for increased demand.

Wastewater systems are in the unenviable position of having exfiltration concerns when the pipe is above the water table and infiltration concerns when it is adjacent to a stream and in the water table. As a result, there is both the potential to augment groundwater flows and to reduce groundwater levels.

The actual impact of this is not expected to be significant. If you assume 10 houses per hectare with each house using 200 m^3 of water per year, and there is a 20 percent leakage of water into the ground, monthly increases are expected to be only 3 mm over those generated from inputs of rainfall. This is a negligible increase that would be expected to have a limited effect on groundwater levels.

Concluding Comments

One very important point in considering stream baseflow is the need for planning from a watershed perspective. The protection of, for example, a sensitive trout or salmon stream can only be achieved if it is considered entirely from a watershed perspective. Many program priorities can be addressed by a standardized approach that incorporates impact avoidance principles. Protecting stream baseflows will rely to some degree on these principles, but it will also require fairly detailed land use considerations if the goal of stream baseflow maintenance is to be achieved.

The bottom line of the discussions presented in this chapter is that we need more information in more areas to be able to make predictions for the impact of development on stream baseflow. We do not even have a clear understanding of whether stream baseflow will increase or decrease. There is certainly an expectation that stream baseflows will decrease with increasing watershed imperviousness, but existing studies cannot verify whether that is true.

We cannot expect people to pay thousands of dollars to implement practices that may provide a stream lowflow benefit but may also have little value or even increase groundwater levels above the pre-development one.

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CHAPTER 12

Watershed Management Approaches

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CHAPTER 12

Watershed Management Approaches

The complexity of urban runoff quality and quantity problems has been documented and discussed throughout this book. This chapter discusses the benefits, challenges, and technical requirements of using a watershed-based approach to address these problems and to manage urban runoff in a truly comprehensive manner. To accomplish this, the chapter presents the following topics:

- What is a watershed?
- What is watershed management?
- Why use a watershed management approach to manage urban runoff?
- Which aspects of urban runoff can watershed management address?
- What are the technical and program requirements of watershed management?
- What challenges and difficulties can be expected when utilizing a watershed-based approach?

The chapter also includes information on the development of total maximum daily loads (TMDL), a federally mandated, watershed-based approach to addressing water quality problems along specific water bodies. The chapter concludes with a look at what future watershed management efforts may encounter and address.

As with many of the topics presented in the original 1994 *Fundamentals of Urban Runoff Management*, much has been written regarding watershed management over the last 11 years. This growth is expected to continue and even accelerate in the future due, in part, to the almost limitless range of problems and solutions that could be addressed through a watershed-based approach. A recent Internet search for information on "watershed planning" returned over one million hits.

Not surprisingly, EPA has a number of guidance documents available on watershed management, including the website www.epa.gov/watertrain, which provides online training in a variety of watershed management issues. The site includes a number of topics including watershed change, analysis and planning, watershed ecology, and watershed management practices and community issues. It serves as an excellent starting point to acquire a greater understanding of watershed management issues.

In light of this vastly greater amount of information, it is not the purpose of this new chapter on watershed management to simply repeat or cite information that is readily available from others. Instead, the chapter will discuss those watershed management issues that, in general, have not been considered or addressed by either researchers or program managers. These discussions will seek to identify not only the benefits of watershed-based runoff management planning but also the short- and long-term commitments that must be made to develop an effective watershed plan that will not diminish in value or effectiveness over time. Clearly, watershed-based approaches have proven to be essential components of successful stormwater management and resource protection programs. Identifying not only the benefits but the challenges associated with watershed management in this chapter should increase the number of successful watershed management efforts.

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What is a Watershed?

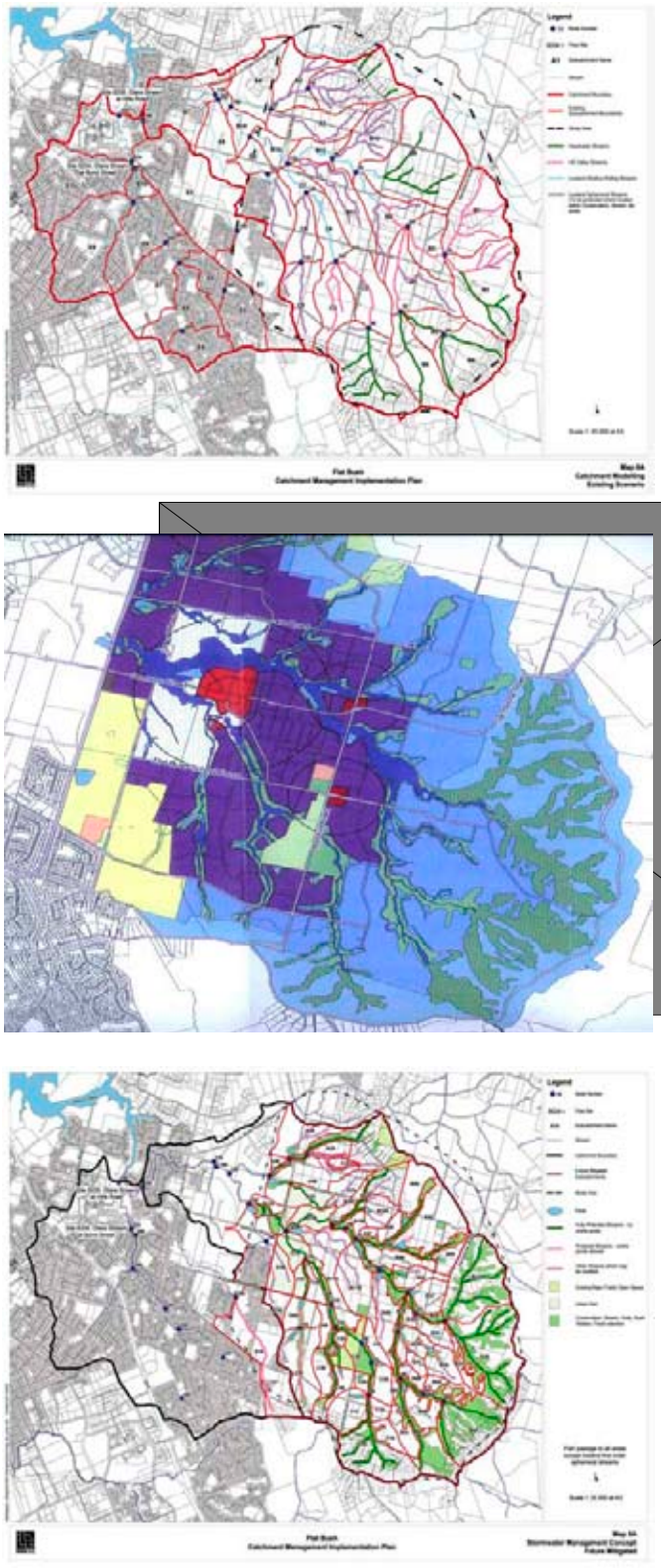
A watershed is a geographical area from which stormwater runoff, and the pollutants and other materials borne by that runoff, drain to a down gradient central collector such as a stream, lake, or estuary. As such, a watershed is often named for the water body that conveys this runoff at the outlet. The term watershed means just that – an area of land that, from rainfall, produces or "sheds" water in the form of runoff and delivers it to a specific point. Figure 12-1 shows a series of watershed maps: the first details ephemeral and perennial streams, the second shows intended land use, and the third shows riparian cover and locations of stormwater wetlands.

A watershed's size is in part defined by the topography of the surrounding land and upon the location chosen as its outlet. Often the latter reflects a point where runoff rates and/or sediment or other pollutant loadings need to be computed. Depending upon the resultant size, a watershed may also be described as a drainage area or catchment, although these terms normally apply to areas smaller than those typically considered watersheds. As the larger of these areas, watersheds can be considered to be comprised of a collection of drainage areas, catchments, or subwatersheds. A watershed may alternately be referred to as a basin, particularly by federal agencies such as the U.S. Army Corps of Engineers. Whatever term is used, the general concept remains the same: When a raindrop falls within a watershed and produces runoff, that runoff will ultimately pass through the watershed's outlet.

What is Watershed Management and Why Should it be Done?

If the goal of an urban stormwater runoff management program is to address a runoff-related problem or protect a water resource at a particular location, and a watershed represents the entire area of land that contributes runoff to that location, using a plan that addresses the problem or protect the resource that is based upon managing runoff over the entire watershed is a technically sound strategy. By basing the plan on the entire watershed rather than a single location or portion

Figure 12-1: Watershed Maps Showing (From Top) Stream Networks, Land Use and Riparian Corridors, and Stormwater Practices



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within it, all of the relevant factors contributing to the problem can be included in the planning process. In addition, this approach increases the number of potential solutions to the problem or threat.

This logic can be used to both describe what watershed management is and why it should be pursued. Basing urban runoff management decisions on the entire watershed provides a flexible framework for considering and integrating all pertinent factors and resources into both the analysis of runoff-related problems and threats and the development of their solutions. Watershed management also allows multiple problems to be prioritized and multiple solutions, including their development, implementation, and funding, to be sequenced in the most efficient and effective manner. And where alternative solutions exist, watershed management provides the framework by which they can be comparatively evaluated using the broadest set of factors.

Similarly, if a regulatory, policy, or program approach to a problem or threat is considered to be the most effective solution, watershed management offers the most comprehensive and effective means by which such solutions can be identified, developed, and implemented. Such results cannot be achieved using a localized, piecemeal, or site-specific approach. As previously discussed in Chapters 1 and 2, this is particularly true of the EPA's TMDL approach which defines the pollutants of greatest concern and then uses regulations and discharge permits to achieve required pollutant load reductions from dischargers. Such a result can be achieved only through a watershed-based analysis and implementation effort.

In light of all the above information, it may be more intriguing to ask why watershed management should not be done rather than why it should be.

Watershed-based urban stormwater management continues to expand, a trend that is expected to continue in the future as more runoff-related issues are identified and our watershed management skills and databases increase. The next section of this chapter will discuss those urban runoff- and water resource-related areas that either should or could be addressed from a watershed management perspective.

The Watershed Management Universe

Runoff Quantity Considerations

Runoff quantity impacts have been addressed with a watershed management approach for several decades. Watershed managment was initially used to control or reduce flooding, but now is commonly employed to control development-induced impacts caused by increases in pollutant loading, peak runoff rates and volumes. Such controls have been achieved through structural, nonstructural, and regulatory measures. The various watershed management plans described in detail in Chapter 10 are all examples of this proven use of watershed management.

More recently, watershed management tools have been increasingly used to investigate how to protect stream channels from erosion due to the increased runoff volumes resulting from watershed development. Many questions regarding the mechanisms by which such erosion occurs and the runoff controls required to prevent it, remain unanswered and further research and analysis are needed. Nevertheless, there is growing consensus that a stream channel's physical structure can only be protected if watershed development is designed to occur without causing significant change in watershed runoff rates and volumes. Such results are the fundamental goal of the newer low impact design approaches discussed in detail in Chapter 8. Developing the site design strategies, measures, and requirements necessary to achieve these results can clearly best be done on a watershed-wide basis. Attempting to develop and implement them on a site-by-site basis will be far less successful, and in many cases will not work.

Runoff Quality Considerations

Water quality problems and threats are also best addressed on a watershed basis. This approach can not only best identify the overall extent and severity of the problem or threat, but it also has the greatest potential to identify all of the relevant sources or causes. For example, if downstream water resource protection damage is the problem, such as in the Chesapeake Bay and Puget Sound runoff management programs,

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watershed-based studies are necessary to determine all causes of degradation. Once such a determination has been made, the same watershed-based framework can be utilized to develop a comprehensive range of structural and nonstructural solutions, oversee their implementation, and administer their financing, operation, maintenance, and/or enforcement.

Addressing the causes or sources of runoff quality problems can be used to further illustrate the power of watershed management and its advantages over a limited, site-by-site or piecemeal approach. For example, watershed-based studies of the Upper Waitemata Harbour in New Zealand (NIWA, 2004) demonstrated how a single sub-watershed discharging to the harbor estuary accounted for virtually all of the zinc that was damaging this important aquatic resource. This knowledge will allow the development of a focused zinc control program in the subject watershed only, thereby avoiding the considerable time, effort, and other resources that would have been wasted developing and implementing similar controls throughout all of the estuary's watersheds. Furthermore, the framework established by this watershed management approach can further be used to determine the optimum combination of structural, nonstructural, and regulatory solutions to address the zinc problem. Once again, such results can only be achieved by utilizing a watershed-based approach.

Wastewater Considerations

Watershed management principles and capabilities can be extended to address both wastewater and water supply issues. This applies to both combined sewer overflows (CSOs) and combined sewer systems (systems where both sanitary and stormwater are conveyed to a plant for treatment). In both cases, a watershed-based approach is essential to addressing runoff quality or water body impacts. In the case of a CSO, segregating stormwater from wastewater would eliminate the discharge of untreated wastewater into the receiving system. As for combined sewer systems, separation of wastewater from stormwater would then allow smaller stormwater flows to discharge untreated where they would have gone to a wastewater treatment plant. Very clearly, prioritization needs to be made on water quality issues when combined sewers are considered. In addition, it is absolutely necessary to include consideration of combined wastewater systems in a watershed-based context if the goal is downstream water resource protection. If funding is limited to a given level, a greater return on the expenditure may be realized by prioritizing separation of combined systems ahead of implementing nonpoint source controls on urban area runoff. Such decisions can only be made using a watershed-based approach.

Similarly, the use of separate wastewater systems is important when considering watershed management. The frequency and volume of overflows from a combined sewer system may have a significant effect on receiving water quality. If the combined wastewater and stormwater system is so undersized due to both system age and ongoing watershed urbanization that damaging overflows occur on a frequent basis, upgrading the combined sewer system to reduce the frequency of such overflows may in fact be the best approach to improving receiving water quality. New development or redevelopment in such a watershed may still have stormwater requirements placed on them, but the expenditure of public funds would target the combined sewer system upgrade. Once again, such solutions can only be identified and developed through watershed management.

Water Supply Considerations

There are also situations where continuing watershed urbanization can have significant water supply impacts and where a watershed management approach can best be used to address them. For example, if current public water supplies are inadequate and the expansion of the system is either infeasible or too expensive, the new development will need to rely on on-site groundwater sources of potable water. At such developments, both groundwater recharge to increase the supply of water and water reuse to reduce its demand will help to ensure the success of this water supply strategy.

In addition, both water reuse and groundwater recharge can not only be a valuable water supply tool but they can also reduce development site stormwater runoff volumes. For example, approximately 60 percent of average annual residential water use is for toilet, laundry, and outdoor use. If the water needed for these activities could be obtained from roof runoff that was captured and stored, it would be removed from the stormwater drainage system. Such reuse then becomes a volume reduction practice in addition to reducing

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reliance on potable water. Runoff volume reductions can also be achieved if a portion of a development's site runoff can be recharged into the groundwater.

The effectiveness of such practices can best be evaluated through a watershed management approach that includes consideration of both public water supply and stormwater management needs. Such a watershed-based approach could then include cost considerations to determine whether such on-site measures could effectively replace the need to expand off-site public sources. Benefits of water reuse can become even greater for commercial or industrial sites which traditionally use significant amounts of water. The historic provision of cheap, high-quality water has limited consideration of water reuse in the past, but the additional need to consider volume reduction practices on a stormwater program should lead to greater consideration of water reuse in the future. This is only possible if the issue is considered from a watershed management perspective.

Watershed Management as a Means to Managing Growth

Historically, stormwater runoff impacts have often been considered as simply the effects of land development and watershed growth that can be addressed through management practices after such growth has been planned. This is based on the expectation that stormwater management practices can be relied on to adequately mitigate the effects of almost any type and degree of watershed development. This expectation has led many planners to exclude considerations of stormwater management capabilities and limitations from land development and growth decisions and to include them in the planning process only as a response to those decisions. However, recent studies, including those detailed in earlier chapters of this book, have highlighted the limitations of stormwater management and have demonstrated that adverse, long-term impacts on receiving waters due to watershed development can occur despite the level of stormwater management controls applied to that development. In such cases, the abilities and limitations of stormwater management practices must be considered an integral part of land development and watershed growth decisions and not simply turned to as a response after the fact.

In addition to the specific examples described in the research, there are general examples that highlight this problem. For example, the headwaters of a watershed have very steep slopes that significantly reduce the range of effective stormwater management practices that may be used to address the impacts of development. In other portions, clay soils may preclude the use of infiltration or other runoff volume management practices that would ordinarily be expected to prevent increases in runoff volume. Or conversely, highly permeable sandy soils in any area may achieve significant aquifer recharge and should be left undisturbed rather than built upon and mitigated by stormwater management measures that cannot achieve the same long-term recharge as the existing, natural systems. If such stormwater management factors are not identified and considered during the development of master plans, zoning ordinances, and other land use planning processes, the final development types and levels authorized by those processes may have adverse impacts that exceed the capabilities of the available stormwater management practices. However, if such factors are identified and included in the land use planning process, such impacts can be avoided through the selection of development types, levels, and locations that can be controlled by available stormwater management measures. Unfortunately, land use and development decisions are often reached without regard for stormwater management possibilities and constraints. This can lead to land use decisions that will have severe and even irreversible impacts that could have been avoided.

During land use planning efforts for a given watershed, decisions should be made as to what level or degree of development, if any, can be allowed to occur with a reasonable expectation that the available stormwater management practices in the watershed will be able to manage the resultant adverse stormwater impacts. Only those development levels and types that are controllable by available stormwater management practices should be allowed in the watershed and included in the watershed's land use plans and regulations. Such land use planning and regulation decisions can only be made through a watershed management approach.

Finally, the watershed management approach provides planners and regulators with both the opportunity and framework to combine stormwater management considerations with other traditional land use planning factors, such as:

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- Wetlands;
- Floodplains;
- Existing vegetation;
- Soils;
- Slopes;
- Riparian corridors;
- Historic or cultural sites; and
- Terrestrial ecology and landscape form.

Using New Development to Address Retrofit Needs

Typically, the selection of required stormwater management practices for a proposed land development is based only on preventing the adverse runoff impacts of the development itself. While this may prevent a worsening of existing runoff quantity and quality problems, it does not address already existing quantity or quality problems in the watershed and its water bodies. Addressing these problems typically requires retrofits in existing developed areas. However, due to a number of factors, including lack of available space, higher property values, and greater design and construction constraints, stormwater retrofits can be very difficult, expensive, and disruptive to implement.

However, watershed management planning can provide both land developers and runoff program managers with the tools and framework to incorporate retrofit requirements into the design of a proposed development's on-site stormwater management practices. While this will typically require a larger sized practice or a greater number of practices to be incorporated into the proposed development's design, many of the design and construction complexities normally encountered in retrofits can be avoided. In addition, design and construction of a single, larger on-site stormwater management practice can usually be achieved with less cost and required land than a standard on-site practice combined with a separate, off-site retrofit practice. While the program would be responsible for compensating the developer for the extra design, construction, and land costs of the larger practice, the watershed management approach could also serve to establish a watershed stormwater utility or other assessment program that could be used to generate the required compensatory funds.

While combining retrofit measures with those required for new land developments can appear to be a logical and effective way to address existing runoff and water resource problems, the decision to do so can be very complex and require consideration of many on-site, off-site, and program-related factors. However, it can be seen that such decisions can be much better supported by a watershed-based urban runoff management program than one based upon individual development sites.

In conclusion, an effective urban runoff management program must be pragmatic and based on technically sound data and definitive objectives. The program not only needs to be aware of the required improvements, but where are how those improvements can best be accomplished. This is especially true in an existing urban environment where retrofit options are limited and expensive. These need-to-know answers can best be obtained through a watershed management approach.

Watershed Management Decisions and Considerations

While extolling the capabilities, benefits, and even virtues of watershed management may not require a significant commitment of time, money, and effort, developing and operating an urban runoff management program based upon a watershed management approach certainly can. This is not unusual, since the aspects that yield the most comprehensive and beneficial outcomes, whether they are programs, structures, products, services, or relationships, are usually those that require and receive the most input. Nevertheless, it would be helpful at this point to review some of the important decisions and commitments that must be made to achieve an effective and efficient watershed management program. These range from issues that must be addressed both prior to and following program startup. Unfortunately, there have been far too many instances where a watershed study was completed and then put on a shelf and never touched again. There are a number of issues that need to be considered before going down the watershed management path.

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Watershed Model Selection

As discussed in detail in Chapter 2, the actual process of converting rainfall into runoff is extremely complex. This complexity increases when one begins to include not only the rate or volume of runoff but also pollutant loadings and impacts to water resources. In light of these complexities, the actual physical processes are replaced with mathematical equations and models that are used to predict the results or outcomes of the real processes under various conditions, assumptions, and constraints. Such models may be based upon a single real or hypothetical rainfall-runoff event or a long, continuous series of actual events based upon a similarly long event data record. Since the equations and algorithms that a model is based upon are only approximations of the actual rainfall-runoff processes, the results of actual runoff events are typically needed to adjust and check or, as modelers say, calibrate and verify the model's predictions in order for it to be reliable.

Typically, the complexity of the actual processes also limits the scope or predictive capabilities of rainfall-runoff models. While large advances in model theory and computing power have been made in recent years, along with advances in the range and precision of available databases, there are still relatively few computer models that even attempt to simulate more than a few rainfall-runoff processes or parameters. Those that do sometimes suffer from the effort to predict only a limited range of parameters. For every broad-based computer model that can predict a large range of parameters, there are easily a half dozen more narrowly focused models that can more accurately predict a specific parameter in that range.

Due to the amount of data that must be processed and the number of equations that must be solved, virtually all rainfall-runoff models are run or exercised (another modeling term) on computers. In addition, virtually all watershed management efforts require the use of one or, at times, multiple computer models in order to accurately and efficiently analyze all of the pertinent factors, processes, and conditions. As a result, selection of the appropriate computer model or models is one of the most important decisions associated with watershed-based runoff management. And since model selection typically occurs in the earlier phases of the process, there is generally a limited amount of watershed, resource, or problem information available to base model selection on. As a result, successful watershed modeling efforts are typically performed by those with prior knowledge of a particular model's capabilities, requirements, and limitations and extensive experience in its use.

In selecting a computer model for a watershed management plan or program, the selection process should be relatively straightforward. Based upon a desire to produce the best possible plan, the selected model should be the one that produces the best results. The difficulties, however, come in defining what constitutes 'best', a quality that can be measured from several different reference frames. Some of these include:

- **Applicability and accuracy of predictions** – The selected model must be able to predict the answers or outcomes required by the watershed plan with the required level of accuracy. If, for example, the goal of the plan is to reduce annual TSS and nutrient loadings in runoff, the model must be able to predict these parameters in this time frame.

- **Soundness of model theory and equations** – While the accuracy of model predictions can be checked to some extent against real event data, such checks are usually limited to a relatively narrow range of parameter values and input conditions. Therefore, they cannot be solely relied upon in judging a model's accuracy. The model's theoretical basis, assumptions, equations, and algorithms must all be scientifically sound, reliable, and defensible.

- **Extent, availability, and cost of required input data** – In watershed modeling, data needs can be measured both in terms of the cost required to obtain it and the relative value of the results it produces. With regards to required data, model selection must begin with consideration for overall data acquisition costs in order to ensure that such costs are compatible with the overall watershed management plan budget. Next, the relative value of such an expenditure must be evaluated to determine if the value of the results produced by the acquired data is worth the cost of acquisition. At this point in the model selection process, model input data can be considered an investment in the model's output. Is the cost of the investment in obtaining the required data worth the value of the answers returned by that investment? Unfortunately,

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many well-intentioned modeling efforts are thwarted by excessively high data acquisition costs or diminished by the lack of value produced by that expenditure of program or plan funds.

- **Model familiarity and ease of use** – Of these two model selection factors, model familiarity may be the most important, since a modeler's familiarity with a particular model is usually reflected in the ease with which they use it. However, model familiarity does not only pertain to data acquisition and input requirements, model operating commands, and output options and review procedures. It also includes knowledge of a model's capabilities, limitations, computer requirements, operating bugs, accuracy, precision, and flexibility, as well as the ability, effort, and techniques required to efficiently calibrate and verify it. In other words, model familiarity may be described as the ability to know whether a model's predictions are acceptably accurate and, when they are not, to know how to improve them. Ease of use should also not solely be considered in terms of the number and simplicity of operating commands. Since most watershed-based rainfall-runoff models require a significant amount of geographic data such as subwatershed sizes, land uses and land covers, soil characteristics, slopes, and pollutant loadings, data input can involve considerable effort unless it can be automated. Similarly, model output analysis can be cumbersome and costly unless the model includes sufficient analytical tools, or results can be easily exported to other analytic software.

From the above, it can be seen that the best model for a watershed management plan or program is the optimum combination of capability, accuracy, data needs, ease of use, and past experience. In more general terms, the best model can be seen to be the one that meets output needs without being overly complicated or data-intensive.

Finally, it should be noted that, while model selection typically occurs near the start of a watershed management effort, it should not be the first activity. Too many watershed studies or management plans have begun with model selection, followed by a determination of the study's goals or required answers. In such cases, the answers sought by the study end up being determined by the model's capabilities. Instead, the goals, objectives, and desired answers should be determined first, followed by the selection of the best or most appropriate model capable of achieving them.

Data Needs

Closely linked to model selection is the data required to drive the model or to achieve the level of accuracy that is needed for a required or desired output. As noted above, data acquisition can be an extremely time-consuming and expensive component of the overall watershed planning effort. It is essential to know the data needs of a specific model before initiating the watershed modeling effort. Questions need to be answered regarding the general availability of required data and how time-consuming and costly its acquisition will be.

Typically, types of required watershed model data include the following:

- Rainfall;
- Topography;
- Watershed boundaries;
- Soil and subsurface characteristics;
- Existing and future land use and land cover;
- Runoff conveyance systems and outfalls;
- Wastewater overflow locations and details;
- Existing stormwater management structures;
- Existing water quality data;
- Groundwater levels; and
- Receiving water conditions and characteristics.

In performing the watershed study or analysis, it may be necessary to link watershed conditions with the receiving water responses to determine the effectiveness or benefits of various stormwater management or treatment options. This can be a complex process that may require significant receiving water data from which to predict results. For example, in Figure 12-2, samples of sediments in estuarine areas of the Waitemata Harbour and Manukau Harbours in Auckland, New Zealand were first obtained to provide historic rates of accumulation of metals over time. Then toxicity levels were determined along with trends toward increasing toxicity over time. Figure 12-3 shows changes in zinc and lead over time. Both figures demonstrate the concern that must be given to reducing zinc and copper levels in urban stormwater. Failure to implement a zinc and copper reduction program will cause

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environmental problems in the future. The second figure also shows the reduction in lead in urban stormwater, which probably relates to elimination of lead in gasoline. Based on this information, watershed modeling of the pollutant inputs lead, zinc, and copper was used to both predict future impacts and assess the ability of various stormwater management practices, including source control and runoff treatment measures, to prevent them. This modeling effort was then used to determine the level of pollutant reduction needed to alter the rate of pollutant accumulation in the harbors. While this was a very expensive modeling approach, it was justified first by the need to reduce or reverse pollutant concentrations in bottom sediments and second by the fact that the model could also be used to identify the necessary pollutant control approaches and implement them in a cost-effective manner based upon derived benefits.

Data Accuracy

Modeling in general and watershed modeling in particular are only as good as the data used in the model. Input data errors can cause significant errors in model output. Since these model outputs could result in the expenditure of millions of dollars for implementation and additional millions for subsequent operation

Figure 12-2: Sediment Sampling Program for Waitamata and Manukau Harbours

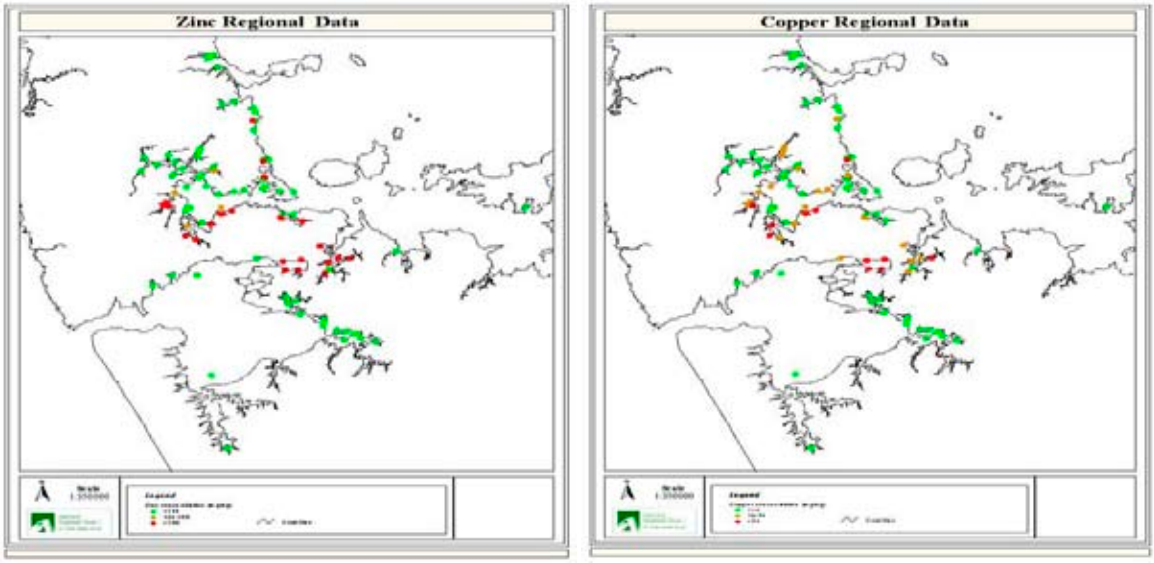
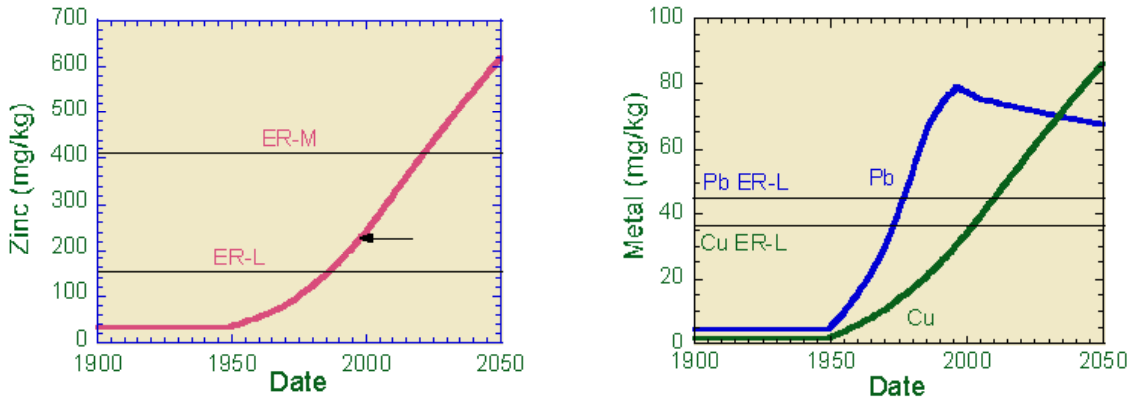


Figure 12-3: Consideration of Zinc, Lead and Copper in a Receiving Environment Showing Concentration Changes Over Time



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and maintenance, input data must be accurate if such amounts are to be well spent. Required input data accuracy can be determined by the extent to which its variation will affect model results.

From a review of past watershed modeling efforts, certain types of model inputs that require improved accuracy have been identified. These include unit runoff pollutant loadings for various land uses and pollutant removal performance data for various stormwater treatment practices. Available data for these two key model input parameters are highly variable and, as a result, can usually only be relied upon to make planning level decisions. Land use loading data is particularly variable and can be read interpreted differently by different people. Experience is the best guide in determining unit loadings for various land uses, so it is important to involve experienced individuals in this component.

In addition, the lack of common input data collection and reporting protocols has meant that much data is not transferable from one watershed study to another. While this situation has been improving recently, it should still be considered indicative of general watershed study conditions. The American Society of Civil Engineers (ASCE) Stormwater Database (www.bmpdatabase.org) is a good start in terms of a consistent protocol for collection of performance data for various practices. At the present time, its data should be considered preliminary, and practices such as constructed wetlands will have variable performance data depending on location.

Another area where input data is extremely limited is the combined effect of runoff treatment practices arranged in series and the performance benefits that can be gained by that approach. Many stormwater management programs, publications, and experts have promoted this stormwater "treatment train" approach for many years. However, we still have only a general understanding of the performance of such an approach, and while we believe in its quality, we need more quantitative information to gain a better understanding of it, particularly for modeling purposes.

A Stepwise Approach Toward Comprehensive Results

It is unrealistic to expect to solve all runoff and water body quantity and quality problems through a watershed management process in the short term. Improvements to actual runoff and receiving water conditions will generally require an iterative process. However, this reality does not prevent significant progress being made in the short to medium term as priorities are identified and addressed through watershed management efforts. Additionally, a long-term vision for watershed-based stormwater management needs to be identified.

Furthermore, since large-scale land development activities have occurred for at least the last century in many urbanized areas, it may similarly have taken a hundred years for receiving waters to reach their present impacted condition. Therefore, it appears reasonable to expect that it will take considerable time for these waters to show significant recovery. For example, many older urbanized areas may still have galvanized metal roofs that, until replaced with a more runoff-neutral material, will continue to be a significant source of zinc to a receiving water and its aquatic environment. Sources of such pollutants need to be identified and strategies developed to address them. Some strategies may be placed in the 'too hard' basket for now and dealt with in the future, while others can be addressed immediately, depending on their relative importance and the availability of funding. Once an overall watershed management plan has been developed, an implementation strategy must be developed with public input to determine the degree to which improvements can be made and when.

Throughout this overall development and implementation period, small steps can be taken to make improvements or reduce the rate of system decline. While such steps are being taken, more information on both impacts and planned solutions will become available, along with new tools or approaches that may augment already identified actions. In other words, it is important to continually take manageable steps toward comprehensive watershed management and not delay the entire process by placing things in the 'too hard' basket. An initial, limited watershed management effort can provide information on the magnitude of a runoff or receiving water problem as well as on the next steps necessary to address it. While certain components of an overall watershed management planning effort may appear too complex or impractical to be implemented in short term, they should nevertheless be developed whenever possible. Their implementation may become more feasible over time as practical, technical, institutional, and social obstacles are overcome by increased research, knowledge, interest, and funding.

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The Need to Update

Development of a watershed management plan and the implementation of its recommendations should only be considered the first step toward receiving water protection or restoration. A second, more difficult and less recognized step is the periodic update of model inputs and outputs to evaluate potential and necessary changes to the plan. Regardless of the accuracy of the original land use data, it is reasonable to expect a different and perhaps greater degree of land development than initially considered.

In addition, initial assumptions about impervious surface coverage will probably have to be adjusted upward over time. Experience has shown that residents can be expected to erect sheds, widen driveways, construct house additions, and create an impervious surface creep above the levels initially used in the watershed management plan development. Furthermore, land that was expected to remain rural may have experienced urbanization sooner or at a rate faster than initially anticipated, and model updates will have to be performed in order to take the effects of these land use changes into account. Without such updates, an initial model can be completed and its results published and acted on, only to become outdated along with the plan it yielded in a couple of years' time.

Therefore, it is important that sufficient funding also be allocated for future updates to ensure that both the model and the plan remain current and effective. If such funding cannot be provided either in the initial project budget or in subsequent annual plan operating budgets, the model's accuracy and the plan's effectiveness will be diminished.

Gaining Acceptance

Once a watershed management model is developed and a range of implementation options identified, it is important to gain plan acceptance from those who will be impacted by such implementation. This could involve residents, farmers, industries, transportation agencies, and local, county, and regional governments. To accomplish this, there will have to be significant public education and public input activities throughout the watershed management plan's development.

This acceptance is necessary due to the nature of the required implementation measures. While the plan may target a specific industry or sector of the watershed in which change can be achieved through the regulatory process, in many stormwater management situations it will be necessary to change human behavior in order to achieve plan goals. And even where plan implementation can be achieved solely through regulation, it will still be necessary to have public funds allocated to developing, administering, and enforcing such regulations. Approval of such allocation and expenditure will proceed more smoothly and with a greater chance of success if those with an interest or stake in the plan's outcome are informed and involved. If the plan's implementation is to proceed as effectively and efficiently as possible, fundamental questions such as the following must be addressed during its development stage:

- Why is there a problem?
- What is causing it?
- What steps are necessary to correct it?
- How much will it cost?
- What will the outcome be?
- How will I be affected?

The advantage of public involvement throughout plan development is that community expectations can be a significant motivator in getting plan recommendations funded or regulations implemented. Seeking out and involving the plan's stakeholders is the key to simplifying plan approval and implementation.

Total Maximum Daily Load (TMDL)

Total maximum daily loads or TMDLs are tools for implementing state water quality standards and management/restoration goals for a specific water body throughout its watershed. A TMDL is an implementation plan that identifies the allowable loading of a specific pollutant a water body can receive from both point and nonpoint sources without violating state water quality standards. Selection of appropriate TMDLs for a water body is based on the relationship between pollutants from both point and nonpoint sources in the watershed and instream water quality conditions. Unlike technology-based stormwater best management practices (BMPs), which ordinarily do not have specific

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numeric requirements or performance values, the use of TMDLs provides the basis for state governments to establish specific numeric pollution controls for a water body. And since the development of TMDLs requires an understanding of pollutant sources and loadings throughout the water body's watershed, they also provide states with both the technical and regulatory basis to undertake watershed-based stormwater management.

The TMDL approach has four major features:

- Targeting of priority problems and pollutants;
- Endorsement and ecouragment of high levels of stakeholder involvement;
- Development of integrated solutions that make use of the expertise and authority of multiple agencies; and
- Measurement of success through monitoring and other data gathering.

The TMDL process represents a view of water quality protection that considers watersheds to be the fundamental unit by which to manage water quality.

The TMDL approach to stormwater management has existed for a number of years, having originally been identified in the original 1972 Clean Water Act. For a number of reasons, including the 1999 promulgation of the EPA's Stormwater Phase II Final Rule, the TMDL approach has recently achieved much higher priority in both national and state water quality programs than it had in the past. There are a number of TMDLs that have been established for a range of water bodies around the country that are now serving as templates or models for future ones. The TMDL approach is evolving fairly rapidly, with new guidance information becoming available on a regular basis.

TMDLs are established for impaired water bodies where standard, technology-based stormwater management measures (i.e., BMPs) are not considered capable of correcting the impairment and restoring the water body to required levels. As contained in Section 303(d)(1) of the Clean Water Act and 40 CFR Section 130.7, where technology-based limits or other pollution control requirements (i.e., stormwater BMPs) are not sufficient to achieve compliance with water quality standards, a TMDL must be established.

TMDL determination must also include a margin of safety that, as described in 40 CFR Section 130.7, is intended to address "any lack of knowledge concerning the relationship between effluent limitations and water quality." This margin of safety may be provided in two ways:

- By using conservative assumptions in calculating the loading capacity and wasteload allocations; or
- By establishing wasteload allocations that are lower than the defined loading capacity.

When evaluating the need for a TMDL for a water body, the first step is to determine whether a technology-based approach will be adequate to ensure that water quality standards are met. This determination will typically be based on available data regarding pollutant levels in the water body and a determination of which pollutants exceed water quality standards. Water quality standards can be considered to represent the water body's assimilative capacity, or the amount of pollutant a water body can assimilate without causing or contributing to a violation of water quality standards.

The next step is to allocate the water body's total assimilative capacity for a particular pollutant between point and nonpoint sources of that pollutant in the watershed. This allocation process must take into account natural background loadings and, as discussed above, include a margin of safety to account for any uncertainties. The resultant TMDL for that pollutant is the sum of the nonpoint, point, and background loadings, and a margin of safety as illustrated in the following equation:

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

where:

LC = Loading capacity

WLA = Wasteload allocation (for point sources)

LA = Load allocation (for non-point sources)

MOS = Margin of safety.

TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. The final TMDL is then used to develop numeric discharge permit limitations for point dischargers and pollutant discharge standards for nonpoint sources. The nonpoint discharge standards based upon the TMDL will typically be technology-based, although numeric limitations may be justified in certain instances. The relative pollutant contributions from point and nonpoint sources are a key factor in TMDL development, and their determinations may require a significant data collection and analysis effort.

As with all watershed-based management efforts, the availability of resources is a major factor in TMDL development. The EPA has estimated the costs to imple-

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ment required TMDLs to range from approximately $1 billion to $4.3 billion per year, depending on the efficiency of TMDLs. Additional EPA cost estimates are summarized below:

- The cost of measures to implement TMDLs for presently identified impaired waters is estimated to be between $900 million and $2.3 billion per year if the problem is approached through the implementation of TMDLs that strictly seek the lowest cost alternatives among all sources of the impairments.
- If the TMDL program was implemented based on an assessment of the reduction needed for the water body and an allocation that includes all sources of impairment, without strict attention to the most cost-effective allocations, these costs would be expected to rise to between $1 billion and $3.4 billion per year.
- In the event that the impaired waters were addressed using a least flexible TMDL scenario, these costs might rise to as high as between $1.9 billion and $4.3 billion per year. In this unlikely scenario, states would simply tighten discharge permits and other national requirements, regardless of the individual contributions of different sources, through a uniform and inflexible approach. This scenario would not benefit from the site-specific tailoring to local conditions that should result from development of a more careful allocation.
- When a moderately cost-effective TMDL program that looks for readily available, cost-effective solutions is used to allocate pollution reduction responsibilities, the costs for both point and nonpoint sources are reduced.
- The nonpoint pollution control measures expected to be implemented under each option would generate some partly offsetting cost savings (e.g., by reducing the frequency of application and the amount of fertilizer used), but these specific savings could not be calculated.

It must be clearly stated that, while it is certainly expensive to address our runoff pollution and water body impairment problems through watershed-based planning and management programs, it will be even more expensive not to follow this approach. The long-term health and well-being of our water resources and, therefore, our society depend on making intelligent decisions and taking effective watershed-based action today.

Regulatory Framework

Once the watershed modeling has been completed and appropriate regulations and requirements developed, a framework for administering these findings must be developed. Presented below are brief discussions of a number of possible regulatory approaches.

Voluntary Compliance

This approach focuses primarily on educating the watershed's population to encourage them to modify behaviors or practices that are causing, contributing to or exacerbating the identified stormwater problems. It may also include cost-sharing assistance if such funding is available. This approach has historically been used to reduce runoff pollution from agricultural lands through changes in farming practices and materials. It has also been used in urban and suburban areas, where residents are asked to reduce their individual pollution contributions by modifying such activities as vehicle washing, hazardous material disposal, lawn care, waste recycling, and litter disposal. Educational measures can include brochures, videos, seminars, demonstrations, group meetings, and other outreach measures and activities.

Permit Requirements for Point Source Discharges

This is a traditional regulatory approach for wastewater discharges that can be adapted to a watershed-based runoff management program. The TMDL program discussed above is an example of how permit limitations for individual point dischargers can be part of a watershed- based approach to runoff management and water resource protection.

This is also an area where pollution trading can provide significant benefits. Where one industry may have great difficulty meeting their discharge requirements, they may trade with another one in the watershed that has excess compliance capacity. This type of cooperation

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is only possible in a watershed management situation in which benefits of such an approach can be identified and quantified.

Requirements for Land Development

Many states and local authorities have watershed-wide stormwater management requirements for proposed land developments. These requirements can be considered a baseline for development in general, but those general requirements may not be adequate to protect a given resource or watershed receiving system. A general requirement such as an 80 percent reduction in total suspended solids may not provide sufficient protection for a particularly sensitive receiving environment. It may also not provide protection if pollutants other than sediments are a particular concern. For example, a BMP that focuses on capturing sediments may not capture a sufficient level of metals or remove an adequate amount of dissolved nutrients to protect or improve downstream receiving systems.

Since permit requirements based on a watershed management plan are clearly based on a cause/effect approach, they provide a greater certainty that the program goals may be attained. This makes them defensible to those impacted by them.

Source Controls

Another technique that can be used to fulfil the pollutant reduction requirements of a watershed management program is the elimination of the pollutant at its source. An excellent example of this is the banning of phosphorus in laundry detergents in areas tributary to the Chesapeake Bay. Another example from Auckland, New Zealand is based on a roof materials runoff study that identified soluble zinc as a significant pollutant from various roof types. A policy requiring treatment of runoff from such roofs at new development sites quickly led to a shift away from those roof types to more benign roofing materials. In a related way, reducing the extent of new impervious surfaces such as streets, sidewalks, and parking lots can be an effective source control approach to reducing downstream flooding and related runoff quantity impacts.

Development Fees

Under this approach, fees from development and redevelopment projects are collected to provide a funding source for projects and activities identified in the watershed management plan. The approach has been used for many years and still remains a viable implementation option, particularly in watersheds with extensive existing urbanization and associated runoff impacts. It necessitates taking the water quality impairment study to a more refined level where specific projects are identified and await funding. It is important to clearly identify those projects for which the fees will be spent in the watershed management plan to avoid the possibility of the fees being used for other, non-stormwater purposes.

General Discussion

In addition to the approaches discussed above, there are certainly other techniques and approaches that can be used to implement the requirements of a TMDL or watershed management plan. Some or even all of them can be used in combination in a specific watershed. Furthermore, approaches such as source controls may be used at a number of levels that involve regulation of specific products, general population education, and industrial site pollution reduction practices.

If the watershed is already highly urbanized, developer levies may be a significant means of funding existing stormwater system improvements. Retrofit and regulations for redevelopment may include treatment or source controls based on the watershed management plan that help restore site runoff quantity and quality.

Regulation of new development in a relatively undeveloped watershed presents a good opportunity to use the results of a watershed management plan to prevent problems from occurring in the first place. Determining and prioritizing where urban growth can best occur, in conjunction with the protection of existing natural features and aquatic resources such as streams and wetlands, is key to downstream resource protection. This approach is neither pro- nor anti-development; it is based on the concept that better balance between development and environmental interests may be achieved if watershed-specific issues are considered in conjunction with development approaches.

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The Future

Clearly, we are following a fairly steep learning curve in developing new approaches to stormwater and aquatic resources issues. We have evolved from a position where runoff was considered the common enemy to the widespread use of runoff treatment practices, source controls, and regional facilities. However, there are still many unanswered questions, and we must maintain our desire and ability to continually strive for improvement. Fortunately, as discussed below, there are a number of recent advances and improvements in our ability to effectively manage urban runoff that bode well for the future.

Availability of More and Better Tools

Computer-based watershed modeling of both runoff quantity and quality is evolving rapidly with excellent recent advances. More programs are now capable of considering stormwater practices in series or performing continuous, long-term rainfall-runoff simulation. For example, recent work at the Cooperative Research Centre for Catchment Hydrology in Australia has produced the Model for Urban Stormwater Improvement Conceptualization or MUSIC. This model provides a flexible tool for watershed modeling, considers stormwater practices in series, and is now being updated to consider whole or life costs for stormwater management practices.

Another computer model that has evolved significantly over the past five years is the Source Loading and Management Model (SLAMM) developed by John Voorhees and Robert Pitt and maintained by USGS. This model was originally developed in the 1970s to gain a better understanding of the relationship between sources of pollutants and runoff quality. It has been continually expanded since and now includes a wide variety of source area, conveyance system, and outfall control practices.

Both of these models are supported by their developers, which is an important consideration in model selection. At this time, both are recommended primarily for planning purposes, but their accuracy and output detail are expected to increase through continued research and development.

Accuracy and Consistency of Data

In addition to improved computer models, it is vital that our store of available data continue to increase and improve. Too often, money can be spent on plan implementation but not on data collection. Every year, more streamflow gages are discontinued, even though the data they provided was extremely valuable. The same applies to water quality and aquatic resource monitoring.

It is also important to have improved consistency in the data that is collected. As noted earlier, the ASCE has made an attempt to provide a protocol for the collection of data related to stormwater practice performance, but similar protocols need to be used for water quality characterization and receiving water evaluation. We will only be able to maximize the value of the data that is collected if we increase its consistency and reliability.

One way to achieve this is to not cut corners on data collection for a specific watershed study. Both rainfall and runoff data must be representative of the entire watershed and not merely portions of it. In data collection, you get what you pay for, and data collected for a specific watershed study must be accurate enough to ensure confidence in the results. There may come a time when data collection needs may be considerably reduced as past experience and new understandings combine to produce new modeling techniques that are less data-dependent. Until that time, however, we have to continue to pursue necessary data collection so that answers may be provided with an acceptable level of confidence.

Linkage of Cause and Effect

If we aggressively implement source control throughout a watershed, as well as all of the stormwater practices that we want to, what will be the impact on downstream water resources? While there are some situations where we know the answer, there are many others where it is unclear and we have to assume we are following the right course.

To a general public that is being asked to fund many different activities, there has to be greater certainty that their taxes will result in a given benefit. Stormwater management has historically been based on an assumption of benefit, but that is not going to be good enough in the future. We have to use case studies of implementation on a watershed basis to evaluate the effectiveness of our activities. This can only be done

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if implementation throughout a watershed allows us to monitor the results, but we have to recognize that evaluation process as an integral component of the overall watershed management planning process.

It is important that the goals of a watershed management plan be measurable in specific terms. In addition, the measurable improvements should address quantity, quality, ecological and user related improvement. These include such improvements as reductions in sediment load, return of sea grasses, reduction in anoxic zones, increase in abundance and diversity of certain aquatic species, greater recreational opportunities, reduction in flood damages, and/or increased property values. In addition, the achievement of these goals and the terms they are expressed in must have meaning and value, not only to the plan developers and administrators but also to the watershed stakeholders, government leaders, and the general public.

The cost of watershed management plan development and implementation has reached sufficiently high levels to now register on the economic radar screen, and as a result, program developers and administrators are going to be held much more accountable in the future.

Greater Community Recognition

In light of the complexities of watershed management plan development, we are often tempted to operate in relative isolation without much consideration for public input or involvement. However, once a watershed management project is initiated, it is vital that focus groups be established that represent all elements of the community, especially those who will be impacted by the plan's results. As mentioned above, people will support stormwater initiatives in many situations if they understand the purpose of the initiative and the benefits of successful implementation. Public outreach is an essential component of watershed management, and there are numerous guidance documents available on many different websites.

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CHAPTER 13

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CHAPTER 13

Maintenance of Stormwater Management Practices

An important component of any successful urban runoff management program is the effective and efficient maintenance of the stormwater management practices it creates. This chapter presents the key elements of a comprehensive maintenance program for such practices, including both structural facilities and nonstructural measures. Program elements include regulatory aspects, pre-construction planning and design considerations, post-construction inspection and maintenance activities.

As described throughout this book, an effective urban runoff management program requires the successful execution of several steps during a land development project. These steps include:

- Comprehensive project planning to analyze site conditions and identify potential adverse environmental impacts of the project;
- Intelligent and informed design of stormwater management practices that will prevent or minimize these adverse impacts without excessive operation or maintenance demands;
- Competent review of facility and measure designs to ensure compliance with the requirements of the urban runoff management program;
- Proper facility construction and measure implementation according to approved plans and applicable permit conditions; and
- Proper and effective maintenance of facilities and measures following their construction to ensure long-term operation and safety.

Although maintenance is listed as a separate step at the end of the above list, both research and experience have shown that to be truly effective, maintenance considerations must be included in all project steps, starting with the development of the urban runoff program, continuing through the project's design and review phases, and ending with the actual maintenance activities (N.J. Department of Environmental Protection, 1989). As the range of stormwater management practices expands beyond structural facilities to also include a wide variety of nonstructural measures (and, consequently, a similarly expanded range of owners, designers, and maintainers), the need for maintenance awareness throughout the entire land development process has become more important than ever.

Despite the importance of comprehensive stormwater management practice maintenance, several factors can complicate or hinder its performance. One is the authority to perform inspections and enforce maintenance requirements. A second factor is operation and maintenance costs. As we attempt to address a wider range of environmental impacts with stormwater management practices, their complexity grows, resulting in greater and more specialized operation and maintenance demands. A third factor is the inherent institutional difficulties of adequately managing the wide range of available practices through their respective planning, design, construction, and operation phases through a regulatory program.

However complex, the benefits of a comprehensive stormwater management practice maintenance program are substantial. Therefore, the goal of this chapter is to provide information that highlights these benefits and helps overcome the complications. The chapter begins with an overview of key maintenance program

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elements. It also discusses the particular operation and maintenance challenges posed by nonstructural stormwater management measures, which are becoming an increasingly important component of many urban runoff management programs. The chapter then explores the interrelationship between effective stormwater management practice maintenance and the practice's planning, design, permitting, and construction phases. Finally, it presents various options for funding stormwater management practice maintenance by public entities.

Operation and Maintenance Program Overview

An effective maintenance program for stormwater management practices has a number of key elements. These include:

- Regulations that help ensure that maintenance is addressed from the practice's pre- to post-construction phases;
- Pre-construction planning and design standards that help reduce and facilitate post-construction maintenance;
- A design review and approval process that helps ensure proper application of the program's maintenance-based planning and design standards;
- Construction inspection activities that ensure proper construction in accordance with the practice design;
- Post-construction monitoring and enforcement of maintenance obligations;
- Responsible ownership that recognizes the importance of regular and thorough maintenance;
- Adequate funding of inspection and maintenance activities; and
- Effective and efficient performance of maintenance activities.

Details of each of these elements are discussed below. This discussion highlights the strong interrelationship between all of the elements and the important role they play individually and jointly in achieving safe and effective practice operation and thorough and efficient maintenance.

Regulatory Aspects

A successful urban stormwater management program must contain strong, effective requirements that ensure that the stormwater management practices it creates are adequately maintained. These requirements must have a sound legal basis and pertain to both structural stormwater management facilities and nonstructural stormwater management measures. They must consider all aspects of a facility's or measure's creation, from planning and design through construction to post-construction operation. In doing so, they must address practice owners, designers, construction inspectors, and maintenance personnel. They must also ensure adequate inspection and maintenance funding, effective enforcement, and efficient record keeping. Details of each of these program components are discussed below.

Legal Authority

In order for an urban stormwater management program to effectively address the maintenance of stormwater management practices, it must include written requirements for such maintenance. For example, the Stormwater Management Rules of the New Jersey Department of Environmental Protection (NJDEP), as published in Section 7:8 of the New Jersey Administrative Code (NJAC), require the designers of structural stormwater management practices to consider several maintenance aspects in their design. As stated at NJAC 7:8-5.7-a-2:

> *Structural stormwater management measures shall be designed to minimize maintenance, facilitate maintenance and repairs, and ensure proper functioning.*

NJAC 7:8-5.7-a-3 further states:

> *Structural stormwater management measures shall be designed, constructed, and installed to be strong, durable, and corrosion resistant.*

Finally, at NJAC 7:8-5.8, the following is required:

> *The design engineer shall prepare a maintenance plan for the stormwater management measures incorporated into the design of a major development. The maintenance plan shall contain specific preventative maintenance tasks*

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and schedules, cost estimates including the cost of sediment, debris, or trash removal, and the name, address, and telephone number of the person or persons responsible for preventative and corrective maintenance (including replacement).

It is important to note that all program maintenance requirements must receive thorough legal review prior to promulgation. Perhaps the most critical aspect of this review are the legal implications of a program that establishes planning and design standards and, in many instances, oversees construction inspections of stormwater management practices. It must be clear to all involved in the program that, unless otherwise declared, the ultimate responsibility for the safe and proper design, construction, and performance of a stormwater management practice rests with the design and construction professionals who participated in its creation and not with program reviewers and inspectors.

An example of this approach can be found in the NJDEP's Dam Safety Standards as published in Section 7:20 of the state's Administrative Code (NJAC 7:20). As stated at NJAC 7:20-1.4-f:

No action shall be brought against the State or the Department or is agents or employees for the recovery of damages caused by the partial or total failure of any dam or reservoir or through the operation of any dam or reservoir upon the grounds that the Department is liable by virtue of any of the following:

1. The approval of the dam or reservoir, or approval of flood handling plans during construction.

2. The issuance or enforcement of orders relative to maintenance or operation of the dam or reservoir.

3. Control, regulation, and inspection of the dam or reservoir.

4. Measures taken to protect against failure during an emergency.

Structural and Nonstructural Practices

The need for thorough maintenance of structural stormwater management facilities should be self-evident, particularly of those intended to reduce nonpoint source pollution and improve runoff quality through the removal of trash, debris, suspended solids, and harmful chemical and biological agents. It is clear that removing these from the stormwater runoff that passes through a structural facility means that they will consequently be deposited in the facility and that failure to remove them in a timely way can result in outlet blockage, loss of detention storage, and excessive structural loads. Each of these consequences can lead to reduced facility performance and, ultimately, facility failure. The physical character of the structural facility itself, in combination with the consequences of poor maintenance described above, illustrates the importance of thorough maintenance: the visualization of a trash-laden outlet structure or a sediment-filled pond makes it easy to appreciate the importance of an effective maintenance program.

However, as the range of stormwater management practices expands beyond traditional structural facilities to include new nonstructural measures, the importance of maintenance can become less apparent. This is because the reduced physical character of nonstructural stormwater management practices may result in a similarly diminished appreciation of the importance of their maintenance. While it may be easy to visualize how such nonstructural practices as open space preservation, protection of indigenous vegetation, steep slope avoidance, and impervious surface limitations can directly impact the quantity and quality of runoff, the lack of tangible physical attributes of such nonstructural measures may weaken the connection between practice and maintenance that is so readily discernible at structural facilities. As a result, there is the chance that an urban stormwater management program will fail to recognize and impose adequate maintenance requirements upon the program's nonstructural measures. This can significantly diminish the program's overall effectiveness, because in spite of their lack of physical characteristics, nonstructural stormwater management measures also require regular, thorough maintenance, albeit through somewhat nontraditional requirements that reflect their nonstructural character.

Therefore, maintenance of nonstructural practices may require new ways of visualizing stormwater management practice operation and new definitions of maintenance actions. For example, in the case of preserved open space, steep slopes, or groundwater recharge areas, maintenance of these nonstructural practices may mean literally that – maintaining the existence of these areas by preventing their elimination, modification, or abuse. Similarly, the movement of runoff and the filtering and deposition of solids in a vegetated buffer or filter strip may not be as easy to

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visualize and understand as a wet pond, wetland, or similar structural facility. Nevertheless, these processes do occur, and the resulting accumulation of solids must be addressed through regular, thorough maintenance. While a plot of turf or meadow grasses or a stand of indigenous trees may not have the distinct structural features of a wet pond's permanent pool or a sand filter's sand bed, these nonstructural measures are nonetheless performing pollutant removal functions similar to their structural counterparts and consequently deserve similar maintenance.

There is another important difference between structural facilities and nonstructural practices that can have disturbing consequences for an urban stormwater management program. In addition to the general lack of readily discernable physical features and the need for somewhat nontraditional maintenance actions, nonstructural practices may also differ from structural facilities in both their total number and their location on a land development or redevelopment site. In general, structural facilities are typically located at a centralized location that receives runoff from a significant portion of the development site. This is normally done to minimize construction mobilization costs and to take advantage of the construction efficiency and economy inherent in large facility size. Stated in other terms, it normally requires considerably less land and money to construct a single, somewhat larger stormwater management facility to serve a particular drainage area than to do so with two or more smaller facilities. In addition, a single structural facility typically requires less overall maintenance effort and expense, and since it is a readily visible and recognized stormwater management practice, it is easier to monitor its performance and condition and enforce required maintenance activity.

Furthermore, due to the limited number, regional effectiveness, and centralized location of structural stormwater management facilities, their maintenance is typically the responsibility of a limited number of public or private entities such as municipal Public Works Departments or property owners' associations. Such entities typically have sufficient legal, financial, and organizational authority to allow them to not only accept and perform required facility maintenance but to allow others to effectively bring enforcement actions against them if they fail to meet their maintenance obligations.

However, it is not uncommon for numerous nonstructural stormwater management measures to be distributed throughout a development site, with each one receiving and treating runoff from only small portions of the overall site. This happens for a number of reasons, the most notable being the fundamental intent or goal of nonstructural stormwater management. As described in detail in Chapter 8, Impact Avoidance, the intent of nonstructural stormwater management is not to respond to the runoff produced by a development site the way structural practices do, but instead to intervene in the rainfall-runoff process in order to minimize the amount of runoff and associated impacts produced by the development. Stated in ideal terms, development site runoff responds to nonstructural practices, while structural practices respond to site runoff. To achieve this, however, nonstructural practices must generally be distributed throughout the site in order to optimally intervene in the rainfall-runoff process.

Other factors can also contribute to the number of nonstructural practices at a land development site being larger than the number of structural ones. These include the physical, chemical, and biological processes that must occur to effectively treat and convey stormwater runoff. Due to their relatively low design depths, widths, and/or heights, nonstructural stormwater management measures can typically manage only relatively small rates and volumes of runoff when compared to structural facilities. As a result, the relative size of their tributary drainage areas must also be small, requiring a greater number of nonstructural measures throughout the development site.

Finally, there is a relationship between nonstructural measure character, size, and efficiency that further promotes the use of more rather than fewer nonstructural measures at a land development site. Since, in addition to their smaller overall size, they have significantly less height, depth, and other distinct physical characteristics, nonstructural measures can more readily be located in the rear, side, and even front yard setback areas on individual development lots. For example, vegetated buffers, preserved open space areas, and pervious areas downstream of unconnected impervious surfaces can easily be located in setback areas. They can also serve as both active and passive open space areas. Since setback and open space areas are typically required at land development sites, using them to also locate nonstructural stormwater management measures can increase site utilization efficiency and even reduce overall site disturbance. It can also reduce or, in certain instances, even eliminate the need for a larger, centralized structural facility, which is typically too large to

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fit within required setback areas and often prohibited in required open space areas.

As a result, nonstructural stormwater management measures can be located on numerous individual lots throughout a land development site. While this conforms to nonstructural stormwater management principles and can increase land utilization efficiency and preserve open space, the maintenance implications can be troubling. For unlike a limited number of centralized structural facilities, a widely dispersed array of nonstructural measures will involve a similarly wide range of individual property owners, each with a different level of interest, ability, and resources to perform required measure maintenance. In addition, maintenance monitoring and inspection by regulatory agencies will be more difficult due to the greater number and dispersed locations of the nonstructural measures. Enforcement of maintenance requirements may also be more difficult due to the direct responsibility of individual property owners rather than a single, representative owners' association. Record keeping and other administrative functions can also be expected to be more complex and costly.

Therefore, it is important for an urban stormwater management program to recognize the maintenance challenges posed by its nonstructural stormwater management component and take appropriate steps to address them. This should include the following:

- Recognize the increased complexity and nontraditional character of nonstructural stormwater management measure maintenance.
- Identify the potential for and consequences of maintenance neglect and measure modification and elimination by private property owners.
- Review available maintenance inspection and enforcement options against such property owners.
- Include in the urban runoff management program only those nonstructural measures that the program's administrators can reasonably guarantee will remain functional in the future.
- Develop a property owner education program on nonstructural measure purpose, operation, and maintenance.
- Adopt appropriate maintenance inspection and enforcement measures.

Design Review

The success of both structural and nonstructural stormwater management practices, including their operation and maintenance, will depend to a great extent on the scope, accuracy, and basis of the planning and design standards used to create them. However, to be effective, such standards must be incorporated into the urban stormwater management program. In addition, it must be ascertained prior to its construction that a stormwater management practice has been designed in accordance with them. As a result, a design review and approval process must also be included in the urban stormwater management program. Such a process can be integrated into existing development review programs such as those conducted by planning boards, boards of adjustment, regional or state agencies, and sewer and water utilities. Lacking such existing programs, a new program must be developed with proper legal authority and appropriate submission, review, and approval requirements and procedures. In such cases, it may be possible to reach an agreement with an existing program at another level of jurisdiction to share or trade off actual project reviews in order to save time, effort, and expense and improve review coordination between agencies.

Construction Inspection

The success of both structural and nonstructural stormwater management practices also depends upon the accuracy and quality of their construction. Similar to design review, inspection of the construction is therefore essential to achieving both individual measure and overall program success. An effective construction inspection program includes:

- A sufficient number of adequately trained and experienced inspectors;
- Inspection standards and procedures for all phases and aspects of facility or measure construction including materials, dimensions, strengths, and construction equipment and practices;
- Pre-construction meetings to review inspection procedures and construction requirements prior to the start of construction;

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- Periodic construction meetings to review progress, address problems, and anticipate and avoid future difficulties; and
- Post-construction documentation including the development, review, approval, and recording of as-built drawings.

Post-Construction Monitoring and Enforcement

Once construction is complete and the stormwater management practices are put into operation, monitoring of their maintenance must be performed to ensure compliance with the maintenance requirements contained in the urban runoff management program's regulations and/or a specific maintenance plan. Such monitoring can be performed directly by the urban stormwater management program agency or the practice owner. Monitoring by the practice owner should include the submission of monitoring reports to the program agency at least once per year. In addition, the program must also have provisions for noncompliance. Such provisions can include, in reverse order of severity:

- Informal, discretionary procedures to deal with isolated or inadvertent maintenance noncompliance;
- Formal, prescribed procedures and measures to address chronic or intentional noncompliance;
- Emergency measures to respond to noncompliance matters that pose an immediate health or safety threat; and
- Maintenance assumption in the case of total maintenance default and abandonment.

Finally, successful post-construction monitoring includes provisions for legal access to the stormwater management practice by program personnel through easements, right-of-ways, and access and inspection agreements with the practice owner. Bonds, letters of credit, and other financial instruments can also be required from the owner to finance emergency measures and overall maintenance assumption by the program agency.

Interagency Coordination

With the promulgation of the EPA's Stormwater Phase II Final Rule, municipal, county, and state governments throughout the country are developing new or upgrading existing stormwater management programs in order to comply with their Phase II Stormwater permits. Under such conditions, it is important that these various levels of government coordinate their efforts to maximize consistency and minimize conflicts between the various programs, including their maintenance components. This can perhaps best be achieved through a hierarchical approach that recognizes both the role each level of government should play in managing urban runoff and the relative proximity each level has to the actual stormwater management practices that must be properly maintained.

This approach can begin at the state program level with language that both mandates proper stormwater management practice maintenance and establishes general or minimum requirements to ensure it is achieved. Such requirements can include the need to design and construct stormwater management practices that require the least practical maintenance effort and cost, as well as the need to prepare a maintenance plan that details the actual maintenance tasks and equipment necessary to perform them. These general requirements can also specify what types of entities can and cannot be assigned maintenance responsibility and establish general record keeping and reporting requirements. Finally, it is important that, having established general maintenance standards and requirements, state and other higher levels of government recognize that those at the municipal and county level will have a more direct physical and regulatory relationship with the actual stormwater management practices and their owners. This recognition should come in the form of state program language that allows municipalities, counties, and other local government entities to both establish more specific maintenance standards and requirements and to decide the optimal procedures for implementing them. As noted in the 1997 *Operation, Maintenance, and Management of Stormwater Management Systems* (Watershed Management Institute, 1997), a key to a successful stormwater management practice maintenance program is providing the flexibility to attain maintenance standards within the institutional framework of the overall stormwater management program, whether at the state, regional, county, and/or municipal level.

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For their part, local government entities must recognize that the general or minimum maintenance standards established for them by higher levels of government only represent the framework of an effective maintenance program. This recognition should then prompt the development and refinement of more specific maintenance standards, procedures, and guarantees that address local regulatory, physical, political, economic, and social conditions. This process begins with the identification of these conditions and the development and promulgation of specific maintenance standards for the various types of projects and stormwater management practices expected within a given jurisdiction.

Summary

The above section on the regulatory aspects of stormwater management practice maintenance presented the following ideas and information:

- To be successful, an urban stormwater management program must include provisions for effective maintenance of stormwater management practices.
- These maintenance provisions should address all applicable types of stormwater management practices, including structural facilities and nonstructural measures. Maintenance of nonstructural stormwater management measures poses unique challenges for an urban stormwater management program.
- The program's maintenance provisions must also encompass all phases of a stormwater management practice's development, from planning and design to construction and, ultimately, operation and maintenance. To do so, the program should include design review, construction inspection, and maintenance inspection, enforcement, and default procedures.
- The maintenance provisions must have a sound legal basis that allows the program to both impose maintenance requirements and check for compliance.
- Interagency coordination of maintenance standards will help avoid conflicts and duplication.

Planning and Design Considerations

It is self-evident that the efforts of planners, designers, and reviewers of stormwater management practices will directly affect the runoff performance of these practices. However, the efforts of these individuals can also have a direct effect on the amount, frequency, and difficulty of required practice maintenance. Research into the maintenance aspects of more than 50 structural stormwater management facilities in New Jersey indicated that approximately two thirds of the maintenance problems encountered at these facilities were at least partly due to shortcomings in the planning, design, and review process (N.J. Department of Environmental Protection, 1989). These shortcomings included:

- Inadequate planning and design standards in the urban runoff management program;
- Inadequate investigation and analysis of facility site conditions;
- Inadequate understanding of facility function and operational needs;
- Inattentive or inept design and design review; and
- Lack of consideration for facility maintenance needs.

The results of these shortcomings included increased maintenance complexity, effort, and cost, reduced facility performance, and decreased facility safety (Watershed Management Institute, 1997). According to the New Jersey research, some of the resultant maintenance problems "were virtually unsolvable without massive infusions of time, money, and hard work."

Fortunately, enlightened and focused planning, design, and review requirements and procedures can eliminate these shortcomings and actually improve maintenance effectiveness and efficiency. This, in turn, can lead to high levels of long-term practice performance and safety. It is therefore important that an urban stormwater management program require planners, designers, and reviewers to include maintenance as a key consideration in their efforts. In addition, the program should provide them with maintenance-based planning and design standards that help achieve the favorable program results described above.

In general, planning and design standards that help minimize and facilitate stormwater management practice maintenance typically include the following

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consideration for four important aspects: durability, constructability, maintainability, and accessibility. Discussions of each is presented below.

Durability

The required use of strong, durable materials, appurtenances, and fasteners can greatly reduce the maintenance required at a structural stormwater management facility. These long-term savings typically exceed the one-time expense of providing higher quality products, which justifies their inclusion in the program's maintenance standards. Durability extends across the entire range of facility components, from concrete outlet structures to vegetative covers and landscaping.

Durability



BAD: Inappropriate materials and poor construction increases maintenance effort and cost.



GOOD: Durable materials and sound construction decreases them.

Constructability

It must be remembered that a stormwater management practice must be properly constructed before it can produce any long-term runoff management benefits with reasonable levels of inspection and maintenance. This high degree of construction quality requires skilled, experienced, and properly equipped constructors and attentive and knowledgeable inspectors. However, achieving high quality construction begins with the creation of stormwater management practices at the planning and design levels that reflect the realities of construction. These realities require that a practice possess a reasonable degree of simplicity, standardization, and component availability. Required materials and equipment should be readily available and construction techniques safe and feasible. Construction plans and specifications, which are the constructors' and inspectors' instruction manual, must be clear, concise, and informative. They must contain all necessary information in a format and form that assists rather than hinders use in the field under all weather conditions. This is not meant to stifle creativity and imagination in the selection and design of a particular stormwater management practice. However, practices or components that require particularly new or complex construction materials, techniques, equipment, or sequencing must be given additional attention in the construction documents in the form of extra detailing, notes, warnings, and references.

Constructability



To help ensure sound construction, required construction materials and procedures should be as standard as practical. Unique procedures and complex components should be thoroughly described and detailed in construction documents.

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Maintainability

Throughout the planning, design, and review process, every attempt should be made to both minimize and facilitate required maintenance. This approach must guide a wide range of decisions, from the type of selected stormwater management practice to its location, configuration, materials, and the techniques and equipment required to both construct and maintain it. The questions governing these decisions include:

- Is the type of selected stormwater management practice and its various components compatible with the physical conditions and constraints of its location?
- Are the selected materials durable? Are they reasonably available for both construction and replacement purposes?
- Are proposed slopes steep enough to promote proper drainage but flat enough to permit safe access and mobility of inspection and maintenance personnel?
- Can required levels of construction quality be reasonably achieved?
- Are the amount, cost, and complexity of required maintenance within the owner's ability to provide it?

Under optimum planning, design, and review conditions, all of the above questions will be answered affirmatively before the design of the stormwater management practice is completed and approved.

Accessibility

According to the New Jersey stormwater management facility maintenance research cited earlier (NJDEP, 1989), lack of accessibility was a major hindrance to stormwater management practice maintenance, with the access to approximately one third of practice components inspected in the field considered inadequate and, at times, unsafe. Lack of safe, adequate access can quickly defeat all planning, design, and review efforts to provide durable, constructable, and maintainable stormwater management practices as well as an owner's efforts to train, equip, fund, and motivate maintenance personnel. In other words, small oversights regarding access can create large maintenance problems. Personnel access to a stormwater management practice and its various components must include not only the personnel themselves, but their equipment and materials as well. Access can range from legal access through an easement or right-of-way to a stormwater management practice to physical access to the interior of its outlet structure through a hatch and ladder rungs.

Efforts to facilitate access and enhance safety during the planning, design, and review phases can often yield significant savings in subsequent inspection and maintenance efforts. For example, a maintenance inspector conducting a post-storm inspection of several stormwater management facilities for excessive debris build-up can complete their task more efficiently if a facility is visible from a road, driveway, or other location accessible by their vehicle. Similarly, the cost to remove

Maintainability



BAD: Lack of adequate bottom slope in dry detention basin causes unintended ponding that prevents mowing and cleaning.



GOOD: Adequate bottom slope in dry detention basin creates intended dry bottom that can be regularly mowed and cleaned.

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any debris noted during the inspection can be reduced if the maintenance personnel have ready access to it. Similar to durability, the long-term savings achieved through enhanced accessibility typically exceed the one-time expense of providing it.

Another important but less noted aspect of stormwater management practice accessibility is how readily visible a particular practice is to people other than maintenance personnel. According to the New Jersey stormwater management facility maintenance research cited earlier, structural stormwater management facilities that were readily visible to pedestrians, motorists, customers, employees, and others not responsible for facility maintenance were more than twice as likely to receive high levels of maintenance than less visible ones. Less visible facilities were in turn three times more likely to receive fair to poor maintenance. This leads to the conclusion that visual accessibility may be equal in importance to physical and legal access for maintenance purposes.

Finally, attempts to minimize and facilitate stormwater management practice maintenance during the planning, design, and review phases can be aided by a series of questions that planners, designers, and reviewers should pose to themselves and each other. These questions include:

Who will perform the maintenance?

Will specialists be required for some or all of the maintenance or can it be performed by someone with general maintenance skills and equipment? The person or agency that will actually be performing the required maintenance must be identified with sufficient accuracy during the planning, design, and review phases so that their level of ability, equipment, and expertise can be taken into consideration.

What maintenance must be performed?

Each type of stormwater management practice requires specific and, at times, unique maintenance tasks. These tasks should be identified prior to final practice selection so that planners, designers, and reviewers can ensure that they correspond to the abilities and equipment of the designated maintainers. In addition, preparing a list of all required maintenance tasks may prompt a redesign that produces a shorter task list.

Accessibility



Lack of access can defeat the best maintenance program requirements and intentions.



BAD: Lack of depressed curb hinders access to practice by maintenance personnel and equipment.



GOOD: Readily accessible practices are easier and cheaper to maintain.

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When will maintenance be required?

Once a day, week, month, or year? Recurring maintenance costs can be substantial over the life of the practice. In addition, certain stormwater management practices and their components require maintenance at specific times of year or only under certain weather conditions. For example, the turf grass in an extended detention basin or grass filter strip can only be moved in dry weather. How will maintenance and operation be affected if prolonged periods of wet weather are common? Finally, are emergency repairs or debris removal possible during a storm event, perhaps during nighttime hours? Addressing such questions during the planning, design, and review phases will be easier than during an actual post-construction emergency and can produce more appropriate practice selections and improved practice designs.

Where will maintenance be required?

Will maintenance personnel be able to get to the area or component that requires maintenance, along with their equipment and materials? Once there, will they have a safe, stable place to work in? In addition, where will the sediment, debris, and other material removed from the practice be disposed? This question becomes more critical when the character of the removed material (such as toxic or hazardous materials) affects the disposal location. Once again, addressing these questions during the planning, design, and review phases will be easier than during the first cleanout effort.

How will maintenance be performed? What equipment, training, and/or materials will be necessary? Will any safety equipment or procedures be necessary? Is a certain maintenance task exceptionally difficult, dangerous, and/or expensive? Can such conditions be eliminated through additional design effort or through selection of a different stormwater management practice?

All of the above questions are intended to make planners, designers, and reviewers more aware of maintenance tasks, schedules, costs, and problems and to encourage them to address these issues during the planning, design, and review phases of the practice. The goal of minimum maintenance cannot be achieved without doing so.

Summary

The above section on planning and design standards presented the following ideas and information:

- The efforts of planners, designers, and reviewers can have a direct effect on the amount, frequency, cost, and complexity of maintenance required at a stormwater management practice.
- As a result, a successful urban runoff management program must include planning, design, and review requirements that minimize and facilitate maintenance and provide specific guidance on how to achieve it.

Accessibility



GOOD AND BAD: Ladder rungs allow access to structure bottom, but large grating openings are hazardous to maintenance personnel.



GOOD: Lightweight, noncorroding aluminum top gratings are safe to stand on and easy to lift.

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- Durability, maintainability, constructability, and accessibility are key planning and design considerations.
- Who, what, where, when, and how maintenance will be conducted are key questions that planners, designers, and reviewers can ask themselves and each other.

Public Maintenance Financing

Regardless of the combined efforts of regulators, planners, designers, reviewers, constructors, and inspectors, successful stormwater management practice maintenance cannot be achieved without adequate funding of required maintenance activities. This funding is not only needed for the direct costs of performing required maintenance tasks, but also to meet the costs of equipment, training, disposal, record keeping, and administration. When maintenance is financed and performed by a private entity such as a property or building owner, there is typically a wider range of available funding sources than if the maintenance is publicly financed. Private funding sources may include rental and lease incomes, tenant fees, service charges, or incorporating maintenance costs into company overhead, product prices, and/or service rates.

Maintenance financing by a public entity such as a municipal or county government can be more difficult, typically due to fewer funding sources, funding competition from other government activities, and the need to secure funding a year or more in advance through the government's budgeting process. This section will review these difficulties and explore ways in which they can be avoided and maintenance funding maximized.

Before reviewing potential funding sources, it is helpful to look at some of the reasons why a public entity would assume the responsibility for stormwater management practice maintenance and its financing. Most obvious is the case where the public entity is required to construct or implement a stormwater management practice to serve its own properties, roadways, buildings, and other public facilities. Such cases are expected to become more numerous with the arrival of the EPA's Phase II Stormwater Rules and associated NPDES permits, which require public entities to implement practices at new public facilities that disturb an acre or more of land.

In addition, a public entity such as a municipality or county may choose to assume the maintenance of a stormwater management practice at a privately-owned project or development in order to ensure it receives adequate care. While most public entities prefer that such maintenance remain in the responsibility of the practice's private owner, research has shown that the level and quality of private maintenance in many instances can be inadequate. As a result, a local government with overall responsibility for public health and safety as well as specific NPDES permit obligations may decide that the best way to meet these obligations and responsibilities is to perform the required maintenance itself. In other instances, a public entity may have been forced to assume maintenance responsibility of a private stormwater management practice due to the owner's failure to adequately perform it. Such assumption typically occurs some time after the practice's construction.

Whatever the reasons, once a public entity becomes responsible for stormwater management practice maintenance, it must develop and implement a program to finance the required maintenance activities. This is true whether the public entity performs the maintenance itself or hires an outside company or agency to do it. There are some general characteristics of a successful maintenance financing program that warrant special consideration (Livingston et al., 1997). These characteristics are summarized below:

- The success of any public financing program is determined in part by the amount and quality of program information provided to the public. This information must explain the purpose of and need for the stormwater management practice maintenance activities as well as sufficient details of the financing program. The information must be able to convince the public and their elected officials that it is in their interests to adequately fund the public entity's stormwater management practice maintenance activities.
- A public financing program should be based upon a stable, reliable source of funds. Stormwater management practice maintenance is a long-term activity that requires a funding source that will remain viable throughout the life of the maintenance program.

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- Whenever possible, a public financing program should fit readily into the billing, collection, and bookkeeping operations of the public entity's existing financial system.
- A public financing program should include provisions not only for the actual maintenance activities but also for record keeping, accounting, and other administrative tasks.
- The fee or rate structure for a public financing program should be equitable, readily understandable, and defensible. It must be perceived by the public as being fair, reasonable, and based upon accurate information and sound decisions.
- In addition, the fee or rate structure should be flexible enough to allow both regular and emergency updating to address changes in maintenance program scope, schedule, and costs.
- Finally, a public financing program must be consistent with all applicable laws and regulations. To ensure such consistency, the program must be reviewed by legal counsel prior to its implementation.

In general, there are three funding sources typically available for public stormwater management practice maintenance (NJDEP, 1989) activities:

1. General Tax Revenues
2. Dedicated Contributions
3. Stormwater Utility Fees

Details of each funding source are presented below, including suggested criteria for evaluating the suitability of each for a particular public entity.

General Tax Revenues

General tax revenues are an obvious source of funding for public maintenance of stormwater management practices. Since taxes are raised to provide for a community's health, safety, and welfare as well as to meet its legal obligations, it can be shown that failure to provide adequate stormwater management practice maintenance can threaten these important objectives. As a result, the use of general tax revenues remains a popular source of funding for stormwater management practice maintenance. To obtain this funding, however, requires preparation of annual maintenance program budgets based upon forecasts or predictions of future maintenance obligations and costs. Low forecasts can lead to budget shortfalls that can prevent the performance of all required maintenance activities, while excessively high forecasts can hinder efforts to secure necessary funding.

Other aspects of the budgeting process can complicate the use of general tax revenues to fund public stormwater management practice maintenance. As part of a government's overall operating budget, stormwater management practice maintenance must compete for funding with all other government operations included in the budget, including police, fire, sanitation, and administrative services. It is in such competitive situations that the value of an effective public information program regarding urban stormwater management noted above becomes apparent. The legal obligation to comply with the maintenance requirements of a municipality's or county's NPDES permit can also give the maintenance program added importance during the budgeting process.

Nevertheless, several other difficulties may exist. First, it may be difficult to justify the use of general tax revenues from the entire community to maintain a stormwater management practice that only directly benefits a portion of that community. Second, the need to provide funding for unforeseen, emergency, or other one-time non-stormwater events occurring in the community may result in the diversion of normal, expected funding away from the stormwater management practice maintenance program. Finally, in light of the public's traditional resistance to tax increases, which can manifest itself at times in the adoption of tax increase caps and even tax cuts, it may be difficult to obtain required funding increases necessitated by increased maintenance costs. As a result, general tax revenues can be both the most readily available and least stable source of maintenance program funding. This realization has led to development of the alternative approaches described below.

Dedicated Contributions

The use of dedicated contributions to finance public maintenance of stormwater management practices is based upon the principle that those creating the need for the stormwater management practice and its maintenance should bear the cost. It applies to stormwater management programs in which a public entity assumes the maintenance responsibility for a stormwater manage-

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ment practice that has been created to serve a privately-owned land development or project. In exchange for the maintenance responsibility, the developer makes a one-time contribution to the public entity to fund the long-term required maintenance. This contribution is then periodically drawn upon by the public entity as the maintenance is performed. As a guarantee, the contribution is typically made prior to final approval of the development. It is placed in a dedicated account that can only be used to finance maintenance of that particular stormwater management practice. Accurate bookkeeping practices must be followed to ensure appropriate use of the funds.

In one sense, the use of dedicated contributions to finance public stormwater management practice maintenance can be considered an extension of the permit or inspection fees traditionally charged by local governments or other public entities to review and/or inspect the construction of a privately-owned development, building, or other project. In this case, the permit or inspection fee is used to offset the administrative and inspection costs incurred by the public entity. The dedicated contribution system extends this concept by applying the "fee" paid in the form of a dedicated contribution 1) only to a specific project or practice and 2) over an extended period of time. The application to a specific project requires, as mentioned above, a dedicated account in which to deposit the contribution and track withdrawals, while use of the contribution over an extended period of time requires consideration of both interest earnings and cost increases.

One key to a successful dedicated contribution financing system is an accurate method for estimating the long-term maintenance costs and then converting that amount into an equivalent one-time payment. Factors that should be considered when estimating the payment include:

- The type and maintenance needs of the specific stormwater management practice to be maintained, including the type, size, and location of the practice as well as the characteristics of the runoff it will receive;
- The number of years that maintenance must be provided;
- The present annual costs of practice maintenance, including maintenance activities, equipment repair and replacement, materials, insurance, record keeping, and other administrative tasks;
- Anticipated maintenance cost increases due to increases in salaries, overhead, materials and equipment costs, insurance premiums, and disposal costs; and
- The anticipated interest rate earned by the contribution over the life of the maintenance financing.

The use of dedicated contributions to finance stormwater management practice maintenance has many advantages (Livingston et al., 1997). The most important one may be that it provides a secure and stable maintenance funding source if properly managed. In addition, the source of the maintenance funding can be directly linked to the need for maintenance, eliminating the need to justify the expenditure of general revenues on a particular facility or area. Difficulties include the need for accurate estimates of annual maintenance costs which, in turn, require similarly accurate estimates of the required time, materials, and equipment. Administrative and insurance costs must also be accurately estimated along with potential cost increases for all aspects of the maintenance program. The duration of the maintenance program and the interest that may be earned on the one-time contribution during this period can also be difficult to accurately estimate. Typically, conservative estimates are used in order to provide a safety factor. The actual computation of the one-time contribution is based upon standard economic principles for capital recovery through a series of payments (Grant and Ireson, 1960). Formulas can be found in standard economics textbooks, particularly those that deal with the principles of engineering economics.

A final difficulty with the use of dedicated contributions is the fact that they are only directly applicable to the maintenance of new, privately-owned and financed stormwater management practices. They cannot be readily used to finance the public maintenance of new, publicly-owned measures or any existing public maintenance activities without special considerations and conditions. Consequently, full public financing of stormwater management practice maintenance may require the combined use of general tax revenues for publicly-owned practices and dedicated contributions for privately-owned ones.

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Stormwater Utility Fees

The uncertainties associated with the use of general tax revenues to finance stormwater management practice maintenance has recently led many communities to create a specialized agency known as a stormwater utility. This agency is assigned responsibility for stormwater management practice maintenance within its jurisdictional area. To finance this maintenance, the utility is allowed to charge property owners within it jurisdiction a fee or other assessment. The amount of the fee is typically related to the property's stormwater impacts and, consequently, its dependence on a well-maintained stormwater management practice. In some instances, the utility's responsibilities may also include storm sewer construction and maintenance, waterway stewardship, and other drainage, erosion, and flood control activities.

The use of utility fees to finance publicly-owned water and sewerage systems began in the early 1990s, and they continue to be a stable source of funding for such systems. Over the last decade, the use of this public financing technique has been extended to the operation and maintenance of stormwater management systems. Once the utility has been established, it offers many advantages over other public financing sources. It can provide maintenance funds for both existing and proposed stormwater management practices. It does not have to compete with other government programs and needs. Moreover, the relationship between the fees for stormwater management practice maintenance and the benefits of performing it is more obvious in this approach. However, first the utility must be created and an equitable fee structure established. This entails the legal and physical establishment of an entirely new entity with sufficient staff and resources to properly function. This requirement can pose the greatest obstacle to the use of utility fees to finance public maintenance of stormwater management practices.

The utility rate structure must be based on several considerations (Livingston et al., 1997). It must, of course, reflect the costs of providing the stormwater management practice maintenance and other services for which the utility was established. But first and perhaps foremost is the premise that the fee is based upon the need for the stormwater management practice maintenance rather than the benefits provided by it. As a result, the fee structure can be based upon characteristics of the assessed properties that influence the volume of runoff they produce, such as their total area, the area of their impervious surfaces, or the type of land use. However, the fee structure should also remain as simple as possible in order to facilitate understanding of and, as a result, acceptance by those paying it. Simplicity will also facilitate utility administration and implementing future rate changes.

Summary

The above section on the public financing of stormwater management practice maintenance presented the following ideas and information:

- Successful implementation of a public stormwater management practice maintenance program requires adequate and stable funding sources.
- The reasons why a public entity would assume the maintenance of a stormwater management practice include direct ownership of the practice, the need or desire to have direct control over a privately-owned practice, and maintenance default by the owner.
- There are three general sources of funds for public stormwater management practice maintenance: 1) general tax revenues, 2) dedicated contributions, and 3) utility charges.
- The use of these financing techniques involves legal, financial, and economic considerations that must be thoroughly addressed before such use can begin.

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Summary and Conclusions

This chapter demonstrates the importance of stormwater management practice maintenance and describes key features of an effective maintenance program. Such features include:

1. Legal authority to require and enforce stormwater management practice maintenance;
2. Planning and design standards that minimize and facilitate maintenance;
3. Design review procedures to ensure compliance with these standards;
4. Construction inspection procedures to ensure that the practice is being constructed in accordance with the design plans;
5. Post-construction monitoring to ensure proper maintenance is being conducted;
6. Recognition of the unique maintenance needs of nonstructural stormwater management practices; and
7. Ensuring that adequate and stable funding is available for maintenance.

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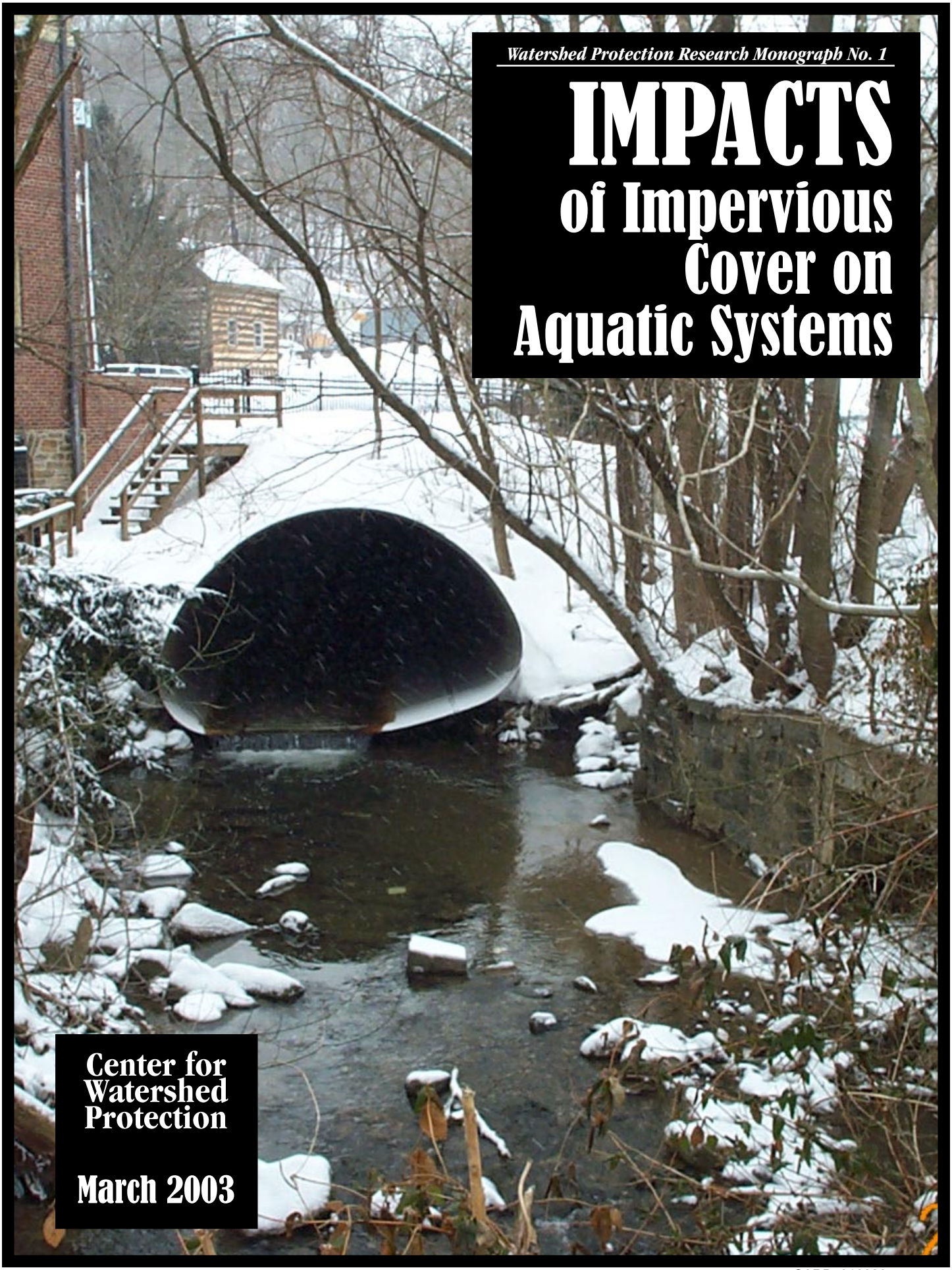

Watershed Protection Research Monograph No. 1

IMPACTS of Impervious Cover on Aquatic Systems

Center for Watershed Protection

March 2003

SARB_016228

Cover photograph Ellicott City, Maryland 2003.
Courtesy Anne Kitchell, Center for Watershed Protection.

Watershed Protection Research Monograph No. 1

Impacts of Impervious Cover on Aquatic Systems

March 2003

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SARB_016230

Foreword

We are extremely pleased to launch the first edition of a new series called *Watershed Protection Research Monographs*. Each monograph will synthesize emerging research within a major topical area in the practice of watershed protection. The series of periodic monographs will replace our journal *Watershed Protection Techniques,* which lapsed in 2002. We hope this new format will provide watershed managers with the science and perspectives they need to better protect and restore their local watersheds.

This monograph was written to respond to many inquiries from watershed managers and policy makers seeking to understand the scientific basis behind the relationship between impervious cover and the health of aquatic ecosystems. It reviews more than 225 research studies that have explored the impact of impervious cover and other indicators of urbanization on aquatic systems. This report comprehensively reviews the available scientific data on how urbanization influences hydrologic, physical, water quality, and biological indicators of aquatic health, as of late 2002.

Our intention was to organize the available scientific data in a manner that was accessible to watershed leaders, policy-makers and agency staff. In addition, the research itself, which spans dozens of different academic departments and disciplines, was conducted in many different eco-regions, climatic zones, and stream types. In order to communicate across such a wide audience, we have resorted to some simplifications, avoided some important particulars, refrained from some jargon, and tried, wherever possible, to use consistent terminology. Thus, the interpretations and conclusions contained in this document are ours alone, and our readers are encouraged to consult the original sources when in doubt.

We would also like to note that the Center for Watershed Protection and the University of Alabama are currently developing a major national database on stormwater quality. The database will contain nearly 4,000 station-storm events collected by municipalities as part of the U.S. EPA's National Pollutant Discharge Elimination System (NPDES) Phase I Stormwater Permit Program. We anticipate releasing a data report in late 2003 that will provide a much needed update of stormwater event mean concentrations (EMCs).

As of this writing, many research efforts are underway that will further test and refine these relationships (most notably, the U.S. Geological Survey gradients initiative, but also many other local, state and academic efforts). We hope that this report provides a useful summary of the existing science, suggests some directions for new research, and stimulates greater discussion of this important topic in watershed management. We also feel it is time for a major conference or symposium, where this diverse community can join together to discuss methods, findings and the important policy implications of their research.

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Acknowledgments

Putting this first research monograph together took a lot of energy, editing and analysis, and many Center staff devoted their time and energy over the last two years to get it done. The project team consisted of Karen Cappiella, Deb Caraco, Samantha Corbin, Heather Holland, Anne Kitchell, Stephanie Linebaugh, Paul Sturm, and Chris Swann. Special thanks are extended to Tiffany Wright, who worked tirelessly to assemble, edit and otherwise polish the final draft.

I am also grateful to Michael Paul of Tetratech, Inc., who graciously provided us with an extensive literature review from his PhD days at the University of Georgia that contained many obscure and hard to find citations. Portions of this monograph were developed as part of a literature review conducted as part of a work assignment for the U.S. EPA Office of Wastewater Management in 2001, which proved indispensable in our efforts. Lastly, I would like to thank the hundreds of scientists who have contributed their time and data to explore and test the relationships between urbanization and aquatic health.

Tom Schueler
Center for Watershed Protection

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Acronyms and Abbreviations

B-IBI	Benthic Index of Biotic Integrity
BOD	Biological Oxygen Demand
BSD	Better Site Design
C-IBI	Combined Index of Biotic Integrity
cfs	cubic feet per second
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
Cu	Copper
DOC	Dissolved Organic Carbon
du/ac	dwelling units per acre
EMC	Event Mean Concentration
EPT	Ephemeroptera, Plecoptera and Trichoptera
FC	Forest Cover
GIS	Geographic Information Systems
IBI	Index of Biotic Integrity
IC	Impervious Cover
ICM	Impervious Cover Model
lbs/ac	pounds per acre
LWD	Large Woody Debris
mg/kg	milligrams per kilogram
mg/l	milligrams per liter (equal to ppm)
MPN	Most Probable Number
MTBE	Methyl Tertiary-Butyl Ether
N	Number of Studies
N/R	data not reported
NO_2	Nitrite
NO_3	Nitrate
NO_x	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
NURP	National Urban Runoff Program
PAH	Polycylic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
ppb	Parts per billion (equal to ug/l)
ppm	Parts per million (equal to mg/l)
RBP	Rapid Bioassessment Protocol
SLAMM	Source Loading Assessment/ Management Model
SPMD	Semi-Permeable Membrane Device
SSO	Sanitary Sewer Overflow
STP	Stormwater Treatment Practice
TC	Turf Cover
TDS	Total Dissolved Solids
TKN	Total Kjeldhal Nitrogen
TMDL	Total Maximum Daily Load
Total N	Total Nitrogen
Total P	Total Phosphorous
TOC	Total Organic Carbon
TSS	Total Suspended Solids
ug/l	micrograms per liter (equal to ppb)
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
WLF	Water Level Fluctuation
WTP	Wastewater Treatment Plant

Chapter 1: Introduction

This research monograph comprehensively reviews the available scientific data on the impacts of urbanization on small streams and receiving waters. These impacts are generally classified according to one of four broad categories: changes in hydrologic, physical, water quality or biological indicators. More than 225 research studies have documented the adverse impact of urbanization on one or more of these key indicators. In general, most research has focused on smaller watersheds, with drainage areas ranging from a few hundred acres up to ten square miles.

Streams vs. Downstream Receiving Waters

Urban watershed research has traditionally pursued two core themes. One theme has evaluated the direct impact of urbanization on small streams, whereas the second theme has explored the more indirect impact of urbanization on downstream receiving waters, such as rivers, lakes, reservoirs, estuaries and coastal areas. This report is organized to profile recent research progress in both thematic areas and to discuss the implications each poses for urban watershed managers.

When evaluating the direct impact of urbanization on streams, researchers have emphasized hydrologic, physical and biological indicators to define urban stream quality. In recent years, impervious cover (IC) has emerged as a key paradigm to explain and sometimes predict how severely these stream quality indicators change in response to different levels of watershed development. The Center for Watershed Protection has integrated these research findings into a general watershed planning model, known as the impervious cover model (ICM). The ICM predicts that most stream quality indicators decline when watershed IC exceeds 10%, with severe degradation expected beyond 25% IC. In the first part of this review, we critically analyze the scientific basis for the ICM and explore some of its more interesting technical implications.

While many researchers have monitored the quality of stormwater runoff from small watersheds, few have directly linked these pollutants to specific water quality problems within streams (e.g., toxicity, biofouling, eutrophication). Instead, the prevailing view is that stormwater pollutants are a downstream export. That is, they primarily influence downstream receiving water quality. Therefore, researchers have focused on how to estimate stormwater pollutant loads and then determine the water quality response of the rivers, lakes and estuaries that receive them. To be sure, there is an increasing recognition that runoff volume can influence physical and biological indicators within some receiving waters, but only a handful of studies have explored this area. In the second part of this review, we review the impacts of urbanization on downstream receiving waters, primarily from the standpoint of stormwater quality. We also evaluate whether the ICM can be extended to predict water quality in rivers, lakes and estuaries.

This chapter is organized as follows:

1.1 A Review of Recent Urban Stream Research and the ICM
1.2 Impacts of Urbanization on Downstream Receiving Waters
1.3 Implications of the ICM for Watershed Managers

1.1 A Review of Recent Urban Stream Research and the ICM

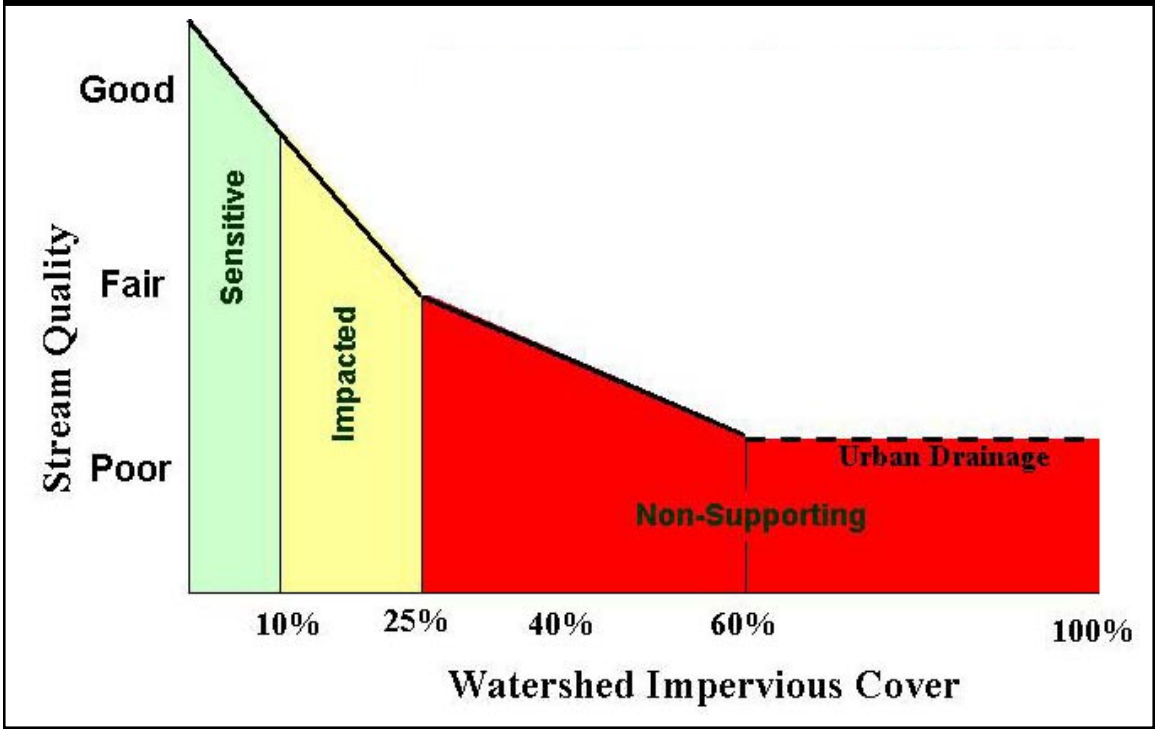
In 1994, the Center published "The Importance of Imperviousness," which outlined the scientific evidence for the relationship between IC and stream quality. At that time, about two dozen research studies documented a reasonably strong relationship between watershed IC and various indicators of stream quality. The research findings were subsequently integrated into the ICM (Schueler, 1994a and CWP, 1998). A brief summary of the basic assumptions of the ICM can be found in Figure 1. The ICM has had a major influence in watershed planning, stream classification and land use regulation in many communities. The ICM is a deceptively simple model that raises extremely complex and profound policy implications for watershed managers.

The ICM has been widely applied in many urban watershed settings for the purposes of small watershed planning, stream classification, and supporting restrictive development regulations and watershed zoning. As such, the ICM has stimulated intense debate among the planning, engineering and scientific communities. This debate is likely to soon spill over into the realm of politics and the courtroom, given its potential implications for local land use and environmental regulation. It is no wonder that the specter of scientific uncertainty is frequently invoked in the ICM debate, given the land use policy issues at stake. In this light, it is helpful to review the current strength of the evidence for and against the ICM.

The ICM is based on the following assumptions and caveats:

- Applies only to 1st, 2nd and 3rd order streams.
- Requires accurate estimates of percent IC, which is defined as the total amount of impervious cover over a subwatershed area.
- Predicts potential rather than actual stream quality. It can and should be expected that some streams will depart from the predictions of the model. For example, monitoring indicators may reveal poor water quality in a stream classified as "sensitive" or a surprisingly high biological diversity

Figure 1: Impervious Cover Model



score in a "non-supporting" one. Consequently, while IC can be used to initially diagnose stream quality, supplemental field monitoring is recommended to actually confirm it.

- Does not predict the precise score of an individual stream quality indicator but rather predicts the average behavior of a group of indicators over a range of IC. Extreme care should be exercised if the ICM is used to predict the fate of individual species (e.g., trout, salmon, mussels).

- "Thresholds" defined as 10 and 25% IC are not sharp "breakpoints," but instead reflect the expected transition of a composite of individual indicators in that range of IC. Thus, it is virtually impossible to distinguish real differences in stream quality indicators within a few percentage points of watershed IC (e.g., 9.9 vs. 10.1%).

- Should only be applied within the ecoregions where it has been tested, including the mid-Atlantic, Northeast, Southeast, Upper Midwest, and Pacific Northwest.

- Has not yet been validated for non-stream conditions (e.g., lakes, reservoirs, aquifers and estuaries).

- Does not currently predict the impact of watershed treatment.

In this section, we review available stream research to answer four questions about the ICM:

1. Does recent stream research still support the basic ICM?
2. What, if any, modifications need to be made to the ICM?
3. To what extent can watershed practices shift the predictions of the ICM?
4. What additional research is needed to test the ICM?

1.1.1 Strength of the Evidence for the ICM

Many researchers have investigated the IC/stream quality relationship in recent years. The Center recently undertook a comprehensive analysis of the literature to assess the scientific basis for the ICM. As of the end of 2002, we discovered more than 225 research studies that measured 26 different urban stream indicators within many regions of North America. We classified the research studies into three basic groups.

The first and most important group consists of studies that directly test the IC/stream quality indicator relationship by monitoring a large population of small watersheds. The second and largest group encompasses secondary studies that indirectly support the ICM by showing significant differences in stream quality indicators between urban and non-urban watersheds. The third and last group of studies includes widely accepted engineering models that explicitly use IC to directly predict stream quality indicators. Examples include engineering models that predict peak discharge or stormwater pollutant loads as a direct function of IC. In most cases, these relationships were derived from prior empirical research.

Table 1 provides a condensed summary of recent urban stream research, which shows the impressive growth in our understanding of urban streams and the watershed factors that influence them. A negative relationship between watershed development and nearly all of the 26 stream quality indicators has been established over many regions and scientific disciplines. About 50 primary studies have tested the IC/stream quality indicator relationship, with the largest number looking at biological indicators of stream health, such as the diversity of aquatic insects or fish. Another 150 or so secondary studies provide evidence that stream quality indicators are significantly different between urban and non-urban watersheds, which lends at least indirect support for the ICM and suggests that additional research to directly test the IC/stream quality indicator

**Table 1: The Strength of Evidence:
A Review of the Current Research on Urban Stream Indicators**

Stream Quality Indicator	#	IC	UN	EM	RV	Notes
Increased Runoff Volume	2	Y	Y	Y	N	extensive national data
Increased Peak Discharge	7	Y	Y	Y	Y	type of drainage system key
Increased Frequency of Bankfull Flow	2	?	Y	N	N	hard to measure
Diminished Baseflow	8	?	Y	N	Y	inconclusive data
Stream Channel Enlargement	8	Y	Y	N	Y	stream type important
Increased Channel Modification	4	Y	Y	N	?	stream enclosure
Loss of Riparian Continuity	4	Y	Y	N	?	can be affected by buffer
Reduced Large Woody Debris	4	Y	Y	N	?	Pacific NW studies
Decline in Stream Habitat Quality	11	Y	Y	N	?	
Changes in Pool Riffle/Structure	4	Y	Y	N	?	
Reduced Channel Sinuosity	1	?	Y	N	?	straighter channels
Decline in Streambed Quality	2	Y	Y	N	?	embeddedness
Increased Stream Temperature	5	Y	Y	N	?	buffers and ponds also a factor
Increased Road Crossings	3	?	Y	N	?	create fish barriers
Increased Nutrient Load	30+	?	Y	Y	N	higher stormwater EMCs
Increased Sediment Load	30+	?	Y	N	Y	higher EMCs in arid regions
Increased Metals & Hydrocarbons	20+	?	Y	Y	N	related to traffic/VMT
Increased Pesticide Levels	7	?	Y	N	Y	may be related to turf cover
Increased Chloride Levels	5	?	Y	N	Y	related to road density
Violations of Bacteria Standards	9	Y	Y	N	Y	indirect association
Decline in Aquatic Insect Diversity	33	Y	Y	N	N	IBI and EPT
Decline in Fish Diversity	19	Y	Y	N	N	regional IBI differences
Loss of Coldwater Fish Species	6	Y	Y	N	N	trout and salmon
Reduced Fish Spawning	3	Y	Y	N	?	
Decline in Wetland Plant Diversity	2	N	Y	N	?	water level fluctuation
Decline in Amphibian Community	5	Y	Y	N	?	few studies

***#**: total number of all studies that evaluated the indicator for urban watersheds*
***IC**: does balance of studies indicate a progressive change in the indicator as IC increases? Answers: Yes, No or No data (?)*
***UN**: If the answer to IC is no, does the balance of the studies show a change in the indicator from non-urban to urban watersheds? Yes or No*
***EM** Is the IC/stream quality indicator relationship implicitly assumed within the framework of widely accepted engineering models? Yes, No or No models yet exist (?)*
***RV**: If the relationship has been tested in more than one eco-region, does it generally show major differences between ecoregions? Answers: Yes, No, or insufficient data (?)*

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relationship is warranted. In some cases, the IC/stream quality indicator relationship is considered so strongly established by historical research that it has been directly incorporated into accepted engineering models. This has been particularly true for hydrological and water quality indicators.

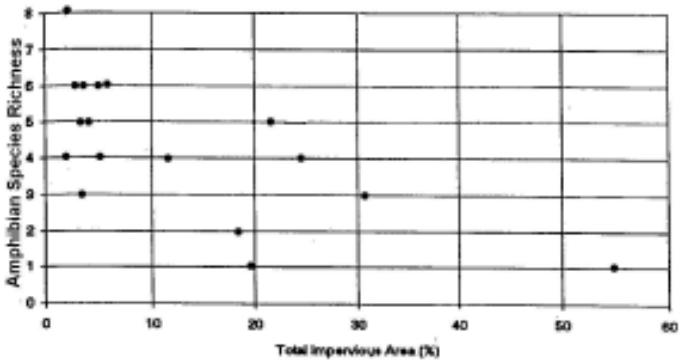
1.1.2 Reinterpretation of the ICM

Although the balance of recent stream research generally supports the ICM, it also offers several important insights for interpreting and applying the ICM, which are discussed next.

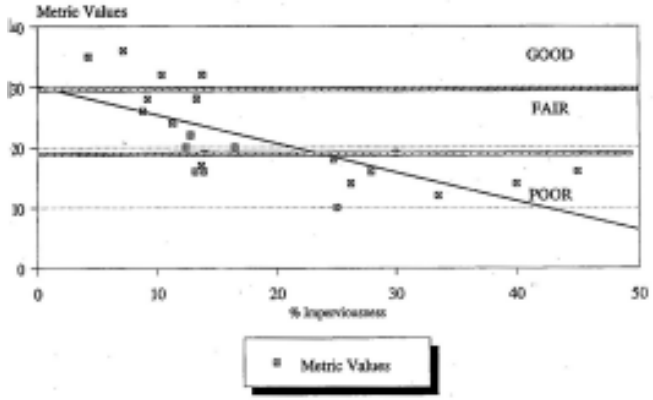
Statistical Variability

Scatter is a common characteristic of most IC/stream quality indicator relationships. In most cases, the overall trend for the indicator is down, but considerable variation exists along the trend line. Often, linear regression equations between IC and individual stream quality indicators produce relatively modest correlation coefficients (reported r^2 of 0.3 to 0.7 are often considered quite strong).

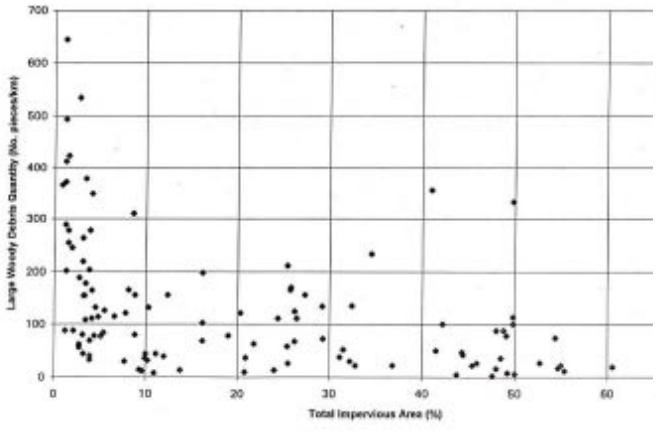
Figure 2 shows typical examples of the IC/stream quality indicator relationship that illustrate the pattern of statistical variability. Variation is always encountered when dealing with urban stream data (particularly so for biological indicators), but several patterns exist that have important implications for watershed managers.



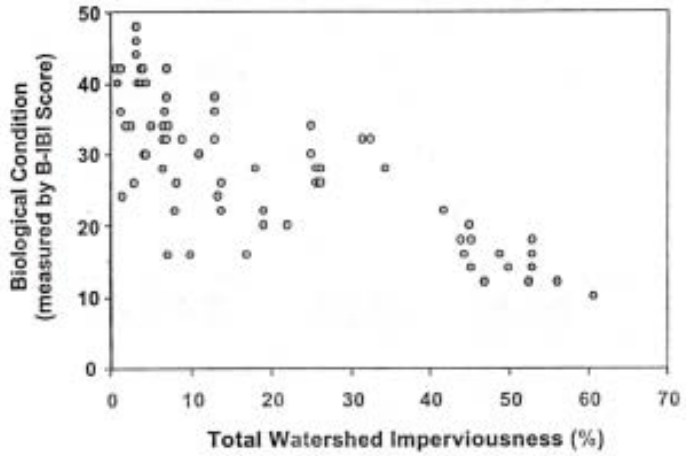
a. Fish IBI vs. IC in Fairfax, VA (Fairfax County, 2001)



b. CPSS vs. IC in Montgomery County, MD (MNCPPC, 2000)



c. Large Woody Debris vs. IC (Booth *et al.*, 1997)



d. Biological Condition vs. Total Watershed IC (Booth, 2000)

Figure 2: Typical Scatter Found in IC/Stream Quality Indicator Research

The first pattern to note is that the greatest scatter in stream quality indicator scores is frequently seen in the range of one to 10% IC. These streams, which are classified as "sensitive" according to the ICM, often exhibit low, moderate or high stream quality indicator scores, as shown in Figure 2. The key interpretation is that sensitive streams have the potential to attain high stream quality indicator scores, but may not always realize this potential.

Quite simply, the influence of IC in the one to 10% range is relatively weak compared to other potential watershed factors, such as percent forest cover, riparian continuity, historical land use, soils, agriculture, acid mine drainage or a host of other stressors. Consequently, watershed managers should never rely on IC alone to classify and manage streams in watersheds with less than 10% IC. Rather, they should evaluate a range of supplemental watershed variables to measure or predict actual stream quality within these lightly developed watersheds.

The second important pattern is that variability in stream quality indicator data is usually dampened when IC exceeds 10%, which presumably reflects the stronger influence of stormwater runoff on stream quality indicators. In particular, the chance that a stream quality indicator will attain a high quality score is sharply diminished at higher IC levels. This trend becomes pronounced within the 10 to 25% IC range and almost inevitable when watershed IC exceeds 25%. Once again, this pattern suggests that IC is a more robust and reliable indicator of overall stream quality beyond the 10% IC threshold.

Other Watershed Variables and the ICM

Several other watershed variables can potentially be included in the ICM. They include forest cover, riparian forest continuity and turf cover.

Forest cover (FC) is clearly the main rival to IC as a useful predictor of stream quality in urban watersheds, at least for humid regions of North America. In some regions, FC is simply the reciprocal of IC. For example, Horner and May (1999) have demonstrated a strong interrelationship between IC and FC for subwatersheds in the Puget Sound region (Figure 3). In other regions, however, "pre-

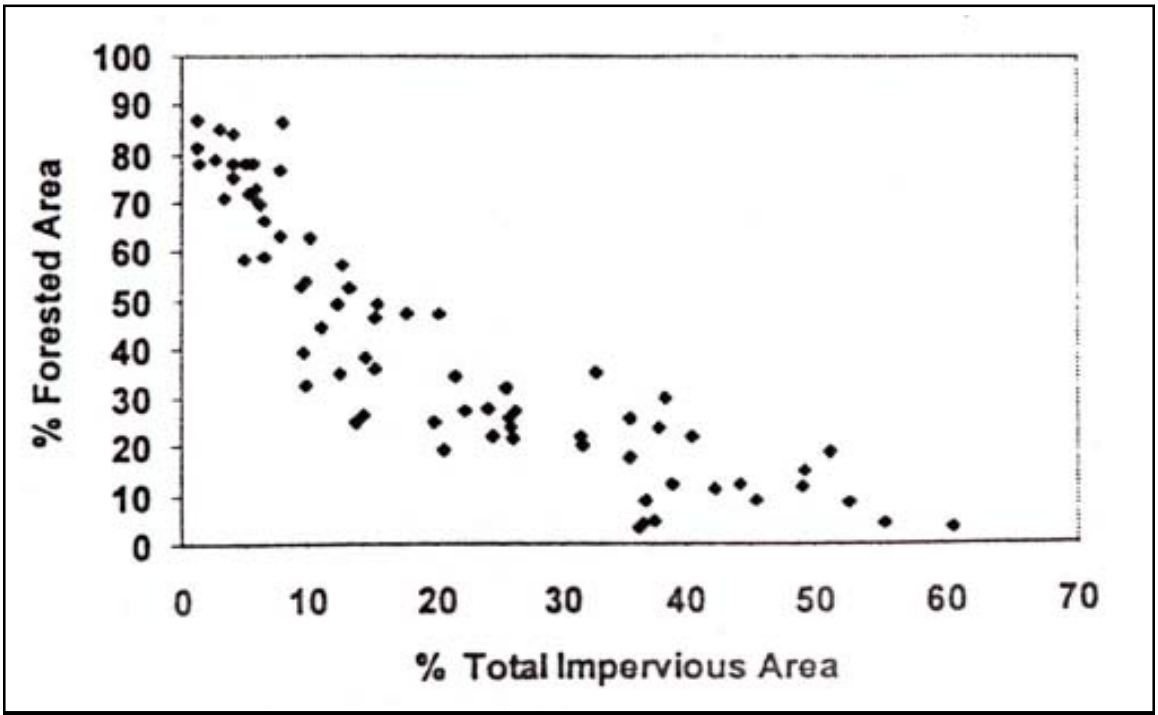


Figure 3: Relationship of IC and FC in Puget Sound Subwatersheds (Horner and May, 1999)

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development" land use represents a complex mosaic of crop land, pasture and forest. Therefore, an inverse relationship between FC and IC may not be universal for subwatersheds that have witnessed many cycles of deforestation and cultivation.

It should come as little surprise that the progressive loss of FC has been linked to declining stream quality indicators, given that forested watersheds are often routinely used to define natural reference conditions for streams (Booth, 2000 and Horner *et al.*, 2001). Mature forest is considered to be the main benchmark for defining pre-development hydrology within a subwatershed, as well. Consequently, FC is perhaps the most powerful indicator to predict the quality of streams within the "sensitive" category (zero to 10% IC).

To use an extreme example, one would expect that stream quality indicators would respond quite differently in a subwatershed that had 90% FC compared to one that had 90% crop cover. Indeed, Booth (1991) suggests that stream quality can only be maintained when IC is limited to less than 10% and at least 65% FC is retained within a subwatershed. The key management implication then is that stream health is best managed by simultaneously minimizing the creation of IC and maximizing the preservation of native FC.

FC has also been shown to be useful in predicting the quality of terrestrial variables in a subwatershed. For example, the Mid-Atlantic Integrated Assessment (USEPA, 2000) has documented that watershed FC can reliably predict the diversity of bird, reptile and amphibian communities in the mid-Atlantic region. Moreover, the emerging discipline of landscape ecology provides watershed managers with a strong scientific foundation for deciding where FC should be conserved in a watershed. Conservation plans that protect and connect large forest fragments have been shown to be effective in conserving terrestrial species.

Riparian forest continuity has also shown considerable promise in predicting at least some indicators of stream quality for urban watersheds. Researchers have yet to come up with a standard definition of riparian continuity, but it is usually defined as the proportion of the perennial stream network in a subwatershed that has a fixed width of mature streamside forest. A series of studies indicates that aquatic insect and fish diversity are associated with high levels of riparian continuity (Horner *et al.,* 2001; May *et al.*, 1997; MNCPPC, 2000; Roth *et al.,* 1998). On the other hand, not much evidence has been presented to support the notion that riparian continuity has a strong influence on hydrology or water quality indicators.

One watershed variable that received little attention is the fraction of watershed area maintained in turf cover (TC). Grass often comprises the largest fraction of land area within low-density residential development and could play a significant role in streams that fall within the "impacted" category (10 to 25% IC). Although lawns are pervious, they have sharply different properties than the forests and farmlands they replace (i.e., irrigation, compacted soils, greater runoff, and much higher input of fertilizers and pesticides, etc.). It is interesting to speculate whether the combined area of IC and TC might provide better predictions about stream health than IC area alone, particularly within impacted subwatersheds.

Several other watershed variables might have at least supplemental value in predicting stream quality. They include the presence of extensive wetlands and/or beaverdam complexes in a subwatershed; the dominant form of drainage present in the watershed (tile drains, ditches, swales, curb and gutters, storm drain pipes); the average age of development; and the proximity of sewer lines to the stream. As far as we could discover, none of these variables has been systematically tested in a controlled population of small watersheds. We have observed that these factors could be important in our field investigations and often measure them to provide greater insight into subwatershed behavior.

Lastly, several watershed variables that are closely related to IC have been proposed to predict stream quality. These include popula-

tion, percent urban land, housing density, road density and other indices of watershed development. As might be expected, they generally track the same trend as IC, but each has some significant technical limitations and/or difficulties in actual planning applications (Brown, 2000).

Individual vs. Multiple Indicators

The ICM does not predict the precise score of individual stream quality indicators, but rather predicts the average behavior of a group of indicators over a range of IC. Extreme care should be exercised if the ICM is used to predict the fate of individual indicators and/or species. This is particularly true for sensitive aquatic species, such as trout, salmon, and freshwater mussels. When researchers have examined the relationship between IC and individual species, they have often discovered lower thresholds for harm. For example, Boward *et al.* (1999) found that brook trout were not found in subwatersheds that had more than 4% IC in Maryland, whereas Horner and May (1999) asserted an 8% threshold for sustaining salmon in Puget Sound streams.

The key point is that if watershed managers want to maintain an individual species, they should be very cautious about adopting the 10% IC threshold. The essential habitat requirements for many sensitive or endangered species are probably determined by the *most sensitive* stream quality indicators, rather than the *average behavior* of all stream quality indicators.

Direct Causality vs. Association

A strong relationship between IC and declining stream quality indicators does not always mean that the IC is directly responsible for the decline. In some cases, however, causality can be demonstrated. For example, increased stormwater runoff volumes are directly caused by the percentage of IC in a subwatershed, although other factors such as conveyance, slope and soils may play a role.

In other cases, the link is much more indirect. For these indicators, IC is merely an index of the cumulative amount of watershed development, and more IC simply means that a greater number of known or unknown pollutant sources or stressors are present. In yet other cases, a causal link appears likely but has not yet been scientifically demonstrated. A good example is the more than 50 studies that have explored how fish or aquatic insect diversity changes in response to IC. While the majority of these studies consistently shows a very strong negative association between IC and biodiversity, they do not really establish which stressor or combination of stressors contributes most to the decline. The widely accepted theory is that IC changes stream hydrology, which degrades stream habitat, and in turn leads to reduced stream biodiversity.

Regional Differences

Currently, the ICM has been largely confirmed within the following regions of North America: the mid-Atlantic, the Northeast, the Southeast, the upper Midwest and the Pacific Northwest. Limited testing in Northern California, the lower Midwest and Central Texas generally agrees with the ICM. The ICM has not been tested in Florida, the Rocky Mountain West, and the Southwest. For a number of reasons, it is not certain if the ICM accurately predicts biological indicators in arid and semiarid climates (Maxted, 1999).

Measuring Impervious Cover

Most researchers have relied on total impervious cover as the basic unit to measure IC at the subwatershed level. The case has repeatedly been made that effective impervious cover is probably a superior metric (e.g., only counting IC that is hydraulically connected to the drainage system). Notwithstanding, most researchers have continued to measure total IC because it is generally quicker and does not require extensive (and often subjective) engineering judgement as to whether it is connected or not. Researchers have used a wide variety of techniques to estimate subwatershed IC, including satellite imagery, analysis of aerial photographs, and derivation from GIS land use layers. Table 2 presents some standard land use/IC relationships that were developed for suburban regions of the Chesapeake Bay.

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Table 2: Land Use/IC Relationships for Suburban Areas of the Chesapeake Bay
(Cappiella and Brown, 2001)

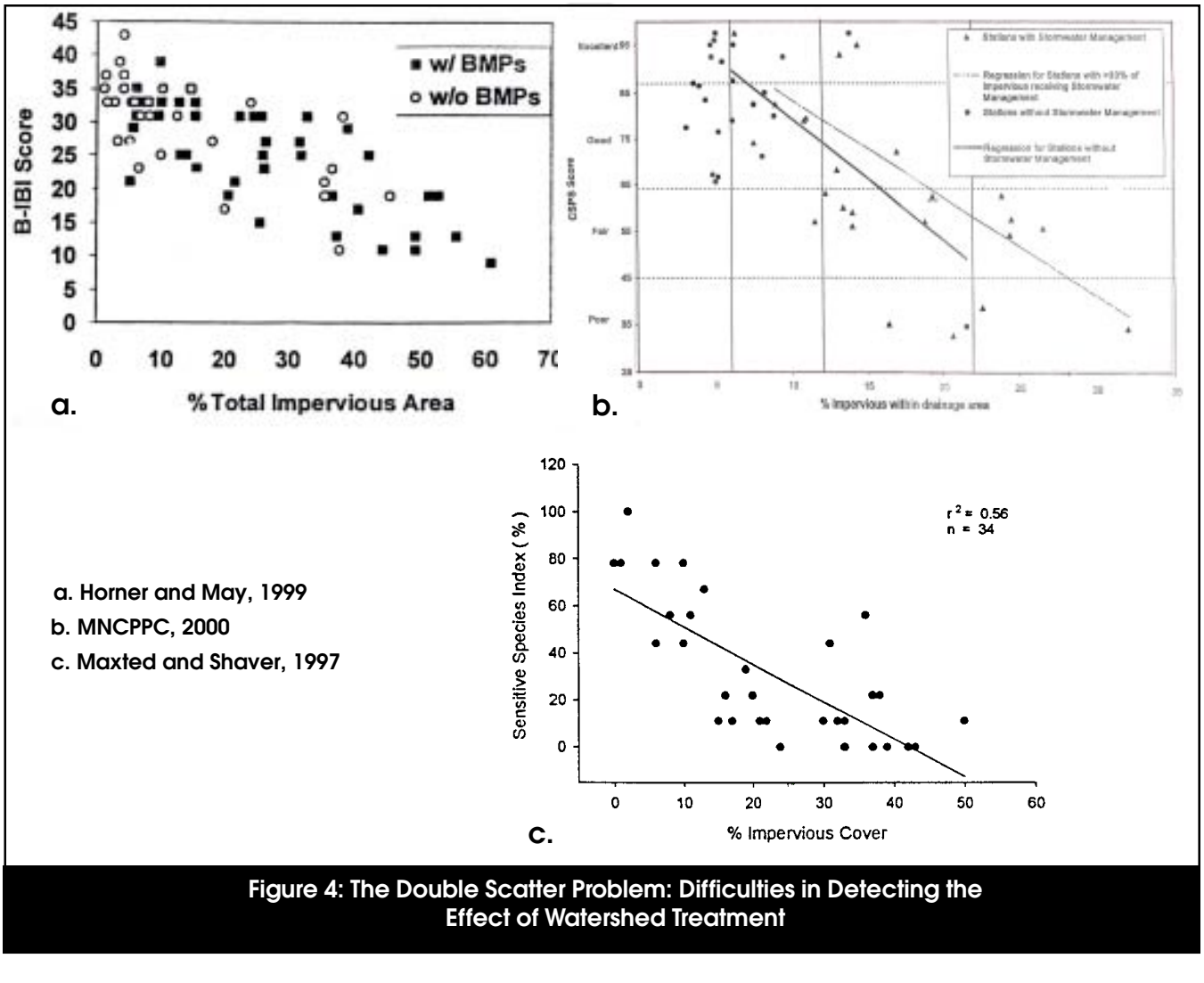
Land Use Category	Sample Number (N)	Mean IC (SE)	Land Use Category	Sample Number (N)	Mean IC (SE)
Agriculture	8	**1.9** – 0.3	Institutional	30	**34.4** – 3.45
Open Urban Land	11	**8.6** – 1.64	Light	20	**53.4** – 2.8
2 Acre Lot Residential	12	**10.6** – 0.65	Commercia	23	**72.2** – 2.0
1 Acre Lot Residential	23	**14.3** – 0.53	Churches	8	**39.9** – 7.8 1
1/2 Acre Lot Residential	20	**21.2** – 0.78	Schools	13	**30.3** – 4.8
1/4 Acre Lot Residential	23	**27.8** – 0.60	Municipals	9	**35.4** – 6.3
1/8 Acre Lot Residential	10	**32.6** – 1.6	Golf	4	**5.0** – 1.7
Townhome Residential	20	**40.9** – 1.39	Cemeteries	3	**8.3** – 3.5
Multifamily Residential	18	**44.4** – 2.0	Parks	4	**12.5** – 0.7

Three points are worth noting. First, it is fair to say that most researchers have spent more quality control effort on their stream quality indicator measurements than on their subwatershed IC estimates. At the current time, no standard protocol exists to estimate subwatershed IC, although Cappiella and Brown (2001) presented a useful method. At best, the different methods used to measure IC make it difficult to compare results from different studies, and at worst, it can introduce an error term of perhaps +/- 10% from the true value within an individual subwatershed. Second, it is important to keep in mind that IC is not constant over time; indeed, major changes in subwatershed IC have been observed within as few as two years. Consequently, it is sound practice to obtain subwatershed IC estimates from the most recent possible mapping data, to ensure that it coincides with stream quality indicator measurements. Lastly, it is important to keep in mind that most suburban and even rural zoning categories exceed 10% IC (see Table 2). Therefore, from a management standpoint, planners should try to project future IC, in order to determine the future stream classification for individual subwatersheds.

1.1.3 Influence of Watershed Treatment Practices on the ICM

The most hotly debated question about the ICM is whether widespread application of watershed practices such as stream buffers or stormwater management can mitigate the impact of IC, thereby allowing greater development density for a given watershed. At this point in time, there are fewer than 10 studies that directly bear on this critical question. Before these are reviewed, it is instructive to look at the difficult technical and scientific issues involved in detecting the effect of watershed treatment, given its enormous implications for land use control and watershed management.

The first tough issue is how to detect the effect of watershed treatment, given the inherent scatter seen in the IC/stream quality indicator relationship. Figure 4 illustrates the "double scatter" problem, based on three different urban stream research studies in Delaware, Maryland and Washington. A quick inspection of the three plots shows how intrinsically hard it is to distinguish the watershed treatment effect. As can be seen, stream quality indicators in subwatersheds with treatment tend to



a. Horner and May, 1999
b. MNCPPC, 2000
c. Maxted and Shaver, 1997

Figure 4: The Double Scatter Problem: Difficulties in Detecting the Effect of Watershed Treatment

overplot those in subwatersheds that lack treatment. While subtle statistical differences may be detected, they are not visibly evident. This suggests that the impact of watershed treatment would need to be extremely dramatic to be detected, given the inherent statistical variability seen in small watersheds (particularly so within the five to 25% IC range where scatter is considerable).

In an ideal world, a watershed study design would look at a controlled population of small urban watersheds that were developed with and without watershed practices to detect the impact of "treatment." In the real world, however, it is impossible to strictly control subwatershed variables. Quite simply, no two subwatersheds are ever alike. Each differs slightly with respect to drainage area, IC, forest cover, riparian continuity, historical land use, and percent watershed treatment. Researchers must also confront other real world issues when designing their watershed treatment experiments.

For example, researchers must carefully choose which indicator or group of indicators will be used to define stream health. IC has a negative influence on 26 stream quality indicators, yet nearly all of the watershed treatment research so far has focused on just a few biological indicators (e.g., aquatic insect or fish diversity) to define stream health. It is conceivable that watershed treatment might have no effect on biological indicators, yet have a positive influence on hydrology, habitat or water quality indicators. At this point, few of these indicators have been systematically

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tested in the field. It is extremely doubtful that any watershed practice can simultaneously improve or mitigate all 26 stream quality indicators, so researchers must carefully interpret the outcomes of their watershed treatment experiments.

The second issue involves how to quantify watershed treatment. In reality, watershed treatment collectively refers to dozens of practices that are installed at individual development sites in the many years or even decades it takes to fully "build out" a subwatershed. Several researchers have discovered that watershed practices are seldom installed consistently across an entire subwatershed. In some cases, less than a third of the IC in a subwatershed was actually treated by any practice, because development occurred prior to regulations; recent projects were exempted, waived or grandfathered; or practices were inadequately constructed or maintained (Horner and May, 1999 and MNCPPC, 2000).

Even when good coverage is achieved in a watershed, such as the 65 to 90% reported in studies of stormwater ponds (Jones *et al*., 1996; Maxted, 1999; Maxted and Shaver, 1997), it is still quite difficult to quantify the actual quality of treatment. Often, each subwatershed contains its own unique mix of stormwater practices installed over several decades, designed under diverse design criteria, and utilizing widely different stormwater technologies. Given these inconsistencies, researchers will need to develop standard protocols to define the extent and quality of watershed treatment.

Effect of Stormwater Ponds

With this in mind, the effect of stormwater ponds and stream buffers can be discussed. The effect of larger stormwater ponds in mitigating the impacts of IC in small watersheds has received the most scrutiny to date. This is not surprising, since larger ponds often control a large fraction of their contributing subwatershed area (e.g. 100 to 1,000 acres) and are located on the stream itself, therefore lending themselves to easier monitoring. Three studies have evaluated the impact of large stormwater ponds on downstream aquatic insect communities (Jones *et al.*, 1996; Maxted and Shaver, 1997; Stribling *et al.*, 2001). Each of these studies was conducted in small headwater subwatersheds in the mid-Atlantic Region, and none was able to detect major differences in aquatic insect diversity in streams with or without stormwater ponds.

Four additional studies statistically evaluated the stormwater treatment effect in larger populations of small watersheds with varying degrees of IC (Horner and May, 1999; Horner *et al.,* 2001; Maxted, 1999; MNCPPC, 2000). These studies generally sampled larger watersheds that had many stormwater practices but not necessarily complete watershed coverage. In general, these studies detected a small but positive effect of stormwater treatment relative to aquatic insect diversity. This positive effect was typically seen only in the range of five to 20% IC and was generally undetected beyond about 30% IC. Although each author was hesitant about interpreting his results, all generally agreed that perhaps as much as 5% IC could be added to a subwatershed while maintaining aquatic insect diversity, given effective stormwater treatment. Forest retention and stream buffers were found to be very important, as well. Horner *et al.* (2001) reported a somewhat stronger IC threshold for various species of salmon in Puget Sound streams.

Some might conclude from these initial findings that stormwater ponds have little or no value in maintaining biological diversity in small streams. However, such a conclusion may be premature for several reasons. First, the generation of stormwater ponds that was tested was not explicitly designed to protect stream habitat or to prevent downstream channel erosion, which would presumably promote aquatic diversity. Several states have recently changed their stormwater criteria to require extended detention for the express purpose of preventing downstream channel erosion, and these new criteria may exert a stronger influence on aquatic diversity. Instead, their basic design objective was to maximize pollutant removal, which they did reasonably well.

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The second point to stress is that streams with larger stormwater ponds should be considered "regulated streams" (Ward and Stanford, 1979), which have a significantly altered aquatic insect community downstream of the ponds. For example, Galli (1988) has reported that on-stream wet stormwater ponds shift the trophic structure of the aquatic insect community. The insect community above the pond was dominated by shredders, while the insect community below the pond was dominated by scrapers, filterers and collectors. Of particular note, several pollution-sensitive species were eliminated below the pond. Galli reported that changes in stream temperatures, carbon supply and substrate fouling were responsible for the downstream shift in the aquatic insect community. Thus, while it is clear that large stormwater ponds can be expected to have a negative effect on aquatic insect diversity, they could still exert positive influence on other stream quality indicators.

Effect of Stream Buffers

A handful of studies have evaluated biological indicator scores for urban streams that have extensive forest buffers, compared to streams where they were mostly or completely absent (Horner and May, 1999; Horner *et al.,* 2001; May *et al.*, 1997; MNCPPC, 2000; Roth *et al.,* 1998; Steedman, 1988). Biological indicators included various indices of aquatic insect, fish and salmon diversity. Each study sampled a large population of small subwatersheds over a range of IC and derived a quantitative measure to express the continuity, width and forest cover of the riparian buffer network within each subwatershed. Riparian forests were hypothesized to have a positive influence on stream biodiversity, given the direct ways they contribute to stream habitat (e.g., shading, woody debris, leaf litter, bank stability, and organic carbon supply).

All five studies detected a small to moderate positive effect when forested stream buffers were present (frequently defined as at least two-thirds of the stream network with at least 100 feet of stream side forest). The greatest effect was reported by Horner and May (1999) and Horner *et al.* (2001) for salmon streams in the Puget Sound ecoregion. If excellent riparian habitats were preserved, they generally reported that fish diversity could be maintained up to 15% IC, and good aquatic insect diversity could be maintained with as much as 30% IC. Steedman (1988) reported a somewhat smaller effect for Ontario streams. MNCPPC (2000), May *et al.* (1997), and Roth *et al.* (1998) could not find a statistically significant relationship between riparian quality and urban stream quality indicators but did report that most outliers (defined as higher IC subwatersheds with unusually high biological indicator scores) were generally associated with extensive stream side forest.

1.1.4 Recommendations for Further ICM Research

At this point, we recommend three research directions to improve the utility of the ICM for watershed managers. The **first direction** is to expand basic research on the relationship between IC and stream quality indicators that have received little scrutiny. In particular, more work is needed to define the relationship between IC and hydrological and physical indicators such as the following:

- Physical loss or alteration of the stream network
- Stream habitat measures
- Riparian continuity
- Baseflow conditions during dry weather

In addition, more watershed research is needed in ecoregions and physiographic areas where the ICM has not yet been widely tested. Key areas include Florida, arid and semiarid climates, karst areas and mountainous regions. The basic multiple subwatershed monitoring protocol set forth by Schueler (1994a) can be used to investigate IC/stream quality relationships, although it would be wise to measure a wider suite of subwatershed variables beyond IC (e.g., forest cover, turf cover, and riparian continuity).

The **second** research direction is to more clearly define the impact of watershed treatment on stream quality indicators. Based on

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the insurmountable problems encountered in controlling variation at the subwatershed level, it may be necessary to abandon the multiple watershed or paired watershed sampling approaches that have been used to date. Instead, longitudinal monitoring studies within individual subwatersheds may be a more powerful tool to detect the effect of watershed treatment. These studies could track changes in stream quality indicators in individual subwatersheds over the entire development cycle: pre-development land use, clearing, construction, build out, and post construction. In most cases, longitudinal studies would take five to 10 years to complete, but they would allow watershed managers to measure and control the inherent variability at the subwatershed level and provide a "before and after" test of watershed treatment. Of course, a large population of test subwatersheds would be needed to satisfactorily answer the watershed treatment question.

The **third** research direction is to monitor more non-supporting streams, in order to provide a stronger technical foundation for crafting more realistic urban stream standards and to see how they respond to various watershed restoration treatments. As a general rule, most researchers have been more interested in the behavior of sensitive and impacted streams. The non-supporting stream category spans a wide range of IC, yet we do not really understand how stream quality indicators behave over the entire 25 to 100% IC range.

For example, it would be helpful to establish the IC level at the upper end of the range where streams are essentially transformed into an artificial conveyance system (i.e., become pipes or artificial channels). It would also be interesting to sample more streams near the lower end of the non-supporting category (25 to 35% IC) to detect whether stream quality indicators respond to past watershed treatment or current watershed restoration efforts. For practical reasons, the multiple subwatershed sampling approach is still recommended to characterize indicators in non-supporting streams. However, researchers will need to screen a large number of non-supporting subwatersheds in order to identify a few subwatersheds that are adequate for subsequent sampling (i.e., to control for area, IC, development age, percent watershed treatment, type of conveyance systems, etc.).

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1.2 Impacts of Urbanization on Downstream Receiving Waters

In this section, we review the impacts of urbanization on downstream receiving waters, primarily from the standpoint of impacts caused by poor stormwater quality. We begin by looking at the relationship between IC and stormwater pollutant loadings. Next, we discuss the sensitivity of selected downstream receiving waters to stormwater pollutant loads. Lastly, we examine the effect of watershed treatment in reducing stormwater pollutant loads.

1.2.1 Relationship Between Impervious Cover and Stormwater Quality

Urban stormwater runoff contains a wide range of pollutants that can degrade downstream water quality (Table 3). Several generalizations can be supported by the majority of research conducted to date. First, the unit area pollutant load delivered by stormwater runoff to receiving waters increases in direct proportion to watershed IC. This is not altogether surprising, since pollutant load is the product of the average pollutant concentration and stormwater runoff volume. Given that runoff volume increases in direct proportion to IC, pollutant loads must automatically increase when IC increases, as long the average pollutant concentration stays the same (or increases). This relationship is a central assumption in most simple and complex pollutant loading models (Bicknell *et al.*, 1993; Donigian and Huber, 1991; Haith *et al.*, 1992; Novotny and Chester, 1981; NVPDC, 1987; Pitt and Voorhees, 1989).

The second generalization is that stormwater pollutant concentrations are generally similar

Table 3: Summary of Urban Stormwater Pollutant Loads on Quality of Receiving Waters

Pollutants in Urban Stormwater	WQ Impacts To:					Higher Unit Load?	Load a function of IC?	Other Factors Important in Loading
	R	L	E	A	W			
Suspended Sediment	Y	Y	Y	N	Y	Y (ag)	Y	channel erosion
Total Nitrogen	N	N	Y	Y	N	Y (ag)	Y	septic systems
Total Phosphorus	Y	Y	N	N	Y	Y (ag)	Y	tree canopy
Metals	Y	Y	Y	?	N	Y	Y	vehicles
Hydrocarbons	Y	Y	Y	Y	Y	Y	?	related to VMTs and hotspots
Bacteria/Pathogens	Y	Y	Y	N	Y	Y	Y	many sources
Organic Carbon	N	?	?	?	Y	Y	Y	
MTBE	N	N	N	Y	Y	Y	?	roadway, VMTs
Pesticides	?	?	?	?	Y	Y	?	turf/landscaping
Chloride	?	Y	N	Y	Y	Y	?	road density
Trash/Debris	Y	Y	Y	N	?	Y	Y	curb and gutters

Major Water Quality Impacts Reported for:
R = River, L = Lake, E = Estuary, A = Aquifer, W = Surface Water Supply
Higher Unit Area Load? Yes (compared to all land uses) (ag): with exception of cropland
Load a function of IC? Yes, increases proportionally with IC

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at the catchment level, regardless of the mix of IC types monitored (e.g., residential, commercial, industrial or highway runoff). Several hundred studies have examined stormwater pollutant concentrations from small urban catchments and have generally found that the variation within a catchment is as great as the variation between catchments. Runoff concentrations tend to be log-normally distributed, and therefore the long term "average" concentration is best expressed by a median value. It should be kept in mind that researchers have discovered sharp differences in pollutant concentrations for smaller, individual components of IC (e.g., rooftops, parking lots, streets, driveways and the like). Since most urban catchments are composed of many kinds of IC, this mosaic quality tempers the variability in long term pollutant concentrations at the catchment or subwatershed scale.

The third generalization is that median concentrations of pollutants in urban runoff are usually higher than in stormwater runoff from most other non-urban land uses. Consequently, the unit area nonpoint pollutant load generated by urban land normally exceeds that of nearly all watershed land uses that it replaces (forest, pasture, cropland, open space — see Table 3). One important exception is cropland, which often produces high unit area sediment and nutrient loads in many regions of the country. In these watersheds, conversion of intensively managed crops to low density residential development may actually result in a slightly decreased sediment or nutrient load. On the other hand, more intensive land development (30% IC or more) will tend to equal or exceed cropland loadings.

The last generalization is that the effect of IC on stormwater pollutant loadings tends to be weakest for subwatersheds in the one to 10% IC range. Numerous studies have suggested that other watershed and regional factors may have a stronger influence, such as the underlying geology, the amount of carbonate rock in the watershed, physiographic region, local soil types, and most important, the relative fraction of forest and crop cover in the subwatershed (Herlihy *et al*., 1998 and Liu *et al.,* 2000). The limited influence of IC on pollutant loads is generally consistent with the finding for hydrologic, habitat and biological indicators over this narrow range of IC. Once again, watershed managers are advised to track other watershed indicators in the sensitive stream category, such as forest or crop cover.

1.2.2 Water Quality Response to Stormwater Pollution

As noted in the previous section, most ICM research has been done on streams, which are directly influenced by increased stormwater. Many managers have wondered whether the ICM also applies to downstream receiving waters, such as lakes, water supply reservoirs and small estuaries. In general, the exact water quality response of downstream receiving waters to increased nonpoint source pollutant loads depends on many factors, including the specific pollutant, the existing loading generated by the converted land use, and the geometry and hydraulics of the receiving water. Table 3 indicates the sensitivity of rivers, lakes, estuaries, aquifers and water supply reservoirs to various stormwater pollutants.

Lakes and the ICM

The water column and sediments of urban lakes are impacted by many stormwater pollutants, including sediment, nutrients, bacteria, metals, hydrocarbons, chlorides, and trash/debris. Of these pollutants, limnologists have always regarded phosphorus as the primary lake management concern, given that more than 80% of urban lakes experience symptoms of eutrophication (CWP, 2001a).

In general, phosphorus export steadily increases as IC is added to a lake watershed, although the precise amount of IC that triggers eutrophication problems is unique to each urban lake. With a little effort, it is possible to calculate the specific IC threshold for an individual lake, given its internal geometry, the size of its contributing watershed, current in-lake phosphorus concentration, degree of watershed treatment, and the desired water quality goals for the lake (CWP, 2001a). As a general rule, most lakes are extremely sensitive

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to increases in phosphorus loads caused by watershed IC. Exceptions include lakes that are unusually deep and/or have very small drainage area/lake area ratios. In most lakes, however, even a small amount of watershed development will result in an upward shift in trophic status (CWP, 2001a).

Reservoirs and the ICM

While surface water supply reservoirs respond to stormwater pollutant loads in the same general manner as lakes, they are subject to stricter standards because of their uses for drinking water. In particular, water supply reservoirs are particularly sensitive to increased turbidity, pathogens, total organic carbon, chlorides, metals, pesticides and hydrocarbon loads, in addition to phosphorus (Kitchell, 2001). While some pollutants can be removed or reduced through expanded filtering and treatment at drinking water intakes, the most reliable approach is to protect the source waters through watershed protection and treatment.

Consequently, we often recommend that the ICM be used as a "threat index" for most drinking water supplies. Quite simply, if current or future development is expected to exceed 10% IC in the contributing watershed, we recommend that a very aggressive watershed protection strategy be implemented (Kitchell, 2001). In addition, we contend that drinking water quality cannot be sustained once watershed IC exceeds 25% and have yet to find an actual watershed where a drinking water utility has been maintained under these conditions.

Small Tidal Estuaries and Coves and the ICM

The aquatic resources of small tidal estuaries, creeks, and coves are often highly impacted by watershed development and associated activities, such as boating/marinas, wastewater discharge, septic systems, alterations in freshwater flow and wetland degradation and loss. Given the unique impacts of eutrophication on the marine system and stringent water quality standards for shellfish harvesting, the stormwater pollutants of greatest concern in the estuarine water column are nitrogen and fecal coliform bacteria. Metals and hydrocarbons in stormwater runoff can also contaminate bottom sediments, which can prove toxic to local biota (Fortner *et al*., 1996; Fulton *et al.*, 1996; Kucklick *et al.*, 1997; Lerberg *et al.*, 2000; Sanger *et al.,* 1999; Vernberg *et al.*, 1992).

While numerous studies have demonstrated that physical, hydrologic, water quality and biological indicators differ in urban and non-urban coastal watersheds, only a handful of studies have used watershed IC as an indicator of estuarine health. These studies show significant correlations with IC, although degradation thresholds may not necessarily adhere to the ICM due to tidal dilution and dispersion. Given the limited research, it is not fully clear if the ICM can be applied to coastal systems without modification.

Atmospheric deposition is considered a primary source of nitrogen loading to estuarine watersheds. Consequently, nitrogen loads in urban stormwater are often directly linked to IC. Total nitrogen loads have also been linked to groundwater input, especially from subsurface discharges from septic systems, which are common in low density coastal development (Swann, 2001; Valiela *et al.*, 1997; Vernberg *et al.*, 1996a). Nitrogen is generally considered to be the limiting nutrient in estuarine systems, and increased loading has been shown to increase algal and phytoplankton biomass and cause shifts in the phytoplankton community and food web structure that may increase the potential for phytoplankton blooms and fish kills (Bowen and Valiela, 2001; Evgenidou *et al.*, 1997; Livingston, 1996).

Increased nitrogen loads have been linked to declining seagrass communities, finfish populations, zooplankton reproduction, invertebrate species richness, and shellfish populations (Bowen and Valiela, 2001; Rutkowski *et al*., 1999; Short and Wyllie-Echeverria, 1996; Valiela and Costa, 1988). Multiple studies have shown significant increases in nitrogen loading as watershed land use becomes more urban (Valiela *et al.,* 1997; Vernberg *et al.* 1996a; Wahl *et al.,* 1997). While a few studies

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link nitrogen loads with building and population density, no study was found that used IC as an indicator of estuarine nitrogen loading.

The second key water quality concern in small estuaries is high fecal coliform levels in stormwater runoff, which can lead to the closure of shellfish beds and swimming beaches. Waterfowl and other wildlife have also been shown to contribute to fecal coliform loading (Wieskel *et al.*, 1996). Recent research has shown that fecal coliform standards are routinely violated during storm events at very low levels of IC in coastal watersheds (Mallin *et al.,* 2001; Vernberg *et al.*, 1996b; Schueler, 1999). Maiolo and Tschetter (1981) found a significant correlation between human population and closed shellfish acreage in North Carolina, and Duda and Cromartie (1982) found greater fecal coliform densities when septic tank density and IC increased, with an approximate threshold at 10% watershed IC.

Recently, Mallin *et al.* (2000) studied five small North Carolina estuaries of different land uses and showed that fecal coliform levels were significantly correlated with watershed population, developed land and IC. Percent IC was the most statistically significant indicator and could explain 95% of the variability in fecal coliform concentrations. They also found that shellfish bed closures were possible in watersheds with less than 10% IC, common in watersheds above 10% IC, and almost certain in watersheds above 20% IC. While higher fecal coliform levels were observed in developed watersheds, salinity, flushing and proximity to pollution sources often resulted in higher concentrations at upstream locations and at high tides (Mallin *et al.*, 1999). While these studies support the ICM, more research is needed to prove the reliability of the ICM in predicting shellfish bed closures based on IC.

Several studies have also investigated the impacts of urbanization on estuarine fish, macrobenthos and shellfish communities. Increased PAH accumulation in oysters, negative effects of growth in juvenile sheepshead minnows, reduced molting efficiency in copepods, and reduced numbers of grass shrimp have all been reported for urban estuaries as compared to forested estuaries (Fulton *et al.,* 1996). Holland *et al. (*1997) reported that the greatest abundance of penaid shrimp and mummichogs was observed in tidal creeks with forested watersheds compared to those with urban cover. Porter *et al.* (1997) found lower grass shrimp abundance in small tidal creeks adjacent to commercial and urban development, as compared to non-urban watersheds.

Lerberg *et al.* (2000) studied small tidal creeks and found that highly urban watersheds (50% IC) had the lowest benthic diversity and abundance as compared to suburban and forested creeks, and benthic communities were numerically dominated by tolerant oligochaetes and polychaetes. Suburban watersheds (15 to 35% IC) also showed signs of degradation and had some pollution tolerant macrobenthos, though not as markedly as urban creeks. Percent abundance of pollution-indicative species showed a marked decline at 30% IC, and the abundance of pollution-sensitive species also significantly correlated with IC (Lerberg *et al*., 2000). Holland *et al*. (1997) reported that the variety and food availability for juvenile fish species was impacted at 15 to 20% IC.

Lastly, a limited amount of research has focused on the direct impact of stormwater runoff on salinity and hypoxia in small tidal creeks. Blood and Smith (1996) compared urban and forested watersheds and found higher salinities in urban watersheds due to the increased number of impoundments. Fluctuations in salinity have been shown to affect shellfish and other aquatic populations (see Vernberg, 1996b). When urban and forested watersheds were compared, Lerberg *et al.* (2000) reported that higher salinity fluctuations occurred most often in developed watersheds; significant correlations with salinity range and IC were also determined. Lerberg *et al.* (2000) also found that the most severe and frequent hypoxia occurred in impacted salt marsh creeks and that dissolved oxygen dynamics in tidal creeks were comparable to dead-end canals common in residential marina-style

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coastal developments. Suburban watersheds (15 to 35% IC) exhibited signs of degradation and had some pollution-tolerant macrobenthic species, though not to the extent of urban watersheds (50% IC).

In summary, recent research suggests that indicators of coastal watershed health are linked to IC. However, more research is needed to clarify the relationship between IC and estuarine indicators in small tidal estuaries and high salinity creeks.

1.2.3 Effect of Watershed Treatment on Stormwater Quality

Over the past two decades, many communities have invested in watershed protection practices, such as stormwater treatment practices (STPs), stream buffers, and better site design, in order to reduce pollutant loads to receiving waters. In this section, we review the effect of watershed treatment on the quality of stormwater runoff.

Effect of Stormwater Treatment Practices
We cannot directly answer the question as to whether or not stormwater treatment practices can significantly reduce water quality impacts at the watershed level, simply because no controlled monitoring studies have yet been conducted at this scale. Instead, we must rely on more indirect research that has tracked the change in mass or concentration of pollutants as they travel through individual stormwater treatment practices. Thankfully, we have an abundance of these performance studies, with nearly 140 monitoring studies evaluating a diverse range of STPs, including ponds, wetlands, filters, and swales (Winer, 2000).

These studies have generally shown that stormwater practices have at least a moderate ability to remove many pollutants in urban stormwater. Table 4 provides average removal efficiency rates for a range of practices and stormwater pollutants, and Table 5 profiles the mean storm outflow concentrations for various practices. As can be seen, some groups of practices perform better than others in removing certain stormwater pollutants. Consequently, managers need to carefully choose which practices to apply to solve the primary water quality problems within their watersheds.

It is also important to keep in mind that site-based removal rates cannot be extrapolated to the watershed level without significant adjustment. Individual site practices are never implemented perfectly or consistently across a watershed. At least three discount factors need to be considered: bypassed load, treatability and loss of performance over time. For a review on how these discounts are derived, consult Schueler and Caraco (2001). Even under the most optimistic watershed implementation scenarios, overall pollutant reduc-

Table 4: The Effectiveness of Stormwater Treatment Practices in Removing Pollutants - Percent Removal Rate (Winer, 2000)

Practice	N	TSS	TP	OP	TN	NOx	Cu	Zn	Oil/ Grease[1]	Bacteria
Dry Ponds	9	47	19	N/R	25	3.5	26	26	3	44
Wet Ponds	43	80	51	65	33	43	57	66	78	70
Wetlands	36	76	49	48	30	67	40	44	85	78
Filtering Practices[2]	18	86	59	57	38	-14	49	88	84	37
Water Quality Swales	9	81	34	1.0	84	31	51	71	62	-25
Ditches[3]	9	31	-16	N/R	-9.0	24	14	0	N/R	0
Infiltration	6	95	80	85	51	82	N/R	N/R	N/R	N/R

1: Represents data for Oil and Grease and PAH
2: Excludes vertical sand filters
3: Refers to open channel practices not designed for water quality
N/R = Not Reported

Table 5: Median Effluent Concentrations from Stormwater Treatment Practices (mg/l) (Winer, 2000)

Practice	N	TSS	TP	OP	TN	NOx	Cu[1]	Zn[1]
Dry Ponds[2]	3	28	0.18	N/R	0.86	N/R	9.0	98
Wet Ponds	25	17	0.11	0.03	1.3	0.26	5.0	30
Wetlands	19	22	0.20	0.07	1.7	0.36	7.0	31
Filtering Practices[3]	8	11	0.10	0.07	1.1	0.55	9.7	21
Water Quality Swales	7	14	0.19	0.09	1.1	0.35	10	53
Ditches[4]	3	29	0.31	N/R	2.4	0.72	18	32

1. Units for Zn and Cu are micrograms per liter (Fg/l)
2. Data available for Dry Extended Detention Ponds only
3. Excludes vertical sand filters
4. Refers to open channel practices not designed for water quality
N/R = Not Reported

tions by STPs may need to be discounted by at least 30% to account for partial watershed treatment.

Even with discounting, however, it is evident that STPs can achieve enough pollutant reduction to mimic rural background loads for many pollutants, as long as the watershed IC does not exceed 30 to 35%. This capability is illustrated in Figure 5, which shows phosphorus load as a function of IC, with and without stormwater treatment.

Effect of Stream Buffers/Riparian Areas

Forested stream buffers are thought to have very limited capability to remove stormwater pollutants, although virtually no systematic monitoring data exists to test this hypothesis. The major reason cited for their limited removal capacity is that stormwater generated from upland IC has usually concentrated before it reaches the forest buffer and therefore crosses the buffer in a channel, ditch or storm drain pipe. Consequently, the opportunity to filter runoff is lost in many forest buffers in urban watersheds.

Effect of Better Site Design

Better site design (BSD) is a term for nonstructural practices that minimize IC, conserve natural areas and distribute stormwater treatment across individual development sites. BSD is also known by many other names, including conservation development, low-impact development, green infrastructure, and sustainable urban drainage systems. While

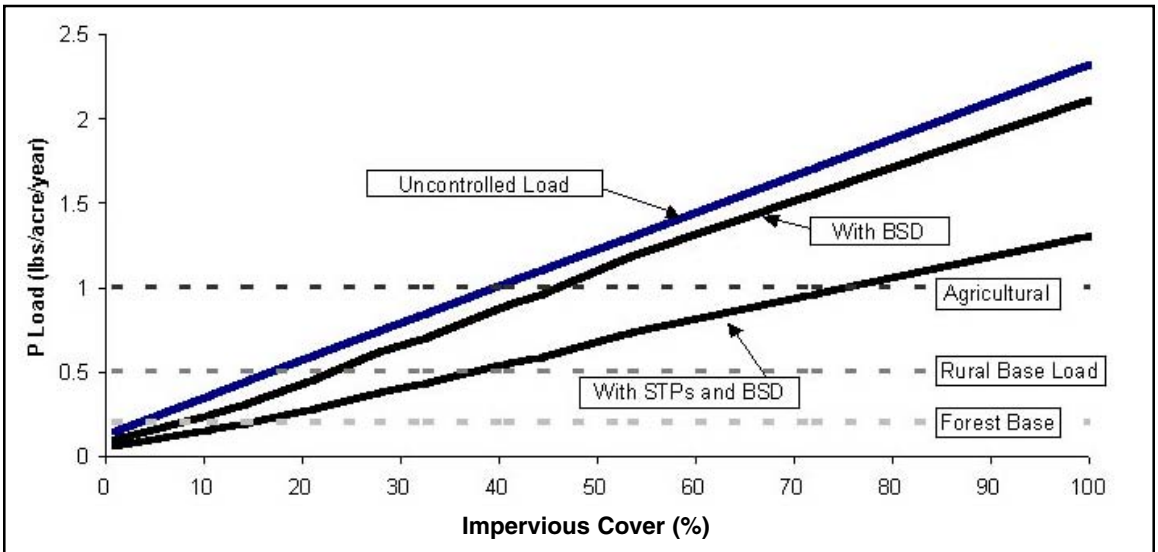

Figure 5: Estimated Phosphorus Load as a Function of Impervious Cover, Discounted Stormwater Treatment and Better Site Design (Schueler and Caraco, 2001)

some maintain that BSD is an alternative to traditional STPs, most consider it to be an important complement to reduce pollutant loads.

While BSD has become popular in recent years, only one controlled research study has evaluated its potential performance, and this is not yet complete (i.e. Jordan Cove, CT).

Indirect estimates of the potential value of BSD to reduce pollutant discharges have been inferred from modeling and redesign analyses (Zielinski, 2000). A typical example is provided in Figure 5, which shows the presumed impact of BSD in reducing phosphorus loadings. As is apparent, BSD appears to be a very effective strategy in the one to 25% IC range, but its benefits diminish beyond that point.

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1.3 Implications of the ICM for Watershed Managers

One of the major policy implications of the ICM is that in the absence of watershed treatment, it predicts negative stream impacts at an extremely low intensity of watershed development. To put this in perspective, consider that a watershed zoned for two-acre lot residential development will generally exceed 10% IC, and therefore shift from a sensitive to an impacted stream classification (Cappiella and Brown, 2001). Thus, if a community wants to protect an important water resource or a highly regarded species (such as trout, salmon or an endangered freshwater mussel), the ICM suggests that there is a maximum limit to growth that is not only quite low, but is usually well below the current zoning for many suburban or even rural watersheds. Consequently, the ICM suggests the unpleasant prospect that massive down-zoning, with all of the associated political and legal carnage involving property rights and economic development, may be required to maintain stream quality.

It is not surprising, then, that the ICM debate has quickly shifted to the issue of whether or not watershed treatment practices can provide adequate mitigation for IC. How much relief can be expected from stream buffers, stormwater ponds, and other watershed practices, which might allow greater development density within a given watershed? Only a limited amount of research has addressed this question, and the early results are not reassuring (reviewed in section 1.1.3). At this early stage, researchers are still having trouble detecting the impact of watershed treatment, much less defining it. As noted earlier, both watershed research techniques and practice implementation need to be greatly improved if we ever expect to get a scientifically defensible answer to this crucial question. Until then, managers should be extremely cautious in setting high expectations for how much watershed treatment can mitigate IC.

1.3.1 Management of Non-Supporting Streams

Most researchers acknowledge that streams with more than 25% IC in their watersheds cannot support their designated uses or attain water quality standards and are severely degraded from a physical and biological standpoint. As a consequence, many of these streams are listed for non-attainment under the Clean Water Act and are subject to Total Maximum Daily Load (TMDL) regulations. Communities that have streams within this regulatory class must prepare implementation plans that demonstrate that water quality standards can ultimately be met.

While some communities have started to restore or rehabilitate these streams in recent years, their efforts have yielded only modest improvements in water quality and biological indicators. In particular, no community has yet demonstrated that they can achieve water quality standards in an urban watershed that exceeds 25% IC. Many communities are deeply concerned that non-supporting streams may never achieve water quality standards, despite massive investments in watershed restoration. The ICM suggests that water quality standards may need to be sharply revised for streams with more than 25% IC, if they are ever to come into attainment. While states have authority to create more achievable standards for non-supporting streams within the regulatory framework of the Clean Water Act (Swietlik, 2001), no state has yet exercised this authority. At this time, we are not aware of any water quality standards that are based on the ICM or similar urban stream classification techniques.

Two political perceptions largely explain why states are so reticent about revising water quality standards. The first is a concern that they will run afoul of anti-degradation provisions within the Clean Water Act or be accused of “backsliding” by the environmental community. The second concern relates to the demographics of watershed organizations across the country. According to recent surveys, slightly more than half of all watershed organizations

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represent moderately to highly developed watersheds (CWP, 2001a). These urban watershed organizations often have a keen interest in keeping the existing regulatory structure intact, since it is perceived to be the only lever to motivate municipalities to implement restoration efforts in non-supporting streams.

However, revised water quality standards are urgently needed to support smart growth efforts. A key premise of smart growth is that it is more desirable to locate new development within a non-supporting subwatershed rather than a sensitive or impacted one (i.e., concentrating density and IC within an existing subwatershed helps prevent sprawl from encroaching on a less developed one). Yet while smart growth is desirable on a regional basis, it will usually contribute to already serious problems in non-supporting watersheds, which makes it even more difficult to meet water quality standards.

This creates a tough choice for regulators: if they adopt stringent development criteria for non-supporting watersheds, their added costs can quickly become a powerful barrier to desired redevelopment. If, on the other hand, they relax or waive environmental criteria, they contribute to the further degradation of the watershed. To address this problem, the Center has developed a "smart watersheds" program to ensure that any localized degradation caused by development within a non-supporting subwatershed is more than compensated for by improvements in stream quality achieved through municipal restoration efforts (CWP, in press). Specifically, the smart watersheds program includes 17 public sector programs to treat stormwater runoff, restore urban stream corridors and reduce pollution discharges in highly urban watersheds. It is hoped that communities that adopt and implement smart watershed programs will be given greater flexibility to meet state and federal water quality regulations and standards within non-supporting watersheds.

1.3.2 Use of the ICM for Urban Stream Classification

The ICM has proven to be a useful tool for classifying and managing the large inventory of streams that most communities possess. It is not unusual for a typical county to have several thousand miles of headwater streams within its political boundaries, and the ICM provides a unified framework to identify and manage these subwatersheds. In our watershed practice, we use the ICM to make an initial diagnosis rather than a final determination for stream classification. Where possible, we conduct rapid stream and subwatershed assessments as a final check for an individual stream classification, particularly if it borders between the sensitive and impacted category. As noted earlier, the statistical variation in the IC/stream quality indicator makes it difficult to distinguish between a stream with 9% versus 11% IC. Some of the key criteria we use to make a final stream classification are provided in Table 6.

1.3.3 Role of the ICM in Small Watershed Planning

The ICM has also proven to be an extremely important tool for watershed planning, since it can rapidly project how streams will change in response to future land use. We routinely estimate existing and future IC in our watershed planning practice and find that it is an excellent indicator of change for subwatersheds in the zero to 30% IC range. In particular, the ICM often forces watershed planners to directly confront land use planning and land conservation issues early in the planning process.

On the other hand, we often find that the ICM has limited planning value when subwatersheds exceed 30% IC for two practical reasons. First, the ICM does not differentiate stream conditions within this very large span of IC (i.e., there is no difference in the stream quality prediction for a subwatershed that has 39.6% IC versus one that has 58.4% IC). Second, the key management question for non-supporting watersheds is whether or not

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they are potentially restorable. More detailed analysis and field investigations are needed to determine, in each subwatershed, the answer to this question. While a knowledge of IC is often used in these feasibility assessments, it is but one of many factors that needs to be considered.

Lastly, we have come to recognize several practical factors when applying the ICM for small watershed planning. These include thoughtful delineation of subwatershed boundaries, the proper accounting of a direct drainage area in larger watersheds, and the critical need for the most recent IC data. More guidance on these factors can be found in Zielinski (2001).

Impervious cover is not a perfect indicator of existing stream quality. A number of stream and subwatershed criteria should be evaluated in the field before a final classification decision is made, particularly when the stream is on the borderline between two classifications. We routinely look at the stream and subwatershed criteria to decide whether a borderline stream should be classified as sensitive or impacted. Table 6 reviews these additional criteria.

Table 6: Additional Considerations for Urban Stream Classification

Stream Criteria
Reported presence of rare, threatened or endangered species in the aquatic community (e.g., freshwater mussels, fish, crayfish or amphibians)
Confirmed spawning of cold-water fish species (e.g., trout)
Fair/good, good, or good to excellent macro invertebrate scores
More than 65% of EPT species present in macro-invertebrate surveys
No barriers impede movement of fish between the subwatershed and downstream receiving waters
Stream channels show little evidence of ditching, enclosure, tile drainage or channelization
Water quality monitoring indicates no standards violations during dry weather
Stream and flood plain remain connected and regularly interact
Stream drains to a downstream surface water supply
Stream channels are generally stable, as determined by the Rosgen level analysis
Stream habitat scores are rated at least fair to good
Subwatershed Criteria
Contains terrestrial species that are documented as rare, threatened and endangered
Wetlands, flood plains and/or beaver complexes make up more than 10% of subwatershed area
Inventoried conservation areas comprise more than 10% of subwatershed area
More than 50% of the riparian forest corridor has forest cover and is either publicly owned or regulated
Large contiguous forest tracts remain in the subwatershed (more than 40% in forest cover)
Significant fraction of subwatershed is in public ownership and management
Subwatershed connected to the watershed through a wide corridor
Farming, ranching and livestock operations in the subwatershed utilize best management practices
Prior development in the subwatershed has utilized stormwater treatment practices

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1.4 Summary

The remainder of this report presents greater detail on the individual research studies that bear on the ICM. Chapter 2 profiles research on hydrologic indicators in urban streams, while Chapter 3 summarizes the status of current research on the impact of urbanization on physical habitat indicators. Chapter 4 presents a comprehensive review of the impact of urbanization on ten major stormwater pollutants. Finally, Chapter 5 reviews the growing body of research on the link between IC and biological indicators within urban streams and wetlands.



Chapter 2: Hydrologic Impacts of Impervious Cover

The natural hydrology of streams is fundamentally changed by increased watershed development. This chapter reviews the impacts of watershed development on selected indicators of stream hydrology.

This chapter is organized as follows:

2.1 Introduction
2.2 Increased Runoff Volume
2.3 Increased Peak Discharge Rates
2.4 Increased Bankfull Flow
2.5 Decreased Baseflow
2.6 Conclusions

2.1 Introduction

Fundamental changes in urban stream hydrology occur as a result of three changes in the urban landscape that accompany land development. First, large areas of the watershed are paved, rendering them impervious. Second, soils are compacted during construction, which significantly reduces their infiltration capabilities. Lastly, urban stormwater drainage systems are installed that increase the efficiency with which runoff is delivered to the stream (i.e., curbs and gutters, and storm drain pipes). Consequently, a greater fraction of annual rainfall is converted to surface runoff, runoff occurs more quickly, and peak flows become larger. Additionally, dry weather flow in streams may actually decrease because less groundwater recharge is available. Figure 6 illustrates the change in hydrology due to increased urban runoff as compared to pre-development conditions.

Research has demonstrated that the effect of watershed urbanization on peak discharge is more marked for smaller storm events. In particular, the bankfull, or channel forming flow, is increased in magnitude, frequency and duration. Increased bankfull flows have strong ramifications for sediment transport and channel enlargement. All of these changes in the natural water balance have impacts on the physical structure of streams, and ultimately affect water quality and biological diversity.

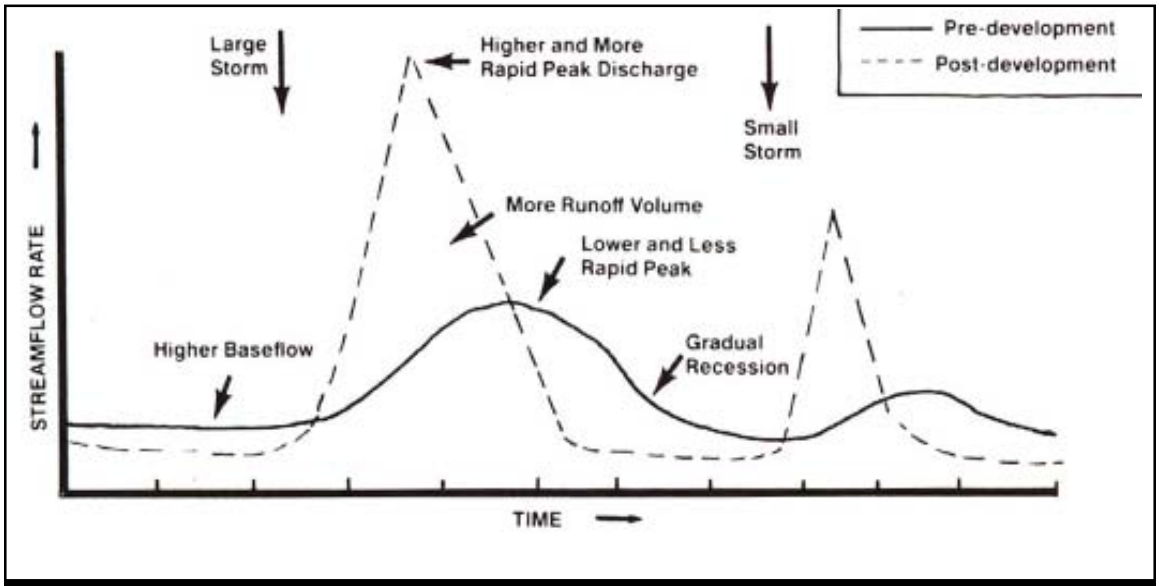
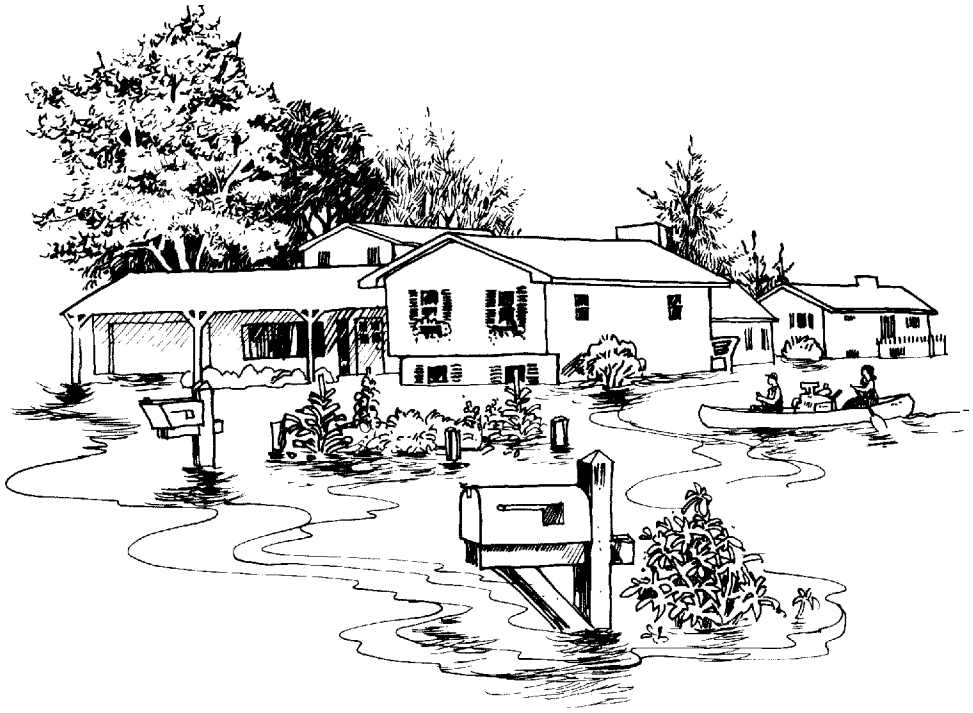


Figure 6: Altered Hydrograph in Response to Urbanization (Schueler, 1987)

The relationship between watershed IC and stream hydrology is widely accepted, and has been incorporated into many hydrologic engineering models over the past three decades. Several articles provide a good summary of these (Bicknell *et al.*, 1993; Hirsch *et al.*, 1990; HEC, 1977; Huber and Dickinson, 1988; McCuen and Moglen, 1988; Overton and Meadows, 1976; Pitt and Voorhees, 1989; Schueler, 1987; USDA, 1992; 1986).

The primary impacts of watershed development on stream hydrology are as follows:

- Increased runoff volume
- Increased peak discharge rates
- Increased magnitude, frequency, and duration of bankfull flows
- Diminished baseflow



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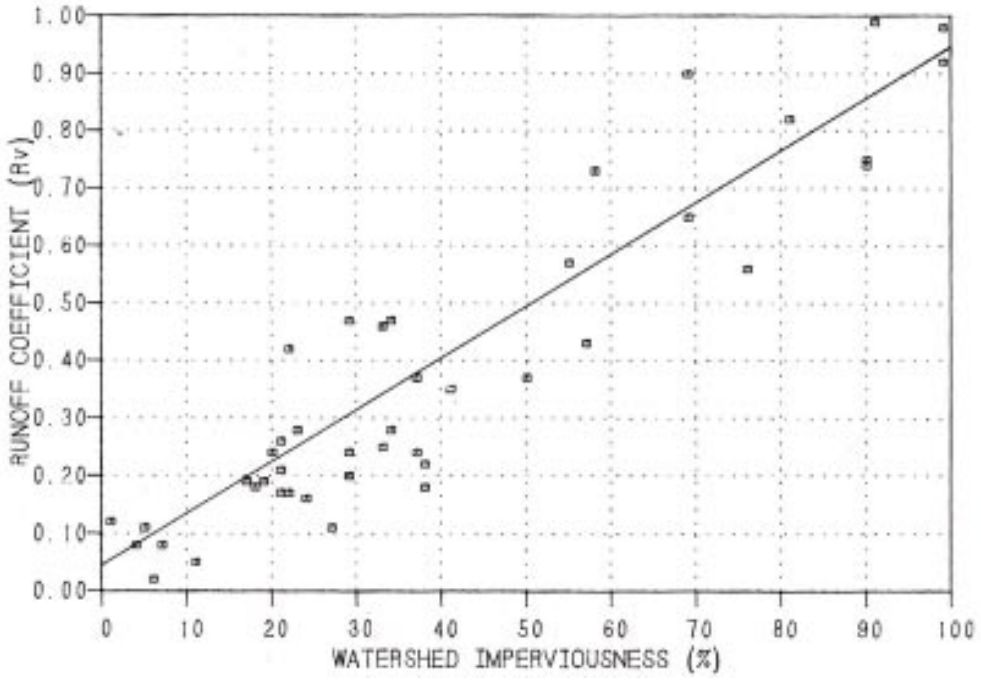
2.2 Increased Runoff Volume

Impervious cover and other urban land use alterations, such as soil compaction and storm drain construction, alter infiltration rates and increase runoff velocities and the efficiency with which water is delivered to streams. This decrease in infiltration and basin lag time can significantly increase runoff volumes. Table 7 reviews research on the impact of IC on runoff volume in urban streams. Schueler (1987) demonstrated that runoff values are directly related to subwatershed IC (Figure 7). Runoff data was derived from 44 small catchment areas across the country for EPA's Nationwide Urban Runoff Program.

Table 8 illustrates the difference in runoff volume between a meadow and a parking lot, as compiled from engineering models. The parking lot produces more than 15 times more runoff than a meadow for the same storm event.

Urban soils are also profoundly modified during the construction process. The compaction of urban soils and the removal of topsoil can decrease the infiltration capacity, causing increases in runoff volumes (Schueler, 2000). Bulk density is often used to measure soil compaction, and Table 9 illustrates how bulk density increases in many urban land uses.



Note: 44 small urban catchments monitored during the national NURP study

Figure 7: Runoff Coefficient vs. IC (Schueler, 1987)

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Table 7: Research Review of Increased Runoff Volume and Peak Discharge in Urban Streams		
Reference	**Key Finding**	**Location**
Increased Runoff Volume		
Schueler, 1987	Runoff coefficients were found to be strongly correlated with IC at 44 sites nationwide.	U.S.
Neller, 1988	Urban watershed produced more than seven times as much runoff as a similar rural watershed. Average time to produce runoff was reduced by 63% in urban watersheds compared to rural watersheds.	Australia
Increased Peak Discharge		
Hollis, 1975	Review of data from several studies showed that floods with a return period of a year or longer are not affected by a 5% watershed IC; small floods may be increased 10 times by urbanization; flood with a return period of 100 years may be doubled in size by a 30% watershed IC.	N/A
Leopold, 1968	Data from seven nationwide studies showed that 20% IC can cause the mean annual flood to double.	U.S.
Neller, 1988	Average peak discharge from urban watersheds was 3.5 times higher than peak runoff from rural watersheds.	Australia
Doll *et al.,* 2000	Peak discharge was greater for 18 urban streams versus 11 rural Piedmont streams.	NC
Sauer *et al.,* 1983	Estimates of flood discharge for various recurrence intervals showed that less than 50% watershed IC can result in a doubling of the 2-year, 10-year, and 100-year floods.	U.S.
Leopold, 1994	Watershed development over a 29-year period caused the peak discharge of the 10-year storm to more than double.	MD
Kibler *et al.,* 1981	Rainfall/runoff model for two watersheds showed that an increase in IC caused a significant increase in mean annual flood.	PA
Konrad and Booth, 2002	Evaluated streamflow data at 11 streams and found that the fraction of annual mean discharges was exceeded and maximum annual instantaneous discharges were related to watershed development and road density for moderately and highly developed watersheds.	WA

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Table 8: Hydrologic Differences Between a Parking Lot and a Meadow (Schueler, 1994a)		
Hydrologic or Water Quality Parameter	**Parking Lot**	**Meadow**
Runoff Coefficient	0.95	0.06
Time of Concentration (minutes)	4.8	14.4
Peak Discharge, two-year, 24-hour storm (cfs)	4.3	0.4
Peak Discharge Rate, 100-year storm (cfs)	12.6	3.1
Runoff Volume from one-inch storm (cu. ft)	3,450	218
Runoff Velocity @ two-year storm (ft/sec)	8	1.8
Key Assumptions: *2-yr, 24-hr storm = 3.1 in; 100-yr storm = 8.9 in.* *Parking Lot: 100% imperviousness; 3% slope; 200ft flow length; hydraulic radius =.03; concrete channel; suburban Washington C values* *Meadow: 1% impervious; 3% slope; 200 ft flow length; good vegetative condition; B soils; earthen channel* *Source: Schueler, 1994a*		

Table 9: Comparison of Bulk Density for Undisturbed Soils and Common Urban Conditions (Schueler, 2000)			
Undisturbed Soil Type or Urban Condition	**Surface Bulk Density (grams/cubic centimeter)**	**Urban Condition**	**Surface Bulk Density (grams/cubic centimeter)**
Peat	0.2 to 0.3	Urban Lawns	1.5 to 1.9
Compost	1.0	Crushed Rock Parking Lot	1.5 to 1.9
Sandy Soils	1.1 to 1.3	Urban Fill Soils	1.8 to 2.0
Silty Sands	1.4	Athletic Fields	1.8 to 2.0
Silt	1.3 to 1.4	Rights-of-Way and Building Pads (85%)	1.5 to 1.8
Silt Loams	1.2 to 1.5	Rights-of-Way and Building Pads (95%)	1.6 to 2.1
Organic Silts/Clays	1.0 to 1.2	Concrete Pavement	2.2
Glacial Till	1.6 to 2.0	Rock	2.65

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2.3 Increased Peak Discharge Rate

Watershed development has a strong influence on the magnitude and frequency of flooding in urban streams. Peak discharge rates are often used to define flooding risk. Doll *et al.* (2000) compared 18 urban streams with 11 rural streams in the North Carolina Piedmont and found that unit area peak discharge was always greater in urban streams (Figure 8). Data from Seneca Creek, Maryland also suggest a similar increase in peak discharge. The watershed experienced significant growth during the 1950s and 1960s. Comparison of pre- and post-development gage records suggests that the peak 10-year flow event more than doubled over that time (Leopold, 1994).

Hollis (1975) reviewed numerous studies on the effects of urbanization on floods of different recurrence intervals and found that the effect of urbanization diminishes when flood recurrence gets longer (i.e., 50 and 100 years). Figure 9 shows the effect on flood magnitude in urban watersheds with 30% IC, and shows the one-year peak discharge rate increasing by a factor of 10, compared to an undeveloped watershed. In contrast, floods with a 100-year recurrence interval only double in size under the same watershed conditions.

Sauer *et al.* (1983) evaluated the magnitude of flooding in urban watersheds throughout the United States. An equation was developed for estimating discharge for floods of two-year, 10-year, and 100-year recurrence intervals. The equations used IC to account for increased runoff volume and a basin development factor to account for sewers, curbs and gutters, channel improvements and drainage development. Sauer noted that IC is not the dominant factor in determining peak discharge rates for extreme floods because these storm events saturate the soils of undeveloped watersheds and produce high peak discharge rates. Sauer found that watersheds with 50% IC can increase peak discharge for the two-year flood by a factor of four, the 10-year flood by a factor of three, and the 100-year flood by a factor of 2.5, depending on the basin development factor (Figure 10).

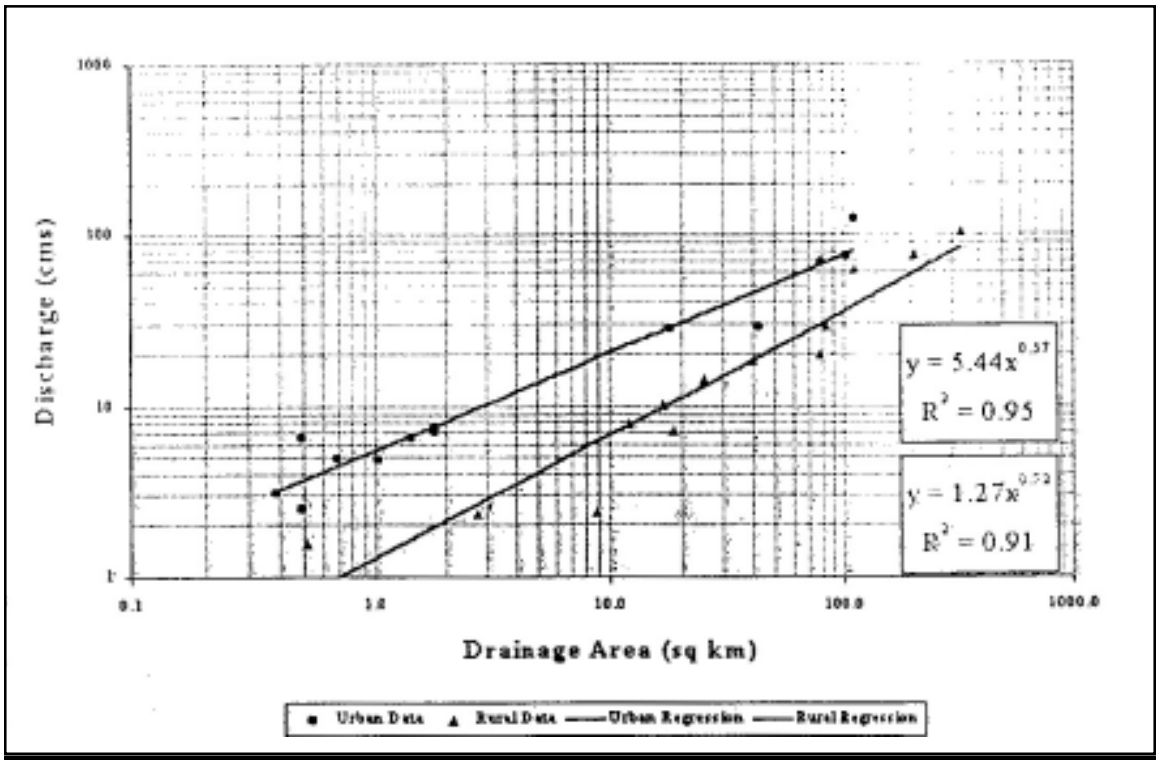

Figure 8: Peak Discharge for Urban and Rural Streams in North Carolina (Doll *et al.*, 2000)

2.4 Increased Bankfull Flow

Urbanization also increases the frequency and duration of peak discharge associated with smaller flood events (i.e., one- to two-year return storms). In terms of stream channel morphology, these more frequent bankfull flows are actually much more important than large flood events in forming the channel. In fact, Hollis (1975) demonstrated that urbanization increased the frequency and magnitude of bankfull flow events to a greater degree than the larger flood events.

An example of the increase in bankfull flow in arid regions is presented by the U.S. Geological Survey (1996), which compared the peak discharge rate from two-year storm events before and after watersheds urbanized in Parris Valley, California. Over an approximately 20-year period, watershed IC increased by 13.5%, which caused the two-year peak flow to more than double. Table 10 reviews other research studies on the relationship between watershed IC and bankfull flows in urban streams.

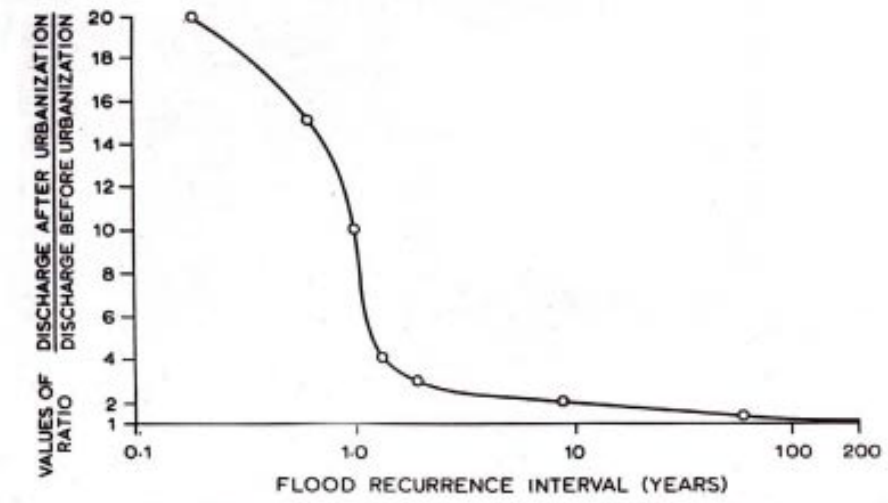

Fig. 3. Effect on flood magnitudes of paving 20% of a basin (based on Figure 2).

Figure 9: Effect on Flood Magnitudes of 30% Basin IC (Hollis, 1975)

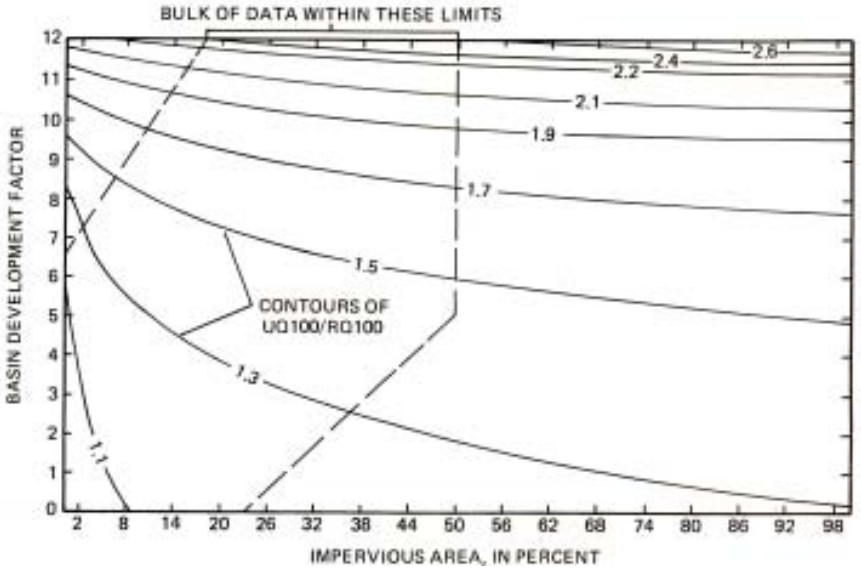

Figure 10: Relationship of Urban/Rural 100-Year Peak Flow Ratio to Basin Development Factor and IC (Sauer *et al.*, 1983)

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Table 10: Research Review of Increased Bankfull Discharge in Urban Streams		
Reference	**Key Finding**	**Location**
Booth and Reinelt, 1993	Using a simulation model and hydrologic data from four watersheds, it was estimated that more than 10% watershed IC may cause discharge from the two-year storm under current conditions to equal or exceed discharge from the 10-year storm under forested conditions.	WA
Fongers and Fulcher, 2001	Bankfull flow of 1200 cfs was exceeded more frequently over time with urbanization, and exceedence was three times as frequent from 1930s to 1990s.	MI
USGS, 1996	Over a 20-year period, IC increased 13.5%, and the two-year peak flow more than doubled in a semi-arid watershed.	CA
Henshaw and Booth, 2000	Two of three watersheds in the Puget Sound lowlands showed increasing flashiness over 50 years with urbanization.	WA
Leopold, 1968	Using hydrologic data from a nine-year period for North Branch Brandywine Creek, it was estimated that for a 50% IC watershed, bankfull frequency would be increased fourfold.	PA
Leopold, 1994	Bankfull frequency increased two to seven times after urbanization in Watts Branch.	MD
MacRae, 1996	For a site downstream of a stormwater pond in Markham, Ontario hours of exceedence of bankfull flows increased by 4.2 times after the watershed urbanized (34% IC)	Ontario

Leopold (1968) evaluated data from seven nationwide studies and extrapolated this data to illustrate the increase in bankfull flows due to urbanization. Figure 11 summarizes the relationship between bankfull flows over a range of watershed IC. For example, watersheds that have 20% IC increase the number of flows equal to or greater than bankfull flow by a factor of two. Leopold (1994) also observed a dramatic increase in the frequency of the bankfull event in Watts Branch, an urban subwatershed in Rockville, Maryland. This watershed experienced significant urban development during the 1950s and 1960s. Leopold compared gage records and found that the bankfull storm event frequency increased from two to seven times per year from 1958 to 1987.

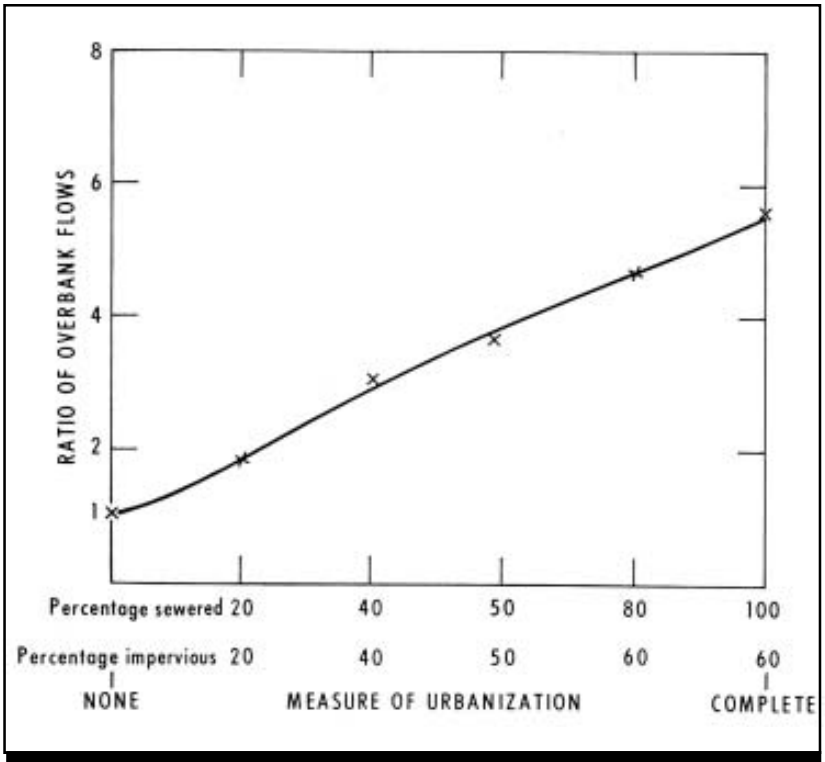

Figure 11: Increase in Bankfull Flows Due to Urbanization (Leopold, 1968)

More recent data on bankfull flow frequency was reported for the Rouge River near Detroit, Michigan by Fongers and Fulcher (2001). They noted that channel-forming flow (1200 cfs) was exceeded more frequently as urbanization increased in the watershed and had become three times more frequent between 1930 and 1990 (Figure 12).

McCuen and Moglen (1988) have documented the increase in duration of bankfull flows in response to urbanization using hydrology models. MacRae (1996), monitored a stream in Markham, Ontario downstream of a stormwater pond and found that the hours of

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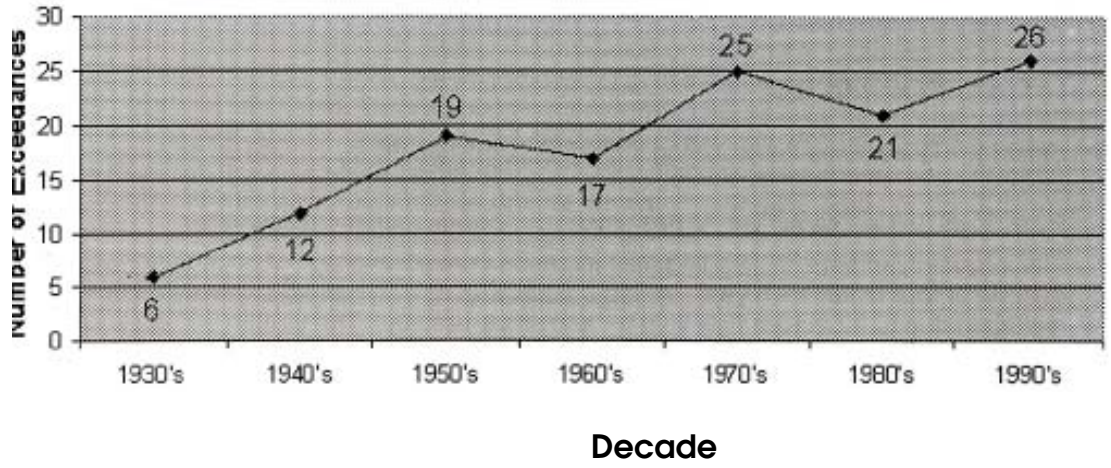

Figure 12: Increase in Number of Exceedences of Bankfull Flow Over Time With Urbanization in the Rouge River, MT (Fongers and Fulcher, 2001)

exceedence of bankfull flows increased by a factor of 4.2 once watershed IC exceeded 30%. Modeling for seven streams also downstream of stormwater ponds in Surrey, British Columbia also indicated an increase in bankfull flooding in response to watershed development (MacRae, 1996).

Watershed IC also increases the "flashiness" of stream hydrographs. Flashiness is defined here as the percent of daily flows each year that exceeds the mean annual flow. Henshaw and Booth (2000) evaluated seven urbanized watersheds in the Puget Sound lowland streams and tracked changes in flashiness over 50 years (Figure 13). The most urbanized watersheds experienced flashy discharges. Henshaw and Booth concluded that increased runoff in urban watersheds leads to higher but shorter-duration peak discharges.

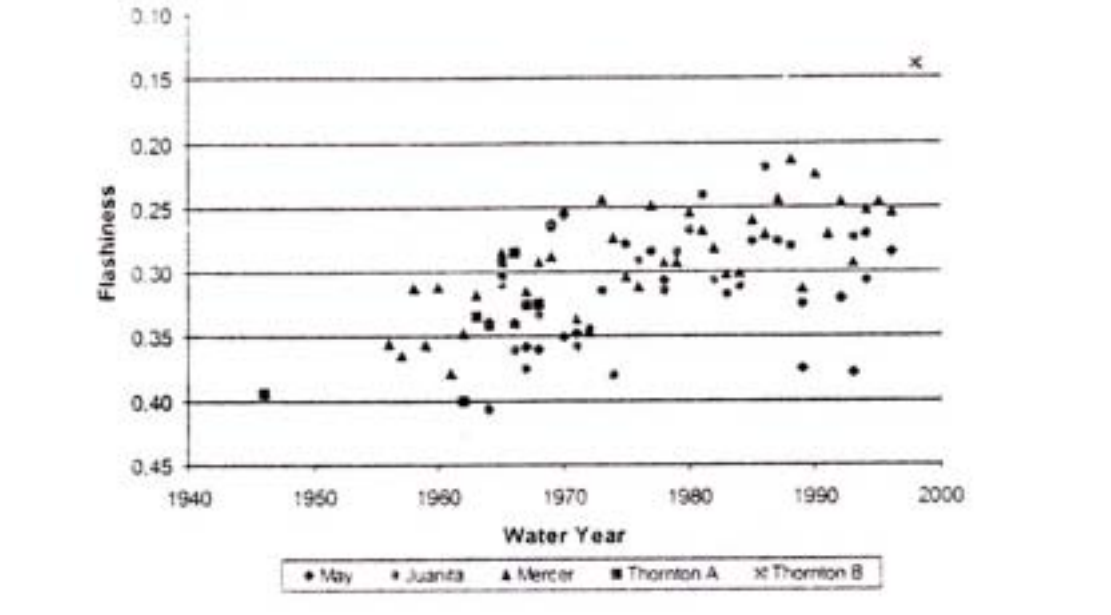

Figure 13: Percent of Gage Reading Above Mean Annual Flow for Puget Sound Lowland Streams (Henshaw and Booth, 2000)

2.5 Decreased Baseflow

As IC increases in a watershed, less groundwater infiltration is expected, which can potentially decrease stream flow during dry periods, (i.e. baseflow). Several East Coast studies provide support for a decrease in baseflow as a result of watershed development. Table 11 reviews eight research studies on baseflow in urban streams.

Klein (1979) measured baseflow in 27 small watersheds in the Maryland Piedmont and reported an inverse relationship between IC and baseflow (Figure 14). Spinello and Simmons (1992) demonstrated that baseflow in two urban Long Island streams declined seasonally as a result of urbanization (Figure 15). Saravanapavan (2002) also found that percentage of baseflow decreased in direct proportion to percent IC for 13 subwatersheds of the Shawsheen River watershed in Massachusetts (Figure 16).

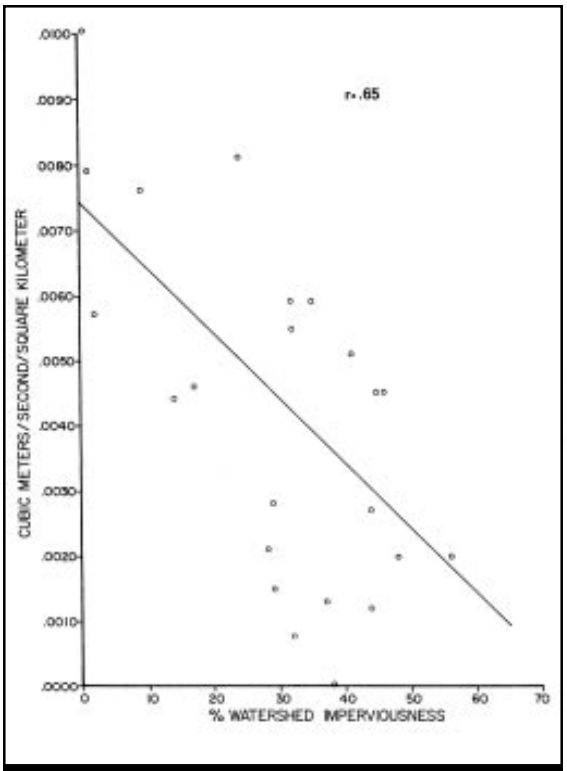

Figure 14: Relationship Between Baseflow and Watershed IC in the Streams on Maryland Piedmont (Klein, 1979)

Table 11: Research Review of Decreased Baseflow in Urban Streams		
Reference	**Key Finding**	**Location**
Finkenbine *et al.*, 2000	Summer base flow was uniformly low in 11 streams when IC reached 40% or greater.	Vancouver
Klein, 1979	Baseflow decreased as IC increased in Piedmont streams.	MD
Saravanapavan, 2002	Percentage of baseflow decreased linearly as IC increased for 13 subwatersheds of Shawsheen River watershed.	MA
Simmons and Reynolds, 1982	Dry weather flow dropped 20 to 85% after development in several urban watersheds on Long Island.	NY
Spinello and Simmons, 1992	Baseflow in two Long Island streams went dry as a result of urbanization.	NY
Konrad and Booth, 2002	No discernable trend over many decades in the annual seven day low flow discharge for 11 Washington streams.	WA
Wang *et al.*, 2001	Stream baseflow was negatively correlated with watershed IC in 47 small streams, with an apparent breakpoint at 8 to 12% IC.	WI
Evett *et al.*, 1994	No clear relationship between dry weather flow and urban and rural streams in 21 larger watersheds.	NC

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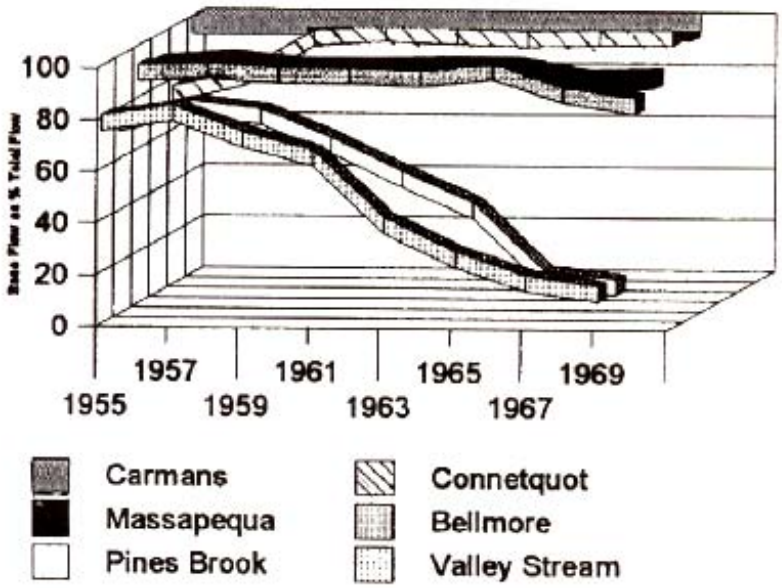

Notes:

Carmans and Connetquot: Rural/suburban, watersheds are unsewered

Bellmore and Massapequa: Moderately urbanized, not sewered until 1989

Valley Stream and Pine Brook: Urbanized and densely populated watersheds, sewer systems completed in 1960s

1953-1964: Period of sanitary sewer construction in eastern Nassau County

1962-1966: Drought years

Figure 15: Baseflow Response to Urbanization in Long Island Streams (Spinello and Simmons, 1992)

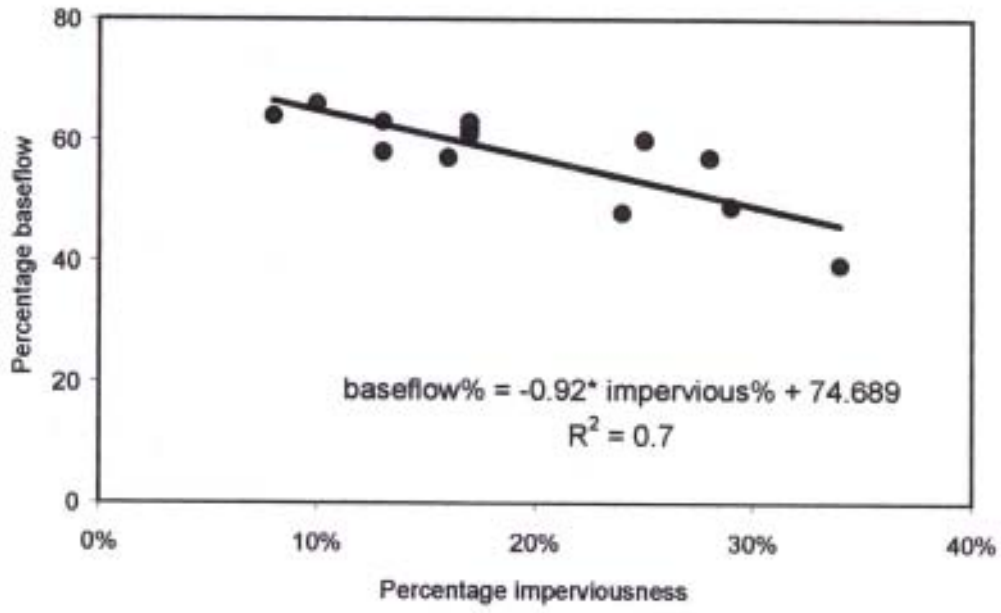

Figure 16: Relationship Between Percentage Baseflow and Percent IC in Massachusetts Streams (Saravanapan, 2002)

Finkebine *et al.* (2000) monitored summer baseflow in 11 streams near Vancouver, British Columbia and found that stream base flow was uniformly low due to decreased groundwater recharge in watersheds with more than 40% IC (Figure 17). Baseflow velocity also consistently decreased when IC increased (Figure 18). The study cautioned that other factors can affect stream baseflow, such as watershed geology and age of development.

Other studies, however, have not been able to establish a relationship between IC and declining baseflow. For example, a study in North Carolina could not conclusively determine that urbanization reduced baseflow in larger urban and suburban watersheds in that area (Evett *et al.*, 1994). In some cases, stream baseflow is supported by deeper aquifers or originate in areas outside the surface watershed boundary. In others, baseflow is augmented by leaking sewers, water pipes and irrigation return flows.

This appears to be particularly true in arid and semi-arid areas, where baseflow can actually increase in response to greater IC (Hollis, 1975). For instance, Crippen and Waananen (1969) found that Sharon Creek near San Francisco changed from an ephemeral stream into a perennial stream after urban development. Increased infiltration from lawn watering and return flow from sewage treatment plants are two common sources of augmented baseflows in these regions (Caraco, 2000a).

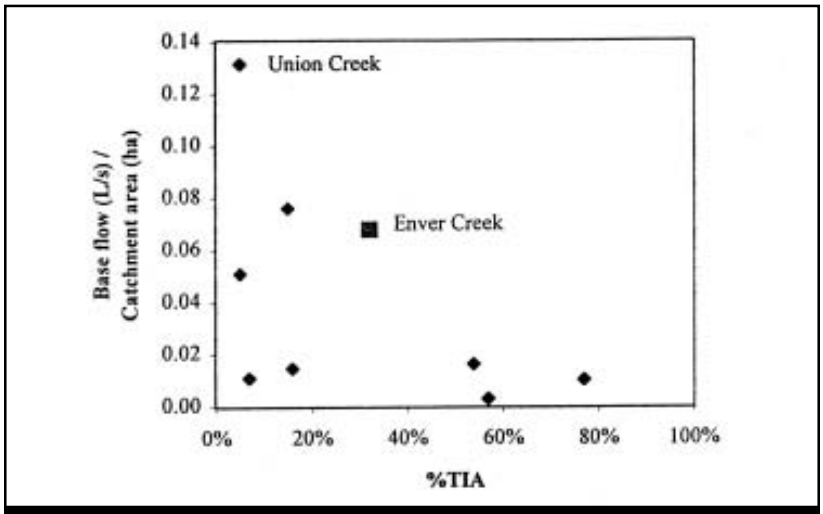

Figure 17: Effect of IC on Summer Baseflow in Vancouver Streams (Finkerbine *et al.*, 2000)

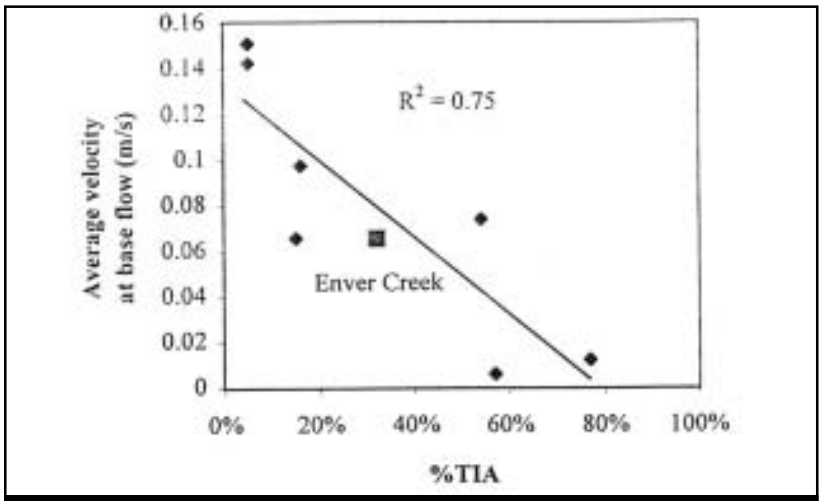

Figure 18: Effect of Watershed IC on Summer Stream Velocity in Vancouver Streams (Finkerbine *et al.*, 2000)

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2.6 Conclusions

The changes in hydrology indicators caused by watershed urbanization include increased runoff volume; increased peak discharge; increased magnitude, frequency and duration of bankfull flows; flashier/less predictable flows; and decreased baseflow. Many studies support the direct relationship between IC and these indicators. However, at low levels of watershed IC, site-specific factors such as slope, soils, types of conveyance systems, age of development, and watershed dimensions often play a stronger role in determining a watershed's hydrologic response.

Overall, the following conclusions can be drawn from the relationship between watershed IC and hydrology indicators:

- Strong evidence exists for the direct relationship between watershed IC and increased stormwater runoff volume and peak discharge. These relationships are considered so strong that they have been incorporated into widely accepted engineering models.
- The relationship between IC and bankfull flow frequency has not been extensively documented, although abundant data exists for differences between urban and non-urban watersheds.
- The relationship between IC and declining stream flow is more ambiguous and appears to vary regionally in response to climate and geologic factors, as well as water and sewer infrastructure.

The changes in hydrology indicators caused by watershed urbanization directly influence physical and habitat characteristics of streams. The next chapter reviews how urban streams physically respond to the major changes to their hydrology.



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Chapter 3: Physical Impacts of Impervious Cover

A growing body of scientific literature documents the physical changes that occur in streams undergoing watershed urbanization. This chapter discusses the impact of watershed development on various measures of physical habitat in urban stream channels and is organized as follows:

3.1 Difficulty in Measuring Habitat
3.2 Changes in Channel Geometry
3.3 Effect on Composite Indexes of Stream Habitat
3.4 Effect on Individual Elements of Stream Habitat
3.5 Increased Stream Warming
3.6 Alteration of Stream Channel Network
3.7 Conclusion

This chapter reviews the available evidence on stream habitat. We begin by looking at geomorphological research that has examined how the geometry of streams changes in response to altered urban hydrology. The typical response is an enlargement of the cross-sectional area of the stream channel through a process of channel incision, widening, or a combination of both. This process triggers an increase in bank and/or bed erosion that increases sediment transport from the stream, possibly for several decades or more.

Next, we examine the handful of studies that have evaluated the relationship between watershed development and composite indicators of stream habitat (such as the habitat Rapid Bioassessment Protocol, or RBP). In the fourth section, we examine the dozen studies that have evaluated how individual habitat elements respond to watershed development. These studies show a consistent picture. Generally, streams with low levels of IC have stable banks, contain considerable large woody debris (LWD) and possess complex habitat structure. As watershed IC increases, however, urban streambanks become increasingly unstable, streams lose LWD, and they develop a more simple and uniform habitat structure. This is typified by reduced pool depths, loss of pool and riffle sequences, reduced channel roughness and less channel sinuosity.

Water temperature is often regarded as a key habitat element, and the fifth section describes the stream warming effect observed in urban streams in six studies. The last section looks at the effect of watershed development on the stream channel network as a whole, in regard to headwater stream loss and the creation of fish barriers.

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3.1 Difficulty in Measuring Habitat

The physical transformation of urban streams is perhaps the most conspicuous impact of watershed development. These dramatic physical changes are easily documented in sequences of stream photos with progressively greater watershed IC (see Figure 19). Indeed, the network of headwater stream channels generally disappears when watershed IC exceeds 60% (CWP).

3.1.1 The Habitat Problem

It is interesting to note that while the physical impacts of urbanization on streams are widely accepted, they have rarely been documented by the research community. As a consequence, no predictive models exist to quantify how physical indicators of stream habitat will decline in response to watershed IC, despite the fact that most would agree that some kind of decline is expected (see Table 12).

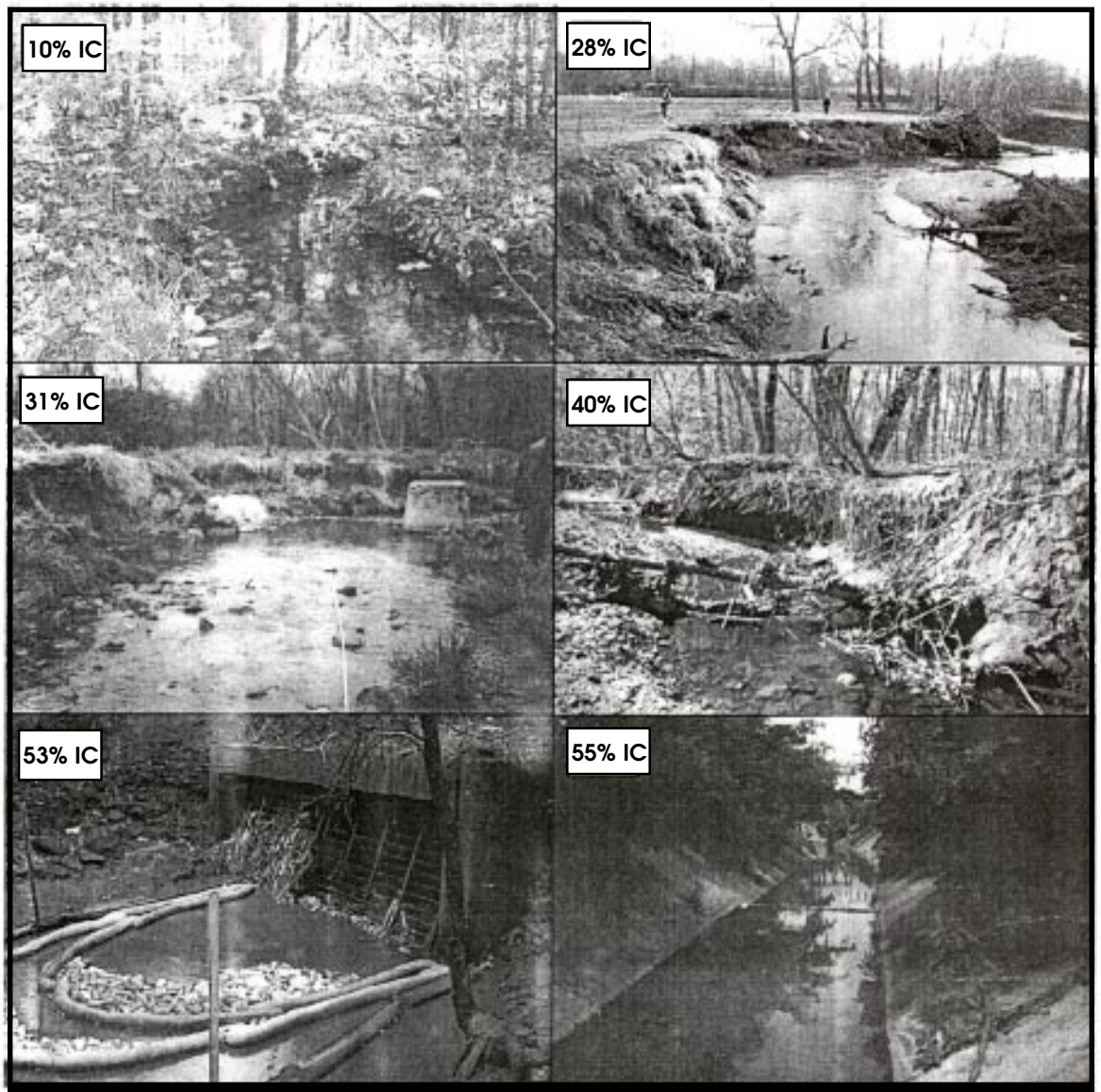

Figure 19: Urban Stream Channels with Progressively Greater IC

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The main reason for this gap is that "habitat" is extremely hard to define, and even more difficult to measure in the field. Most indices of physical habitat involve a visual and qualitative assessment of 10 or more individual habitat elements that are perceived by fishery and stream biologists to contribute to quality stream habitat. Since these indices include many different habitat elements, each of which is given equal weight, they have not been very useful in discriminating watershed effects (Wang *et al.*, 2001).

Researchers have had greater success in relating individual habitat elements to watershed conditions, such as large woody debris (LWD), embeddedness, or bank stability. Even so, direct testing has been limited, partly because individual habitat elements are hard to measure and are notoriously variable in both space and time. Consider bank stability for a moment. It would be quite surprising to see a highly urban stream that did not have unstable banks. Yet, the hard question is exactly how would bank instability be quantitatively measured? Where would it be measured — at a point, a cross-section, along a reach, on the left bank or the right?

Geomorphologists stress that no two stream reaches are exactly alike, due to differences in gradient, bed material, sediment transport, hydrology, watershed history and many other factors. Consequently, it is difficult to make controlled comparisons among different streams. Indeed, geomorphic theory stresses that individual stream reaches respond in a highly dynamic way to changes in watershed hydrology and sediment transport, and can take several decades to fully adjust to a new equilibrium.

Table 12: Physical Impacts of Urbanization on Streams

Specific Impacts
Sediment transport modified
Channel enlargement
Channel incision
Stream embeddedness
Loss of large woody debris
Changes in pool/riffle structure
Loss of riparian cover
Reduced channel sinuosity
Warmer in-stream temperatures
Loss of cold water species and diversity
Channel hardening
Fish blockages
Loss of 1st and 2nd order streams through storm drain enclosure

Returning to our example of defining bank stability, how might our measure of bank instability change over time as its watershed gradually urbanizes, is built out, and possibly reaches a new equilibrium over several decades? It is not very surprising that the effect of watershed development on stream habitat is widely observed, yet rarely measured.

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3.2 Changes in Stream Geometry

As noted in the last chapter, urbanization causes an increase in the frequency and duration of bankfull and sub-bankfull flow events in streams. These flow events perform more "effective work" on the stream channel, as defined by Leopold (1994). The net effect is that an urban stream channel is exposed to more shear stress above the critical threshold needed to move bank and bed sediments (Figure 20). This usually triggers a cycle of active bank erosion and greater sediment transport in urban streams. As a consequence, the stream channel adjusts by expanding its cross-sectional area, in order to effectively accommodate greater flows and sediment supply. The stream channel can expand by incision, widening, or both. Incision refers to stream down-cutting through the streambed, whereas widening refers to lateral erosion of the stream bank and its flood plain (Allen and Narramore, 1985; Booth, 1990; Morisawa and LaFlure, 1979).

3.2.1 Channel Enlargement

A handful of research studies have specifically examined the relationship between watershed development and stream channel enlargement (Table 13). These studies indicate that stream cross-sectional areas can enlarge by as much as two to eight times in response to urbanization, although the process is complex and may take several decades to complete (Pizzuto *et al*., 2000; Caraco, 2000b; Hammer, 1972). An example of channel enlargement is provided in Figure 21, which shows how a stream cross-section in Watts Branch near Rockville, Maryland has expanded in response to nearly five decades of urbanization (i.e., watershed IC increased from two to 27%).

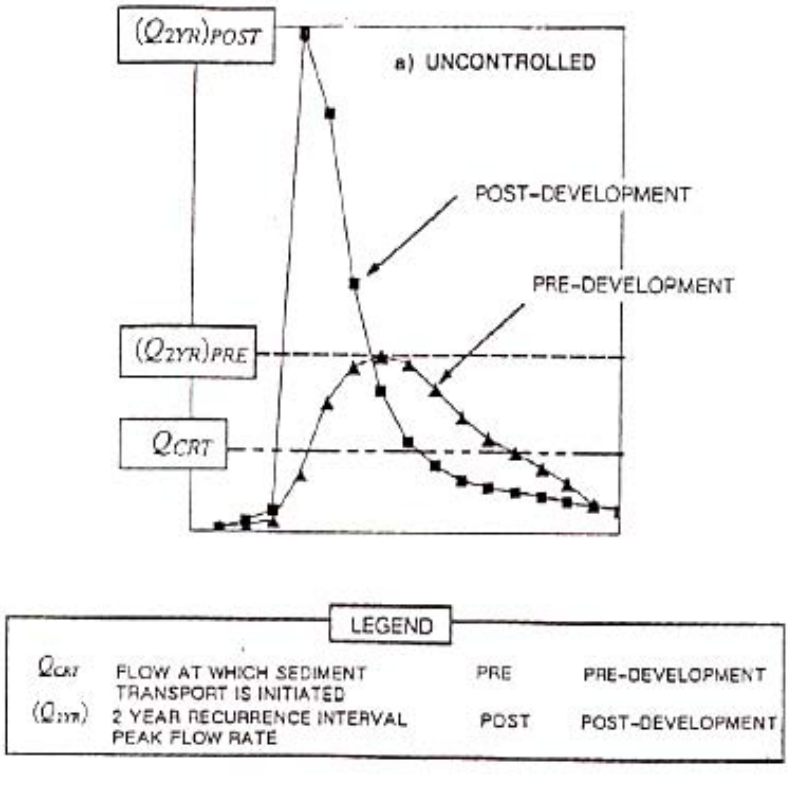

Figure 20: Increased Shear Stress from a Hydrograph (MacRae and Rowney, 1992)

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Table 13: Research Review of Channel Enlargement and Sediment Transport in Urban Streams		
Reference	**Key Finding**	**Location**
% IC used as Indicator		
Caraco, 2000b	Reported enlargement in ratios of 1.5 to 2.2 for 10 stream reaches in Watts Branch and computed ultimate enlargement ratios of 2.0	MD
MacCrae and De Andrea, 1999	Introduced the concept of ultimate channel enlargement based on watershed IC and channel characteristics.	Ontario, TX
Morse, 2001	Demonstrated increased erosion rates with increases in IC (channels were generally of the same geomorphic type).	ME
Urbanization Used as Indicator		
Allen and Narramore, 1985	Enlargement ratios in two urban streams ranged from 1.7 to 2.4.	TX
Bledsoe, 2001	Reported that channel response to urbanization depends on other factors in addition to watershed IC including geology, vegetation, sediment and flow regimes.	N/A
Booth and Henshaw, 2001	Evaluated channel cross section erosion rates and determined that these rates vary based on additional factors including the underlying geology, age of development and gradient.	WA
Hammer, 1972	Enlargement ratios ranged from 0.7 to 3.8 in urban watersheds.	PA
Neller, 1989	Enlargement ratios in small urban catchments ranged from two to 7.19, the higher enlargement ratios were primarily from incision occurring in small channels.	Australia
Pizzuto *et al.*, 2000	Evaluated channel characteristics of paired urban and rural streams and demonstrated median bankfull cross sectional increase of 180%. Median values for channel sinuosity were 8% lower in urban streams; Mannings N values were found to be 10% lower in urban streams.	PA
Hession *et al., in press*	Bankfull widths for urban streams were significantly wider than non-urban streams in 26 paired streams. Forested reaches were consistently wider than non-forested reaches in urban streams.	MD, DE, PA
Dartiguenave *et al.,* 1997	Bank erosion accounted for up to 75% of the sediment transport in urban watersheds.	TX
Trimble, 1997	Demonstrated channel enlargement over time in an urbanizing San Diego Creek; Bank erosion accounted for over 66% of the sediment transport.	CA

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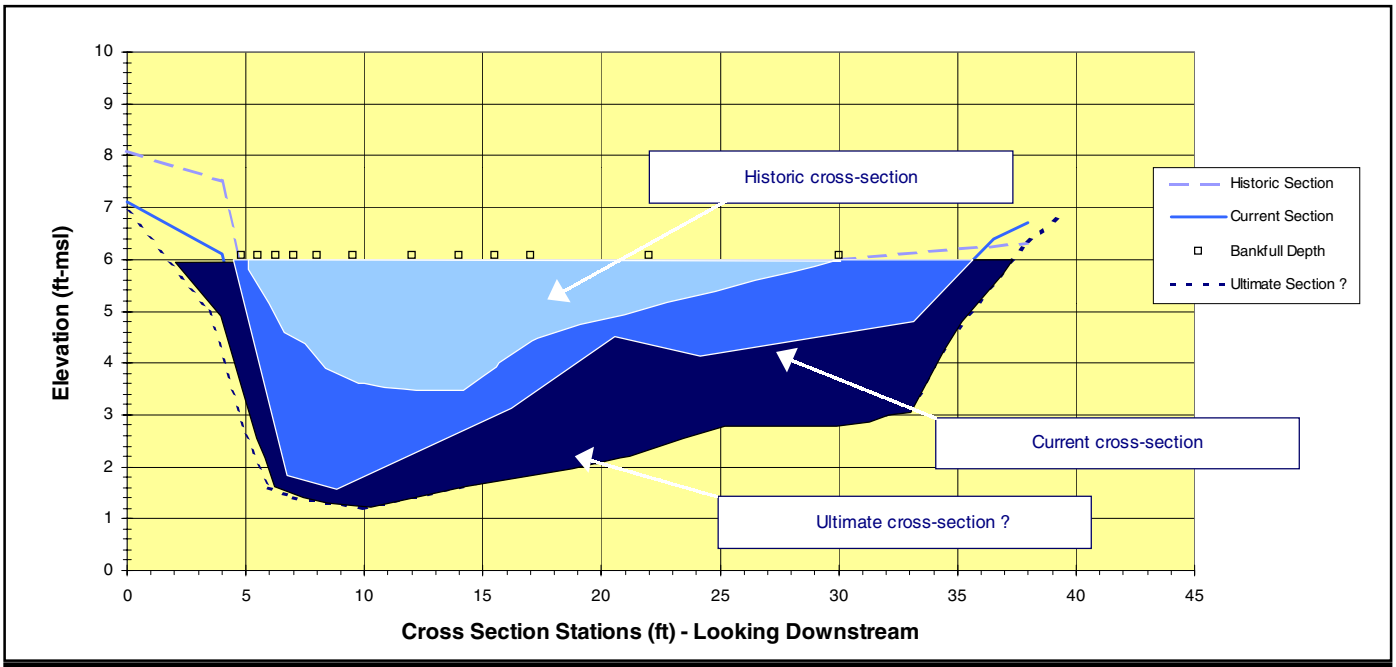

Figure 21: Stream Channel Enlargement in Watts Branch, MD 1950-2000 (Caraco, 2000b)

Some geomorphologists suggest that urban stream channels will reach an "ultimate enlargement" relative to pre-developed channels (MacRae and DeAndrea, 1999) and that this can be predicted based on watershed IC, age of development, and the resistance of the channel bed and banks. A relationship between ultimate stream channel enlargement and watershed IC has been developed for alluvial streams in Texas, Vermont and Maryland (Figure 22). Other geomorphologists such as Bledsoe (2001) and Booth and Henshaw (2001) contend that channel response to urbanization is more complex, and also depends on geology, grade control, stream gradient and other factors.

Channel incision is often limited by grade control caused by bedrock, cobbles, armored substrates, bridges, culverts and pipelines. These features can impede the downward erosion of the stream channel and thereby limit the incision process. Stream incision can become severe in streams that have softer substrates such as sand, gravel and clay (Booth, 1990). For example, Allen and Narramore (1985) showed that channel enlargement in chalk channels was 12 to 67% greater than in shale channels near Dallas, Texas. They attributed the differences to the softer substrate, greater velocities and higher shear stress in the chalk channels.

Neller (1989) and Booth and Henshaw (2001) also report that incised urban stream channels possess cross-sectional areas that are larger than would be predicted based on watershed area or discharge alone. This is due to the fact that larger floods are often contained within the stream channel rather than the floodplain. Thus, incised channels often result in greater erosion and geomorphic change. In general, stream conditions that can foster incision include erodible substrates, moderate to high stream gradients, and an absence of grade control features.

Channel widening occurs more frequently when streams have grade control and the stream has cut into its bank, thereby expanding its cross-sectional area. Urban stream channels often have artificial grade controls caused by frequent culverts and road crossings. These grade controls often cause localized sediment deposition that can reduce the capacity of culverts and bridge crossings to pass flood waters.

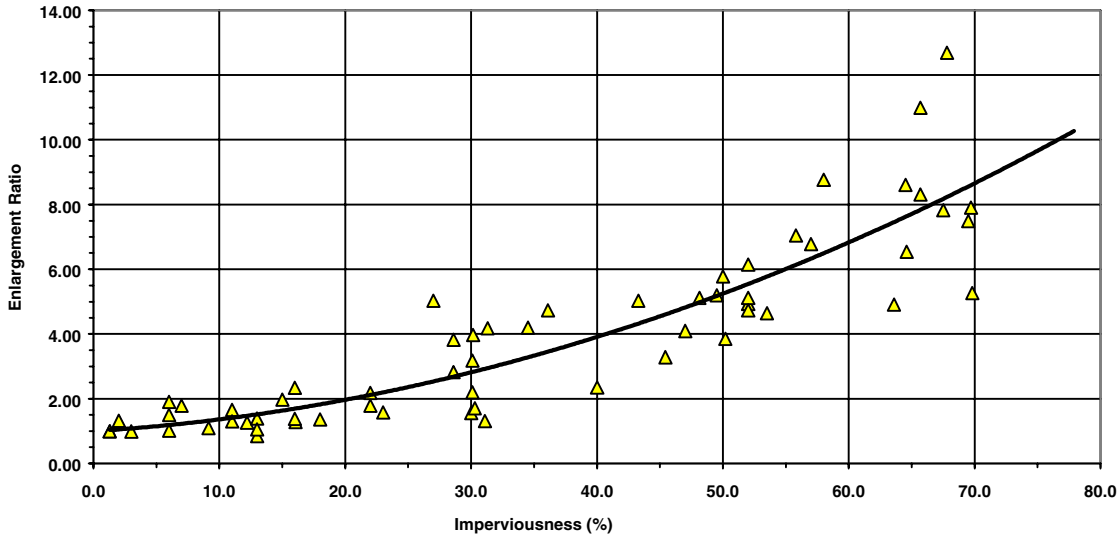

Figure 22: Ultimate Channel Enlargement in MD, UT and TX Alluvial Streams (MacRae and DeAndrea, 1999 and CWP, 2001b)

The loss of flood plain and riparian vegetation has been strongly associated with watershed urbanization (May *et al.*, 1997). A few studies have shown that the loss of riparian trees can result in increased erosion and channel migration rates (Beeson and Doyle, 1995 and Allmendinger *et al.*, 1999). For example, Beeson and Doyle (1995) found that meander bends with vegetation were five times less likely to experience significant erosion from a major flood than non-vegetated meander bends.Hession *et al.* (in press) observed that forested reaches consistently had greater bankfull widths than non-forested reaches in a series of urban streams in Pennsylvania, Maryland and Delaware.

3.2.2 Effect of Channel Enlargement on Sediment Yield

Regardless of whether a stream incises, widens, or does both, it will greatly increase sediment transport from the watershed due to erosion. Urban stream research conducted in California and Texas suggests that 60 to 75% of the sediment yield of urban watersheds can be derived from channel erosion (Trimble, 1997 and Dartingunave *et al.*, 1997) This can be compared to estimates for rural streams where channel erosion accounts for only five to 20% of the annual sediment yield (Collins *et al.*, 1997 and Walling and Woodward, 1995).

Some geomorphologists speculate that urban stream channels will ultimately adjust to their post-development flow regime and sediment supply. Finkenbine *et al.* (2000) observed these conditions in Vancouver streams, where study streams eventually stabilized two decades after the watersheds were fully developed. In older urban streams, reduced sediment transport can be expected when urbanization has been completed. At this point, headwater stream channels are replaced by storm drains and pipes, which can transport less sediment. The lack of available sediment may cause downstream channel erosion, due to the diminished sediment supply found in the stream.

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3.3 Effect on Composite Measures of Stream Habitat

Composite measures of stream habitat refer to assessments such as EPA's Habitat Rapid Bioassessment Protocol (RBP) that combine multiple habitat elements into a single score or index (Barbour *et al*., 1999). For example, the RBP requires visual assessment of 10 stream habitat elements, including embeddedness, epifaunal substrate quality, velocity/depth regime, sediment deposition, channel flow status, riffle frequency, bank stabilization, streambank vegetation and riparian vegetation width. Each habitat element is qualitatively scored on a 20 point scale, and each element is weighted equally to derive a composite score for the stream reach.

To date, several studies have found a relationship between declining composite habitat indicator scores and increasing watershed IC in different eco-regions of the United States. A typical pattern in the composite habitat scores is provided for headwater streams in Maine (Morse, 2001; Figure 23). This general finding has been reported in the mid-Atlantic, Northeast and the Northwest (Black and Veatch, 1994; Booth and Jackson, 1997; Hicks and Larson, 1997; Maxted and Shaver, 1997; Morse, 2001; Stranko and Rodney, 2001).

However, other researchers have found a much weaker relationship between composite habitat scores and watershed IC. Wang and his colleagues (2001) found that composite habitat scores were not correlated with watershed IC in Wisconsin streams, although it was correlated with individual habitat elements, such as streambank erosion. They noted that many agricultural and rural streams had fair to poor composite habitat scores, due to poor riparian management and sediment deposition. The same basic conclusion was also reported for streams of the Maryland Piedmont (MNCPPC, 2000).

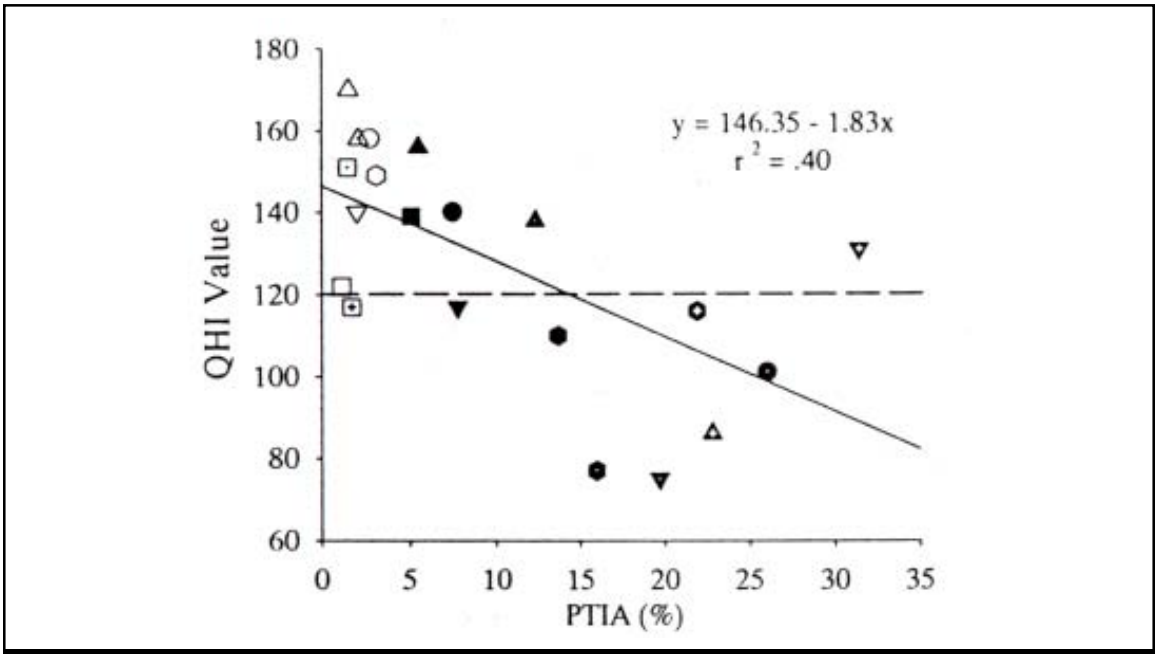

Figure 23: Relationship Between Habitat Quality and IC in Maine Streams (Morse, 2001)

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3.4 Effect on Individual Elements of Stream Habitat

Roughly a dozen studies have examined the effect of watershed development on the degradation of individual stream habitat features such as bank stability, embeddedness, riffle/pool quality, and loss of LWD (Table 14). Much of this data has been acquired from the Pacific Northwest, where the importance of such habitat for migrating salmon has been a persistent management concern.

3.4.1 Bank Erosion and Bank Stability

It is somewhat surprising that we could only find one study that related bank stability or bank erosion to watershed IC. Conducted by Booth (1991) in the streams of the Puget Sound lowlands, the study reported that stream banks were consistently rated as stable in watersheds with less than 10% IC, but became progressively more unstable above this threshold. Dozens of stream assessments have found high rates of bank erosion in urban streams, but none, to our knowledge, has systematically related the prevalence or severity of bank erosion to watershed IC. As noted earlier, this may reflect the lack of a universally recognized method to measure comparative bank erosion in the field.

3.4.2 Embeddedness

Embeddedness is a term that describes the extent to which the rock surfaces found on the stream bottom are filled in with sand, silts and clay. In a healthy stream, the interstitial pores between cobbles, rock and gravel generally lack fine sediments, and are an active habitat zone and detrital processing area. The increased sediment transport in urban streams can rapidly fill up these pores in a process known as embedding. Normally, embeddedness is visually measured in riffle zones of streams. Riffles tend to be an important habitat for aquatic insects and fish (such as darters and sculpins). Clean stream substrates are also critical to trout and salmon egg incubation and embryo development. May *et al.* (1997) demonstrated that the percent of fine sediment particles in riffles generally increased with watershed IC (Figure 24). However, Finkenbine *et al.* (2000) reported that embeddedness eventually decreased slightly after watershed land use and sediment transport had stabilized for 20 years.

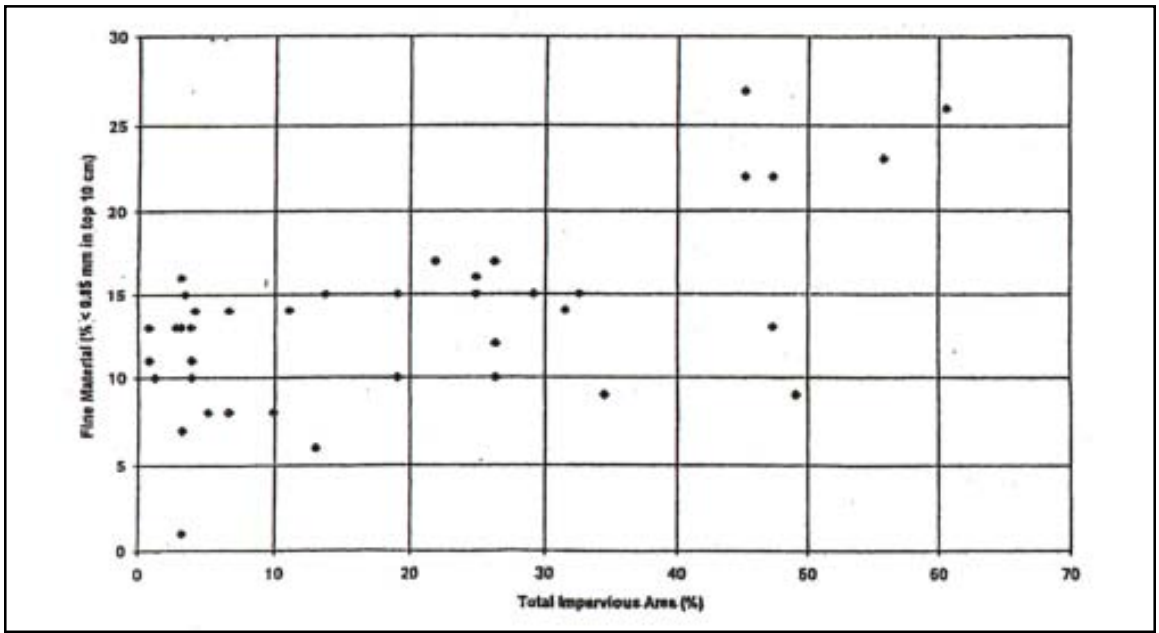

Figure 24: Fine Material Sediment Deposition as a Function of IC in Pacific Northwest Streams (Horner *et al.*, 1997)

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Table 14: Research Review of Changes in Urban Stream Habitat		
Reference	**Key Finding**	**Location**
% IC Used as Indicator		
Black & Veatch, 1994	Habitat scores were ranked as poor in five subwatersheds that had greater than 30% IC.	MD
Booth and Jackson, 1997	Increase in degraded habitat conditions with increases in watershed IC.	WA
Hicks and Larson, 1997	Reported a reduction in composite stream habitat indices with increasing watershed IC.	MA
May *et al.,* 1997	Composite stream habitat declined most rapidly during the initial phase of the watershed urbanization, when percent IC exceeded the 5-10% range.	WA
Stranko and Rodney, 2001	Composite index of stream habitat declined with increasing watershed IC in coastal plain streams.	MD
Wang *et al.,* 2001	Composite stream habitat scores were not correlated with watershed IC in 47 small watersheds, although channel erosion was. Non-urban watersheds were highly agricultural and often lacked riparian forest buffers.	WI
MNCPPC, 2000	Reported that stream habitat scores were not correlated with IC in suburban watersheds.	MD
Morse, 2001	Composite habitat values tended to decline with increases in watershed IC.	ME
Booth, 1991	Channel stability and fish habitat quality declined rapidly after 10% watershed IC.	WA
Booth *et al.,* 1997	Decreased LWD with increased IC.	PNW
Finkenbine *et al.,* 2000	LWD was scarce in streams with greater than 20% IC in Vancouver.	B.C.
Horner & May, 1999	When IC levels were >5%, average LWD densities fell below 300 pieces/kilometer.	PNW
Horner *et al.*, 1997	Interstitial spaces in streambed sediments begin to fill with increasing watershed IC.	PNW
Urbanization Used as Indicator		
Dunne and Leopold, 1978	Natural channels replaced by storm drains and pipes; increased erosion rates observed downstream.	MD
May *et al.,* 1997	Forested riparian corridor width declines with increased watershed IC.	PNW
MWCOG, 1992	Fish blockages caused by bridges and culverts noted in urban watersheds.	D.C.
Pizzuto *et al.,* 2000	Urban streams had reduced pool depth, roughness, and sinuosity, compared to rural streams; Pools were 31% shallower in urban streams compared to non-urban ones.	PA
Richey, 1982	Altered pool/riffle sequence observed in urban streams.	WA
Scott *et al.,* 1986	Loss of habitat diversity noted in urban watersheds.	PNW
Spence *et al.,* 1996	Large woody debris is important for habitat diversity and anadromous fish.	PNW

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3.4.3 Large Woody Debris (LWD)

LWD is a habitat element that describes the approximate volume of large woody material (< four inches in diameter) found in contact with the stream. The presence and stability of LWD is an important habitat parameter in streams. LWD can form dams and pools, trap sediment and detritus, stabilize stream channels, dissipate flow energy, and promote habitat complexity (Booth *et al.,* 1997). LWD creates a variety of pool features (plunge, lateral, scour and backwater); short riffles; undercut banks; side channels; and a range of water depths (Spence *et al.*, 1996). Urban streams tend to have a low supply of LWD, as increased stormwater flows transport LWD and clears riparian areas. Horner *et al.* (1997) presents evidence from Pacific Northwest streams that LWD decreases in response to increasing watershed IC (Figure 25).

3.4.4 Changes in Other Individual Stream Parameters

One of the notable changes in urban stream habitat is a decrease in pool depth and a general simplification of habitat features such as pools, riffles and runs. For example, Richey (1982) and Scott *et al.* (1986) reported an increase in the prevalence of glides and a corresponding altered riffle/pool sequence due to urbanization. Pizzuto *et al.* (2000) reported a median 31% decrease in pool depth in urban streams when compared to forested streams. Pizzuto *et al.* also reported a modest decrease in channel sinuosity and channel roughness in the same urban streams in Pennsylvania.

Several individual stream habitat parameters appear to have received no attention in urban stream research to date. These parameters include riparian shading, wetted perimeter, various measures of velocity/depth regimes, riffle frequency, and sediment deposition in pools. More systematic monitoring of these individual stream habitat parameters may be warranted.

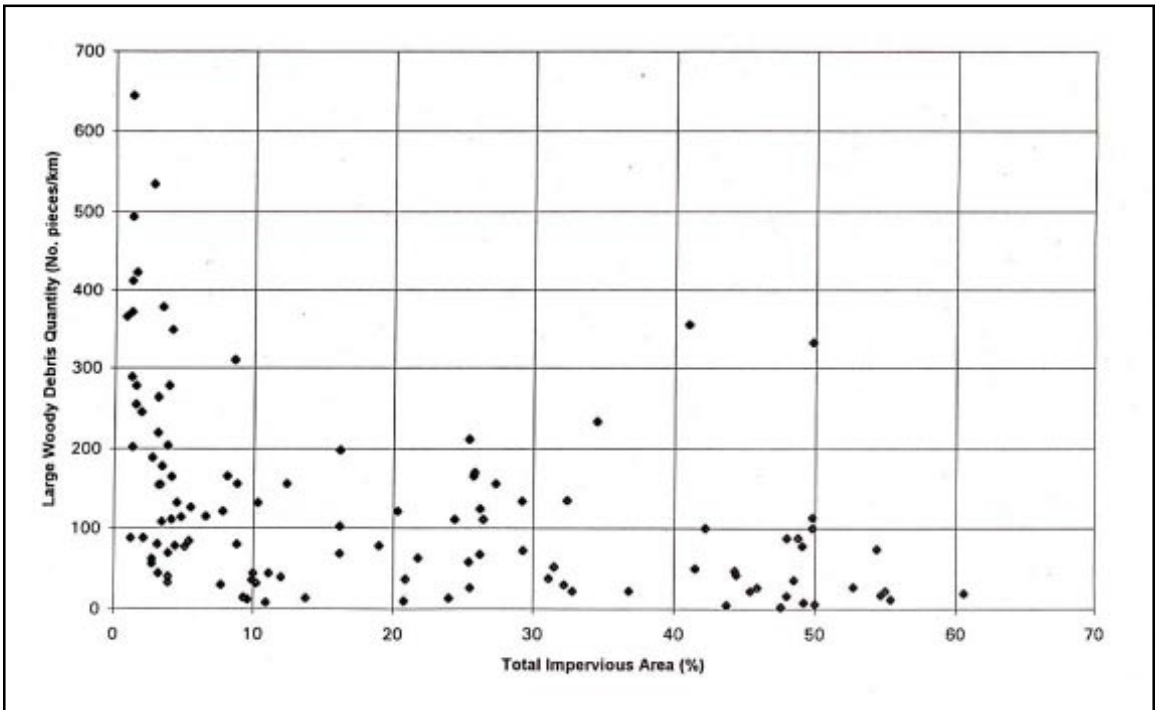

Figure 25: LWD as a Function of IC in Puget Sound Streams (Horner *et al.*, 1997)

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3.5 Increased Stream Warming

IC directly influences our local weather in urban areas. This effect is obvious to anyone walking across a parking lot on a hot summer day, when temperatures often reach a scorching 110 to 120 degrees F. Parking lots and other hard surfaces tend to absorb solar energy and release it slowly. Furthermore, they lack the normal cooling properties of trees and vegetation, which act as natural air conditioners. Finally, urban areas release excess heat as a result of the combustion of fossil fuels for heating, cooling and transportation. As a result, highly urban areas tend to be much warmer than their rural counterparts and are known as urban heat islands. Researchers have found that summer temperatures tend to be six to eight degrees F warmer in the summer and two to four degrees F warmer during the winter months.

Water temperature in headwater streams is strongly influenced by local air temperatures. Summer temperatures in urban streams have been shown to increase by as much as five to 12 degrees F in response to watershed development (Table 15). Increased water temperatures can preclude temperature-sensitive species from being able to survive in urban streams.

Figure 26 shows the stream warming phenomenon in small headwater streams in the Maryland Piedmont.

Galli (1990) reported that stream temperatures throughout the summer increased in urban watersheds. He monitored five headwater streams in the Maryland Piedmont with different levels of IC. Each urban stream had mean temperatures that were consistently warmer than a forested reference stream, and stream warming appeared to be a direct function of watershed IC. Other factors, such as lack of riparian cover and the presence of ponds, were also demonstrated to amplify stream warming, but the primary contributing factor appeared to be watershed IC.

Johnson (1995) studied how stormwater influenced an urban trout stream in Minnesota and reported up to a 10 degree F increase in stream water temperatures after summer storm events. Paul *et al.* (2001) evaluated stream temperatures for 30 subwatersheds to the Etowah River in Georgia, which ranged from five to 61% urban land. They found a correlation between summer daily mean water temperatures and the percentage of urban land in a subwatershed.

Table 15: Research Review of Thermal Impacts in Urban Streams

Reference	Key Finding	Location
%IC Used as Indicator		
Galli, 1990	Increase in stream temperatures of five to 12 degrees Fahrenheit in urban watersheds; stream warming linked to IC.	MD
Urbanization Used as Indicator		
Johnson, 1995	Up to 10 degrees Fahrenheit increases in stream temperatures after summer storm events in an urban area	MN
LeBlanc *et al.*, 1997	Calibrated a model predicting stream temperature increase as a result of urbanization	Ontario
MCDEP, 2000	Monitoring effect of urbanization and stormwater ponds on stream temperatures revealed stream warming associated with urbanization and stormwater ponds	MD
Paul *et al.*, 2001	Daily mean stream temperatures in summer increased with urban land use	GA

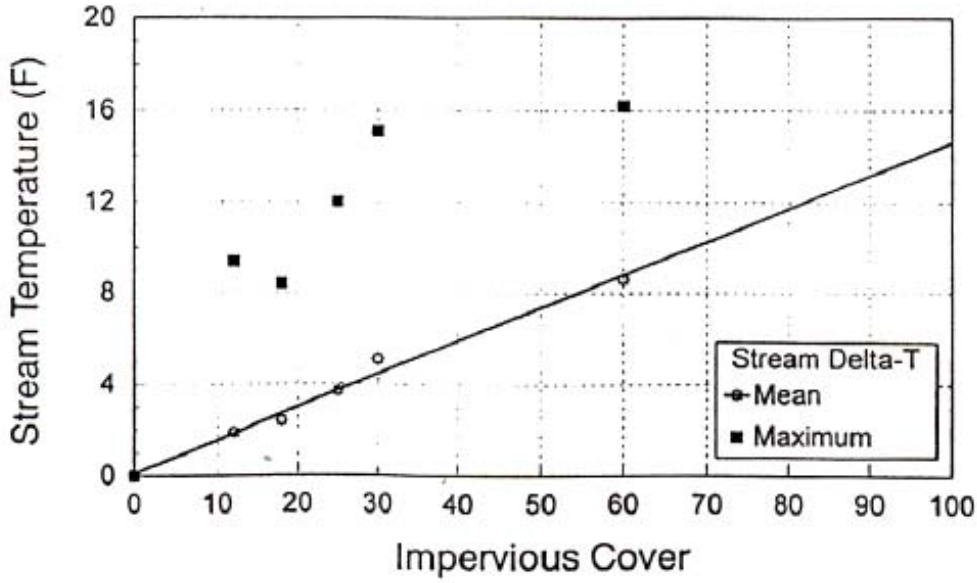

Figure 26: Stream Temperature Increase in Response to IC in Maryland Piedmont Streams (Galli, 1990)

Discharges from stormwater ponds can also contribute to stream warming in urban watersheds. Three studies highlight the temperature increase that can result from stormwater ponds. A study in Ontario found that baseflow temperatures below wet stormwater ponds increased by nine to 18 degrees F in the summer (SWAMP, 2000a, b). Oberts (1997) also measured change in the baseflow temperature as it flowed through a wetland/wet pond system in Minnesota. He concluded that the temperature had increased by an average of nine degrees F during the summer months. Galli (1988) also observed a mean increase of two to 10 degrees F in four stormwater ponds located in Maryland.

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3.6 Alteration of Stream Channel Networks

Urban stream channels are often severely altered by man. Channels are lined with rip rap or concrete, natural channels are straightened, and first order and ephemeral streams are enclosed in storm drain pipes. From an engineering standpoint, these modifications rapidly convey flood waters downstream and locally stabilize stream banks. Cumulatively, however, these modifications can have a dramatic effect on the length and habitat quality of headwater stream networks.

3.6.1 Channel Modification

Over time, watershed development can alter or eliminate a significant percentage of the perennial stream network. In general, the loss of stream network becomes quite extensive when watershed IC exceeds 50%. This loss is striking when pre- and post-development stream networks are compared (Figure 27). The first panel illustrates the loss of stream network over time in a highly urban Northern Virginia watershed; the second panel shows how the drainage network of Rock Creek has changed in response to watershed development.

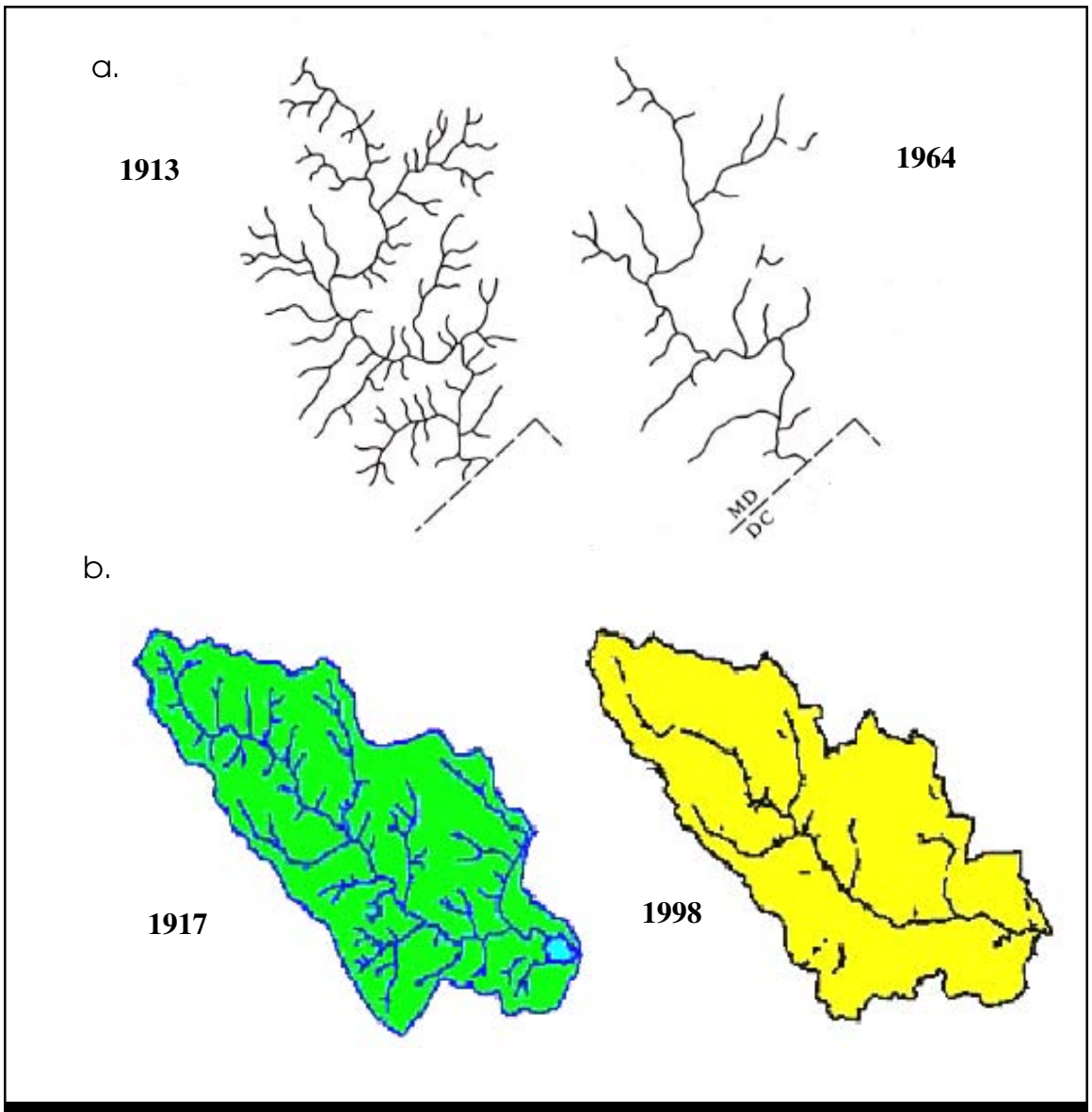

Figure 27: a. Drainage Network of Rock Creek, D.C. (Dunne and Leopold, 1978) and b. Drainage Network of Four Mile Run, VA Before and After Urbanization (NVRC, 2001)

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In a national study of 269 gaged urban watersheds, Sauer *et al.* (1983) observed that channelization and channel hardening were important watershed variables that control peak discharge rates. The channel modifications increase the efficiency with which runoff is transported through the stream channel, increasing critical shear stress velocities and causing downstream channel erosion.

3.6.2 Barriers to Fish Migration

Infrastructure such as bridges, dams, pipelines and culverts can create partial or total barriers to fish migration and impair the ability of fish to move freely in a watershed. Blockages can have localized effects on small streams where non-migratory fish species can be prevented from re-colonizing upstream areas after acutely toxic events. The upstream movement of anadromous fish species such as shad, herring, salmon and steelhead can also be blocked by these barriers. Figure 28 depicts the prevalence of fish barriers in the Anacostia Watershed (MWCOG, 1992).

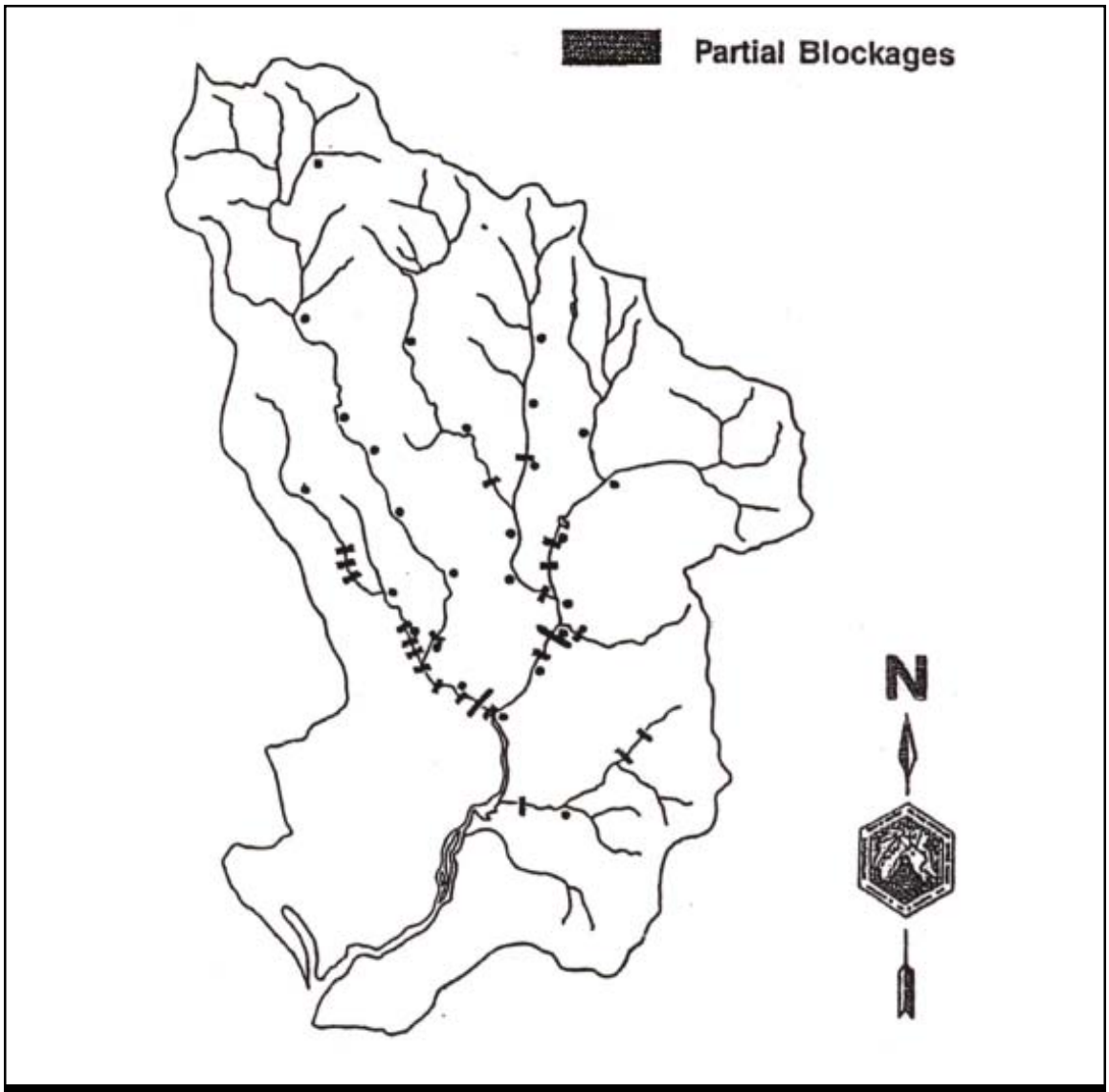

Figure 28: Fish Migration Barriers in the Anacostia Watershed of D.C. and MD (MWCOG, 1992)

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3.7 Conclusion

Watershed development and the associated increase in IC have been found to significantly degrade the physical habitat of urban streams. In alluvial streams, the effects of channel enlargement and sediment transport can be severe at relatively low levels of IC (10 to 20%). However, the exact response of any stream is also contingent upon a combination of other physical factors such as geology, vegetation, gradient, the age of development, sediment supply, the use and design of stormwater treatment practices, and the extent of riparian buffers (Bledsoe, 2001).

Despite the uncertainty introduced by these factors, the limited geomorphic research to date suggests that physical habitat quality is almost always degraded by higher levels of watershed IC. Even in bedrock-controlled channels, where sediment transport and channel enlargement may not be as dramatic, researchers have noted changes in stream habitat features, such as embeddedness, loss of LWD, and stream warming.

Overall, the following conclusions can be made about the influence of watershed development on the physical habitat of urban streams:

- The major changes in physical habitat in urban streams are caused by the increased frequency and duration of bankfull and sub-bankfull discharges, and the attendant changes in sediment supply and transport. As a consequence, many urban streams experience significant channel enlargement. Generally, channel enlargement is most evident in alluvial streams.

- Typical habitat changes observed in urban streams include increased embeddedness, reduced supply of LWD, and simplification of stream habitat features such as pools, riffles and runs, as well as reduced channel sinuosity.

- Stream warming is often directly linked to watershed development, although more systematic subwatershed sampling is needed to precisely predict the extent of warming.

- Channel straightening, hardening and enclosure and the creation of fish barriers are all associated with watershed development. More systematic research is needed to establish whether these variables can be predicted based on watershed IC.

- In general, stream habitat diminishes at about 10% watershed IC, and becomes severely degraded beyond 25% watershed IC.

While our understanding of the relationship between stream habitat features and watershed development has improved in recent years, the topic deserves greater research in three areas. First, more systematic monitoring of composite habitat variables needs to be conducted across the full range of watershed IC. In particular, research is needed to define the approximate degree of watershed IC where urban streams are transformed into urban drainage systems.

Second, additional research is needed to explore the relationship between watershed IC and individual and measurable stream habitat parameters, such as bank erosion, channel sinuosity, pool depth and wetted perimeter. Lastly, more research is needed to determine if watershed treatment such as stormwater practices and stream buffers can mitigate the impacts of watershed IC on stream habitat. Together, these three research efforts could provide a technical foundation to develop a more predictive model of how watershed development influences stream habitat.

Chapter 4: Water Quality Impacts of Impervious Cover

This chapter presents information on pollutant concentrations found in urban stormwater runoff based on a national and regional data assessment for nine categories of pollutants. Included is a description of the Simple Method, which can be used to estimate pollutant loads based on the amount of IC found in a catchment or subwatershed. This chapter also addresses specific water quality impacts of stormwater pollutants and explores research on the sources and source areas of stormwater pollutants.

This chapter is organized as follows:

4.1 Introduction
4.2 Summary of National and Regional Stormwater Pollutant Concentration Data
4.3 Relationship Between Pollutant Loads and IC: The Simple Method
4.4 Sediment
4.5 Nutrients
4.6 Trace Metals
4.7 Hydrocarbons (PAH and Oil and Grease)
4.8 Bacteria and Pathogens
4.9 Organic Carbon
4.10 MTBE
4.11 Pesticides
4.12 Deicers
4.13 Conclusion

4.1 Introduction

Streams are usually the first aquatic system to receive stormwater runoff, and their water quality can be compromised by the pollutants it contains. Stormwater runoff typically contains dozens of pollutants that are detectable at some concentration, however small. Simply put, any pollutant deposited or derived from an activity on land will likely end up in stormwater runoff, although certain pollutants are consistently more likely to cause water quality problems in receiving waters. Pollutants that are frequently found in stormwater runoff can be grouped into nine broad categories: sediment, nutrients, metals, hydrocarbons, bacteria and pathogens, organic carbon, MTBE, pesticides, and deicers.

The impact that stormwater pollutants exert on water quality depends on many factors, including concentration, annual pollutant load, and category of pollutant. Based on nationally reported concentration data, there is considerable variation in stormwater pollutant concentrations. This variation has been at least partially attributed to regional differences, including rainfall and snowmelt. The volume and regularity of rainfall, the length of snow accumulation, and the rate of snowmelt can all influence stormwater pollutant concentrations.

The annual pollutant load can have long-term effects on stream water quality, and is particularly important information for stormwater managers to have when dealing with non-point source pollution control. The Simple Method is a model developed to estimate the pollutant load for chemical pollutants, assuming that the annual pollutant load is a function of IC. It is an effective method for determining annual sediment, nutrient, and trace metal loads. It cannot always be applied to other stormwater pollutants, since they are not always correlated with IC.

The direct water quality impact of stormwater pollutants also depends on the type of pollutant, as different pollutants impact streams differently. For example, sediments affect stream habitat and aquatic biodiversity; nutrients cause eutrophication; metals, hydrocarbons, deicers, and MTBE can be toxic to aquatic life; and organic carbon can lower dissolved oxygen levels.

The impact stormwater pollutants have on

water quality can also directly influence human uses and activities. Perhaps the pollutants of greatest concern are those with associated public health impacts, such as bacteria and pathogens. These pollutants can affect the availability of clean drinking water and limit consumptive recreational activities, such as swimming or fishing. In extreme situations, these pollutants can even limit contact recreational activities such as boating and wading.

It should be noted that although there is much research available on the effects of urbanization on water quality, the majority has not been focused on the impact on streams, but on the response of lakes, reservoirs, rivers and estuaries. It is also important to note that not all pollutants are equally represented in monitoring conducted to date. While we possess excellent monitoring data for sediment, nutrients and trace metals, we have relatively little monitoring data for pesticides, hydrocarbons, organic carbon, deicers, and MTBE.

4.2 Summary of National and Regional Stormwater Pollutant Concentration Data

4.2.1 National Data

National mean concentrations of typical stormwater pollutants are presented in Table 16. National stormwater data are compiled from the Nationwide Urban Runoff Program (NURP), with additional data obtained from the U.S.Geological Survey (USGS), as well as initial stormwater monitoring conducted for EPA's National Pollutant Discharge Elimination System (NPDES) Phase I stormwater program.

In most cases, stormwater pollutant data is reported as an event mean concentration (EMC), which represents the average concentration of the pollutant during an entire stormwater runoff event.

When evaluating stormwater EMC data, it is important to keep in mind that regional EMCs can differ sharply from the reported national pollutant EMCs. Differences in EMCs between regions are often attributed to the variation in the amount and frequency of rainfall and snowmelt.

4.2.2 Regional Differences Due to Rainfall

The frequency of rainfall is important, since it influences the accumulation of pollutants on IC that are subsequently available for wash-off during storm events. The USGS developed a national stormwater database encompassing 1,123 storms in 20 metropolitan areas and used it as the primary data source to define regional differences in stormwater EMCs. Driver (1988) performed regression analysis to determine which factors had the greatest influence on stormwater EMCs and determined that annual rainfall depth was the best overall predictor. Driver grouped together stormwater EMCs based on the depth of average annual rainfall, and Table 17 depicts the regional rainfall groupings and general trends for each

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region. Table 18 illustrates the distribution of stormwater EMCs for a range of rainfall regions from 13 local studies, based on other monitoring studies. In general, stormwater EMCs for nutrients, suspended sediment and metals tend to be higher in arid and semi-arid

Table 16: National EMCs for Stormwater Pollutants

Pollutant	Source	EMCs		Number of Events
		Mean	Median	
Sediments (mg/l)				
TSS	(1)	78.4	54.5	3047
Nutrients (mg/l)				
Total P	(1)	0.32	0.26	3094
Soluble P	(1)	0.13	0.10	1091
Total N	(1)	2.39	2.00	2016
TKN	(1)	1.73	1.47	2693
Nitrite & Nitrate	(1)	0.66	0.53	2016
Metals (Fg/l)				
Copper	(1)	13.4	11.1	1657
Lead	(1)	67.5	50.7	2713
Zinc	(1)	162	129	2234
Cadmium	(1)	0.7	N/R	150
Chromium	(4)	4	7	164
Hydrocarbons (mg/l)				
PAH	(5)	3.5	N/R	N/R
Oil and Grease	(6)	3	N/R	N/R
Bacteria and Pathogens (colonies/ 100ml)				
Fecal Coliform	(7)	15,038	N/R	34
Fecal Streptococci	(7)	35,351	N/R	17
Organic Carbon (mg/l)				
TOC	(11)	17	15.2	19 studies
BOD	(1)	14.1	11.5	1035
COD	(1)	52.8	44.7	2639
MTBE	(8)	N/R	1.6	592
Pesticides (Fg/l)				
Diazinon	(10)	N/R	0.025	326
	(2)	N/R	0.55	76
Chlorpyrifos	(10)	N/R	N/R	327
Atrazine	(10)	N/R	0.023	327
Prometon	(10)	N/R	0.031	327
Simazine	(10)	N/R	0.039	327
Chloride (mg/l)				
Chloride	(9)	N/R	397	282

Sources: [1] Smullen and Cave, 1998; [2] Brush et al., 1995; [3] Baird et al., 1996; [4] Bannerman et al., 1996; [5] Rabanal and Grizzard, 1995; [6] Crunkilton et al., 1996; [7] Schueler, 1999; [8] Delzer, 1996; [9] Environment Canada, 2001; [10] USEPA, 1998; [11] CWP, 2001a N/R - Not Reported

Table 17: Regional Groupings by Annual Rainfall Amount (Driver, 1988)			
Region	**Annual Rainfall**	**States Monitored**	**Concentration Data**
Region I: Low Rainfall	<20 inches	AK, CA, CO, NM, UT	Highest mean and median values for Total N, Total P, TSS and COD
Region II: Moderate Rainfall	20 40 inches	HA, IL, MI, MN, MI, NY, TX, OR, OH, WA, WI	Higher mean and median values than Region III for TSS, dissolved phosphorus and cadmium
Region III: High Rainfall	>40 inches	FL, MD, MA, NC, NH, NY, TX, TN, AR	Lower values for many parameters likely due to the frequency of storms and the lack of build up in pollutants

regions and tend to decrease slightly when annual rainfall increases (Table 19).

It is also hypothesized that a greater amount of sediment is eroded from pervious surfaces in arid or semi-arid regions than in humid regions due to the sparsity of protective vegetative cover. Table 19 shows that the highest concentrations of total suspended solids were recorded in regions with least rainfall. In addition, the chronic toxicity standards for several metals are most frequently exceeded during low rainfall regions (Table 20).

4.2.3 Cold Region Snowmelt Data

In colder regions, snowmelt can have a significant impact on pollutant concentrations. Snow accumulation in winter coincides with pollutant build-up; therefore, greater concentrations of pollutants are measured during snowmelt events. Sources of snowpack pollution in urban areas include wet and dry atmospheric deposition, traffic emissions, urban litter, deteriorated infrastructure, and deicing chemicals and abrasives (WERF, 1999).

Oberts *et al.* (1989) measured snowmelt pollutants in Minnesota streams and found that as much as 50% of annual sediment, nutrient, hydrocarbon and metal loads could be attributed to snowmelt runoff during late winter and early spring. This trend probably applies to any region where snow cover persists through much of the winter. Pollutants accumulate in the snowpack and then contribute high concentrations during snowmelt runoff. Oberts (1994) described four types of snowmelt runoff events and the resulting pollutant characteristics (Table 21).

A typical hydrograph for winter and early spring snow melts in a northern cold climate is portrayed in Figure 29. The importance of snowpack melt on peak runoff during March 1989 can clearly be seen for an urban watershed located in St. Paul, Minnesota.

Major source areas for snowmelt pollutants include snow dumps and roadside snowpacks. Pollutant concentrations in snow dumps can be as much as five times greater than typical stormwater pollutant concentrations (Environment Canada, 2001). Snow dumps and packs accumulate pollutants over the winter months and can release them during a few rain or snow melt events in the early spring. High levels of chloride, lead, phosphorus, biochemical oxygen demand, and total suspended solids have been reported in snow pack runoff (La Barre *et al*, 1973; Oliver *et al.*, 1974; Pierstorff and Bishop, 1980; Scott and Wylie, 1980; Van Loon, 1972).

Atmospheric deposition can add pollutants to snow piles and snowpacks. Deposited pollutants include trace metals, nutrients and particles that are primarily generated by fossil fuel combustion and industrial emissions (Boom and Marsalek, 1988; Horkeby and Malmqvist, 1977; Malmqvist, 1978; Novotny and Chester, 1981; Schrimpff and Herrman, 1979).

Table 18: Stormwater Pollutant Event Mean Concentration for Different U.S. Regions (Units: mg/l, except for metals which are in *F*g/l)

		Region I - Low Rainfall				Region II - Moderate Rainfall			Region III - High Rainfall				Snow
	National	Phoenix, AZ	San Diego, CA	Boise, ID	Denver, CO	Dallas, TX	Marquette, MI	Austin, TX	MD	Louisville, KY	GA	FL	MN
Reference	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(11)	(12)
Annual Rainfall (in.)	N/A	7.1"	10"	11"	15"	28"	32"	32"	41"	43"	51"	52"	N/R
Number of Events	3000	40	36	15	35	32	12	N/R	107	21	81	N/R	49
Pollutant													
TSS	78.4	227	330	116	242	663	159	190	67	98	258	43	112
Total N	2.39	3.26	4.55	4.13	4.06	2.70	1.87	2.35	N/R	2.37	2.52	1.74	4.30
Total P	0.32	0.41	0.7	0.75	0.65	0.78	0.29	0.32	0.33	0.32	0.33	0.38	0.70
Soluble P	0.13	0.17	0.4	0.47	N/R	N/R	0.04	0.24	N/R	0.21	0.14	0.23	0.18
Copper	14	47	25	34	60	40	22	16	18	15	32	1.4	N/R
Lead	68	72	44	46	250	330	49	38	12.5	60	28	8.5	100
Zinc	162	204	180	342	350	540	111	190	143	190	148	55	N/R
BOD	14.1	109	21	89	N/R	112	15.4	14	14.4	88	14	11	N/R
COD	52.8	239	105	261	227	106	66	98	N/R	38	73	64	112

Sources: Adapted from Caraco, 2000a: [1] Smullen and Cave, 1998; [2] Lopes et al.; 1995; [3] Schiff, 1996; [4] Kjelstrom, 1995 (computed); [5] DRCOG, 1983, [6] Brush et al., *1995; [7] Steuer* et al., *1997; [8] Barrett* et al., *1995; [9] Barr, 1997; [10] Evaldi* et al., *1992; [11] Thomas and McClelland, 1995; [12] Oberts, 1994 N/R = Not Reported; N/A = Not Applicable*

Table 19: Mean and Median Nutrient and Sediment Stormwater Concentrations for Residential Land Use Based on Rainfall Regions (Driver, 1988)

Region	Total N (median)	Total P (median)	TSS (mean)
Region I: Low Rainfall	4	0.45	320
Region II: Moderate Rainfall	2.3	0.31	250
Region III: High Rainfall	2.15	0.31	120

Table 20: EPA 1986 Water Quality Standards and Percentage of Metal Concentrations Exceeding Water Quality Standards by Rainfall Region (Driver, 1988)

	Cadmium	Copper	Lead	Zinc
EPA Standards	10 *F*g/l	12 *F*g/l	32 *F*g/l	47 *F*g/l
Percent Exceedance of EPA Standards				
Region I: Low Rainfall	1.5%	89%	97%	97%
Region II: Moderate Rainfall	0	78%	89%	85%
Region III: High Rainfall	0	75%	91%	84%

Table 21: Runoff and Pollutant Characteristics of Snowmelt Stages (Oberts, 1994)

Snowmelt Stage	Duration /Frequency	Runoff Volume	Pollutant Characteristics
Pavement	Short, but many times in winter	Low	Acidic, high concentrations of soluble pollutants; Chloride, nitrate, lead; total load is minimal
Roadside	Moderate	Moderate	Moderate concentrations of both soluble and particulate pollutants
Pervious Area	Gradual, often most at end of season	High	Dilute concentrations of soluble pollutants; moderate to high concentrations of particulate pollutants depending on flow
Rain-on-Snow	Short	Extreme	High concentrations of particulate pollutants; moderate to high concentrations of soluble pollutants; high total load

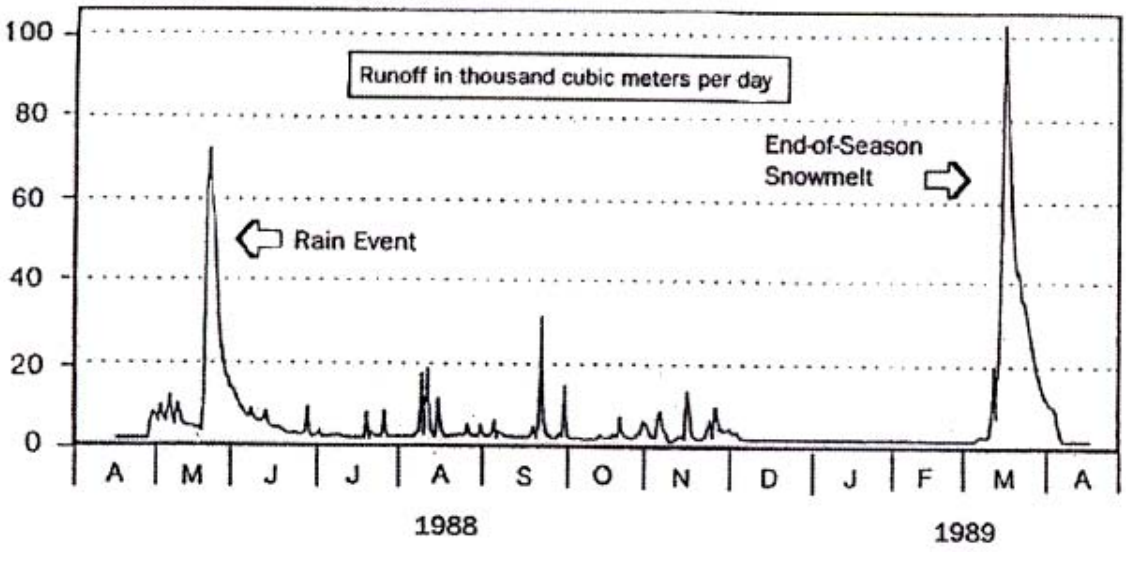

Figure 29: Snowmelt Runoff Hydrograph for Minneapolis Stream (Oberts, 1994)

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4.3 Relationship Between Pollutant Loads and IC: The Simple Method

Urban stormwater runoff contains a wide range of pollutants that can degrade downstream water quality. The majority of stormwater monitoring research conducted to date supports several generalizations. First, the unit area pollutant load delivered to receiving waters by stormwater runoff increases in direct proportion to watershed IC. This is not altogether surprising, since pollutant load is the product of the average pollutant concentration and stormwater runoff volume. Given that runoff volume increases in direct proportion to IC, pollutant loads must automatically increase when IC increases, as long the average pollutant concentration stays the same (or increases). This relationship is a central assumption in most simple and complex pollutant loading models (Bicknell *et al.*, 1993; Donigian and Huber, 1991; Haith *et al.*, 1992; Novotny and Chester, 1981; NVPDC, 1987; Pitt and Voorhees, 1989).

Recognizing the relationship between IC and pollutant loads, Schueler (1987) developed the "Simple Method" to quickly and easily estimate stormwater pollutant loads for small urban watersheds (see Figure 30). Estimates of pollutant loads are important to watershed managers as they grapple with costly decisions on non-point source control. The Simple Method is empirical in nature and utilizes the extensive regional and national database (Driscoll, 1983; MWCOG, 1983; USEPA, 1983). Figure 30 provides the basic equations to estimate pollutant loads using the Simple

Figure 30: The Simple Method - Basic Equations

The Simple Method estimates pollutant loads as the product of annual runoff volume and pollutant EMC, as:

$$(1)\ L = 0.226 * R * C * A$$

Where: L = Annual load (lbs), and:
R = Annual runoff (inches)
C = Pollutant concentration in stormwater, EMC (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$(2)\ L = 1.03 * 10^{-3} * R * C * A$$

Where: L = Annual load (Billion Colonies), and:
R = Annual runoff (inches)
C = Bacteria concentration (#/100 ml)
A = Area (acres)
$1.03 * 10^{-3}$ = Unit conversion factor

Annual Runoff

The Simple Method calculates the depth of annual runoff as a product of annual runoff volume and a runoff coefficient (Rv). Runoff volume is calculated as:

$$(3)\ R = P * P_j * Rv$$

Where: R = Annual runoff (inches), and:
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on IC in the subwatershed. The following equation represents the best fit line for the data set (N=47, R^2=0.71).

$$(4)\ Rv=0.05+0.9Ia$$

Where: Rv = runoff coefficient, and:
Ia = Impervious fraction

Method. It assumes that loads of stormwater pollutants are a direct function of watershed IC, as IC is the key independent variable in the equation.

The technique requires a modest amount of information, including the subwatershed drainage area, IC, stormwater runoff pollutant EMCs, and annual precipitation. With the Simple Method, the investigator can either divide up land use into specific areas (i.e. residential, commercial, industrial, and roadway) and calculate annual pollutant loads for each land use, or utilize a generic urban land use. Stormwater pollutant EMC data can be derived from the many summary tables of local, regional, or national monitoring efforts provided in this chapter (e.g., Tables 16, 18, 22, 28, 30, 35, 36, 40, and 44). The model also requires different IC values for separate land uses within a subwatershed. Representative IC data from Cappiella and Brown (2001) were provided in Table 2 (Chapter 1).

Additionally, the Simple Method should not be used to estimate annual pollutant loads of deicers, hydrocarbons and MTBE, because they have not been found to be correlated with IC. These pollutants have been linked to other indicators. Chlorides, hydrocarbons and MTBE are often associated with road density and vehicle miles traveled (VMT). Pesticides are associated with turf area, and traffic patterns and "hotspots" have been noted as potential indicators for hydrocarbons and MTBE.

Limitations of the Simple Method

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development. However, several caveats should be kept in mind when applying this method.

The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes from different land uses and stormwater treatment scenarios. The Simple Method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to overemphasize the precision of the load estimate obtained. For example, it would be inappropriate to use the Simple Method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% IC). The Simple Method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling is needed to analyze larger and more complex watersheds.

In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow during dry weather. Typically, baseflow is negligible or non-existent at the scale of a single development site and can be safely neglected. However, catchments and subwatersheds do generate significant baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels (NVPDC, 1979).

Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low. For example, in a low density residential subwatershed (IC < 5%), as much as 75% of the annual runoff volume could occur as baseflow. In such a case, annual baseflow load may be equivalent to the annual stormflow load.

4.4 Sediment

Sediment is an important and ubiquitous pollutant in urban stormwater runoff. Sediment can be measured in three distinct ways: Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and turbidity. TSS is a measure of the total mass suspended sediment particles in water. The measurement of TSS in urban stormwater helps to estimate sediment load transported to local and downstream receiving waters. Table 22 summarizes stormwater EMCs for total suspended solids, as reported by Barrett *et al.* (1995), Smullen and Cave (1998), and USEPA (1983). TDS is a measure of the dissolved solids and minerals present in stormwater runoff and is used as a primary indication of the purity of drinking water. Since few stormwater monitoring efforts have focused on TDS, they are not reported in this document. Turbidity is a measure of how suspended solids present in water reduce the ability of light to penetrate the water column. Turbidity can exert impacts on aquatic biota, such as the ability of submerged aquatic vegetation to receive light and the ability of fish and aquatic insects to use their gills (Table 23).

4.4.1 Concentrations

TSS concentrations in stormwater across the country are well documented. Table 18 reviews mean TSS EMCs from 13 communities across the country and reveals a wide range of recorded concentrations. The lowest concentration of 43 mg/l was reported in Florida, while TSS reached 663 mg/l in Dallas, Texas. Variation in sediment concentrations has been attributed to regional rainfall differences (Driver, 1988); construction site runoff (Leopold, 1968); and bank erosion (Dartiguenave *et al.*, 1997). National values are provided in Table 22.

Turbidity levels are not as frequently reported in national and regional monitoring summaries. Barrett and Malina (1998) monitored turbidity at two sites in Austin, Texas and reported a mean turbidity of 53 NTU over 34 storm events (Table 22).

4.4.2 Impacts of Sediment on Streams

The impacts of sediment on aquatic biota are well documented and can be divided into impacts caused by suspended sediment and those caused by deposited sediments (Tables 23 and 24).

In general, high levels of TSS and/or turbidity can affect stream habitat and cause sedimentation in downstream receiving waters. Deposited sediment can cover benthic organisms such as aquatic insects and freshwater mussels. Other problems associated with high sediments loads include stream warming by reflecting radiant energy due to increased turbidity (Kundell and Rasmussen, 1995), decreased flow capacity (Leopold, 1973), and increasing overbank flows (Barrett and Malina, 1998). Sediments also transport other pollutants which bind to sediment particles. Significant levels of pollutants can be transported by sediment during stormwater runoff events,

Table 22: EMCs for Total Suspended Solids and Turbidity

Pollutant	EMCs		Number of Events	Source
	Mean	Median		
TSS (mg/l)	78.4	54.5	3047	Smullen and Cave, 1998
	174	113	2000	USEPA, 1983
Turbidity (NTU)	53	N/R	423	Barrett and Malina, 1998

N/R = Not Reported

Table 23: Summary of Impacts of Suspended Sediment on the Aquatic Environment (Schueler and Holland, 2000)

Abrades and damages fish gills, increasing risk of infection and disease
Scouring of periphyton from stream (plants attached to rocks)
Loss of sensitive or threatened fish species when turbidity exceeds 25 NTU
Shifts in fish community toward more sediment-tolerant species
Decline in sunfish, bass, chub and catfish when month turbidity exceeds 100 NTU
Reduces sight distance for trout, with reduction in feeding efficiency
Reduces light penetration causing reduction in plankton and aquatic plant growth
Adversely impacts aquatic insects, which are the base of the food chain
Slightly increases the stream temperature in the summer
Suspended sediments can be a major carrier of nutrients and metals
Reduces anglers chances of catching fish

Table 24: Summary of Impacts of Deposited Sediments on the Aquatic Environment (Schueler and Holland, 2000)

1. Physical smothering of benthic aquatic insect community
2. Reduced survival rates for fish eggs
3. Destruction of fish spawning areas and eggs
4. Embeddedness of stream bottom reduced fish and macroinvertebrate habitat value
5. Loss of trout habitat when fine sediments are deposited in spawning or riffle-runs
6. Sensitive or threatened darters and dace may be eliminated from fish community
7. Increase in sediment oxygen demand can deplete dissolved oxygen in streams
8. Significant contributing factor in the alarming decline of freshwater mussels
9. Reduced channel capacity, exacerbating downstream bank erosion and flooding
10. Reduced flood transport capacity under bridges and through culverts
11. Deposits diminish scenic and recreational values of waterways

including trace metals, hydrocarbons and nutrients (Crunkilton *et al.,* 1996; Dartiguenave *et al*., 1997; Gavin and Moore, 1982; Novotny and Chester, 1989; Schueler 1994b).

4.4.3 Sources and Source Areas of Sediment

Sediment sources in urban watersheds include stream bank erosion; erosion from exposed soils, such as from construction sites; and washoff from impervious areas (Table 25).

As noted in this chapter, streambank erosion is generally considered to be the primary source of sediment to urban streams. Recent studies by Dartiguenave *et al.* (1997) and Trimble (1997) determined that streambank erosion contributes the majority of the annual sediment budget of urban streams. Trimble (1997) directly measured stream cross sections, sediment aggradation and suspended sediment loads and determined that two-thirds of the annual sediment budget of a San Diego, California watershed was supplied by streambank erosion. Dartiguenave *et al.* (1997) developed a GIS based model in Austin, Texas to determine the effects of stream bank erosion on the annual sediment budget. They compared modeled sediment loads from the watershed with the actual sediment loads measured at USGS gaging stations and concluded that more than 75% of the sediment load came from streambank erosion. Dartiguenave *et al.* (1997) reported that sediment load per unit area increases with increasing IC (Figure 31).

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Sediment loads are also produced by washoff of sediment particles from impervious areas and their subsequent transport in stormwater runoff sediment. Source areas include parking lots, streets, rooftops, driveways and lawns. Streets and parking lots build up dirt and grime from the wearing of the street surface, exhaust particulates, "blown on" soil and organic matter, and atmospheric deposition. Lawn runoff primarily contains soil and organic matter. Urban source areas that produce the highest TSS concentrations include streets, parking lots and lawns (Table 26).

Parking lots and streets are not only responsible for high concentrations of sediment but also high runoff volumes. The SLAMM source loading model (Pitt and Voorhees, 1989) looks at runoff volume and concentrations of pollutants from different urban land uses and predicts stream loading. When used in the Wisconsin and Michigan subwatersheds, it demonstrated that parking lots and streets were responsible for over 70% of the TSS delivered to the stream. (Steuer *et al*., 1997; Waschbusch *et al.*, 2000).

Table 25: Sources and Loading of Suspended Solids Sediment in Urban Areas

Sources	Loading	Source
Bank Erosion	75% of stream sediment budget	Dartinguenave *et al.*, 1997
	66% of stream sediment budget	Trimble, 1997
Overland Flow- Lawns	397 mg/l (geometric mean)	Bannerman *et al.*, 1993
	262 mg/l	Steuer *et al.*, 1997
	11.5% (estimated; 2 sites)	Waschbusch *et al.*, 2000
Construction Sites	200 to 1200 mg/l	Table 27
Washoff from Impervious Surfaces	78 mg/l (mean)	Table 16

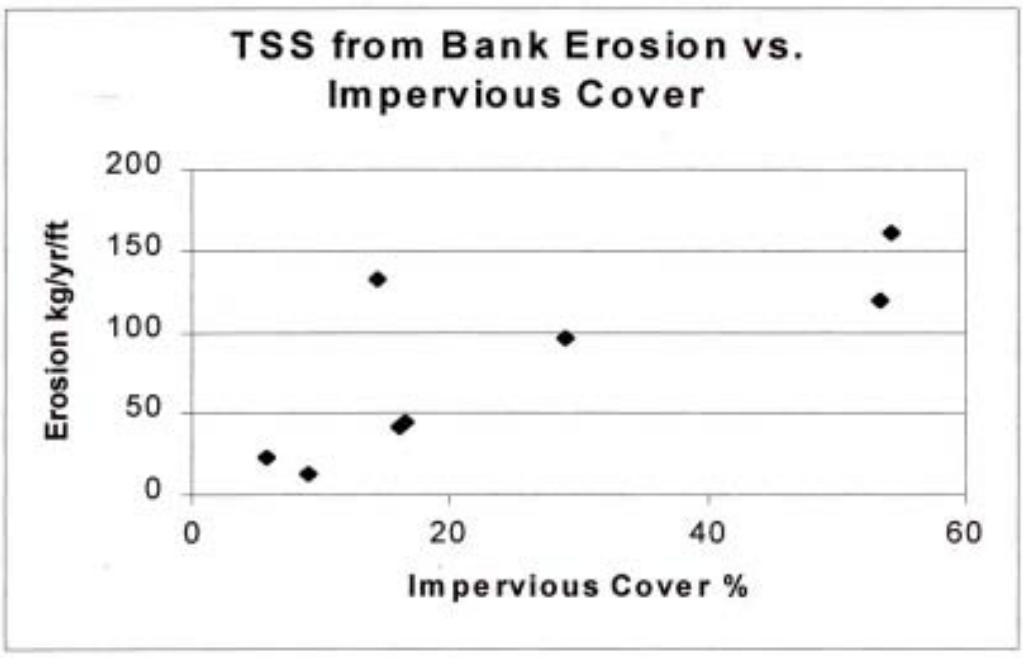

Figure 31: TSS from Bank Erosion vs. IC in Texas Streams (Daringuenave *et al.*, 1997)

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The third major source of sediment loads is erosion from construction sites. Several studies have reported extremely high TSS concentrations in construction site runoff, and these findings are summarized in Table 27. TSS concentrations from uncontrolled construction sites can be more than 150 times greater than those from undeveloped land (Leopold, 1968) and can be reduced if erosion and sediment control practices are applied to construction sites.

Table 26: Source Area Geometric Mean Concentrations for Suspended Solids in Urban Areas

Source Area	Suspended Solids (mg/l)		
Source	(1)	(2)	(3)
Commercial Parking Lot	110	58	51
High Traffic Street	226	232	65
Medium Traffic Street	305	326	51
Low Traffic Street	175	662	68
Commercial Rooftop	24	15	18
Residential Rooftop	36	27	15
Residential Driveway	157	173	N/R
Residential Lawn	262	397	59

Sources: [1] Steuer et al., 1997; [2] Bannerman et al., 1993; [3] Waschbusch et al., 2000; N/R = Not Reported

Table 27: Mean TSS Inflow and Outflow at Uncontrolled, Controlled and Simulated Construction Sites

Source	Mean Inflow TSS Concentration (mg/l)	Mean Outflow TSS Concentration (mg/l)	Location
Uncontrolled Sites			
Horner *et al.*, 1990	7,363	281	PNW
Schueler and Lugbill,1990	3,646	501	MD
York and Herb, 1978	4,200	N/R	MD
Islam *et al.*, 1988	2,950	N/R	OH
Controlled Sites			
Schueler and Lugbill, 1990	466	212	MD
Simulated Sediment Concentrations			
Jarrett, 1996	9,700	800	PA
Sturm and Kirby, 1991	1,500-4,500	200-1,000	GA
Barfield and Clar, 1985	1,000-5,000	200-1,200	MD
Dartiguenave *et al.*, 1997	N/R	600	TX

N/R = Not Reported

4.5 Nutrients

Nitrogen and phosphorus are essential nutrients for aquatic systems. However, when they appear in excess concentrations, they can exert a negative impact on receiving waters. Nutrient concentrations are reported in several ways. Nitrogen is often reported as nitrate (NO_3) and nitrite (NO_2), which are inorganic forms of nitrogen; total nitrogen (Total N), which is the sum of nitrate, nitrite, organic nitrogen and ammonia; and total Kjeldhal nitrogen (TKN), which is organic nitrogen plus ammonia.

Phosphates are frequently reported as soluble phosphorus, which is the dissolved and reactive form of phosphorus that is available for uptake by plants and animals. Total phosphorus (Total P) is also measured, which includes both organic and inorganic forms of phosphorus. Organic phosphorus is derived from living plants and animals, while inorganic phosphate is comprised of phosphate ions that are often bound to sediments.

4.5.1 Concentrations

Many studies have indicated that nutrient concentrations are linked to land use type, with urban and agricultural watersheds producing the highest nutrient loads (Chessman *et al.* 1992; Paul *et al.*, 2001; USGS, 2001b and Wernick *et al.*,1998). Typical nitrogen and phosphorus EMC data in urban stormwater runoff are summarized in Table 28.

Some indication of the typical concentrations of nitrate and phosphorus in stormwater runoff are evident in Figures 32 and 33. These graphs profile average EMCs in stormwater runoff recorded at 37 residential catchments across the U.S. The average nitrate EMC is remarkably consistent among residential neighborhoods, with most clustered around the mean of 0.6 mg/l and a range of 0.25 to 1.4 mg/l. The concentration of phosphorus during storms is also very consistent with a mean of 0.30 mg/l and a rather tight range of 0.1 to 0.66 mg/l (Schueler, 1995).

The amount of annual rainfall can also influence the magnitude of nutrient concentrations in stormwater runoff. For example, both Caraco (2000a) and Driver (1988) reported that the highest nutrient EMCs were found in stormwater from arid or semi-arid regions.

Table 28: EMCs of Phosphorus and Nitrogen Urban Stormwater Pollutants

Pollutant	EMCs (mg/l)		Number of Events	Source
	Mean	Median		
Total P	0.315	0.259	3094	Smullen and Cave, 1998
	0.337	0.266	1902	USEPA, 1983
Soluble P	0.129	0.103	1091	Smullen and Cave, 1998
	0.1	0.078	767	USEPA, 1983
Total N	2.39	2.00	2016	Smullen and Cave, 1998
	2.51	2.08	1234	USEPA, 1983
TKN	1.73	1.47	2693	Smullen and Cave, 1998
	1.67	1.41	1601	USEPA, 1983
Nitrite & Nitrate	0.658	0.533	2016	Smullen and Cave, 1998
	0.837	0.666	1234	USEPA, 1983

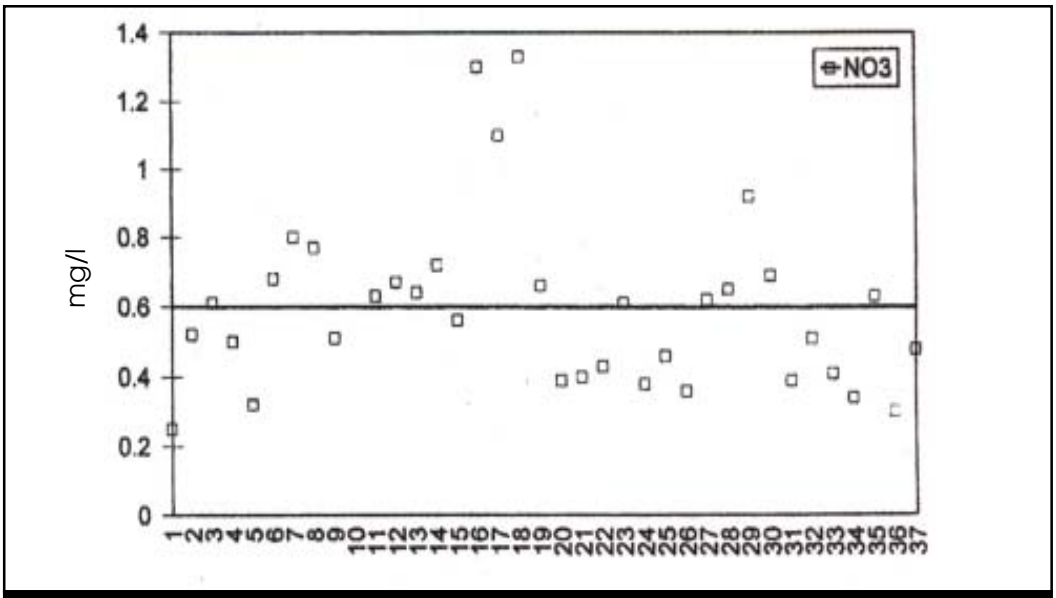

Figure 32: Nitrate-Nitrogen Concentration in Stormwater Runoff at 37 Sites Nationally (Schueler, 1999)

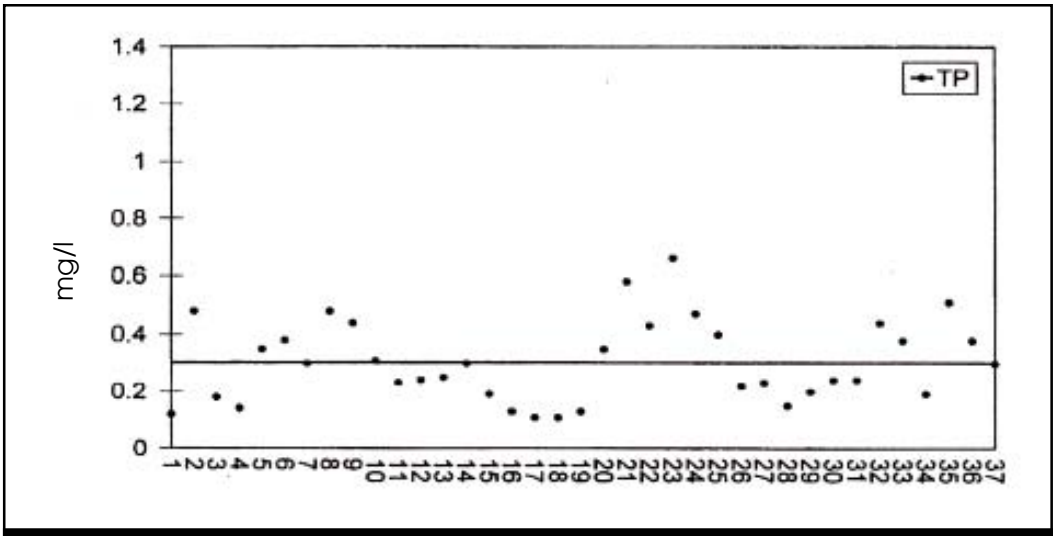

Figure 33: Total Phosphorus Concentration in Stormwater at 37 Sites Nationally (Schueler, 1999)

4.5.2 Impacts of Nutrients on Streams

Much research on the impact of nutrient loads has been focused on lakes, reservoirs and estuaries, which can experience eutrophication. Nitrogen and phosphorus can contribute to algae growth and eutrophic conditions, depending on which nutrient limits growth (USEPA, 1998). Dissolved oxygen is also affected by eutrophication. When algae or aquatic plants that are stimulated by excess nutrients die off, they are broken down by bacteria, which depletes the oxygen in the water. Relatively few studies have specifically explored the impact of nutrient enrichment on urban streams. Chessman *et al*. (1992) studied the limiting nutrients for periphyton growth in a variety of streams and noted that the severity of eutrophication was related to low flow conditions. Higher flow rates in streams may cycle nutrients faster than in slow flow rates, thus diminishing the extent of stream eutrophication.

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4.5.3 Sources and Source Areas of Nutrients

Phosphorus is normally transported in surface water attached to sediment particles or in soluble forms. Nitrogen is normally transported by surface water runoff in urban watersheds. Sources for nitrogen and phosphorus in urban stormwater include fertilizer, pet waste, organic matter (such as leaves and detritus), and stream bank erosion. Another significant source of nutrients is atmospheric deposition. Fossil fuel combustion by automobiles, power plants and industry can supply nutrients in both wet fall and dry fall. The Metropolitan Washington Council of Governments (MWCOG, 1983) estimated total annual atmospheric deposition rates of 17 lbs/ac for nitrogen and 0.7 lbs/ac for phosphorus in the Washington, D.C. metro area.

Research from the upper Midwest suggests "hot spot" sources can exist for both nitrogen and phosphorus in urban watersheds. Lawns, in particular, contribute greater concentrations of Total N, Total P and dissolved phosphorus than other urban source areas. Indeed, source research suggests that nutrient concentrations in lawn runoff can be as much as four times greater than other urban sources such as streets, rooftops or driveways (Bannerman *et al.*, 1993; Steuer *et al.*, 1997 and Waschbusch *et al.*, 2000) (Table 29). This finding is significant, since lawns can comprise more than 50% of the total area in suburban watersheds. Lawn care, however, has seldom been directly linked to elevated nutrient concentrations during storms. A very recent lakeshore study noted that phosphorus concentrations were higher in fertilized lawns compared to unfertilized lawns, but no significant difference was noted for nitrogen (Garn, 2002).

Wash-off of deposited nutrients from IC is thought to be a major source of nitrogen and phosphorus during storms (MWCOG, 1983). While the concentration of nitrogen and phosphorus from parking lots and streets is lower than lawns, the volume of runoff is significantly higher. In two studies using the SLAMM source loading model (Pitt and Voorhees, 1989), parking lots and streets were responsible for over 30% of the nitrogen and were second behind lawns in their contributions to the phosphorus load (Steuer *et al.*, 1997; Waschbusch *et al.*, 2000).

Table 29: Source Area Monitoring Data for Total Nitrogen and Total Phosphorous in Urban Areas

Source Area	Total N (mg/l)	Total P (mg/l)		
Source	(1)	(1)	(2)	(3)
Commercial Parking Lot	1.94	0.20	N/R	0.10
High Traffic Street	2.95	0.31	0.47	0.18
Med. Traffic Street	1.62	0.23	1.07	0.22
Low Traffic Street	1.17	0.14	1.31	0.40
Commercial Rooftop	2.09	0.09	0.20	0.13
Residential Rooftop	1.46	0.06	0.15	0.07
Residential Driveway	2.10	0.35	1.16	N/R
Residential Lawn	9.70	2.33	2.67	0.79
Basin Outlet	1.87	0.29	0.66	N/R

(1) Steuer et al., 1997; (2) Bannerman et al., 1993; (3) Waschbusch et al., 2000; N/R= Not Reported

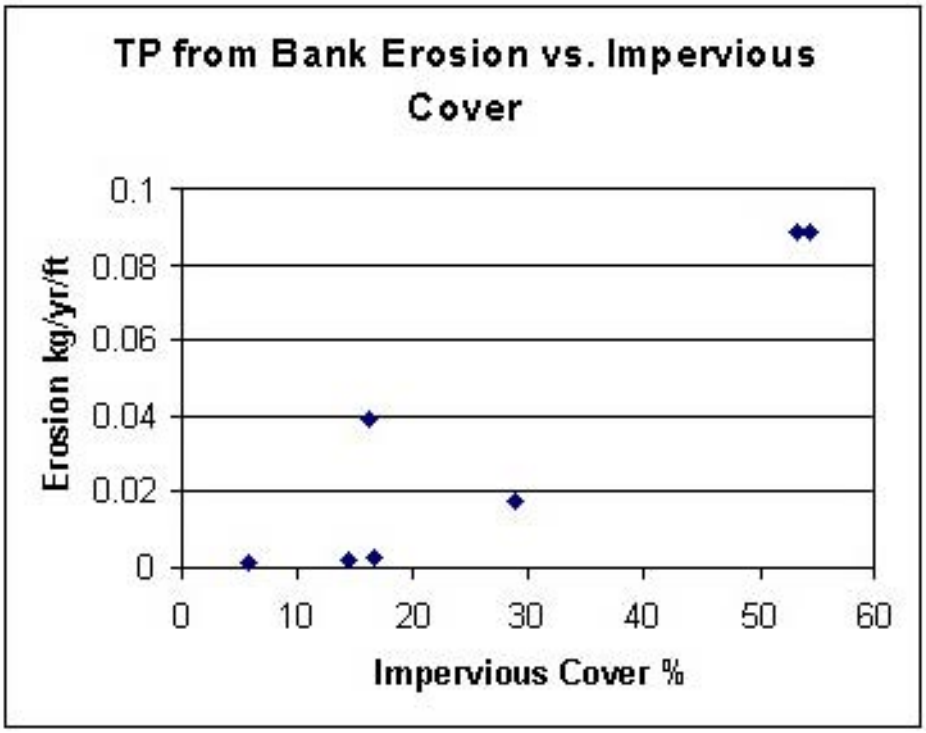

Figure 34: Total Phosphorus from Bank Erosion as a Function of IC in Texas Streams (Dartiguenave *et al.*, 1997)

Streambank erosion also appears to be a major source of nitrogen and phosphorus in urban streams. Both nitrogen and phosphorus are often attached to eroded bank sediment, as indicated in a recent study by Dartiguenave *et al.* (1997) in Austin, Texas. They showed that channel erosion contributed nearly 50% of the Total P load shown for subwatersheds with IC levels between 10 and 60 % (Figure 34). These findings suggest that prevention or reduction of downstream channel erosion may be an important nutrient reduction strategy for urban watersheds.

Snowmelt runoff generally has higher nutrient EMCs, compared to stormwater runoff. Oberts (1994) found that TKN and nitrate EMCs were much higher in snowmelt at all sites. The same pattern has also been observed for phosphorus EMCs during snowmelt and stormwater runoff. Zapf-Gilje *et al*. (1986) found that the first 20% of snowmelt events contained 65% of the phosphorus and 90% of the nitrogen load. Ayers *et al.* (1985) reported that a higher percentage of the annual nitrate, TKN and phosphorus load was derived from snowmelt runoff compared to stormwater runoff in an urban Minnesota watershed, which presumably reflects the accumulation of nutrients in the snowpack during the winter.

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4.6 Trace Metals

Many trace metals can be found at potentially harmful concentrations in urban stormwater. Certain metals, such as zinc, copper, lead, cadmium and chromium, are consistently present at concentrations that may be of concern. These metals primarily result from the use of motor vehicles, weathering of metals and paints, burning of fossil fuels and atmospheric deposition.

Metals are routinely reported as the total recoverable form or the dissolved form. The dissolved form refers to the amount of metal dissolved in the water, which excludes metals attached to suspended particles that cannot pass through a 0.45 micron filter. Total recoverable refers to the concentration of an unfiltered sample that is treated with hot dilute mineral acid. In general, the toxicity of metals is related more to the dissolved form than the recoverable form.

4.6.1 Concentrations

Stormwater EMCs for zinc, copper, lead, cadmium and chromium vary regionally and are reviewed in Table 30. Regional differences in trace metal concentrations and water quality standard exceedence appears to be related to climate. In general, drier regions often have a

Table 30: EMCs and Detection Frequency for Metals in Urban Stormwater

Metal	Detection Frequency[1]	EMCs (µg/l)		Number of Events	Source
		Mean	Median		
Zinc	94%	162	129	2234	Smullen and Cave, 1998
		176	140	1281	USEPA, 1983
Copper	91%	13.5	11.1	1657	Smullen and Cave, 1998
		66.6	54.8	849	USEPA, 1983
Lead	94%	67.5	50.7	2713	Smullen and Cave, 1998
		175[2]	131 [2]	1579	USEPA, 1983
Cadmium	48%	0.7	N/R	150	USEPA, 1983
		0.5	N/R	100	USEPA, 1993
		N/R	0.75 **R** 0.96 **C** 2.1 **I**	30	Baird *et al.,* 1996
		3 **I** 1 **U**	N/R	9	Doerfer and Urbonas, 1993
Chromium	58%	4	N/R	32	Baird *et al.,* 1996
		N/R	2.1 **R** 10 **C** 7 **I**	30	Baird *et al.,* 1996
		N/R	7	164	Bannerman *et al.,* 1993

N/R = Not Reported; R- Residential, C- Commercial, I- Industrial; (1) as reprinted in USEPA, 1983; (2) Lead levels have declined over time with the introduction of unleaded gasoline

Table 31: Average Total Recoverable and Dissolved Metals for 13 Stormwater Flows and Nine Baseflow Samples from Lincoln Creek in 1994 (Crunkilton *et al.*, 1996)

	Total Recoverable		Dissolved	
Metal (*F*g/l)	Storm Flow	Baseflow	Storm Flow	Baseflow
Lead	35	3	1.7	1.2
Zinc	133	22	13	8
Copper	23	7	5	4
Cadmium	0.6	0.1	0.1	0.1

higher risk of exceeding trace metal concentration standards.

Crunkilton *et al.* (1996) measured recoverable and dissolved metals concentrations in Lincoln Creek, Wisconsin and found higher EMCs during storm events compared to baseflow periods (Table 31). They also found that total recoverable metal concentrations were almost always higher than the dissolved concentration (which is the more available form).

4.6.2 Impacts of Trace Metals on Streams

Although a great deal is known about the concentration of metals in urban stormwater, much less is known about their possible toxicity on aquatic biota. The primary concern related to the presence of trace metals in streams is their potential toxicity to aquatic organisms. High concentrations can lead to bioaccumulation of metals in plants and animals, possible chronic or acute toxicity, and contamination of sediments, which can affect bottom dwelling organisms (Masterson and Bannerman, 1994). Generally, trace metal concentrations found in urban stormwater are not high enough to cause acute toxicity (Field and Pitt, 1990). The cumulative accumulation of trace metal concentrations in bottom sediments and animal tissues are of greater concern. Some evidence exists for trace metal accumulation in bottom sediments of receiving waters and for bioaccumulation in aquatic species (Bay and Brown, 2000 and Livingston, 1996).

Relatively few studies have examined the chronic toxicity issue. Crunkilton *et al.* (1996) found that concentrations of lead, zinc and copper exceeded EPA's Chronic Toxicity Criteria more than 75% of the time in stormflow in stormwater samples for Lincoln Creek in Wisconsin. When exposed to storm and base flows in Lincoln Creek, *Ceriodaphnia dubia*, a common invertebrate test species, demonstrated significant mortality in extended flow-through tests. Around 30% mortality was recorded after seven days of exposure and 70% mortality was recorded after 14 days.

Crunkilton *et al.* (1996) also found that significant mortality in bullhead minnows occurred in only 14% of the tests by the end of 14 days, but mortality increased to 100% during exposures of 17 to 61 days (see Table 32). In a related study in the same watershed, Masterson and Bannerman (1994) determined that crayfish in Lincoln Creek had elevated levels of lead, cadmium, chromium and copper when compared to crayfish from a reference stream. The Lincoln Creek research provides limited evidence that prolonged exposure to trace metals in urban streams may result in significant toxicity.

Most toxicity research conducted on urban stormwater has tested for acute toxicity over a short period of time (two to seven days). Shorter term whole effluent toxicity protocols are generally limited to seven days (Crunkilton *et al.*, 1996). Research by Ellis (1986) reported delayed toxicity in urban streams. Field and Pitt (1990) demonstrated that pollutants deposited to the stream during storm events

may take upwards of 10 to 14 days to exert influence. The research suggests that longer term in-situ and flow-through monitoring are needed to definitively answer the question whether metal levels in stormwater can be chronically toxic.

An additional concern is that trace metals co-occur with other pollutants found in urban stormwater, and it is not clear whether they interact to increase or decrease potential toxicity. Hall and Anderson (1988) investigated the toxicity and chemical composition of urban stormwater runoff in British Columbia and found that the interaction of pollutants changed the toxicity of some metals. In laboratory analysis with *Daphnia pulex*, an aquatic invertebrate, they found that the toxicity of iron was low and that its presence reduced the toxicity of other metals. On the other hand, the presence of lead increased the toxicity of copper and zinc.

Interaction with sediment also influences the impact of metals. Often, over half of the trace metals are attached to sediment (MWCOG, 1983). This effectively removes the metals from the water column and reduces the availability for biological uptake and subsequent bioaccumulation (Gavin and Moore, 1982 and OWML, 1983). However, metals accumulated in bottom sediment can then be resuspended during storms (Heaney and Huber, 1978). It is important to note that the toxic effect of metals can be altered when found in conjunction with other substances. For instance, the presence of chlorides can increase the toxicity of some metals. Both metals and chlorides are common pollutants in snowpacks (see section 4.2 for more snow melt information).

4.6.3 Sources and Source Areas of Trace Metals

Research conducted in the Santa Clara Valley of California suggests that cars can be the dominant loading source for many metals of concern, such as cadmium, chromium, copper, lead, mercury and zinc (EOA, Inc., 2001). Other sources are also important and include atmospheric deposition, rooftops and runoff from industrial and residential sites.

The sources and source areas for zinc, copper, lead, chromium and cadmium are listed in Table 33. Source areas for trace metals in the urban environment include streets, parking lots, snowpacks and rooftops. Copper is often found in higher concentrations on urban streets, because some vehicles have brake pads that contain copper. For example, the Santa Clara study estimated that 50% of the total copper load was due to brake pad wear (Woodward-Clyde, 1992). Sources of lead include atmospheric deposition and diesel fuel emissions, which frequently occur along rooftops

Table 32: Percentage of In-situ Flow-through Toxicity Tests Using Daphnia *magna* and Pimephales *promelas* with Significant Toxic Effects from Lincoln Creek (Crunkilton *et al.*, 1996)

Species	Effect	Percent of Tests with Significant ($p<0.05$) Toxic Effects as Compared to Controls According to Exposure				
		48 hours	96 hours	7 days	14 days	17-61 days
D. *magna*	Mortality	0	N/R	36%	93%	N/R
	Reduced Reproduction	0	N/R	36%	93%	N/R
P. *promelas*	Mortality	N/R	0	0	14%	100%
	Reduced Biomass	N/R	N/R	60%	75%	N/R

N/R = Not Reported

and streets. Zinc in urban environments is a result of the wear of automobile tires (estimated 60% in the Santa Clara study), paints, and weathering of galvanized gutters and downspouts. Source area concentrations of trace metals are presented in Table 34. In general, trace metal concentrations vary considerably, but the relative rank among source areas remains relatively constant. For example, a source loading model developed for an urban watershed in Michigan estimated that parking lots, driveways and residential streets were the primary source areas for zinc, copper and cadmium loads (Steuer *et al.*, 1997).

Table 33: Metal Sources and Source Area "Hotspots" in Urban Areas

Metal	Sources	Source Area Hotspots
Zinc	tires, fuel combustion, galvanized pipes, roofs and gutters, road salts **estimate of 60% from tires*	parking lots, commercial and industrial rooftops, and streets
Copper	auto brake linings, pipes and fittings, algacides, and electroplating **estimate of 50% from brake pad wear*	parking lots, commercial roofs and streets
Lead	diesel fuel, paints and stains	parking lots, rooftops, and streets
Cadmium	component of motor oil and corrodes from alloys and plated surfaces	parking lots, rooftops, and streets
Chromium	found in exterior paints and corrodes from alloys and plated surfaces	most frequently found in industrial and commercial runoff

Sources: Bannerman et al., 1993; Barr, 1997; Steuer et al., 1997; Good, 1993; Woodward - Clyde, 1992

Table 34: Metal Source Area Concentrations in the Urban Landscape (*F*g/l)

Source Area	Dissolved Zinc	Total Zinc	Dissolved Copper		Total Copper	Dissolved Lead		Total Lead		
Source	(1)	(2)	(1)	(2)	(2)	(1)	(3)	(1)	(3)	(2)
Commercial Parking Lot	64	178	10.7	9	15	N/R	N/R	40	N/R	22
High Traffic Street	73	508	11.2	18	46	2.1	1.7	37	25	50
Medium Traffic Street	44	339	7.3	24	56	1.5	1.9	29	46	55
Low Traffic Street	24	220	7.5	9	24	1.5	.5	21	10	33
Commercial Rooftop	263	330	17.8	6	9	20	N/R	48	N/R	9
Residential Rooftop	188	149	6.6	10	15	4.4	N/R	25	N/R	21
Residential Driveway	27	107	11.8	9	17	2.3	N/R	52	N/R	17
Residential Lawn	N/R	59	N/R	13	13	N/R	N/R	N/R	N/R	N/R
Basin Outlet	23	203	7.0	5	16	2.4	N/R	49	N/R	32

Sources: (1) Steuer et al., 1997; (2) Bannerman et al., 1993; (3) Waschbusch, 2000; N/R = Not Reported

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4.7 Hydrocarbons: PAH, Oil and Grease

Hydrocarbons are petroleum-based substances and are found frequently in urban stormwater. The term "hydrocarbons" is used to refer to measurements of oil and grease and polycyclic-aromatic hydrocarbons (PAH). Certain components of hydrocarbons, such as pyrene and benzo[b]fluoranthene, are carcinogens and may be toxic to biota (Menzie-Cura , 1995). Hydrocarbons normally travel attached to sediment or organic carbon. Like many pollutants, hydrocarbons accumulate in bottom sediments of receiving waters, such as urban lakes and estuaries. Relatively few studies have directly researched the impact of hydrocarbons on streams.

4.7.1 Concentrations

Table 35 summarizes reported EMCs of PAH and oil and grease derived from storm event monitoring at three different areas of the U.S. The limited research on oil and grease concentrations in urban runoff indicated that the highest concentrations were consistently found in commercial areas, while the lowest were found in residential areas.

4.7.2 Impacts of Hydrocarbons on Streams

The primary concern of PAH and oil and grease on streams is their potential bioaccumulation and toxicity in aquatic organisms. Bioaccumulation in crayfish, clams and fish has been reported by Masterson and Bannerman (1994); Moring and Rose (1997); and Velinsky and Cummins (1994).

Table 35: Hydrocarbon EMCs in Urban Areas

Hydrocarbon Indicator	EMC Mean	Number of Events	Source	Location
PAH (Fg/l)	3.2*	12	Menzie-Cura, 1995	MA
	7.1	19	Menzie-Cura, 1995	MA
	13.4	N/R	Crunkilton *et al.*, 1996	WI
Oil and Grease (mg/l)	1.7 **R**** 9 **C** 3 **I**	30	Baird *et al.*, 1996	TX
	3	N/R	USEPA, 1983	U.S.
	5.4*	8	Menzie-Cura, 1995	MA
	3.5	10	Menzie-Cura, 1995	MA
	3.89 **R** 13.13 **C** 7.10 **I**	N/R	Silverman *et al.*, 1988	CA
	2.35 **R** 5.63 **C** 4.86 **I**	107	Barr, 1997	MD

*N/R = Not Reported; R = Residential, C = Commercial, I = Industrial; * = geometric mean, ** = median*

Moring and Rose (1997) also showed that not all PAH compounds accumulate equally in urban streams. They detected 24 different PAH compounds in semi-permeable membrane devices (SPMDs), but only three PAH compounds were detected in freshwater clam tissue. In addition, PAH levels in the SPMDs were significantly higher than those reported in the clams.

While acute PAH toxicity has been reported at extremely high concentrations (Ireland *et al.*, 1996), delayed toxicity has also been found (Ellis, 1986). Crayfish from Lincoln Creek had a PAH concentration of 360 Fg/kg, much higher than the concentration thought to be carcinogenic (Masterson and Bannerman, 1994). By comparison, crayfish in a non-urban stream had undetectable PAH levels. Toxic effects from PAH compounds may be limited since many are attached to sediment and may be less available, with further reduction occurring through photodegradation (Ireland *et al.,* 1996).

The metabolic effect of PAH compounds on aquatic life is unclear. Crunkilton *et al.* (1996) found potential metabolic costs to organisms, but Masterson and Bannerman (1994) and MacCoy and Black (1998) did not. The long-term effect of PAH compounds in sediments of receiving waters remains a question for further study.

4.7.3 Sources and Source Areas of Hydrocarbons

In most residential stormwater runoff, hydrocarbon concentrations are generally less than 5mg/l, but the concentrations can increase to five to 10 mg/l within some commercial, industrial and highway areas (See Table 35). Specific **"**hotspots**"** for hydrocarbons include gas stations, commuter parking lots, convenience stores, residential parking areas and streets (Schueler and Shepp, 1993). These authors evaluated hydrocarbon concentrations within oil and grease separators in the Washington Metropolitan area and determined that gas stations had significantly higher concentrations of hydrocarbons and trace metals, as compared to other urban source areas. Source area research in an urban catchment in Michigan showed that commercial parking lots contributed 64% of the total hydrocarbon load (Steuer *et al.*, 1997). In addition, highways were found to be a significant contributor of hydrocarbons by Lopes and Dionne (1998).

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4.8 Bacteria and Pathogens

Bacteria are single celled organisms that are too small to see with the naked eye. Of particular interest are coliform bacteria, typically found within the digestive system of warm-blooded animals. The coliform family of bacteria includes fecal coliform, fecal streptococci and Escherichia coli, which are consistently found in urban stormwater runoff. Their presence confirms the existence of sewage or animal wastes in the water and indicates that other harmful bacteria, viruses or protozoans may be present, as well. Coliform bacteria are indicators of potential public health risks and not actual causes of disease.

A pathogen is a microbe that is actually known to cause disease under the right conditions. Two of the most common waterborne pathogens in the U.S. are the protozoans *Cryptosporidium parvum* and *Giardia lambia*. *Cryptosporidium* is a waterborne intestinal parasite that infects cattle and domestic animals and can be transmitted to humans, causing life-threatening problems in people with impaired immune systems (Xiao *et al.*, 2001). *Giardia* can cause intestinal problems in humans and animals when ingested (Bagley *et al.,* 1998). To infect new hosts, protozoans create hard casings known as oocysts (*Cryptosporidium*) or cysts (*Giardia*) that are shed in feces and travel through surface waters in search of a new host.

4.8.1 Concentrations

Concentrations of fecal coliform bacteria in urban stormwater typically exceed the 200 MPN/100 ml threshold set for human contact recreation (USGS, 2001b). Bacteria concentrations also tend to be highly variable from storm to storm. For example, a national summary of fecal coliform bacteria in stormwater runoff is shown in Figure 35 and Table 36. The variability in fecal coliform ranges from 10 to 500,000 MPN/100ml with a mean of 15,038 MPN/100ml (Schueler, 1999). Another national database of more than 1,600 stormwater events computed a mean concentration of 20,000

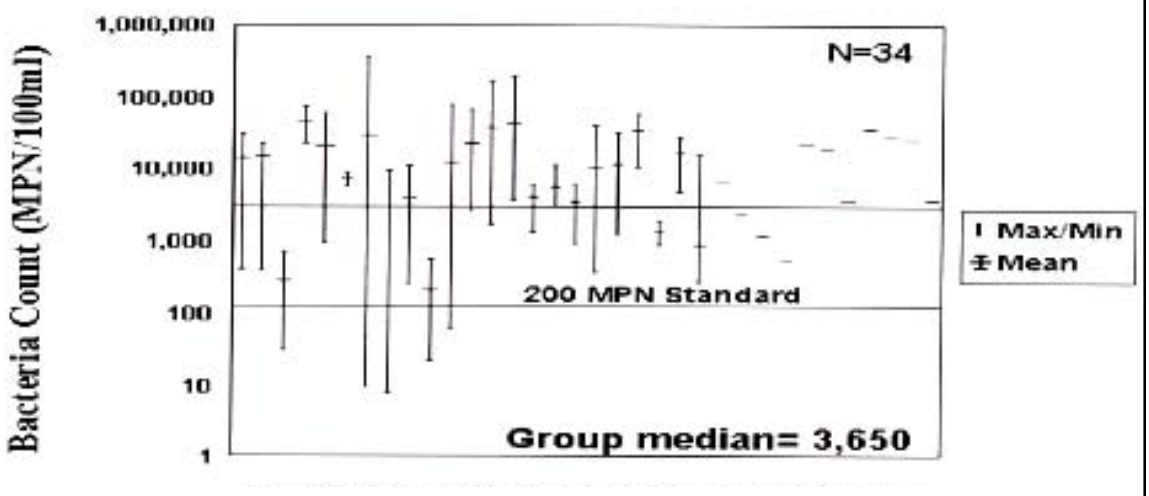

Figure 35: Fecal Coliform Levels in Urban Stormwater (Schueler, 1999)

Table 36: Bacteria EMCs in Urban Areas

Bacteria Type	EMCs (MPN/100ml) Mean	Number of Events	Source	Location
Fecal Coliform	15,038	34	Schueler, 1999	U.S.
	20,000	1600	Pitt, 1998	U.S.
	7,653	27	Thomas and McClelland, 1995	GA
	20,000 **R*** 6900 **C** 9700 **I**	30*	Baird *et al.*, 1996	TX
	77,970	21 watersheds	Chang *et al.*, 1990	TX
	4,500	189	Varner, 1995	WA
	23,500	3	Young and Thackston, 1999	TN
Fecal Strep	35,351	17	Schueler, 1999	U.S.
	28,864 **R**	27	Thomas and McClelland, 1995	GA
	56,000 **R** * 18,000 **C** 6,100 **I**	30*	Baird *et al.*, 1996	TX

*N/R = Not Reported, R = Residential Area, C = Commercial Area, I = Industrial Area, * = Median*

MPN/100ml for fecal coliform (Pitt, 1998). Fecal streptococci concentrations for 17 urban sites across the country had a mean of 35,351 MPN/100ml (Schueler, 1999).

Young and Thackston (1999) showed that bacteria concentrations at four sites in metro Nashville were directly related to watershed IC. Increasing IC reflects the cumulative increase in potential bacteria sources in the urban landscape, such as failing septic systems, sewage overflows, dogs, and inappropriate discharges. Other studies show that concentrations of bacteria are typically higher in urban areas than rural areas (USGS, 1999a), but they are not always directly related to IC. For example, Hydroqual (1996) found that concentrations of fecal coliform in seven subwatersheds of the Kensico watershed in New York were generally higher for more developed basins, but fecal coliform concentrations did not directly increase with IC in the developed basins (Figure 36).

There is some evidence that higher concentrations of coliform are found in arid or semi-arid watersheds. Monitoring data from semi-arid regions in Austin, San Antonio, and Corpus Christi, Texas averaged 61,000, 37,500 and 40,500 MPN/100ml, respectively (Baird *et al.*,1996 and Chang *et al.* 1990). Schiff (1996), in a report of Southern California NPDES monitoring, found that median concentrations of fecal coliform in San Diego were 50,000 MPN/100ml and averaged 130,000 MPN/100ml in Los Angeles. In all of these arid and semi-arid regions, concentrations were significantly higher than the national average of 15,000 to 20,000 MPN/100ml.

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Concentrations of *Cryptosporidium* and *Giardia* in urban stormwater are shown in Table 37. States *et al.* (1997) found high concentrations of *Cryptosporidium* and *Giardia* in storm samples from a combined sewer in Pittsburgh (geometric mean 2,013 oocysts/100ml and 28,881 cysts/100ml). There is evidence that urban stormwater runoff may have higher concentrations of *Cryptosporidium* and *Giardia* than other surface waters, as reported in Table 38 (Stern, 1996). Both pathogens were detected in about 50% of urban stormwater samples, suggesting some concern for drinking water supplies.

4.8.2 Impacts of Bacteria and Pathogens on Streams

Fecal coliform bacteria indicate the potential for harmful bacteria, viruses, or protozoans and are used by health authorities to determine public health risks. These standards were established to protect human health based on exposures to water during recreation and drinking. Bacteria standards for various water uses are presented in Table 39 and are all easily exceeded by typical urban stormwater concentrations. In fact, over 80,000 miles of streams and rivers are currently in non-attain-

Table 37: *Cryptosporidium* and *Giardia* EMCs

Pathogens	Units	EMCs		Number of Events	Source
		Mean	Median		
Cryptosporidium	oocysts	37.2	3.9	78	Stern, 1996
	oocysts/100ml	2013	N/R	N/R	States *et al.*, 1997
Giardia	cysts	41.0	6.4	78	Stern, 1996
	cysts/100ml	28,881	N/R	N/R	States *et al.*, 1997

N/R= Not reported

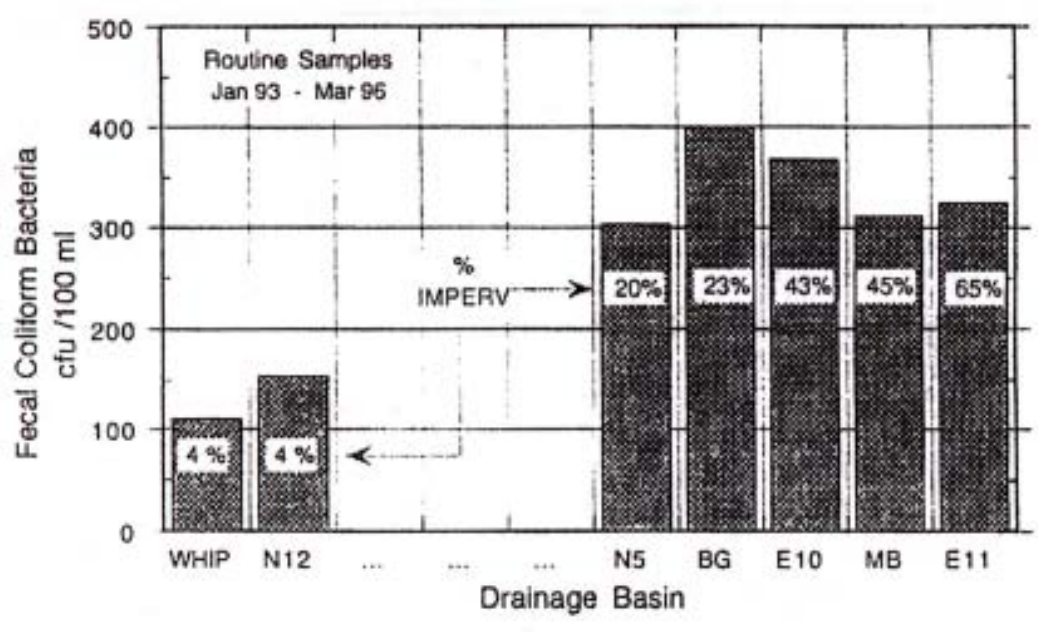

Figure 36: Relationship Between IC and Fecal Coliform Concentrations in New York Streams (Hydroqual, 1996)

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Table 38: Percent Detection of *Giardia* cysts and *Cryptosporidium* oocysts in Subwatersheds and Wastewater Treatment Plant Effluent in the New York City Water Supply Watersheds (Stern, 1996)

Source Water Sampled	Number of Sources/ Number of Samples	Percent Detection			
		Total *Giardia*	Confirmed *Giardia*	Total *Cryptosporidium*	Confirmed *Cryptosporidium*
Wastewater Effluent	8/147	41.5%	12.9%	15.7%	5.4%
Urban Subwatershed	5/78	41.0%	6.4%	37.2%	3.9%
Agricultural Subwatershed	5/56	30.4%	3.6%	32.1%	3.6%
Undisturbed Subwatershed	5/73	26.0%	0.0%	9.6%	1.4%

Table 39: Typical Coliform Standards for Different Water Uses (USEPA, 1998)

Water Use	Microbial Indicator	Typical Water Standard
Water Contact Recreation	Fecal Coliform	<200 MPN per 100ml
Drinking Water Supply	Fecal Coliform	<20 MPN per 100ml
Shellfish Harvesting	Fecal Coliform	<14 MPN/ 100ml
Treated Drinking Water	Total Coliform	No more than 1% coliform positive samples per month
Freshwater Swimming	E.Coli	<126 MPN per 100ml

Important Note: Individual state standards may employ different sampling methods, indicators, averaging periods, averaging methods, instantaneous maximums and seasonal limits. MPN = most probable number. Higher or lower limits may be prescribed for different water use classes.

ment status because of high fecal coliform levels (USEPA, 1998).

4.8.3 Sources and Source Areas of Bacteria and Pathogens

Sources of coliform bacteria include waste from humans and wildlife, including livestock and pets. Essentially, any warm-blooded species that is present in significant numbers in a watershed is a potential culprit. Source identification studies, using methods such as DNA fingerprinting, have put the blame on species such as rats in urban areas, ducks and geese in stormwater ponds, livestock from hobby farms, dogs and even raccoons (Blankenship, 1996; Lim and Olivieri, 1982; Pitt, 1998; Samadpour and Checkowitz, 1998).

Transport of bacteria takes place through direct surface runoff, direct inputs to receiving waters, or indirect secondary sources. Source areas in the urban environment for direct runoff include lawns and turf, driveways, parking lots and streets. For example, dogs have high concentrations of fecal coliform in their feces and have a tendency to defecate in close proximity to IC (Schueler, 1999). Weiskel *et al. (*1996) found that direct inputs of fecal coliform from waterfowl can be very

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important; these inputs accounted for as much as 67% of the annual coliform load to Buttermilk Bay, Massachusetts.

Indirect sources of bacteria include leaking septic systems, illicit discharges, sanitary sewer overflows (SSOs), and combined sewer overflows (CSOs). These sources have the potential to deliver high coliform concentrations to urban streams. In fact, extremely high bacteria concentrations are usually associated with wastewater discharges. CSOs and SSOs occur when the flow into the sewer exceeds the capacity of the sewer lines to drain them. CSOs result from stormwater flow in the lines, and SSOs are a result of infiltration problems or blockages in the lines.

Illicit connections from businesses and homes to the storm drainage system can discharge sewage or washwater into receiving waters. Illicit discharges can often be identified by baseflow sampling of storm sewer systems. Leaking septic systems are estimated to comprise between 10 and 40% of the systems, and individual inspections are the best way to determine failing systems (Schueler, 1999).

There is also evidence that coliform bacteria can survive and reproduce in stream sediments and storm sewers (Schueler, 1999). During a storm event, they often become resuspended and add to the in-stream bacteria load. Source area studies reported that end of pipe concentrations were an order of magnitude higher than any source area on the land surface; therefore, it is likely that the storm sewer system itself acts as a source of fecal coliform (Bannerman *et al.*, 1993 and Steuer *et al.*, 1997). Resuspension of fecal coliform from fine stream sediments during storm events has been reported in New Mexico (NMSWQB, 1999). The sediments in-stream and in the storm sewer system may be significant contributors to the fecal coliform load.

Sources of *Cryptosporidium* and *Giardia* include human sewage and animal feces. *Cryptosporidium* is commonly found in cattle, dogs and geese. Graczyk *et al.* (1998) found that migrating Canada geese were a vector for *Cryptosporidium* and *Giardia*, which has implications for water quality in urban ponds that support large populations of geese.

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4.9 Organic Carbon

Total organic carbon (TOC) is often used as an indicator of the amount of organic matter in a water sample. Typically, the more organic matter present in water, the more oxygen consumed, since oxygen is used by bacteria in the decomposition process. Adequate levels of dissolved oxygen in streams and receiving waters are important because they are critical to maintain aquatic life. Organic carbon is routinely found in urban stormwater, and high concentrations can result in an increase in Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). BOD and COD are measures of the oxygen demand caused by the decay of organic matter.

4.9.1 Concentrations

Urban stormwater has a significant ability to exert a high oxygen demand on a stream or receiving water, even two to three weeks after an individual storm event (Field and Pitt, 1990). Average concentrations of TOC, BOD and COD in urban stormwater are presented in Table 40. Mean concentrations of TOC, BOD and COD during storm events in nationwide studies were 17 mg/l, 14.1 mg/l and 52.8 mg/l, respectively (Kitchell, 2001 and Smullen and Cave,1998).

4.9.2 Impacts of Organic Carbon on Streams

TOC is primarily a concern for aquatic life because of its link to oxygen demand in streams, rivers, lakes and estuaries. The initial effect of increased concentrations of TOC, BOD or COD in stormwater runoff may be a depression in oxygen levels, which may persist for many days after a storm, as deposited organic matter gradually decomposes (Field and Pitt, 1990).

TOC is also a concern for drinking water quality. Organic carbon reacts with chlorine during the drinking water disinfection process and forms trihalomethanes and other disinfection by-products, which can be a serious drinking water quality problem (Water, 1999). TOC concentrations greater than 2 mg/l in treated water and 4 mg/l in source water can result in unacceptably high levels of disinfection byproducts and must be treated to reduce TOC or remove the disinfection byproducts (USEPA, 1998). TOC can also be a carrier for other pollutants, such as trace metals, hydrocarbons and nutrients.

4.9.3 Sources and Source Areas of Total Organic Carbon

The primary sources of TOC in urban areas appear to be decaying leaves and other organic matter, sediment and combustion by-products. Source areas include curbs, storm drains, streets and stream channels. Dartiguenave *et al.* (1997) determined that about half of the annual TOC load in urban watersheds of Austin, TX was derived from the eroding streambanks.

Table 40: EMCs for Organic Carbon in Urban Areas

Organic Carbon Source	EMCs (mg/l)		Number of Events	Source
	Mean	Median		
Total Organic Carbon (TOC)	32.0	N/R	423	Barrett and Malina, 1998
	17	15.2	19 studies	Kitchell, 2001
Biological Oxygen Demand (BOD)	14.1	11.5	1035	Smullen and Cave, 1998
	10.4	8.4	474	USEPA, 1983
Chemical Oxygen Demand (COD)	52.8	44.7	2639	Smullen and Cave, 1998
	66.1	55	1538	USEPA, 1983

N/R = Not Reported

4.10 MTBE

Methyl tertiary butyl-ether (MTBE) is a volatile organic compound (VOC) that is added to gasoline to increase oxygen levels, which helps gas burn cleaner (called an oxygenate). MTBE has been used as a performance fuel additive since the 1970s. In 1990, the use of oxygenates was mandated by federal law and concentrations of MTBE in gasoline increased. Today, MTBE is primarily used in large metropolitan areas that experience air pollution problems. Since 1990, MTBE has been detected at increasing levels in both surface water and groundwater and is one of the most frequently detected VOCs in urban watersheds (USGS, 2001a). EPA has declared MTBE to be a potential human carcinogen at high doses. In March 2000, a decision was made by EPA to follow California's lead to significantly reduce or eliminate the use of MTBE in gasoline.

4.10.1 Concentrations

MTBE is highly soluble in water and therefore not easily removed once it enters surface or ground water. Delzer (1999) detected the presence of MTBE in 27% of the shallow wells monitored in eight urban areas across the country (Figure 37). Detection frequency was significantly higher in New England and Denver, as shown in Table 41. In a second study conducted in 16 metropolitan areas, Delzer (1999) found that 83% of MTBE detections occurred between October and March, the time when MTBE is primarily used as a fuel additive. The median MTBE concentration was 1.5 ppb, well below EPA's draft advisory level of 20 ppb (Delzer, 1996).

4.10.2 Impacts of MTBE on Streams

The primary concerns regarding MTBE are that it is a known carcinogen to small mammals, a suspected human carcinogen at higher

Table 41: MTBE Detection Frequency

Location	Detection Frequency	Source	Year
211 shallow wells in eight urban areas	27%	Delzer	1999
Surface water samples in 16 metro areas	7%	Delzer	1996

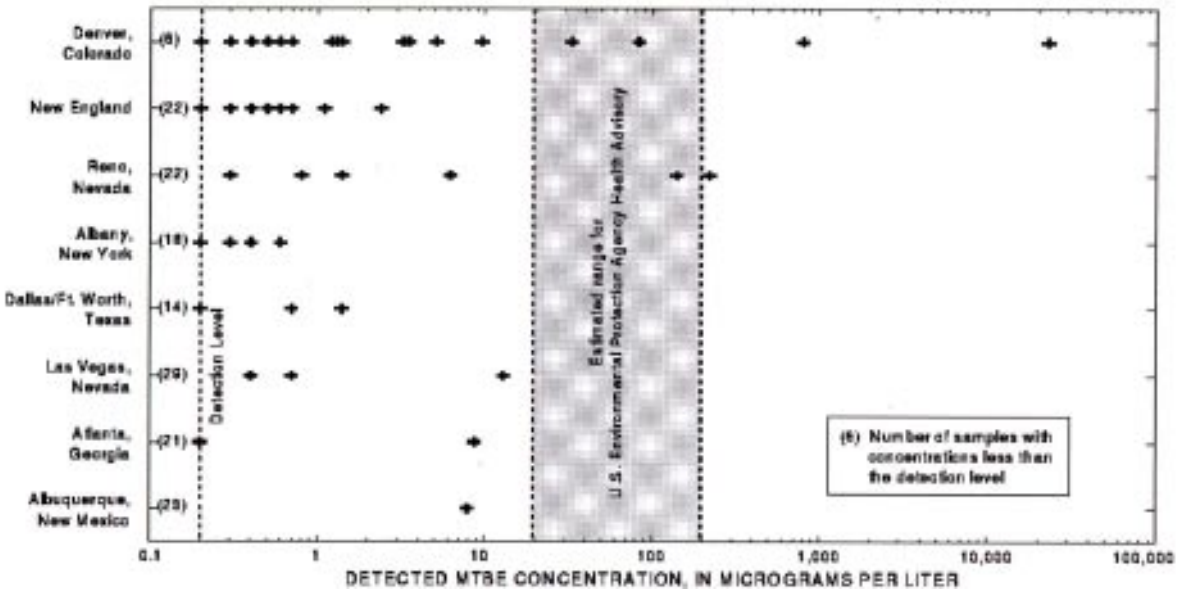

Figure 37: MTBE Concentrations in Surface Water from Eight Cities (Delzer, 1996)

doses and may possibly be toxic to aquatic life in small streams (Delzer, 1996). MTBE can also cause taste and odor problems in drinking water at fairly low concentrations. EPA issued a Drinking Water Advisory in 1997 that indicated that MTBE concentrations less than 20 ppb should not cause taste and odor problems for drinking water. However, the Association of California Water Agencies reports that some consumers can detect MTBE at levels as low as 2.5 ppb (ACWA, 2000). Because MTBE is frequently found in groundwater wells, it is thought to be a potential threat to drinking water (Delzer, 1999). For example, Santa Monica, California reportedly lost half of its groundwater drinking water supply due to MTBE contamination (Bay and Brown, 2000). MTBE has also been detected in human blood, especially in people frequently exposed to gasoline, such as gas station attendants (Squillace *et al.*, 1995).

4.10.3 Sources and Source Areas of MTBE

Since MTBE is a gasoline additive, its potential sources include any area that produces, transports, stores, or dispenses gasoline, particularly areas that are vulnerable to leaks and spills. Leaking underground storage tanks are usually associated with the highest MTBE concentrations in groundwater wells (Delzer, 1999). Vehicle emissions are also an important source of MTBE. Elevated levels are frequently observed along road corridors and drainage ditches. Once emitted, MTBE can travel in stormwater runoff or groundwater. Main source areas include heavily used multilane highways. Gas stations may also be a hotspot source area for MTBE contamination.

Another potential source of MTBE is watercraft, since two cycle engines can discharge as much as 20 to 30% of their fuel through the exhaust (Boughton and Lico, 1998). MTBE concentrations are clearly associated with increased use of gas engines, and there is concern that MTBE is an increasing component of atmospheric deposition (Boughton and Lico, 1998 and UC Davis, 1998).

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4.11 Pesticides

Pesticides are used in the urban environment to control weeds, insects and other organisms that are considered pests. EPA estimates that nearly 70 million pounds of active pesticide ingredients are applied to urban lawns each year as herbicides or insecticides. Herbicides are used on urban lawns to target annual and perennial broadleaf weeds, while insecticides are used to control insects. Many types of pesticides are available for use in urban areas. Immerman and Drummond (1985) report that 338 different active ingredients are applied to lawns and gardens nationally. Each pesticide varies in mobility, persistence and potential aquatic impact. At high levels, many pesticides have been found to have adverse effects on ecological and human health. Several recent research studies by the USGS have shown that insecticides are detected with the greatest frequency in urban streams, and that pesticide detection frequency increases in proportion to the percentage of urban land in a watershed (Ferrari *et al.*, 1997; USGS, 1998, 1999a-b, 2001b). A national assessment by the USGS

Table 42: Median Concentrations and Detection Frequency of Herbicides and Insecticides in Urban Streams

Pollutant	Detection Frequency	Median Concentration (*F*g/l)	Number of Samples	Source
Insecticides				
Diazinon	75%	0.025	326	USGS, 1998b
	92%	0.55	76	Brush *et al.*, 1995
	17%	0.002	1795	Ferrari *et al.*, 1997
Chlorpyrifos	41%	Non Detect	327	USGS, 1998b
	14%	0.004	1218	Brush *et al.*, 1995
Carbaryl	46%	Non Detect	327	USGS, 1998b
	22%	0.003	1128	Ferrari *et al.*, 1997
Herbicides				
Atrazine	86%	0.023	327	USGS, 1998b
	72%	0.099	2076	Ferrari *et al.*, 1997
Prometon	84%	0.031	327	USGS, 1998b
	56%	0.029	1531	Ferrari *et al.*, 1997
Simazine	88%	0.039	327	USGS, 1998b
	17%	0.046	1995	Ferrari *et al.*, 1997
2,4 -D	67%	1.1	11	Dindorf, 1992
	17%	0.035	786	Ferrari *et al.*, 1997
Dicamba	22%	1.8	4	Dindorf, 1992
MCPP	56%	1.8	10	Dindorf, 1992
MCPA	28%	1.0	5	Dindorf, 1992

(2001a) also indicates that insecticides are usually detected at higher concentrations in urban streams than in agricultural streams.

4.11.1 Concentrations

Median concentrations and detection frequency for common pesticides are shown in Table 42. Herbicides that are frequently detected in urban streams include atrazine; simazine; prometon; 2,4-D; dicamba; MCPP; and MCPA. Insecticides are also frequently encountered in urban streams, including diazinon, chlorpyrifos, malathion, and carbaryl. A USGS (1996) study monitored 16 sites in Gills Creek in Columbia, South Carolina over four days. This study reported that pesticide detection frequency increased as percent urban land increased.

Wotzka *et al.* (1994) monitored herbicide levels in an urban stream in Minneapolis, Minnesota during more than 40 storms. They found herbicides, such as 2,4-D; dicamba; MCPP; and MCPA in 85% of storm runoff events sampled. Total herbicide EMCs ranged from less than one to 70 µg/l. Ferrari *et al.* (1997) analyzed 463 streams in the mid-Atlantic region for the presence of 127 pesticide compounds. At least one pesticide was detected at more than 90% of the streams sampled.

Diazinon is one of the most commonly detected insecticides in urban stormwater runoff and dry weather flow. Diazinon was detected in 75% of National Water Quality Assessment (NAWQA) samples, 92% of stormflow samples from Texas, and 100% of urban stormflow samples in King County, Washington (Brush *et al.*, 1995 and USGS, 1999b). Diazinon is most frequently measured at concentrations greater than freshwater aquatic life criteria in urban stormwater (USGS, 1999a). USGS reports that diazinon concentrations were generally higher during urban stormflow (Ferrari *et al.,* 1997).

4.11.2 Impacts of Pesticides on Streams

Many pesticides are known or suspected carcinogens and can be toxic to humans and aquatic species. However, many of the known health effects require exposure to higher concentrations than typically found in the environment, while the health effects of chronic exposure to low levels are generally unknown (Ferrari *et al.*, 1997).

Studies that document the toxicity of insecticides and herbicides in urban stormwater have been focused largely on diazinon. Diazinon is responsible for the majority of acute toxicity in stormwater in Alameda County, California and King County, Washington (S.R. Hansen & Associates, 1995). Concentrations of diazinon in King County stormwater frequently exceed the freshwater aquatic life criteria (Figure 38). Similarly, research on Sacramento, California streams revealed acute toxicity for diazinon in 100% of stormwater samples using *Ceriodaphnia* as the test organism (Connor, 1995). Diazinon has a half-life of 42 days and is very soluble in water, which may explain its detection frequency and persistence in urban stormwater. Diazinon is also reported to attach fairly readily to organic carbon; consequently, it is likely re-suspended during storm events.

Insecticide concentrations exceeding acute and chronic toxicity thresholds for test organisms such as *Ceriodaphnia* have frequently been found in urban stormwater in New York, Texas, California, and Washington (Scanlin and Feng, 1997; Brush *et al.*, 1995; USGS, 1999b). The possibility exists that pesticides could have impacts on larger bodies of water, but there is a paucity of data on the subject at this time.

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4.11.3 Sources and Source Areas of Pesticides

Sources for pesticides in urban areas include applications by homeowners, landscaping contractors and road maintenance crews. Source areas for pesticides in urban areas include lawns in residential areas; managed turf, such as golf courses, parks, and ball fields; and rights-of-way in nonresidential areas. Storage areas, which are subject to spills and leaks, can also be a source area. A study in San Francisco was able to trace high diazinon concentrations in some streams back to just a few households which had applied the pesticide at high levels (Scanlin and Feng, 1997). Two herbicides, simazine and atrazine, were detected in over 60% of samples in King County, WA stormwater but were not identified as being sold in retail stores. It is likely these herbicides are applied to nonresidential areas such as rights-of-way, parks and recreational areas (USGS, 1999b). Because pesticides are typically applied to turf, IC is not a direct indicator for pesticide concentrations, although they can drift onto paved surfaces and end up in stormwater runoff.

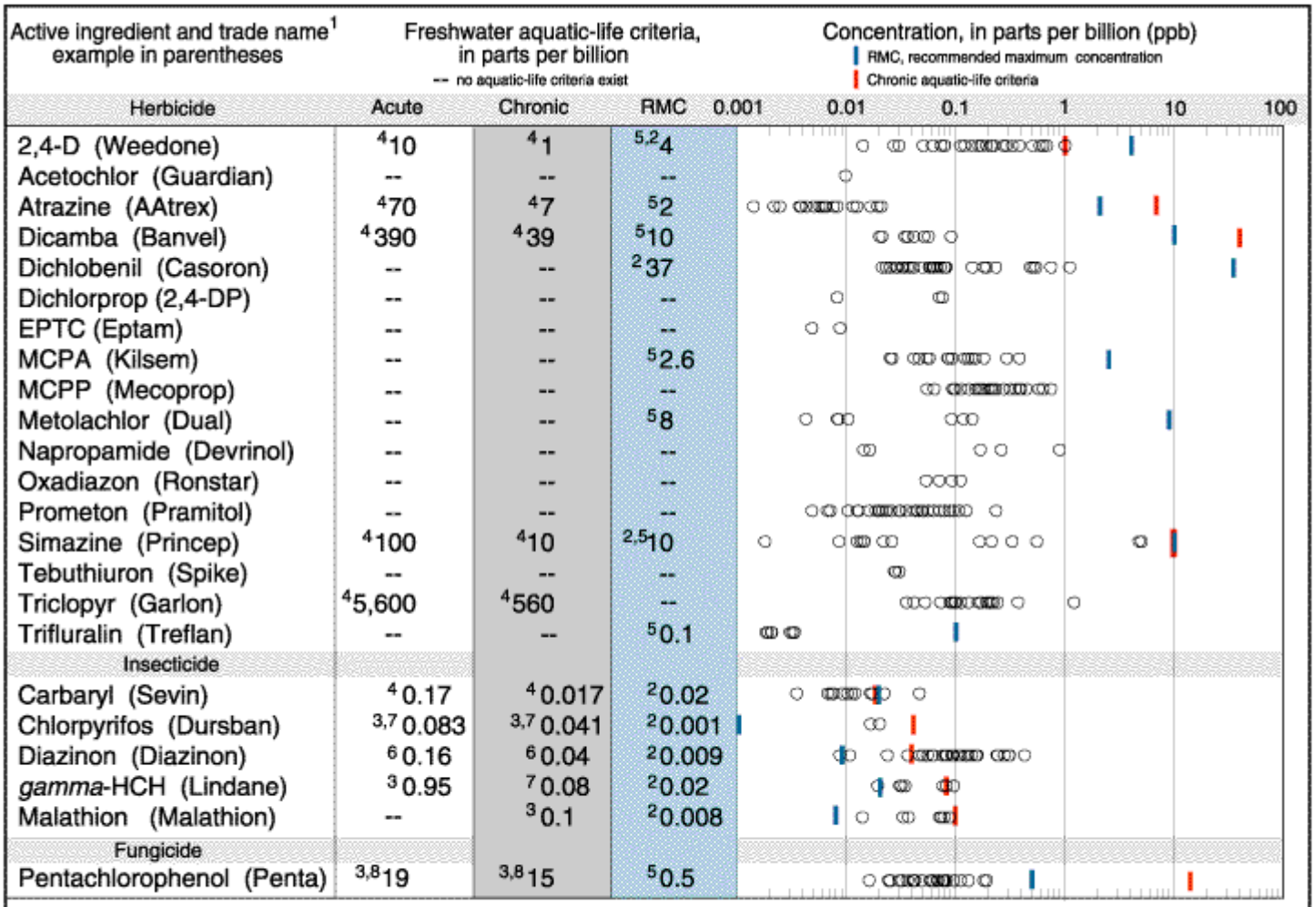

Figure 38: Concentrations of Pesticides in Stormwater in King County, WA (S.R. Hansen & Associates, 1995 and USGS, 1999b)

4.12 Deicers

Deicers are substances used to melt snow and ice to keep roads and walking areas safe. The most commonly used deicer is sodium chloride, although it may also be blended with calcium chloride or magnesium chloride. Other less frequently used deicers include urea and glycol, which are primarily used at airports to deice planes. Table 43 summarizes the composition, use and water quality effects of common deicers.

Chlorides are frequently found in snowmelt and stormwater runoff in most regions that experience snow and ice in the winter months (Oberts, 1994 and Sherman, 1998). Figure 39 shows that the application of deicer salts has increased since 1940 from 200,000 tons to 10 to 20 million tons per year in recent years (Salt Institute, 2001). Several U.S. and Canadian studies indicate severe inputs of road salts on water quality and aquatic life (Environment Canada, 2001 and Novotny *et al.*, 1999).

Table 43: Use and Water Quality Effect of Snowmelt Deicers (Ohrel, 1995; Sills and Blakeslee, 1992)

Deicer	Description	Use	Water Quality Effect
Chlorides	Chloride based deicer usually combined with Na, Ca or Mg	Road Deicer and Residential Use	Cl complexes can release heavy metals, affect soil permeability, impacts to drinking water, potential toxic effects to small streams
Urea	Nitrogen-based fertilizer product	Used as alternative to glycol	Increased nitrogen in water and potential toxicity to organisms
Ethylene Glycol	Petroleum based organic compounds, similar to antifreeze	Used at airports for deicing planes	Toxicity effects, high BOD and COD, hazardous air pollutant

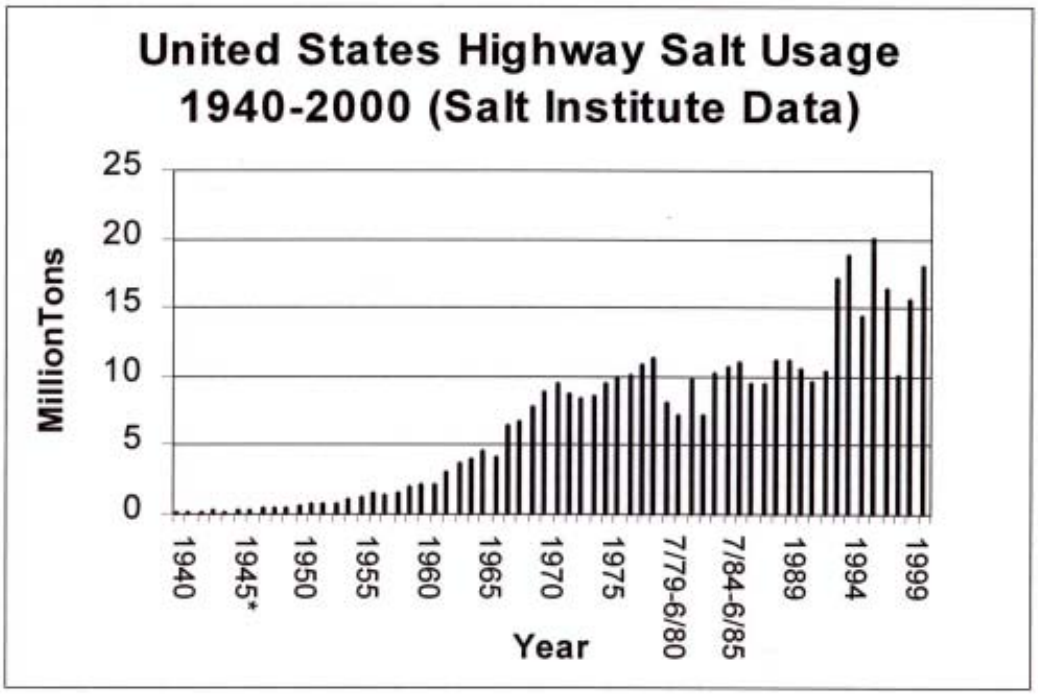

Figure 39: U.S. Highway Salt Usage Data (Salt Institute, 2001)

4.12.1 Concentrations

Chloride concentrations in snowmelt runoff depend on the amount applied and the dilution in the receiving waters. Data for snowmelt and stormwater runoff from several studies are presented in Table 44. For example, chloride concentrations in Lincoln Creek in Wisconsin were 1,612 mg/l in winter snowmelt runoff, as compared to 40 mg/l in non-winter runoff (Novotny *et al.*, 1999 and Masterson and Bannerman, 1994). Chloride concentrations in the range of 2,000 to 5,000 mg/l have been reported for Canadian streams (Environment Canada, 2001). Novotny *et al.* (1999) monitored chloride concentrations in snowmelt near Syracuse, New York and found that residential watersheds had higher chloride concentrations than rural watersheds.

Concentrations of glycol in stormwater runoff are also highly variable and depend on the amount of deicer used, the presence of a recovery system, and the nature of the precipitation event. Corsi *et al*. (2001) monitored streams receiving stormwater runoff from a Wisconsin airport. They found concentrations of propylene glycol as high as 39,000 mg/l at airport outfall sites during deicing operations and concentrations of up to 960 mg/l during low-flow sampling at an airport outfall site.

4.12.2 Impacts of Deicers on Streams

Chloride levels can harm aquatic and terrestrial life and contaminate groundwater and drinking water supplies (Ohrel, 1995). Generally, chloride becomes toxic to many organisms when it reaches concentrations of 500 to1,000 mg/l (Environment Canada, 2001). These concentrations are common in small streams in snow regions, at least for short periods of time. Many plant species are relatively intolerant to high salt levels in wetland swales and roadside corridors. Fish are also negatively affected by high chloride concentrations, with sensitivity as low as 600 mg/l for some species (Scott and Wylie, 1980).

Table 45 compares the maximum chloride concentrations for various water uses in eight states (USEPA, 1988). Snowmelt chloride concentrations typically exceed these levels.

Table 44: EMCs for Chloride in Snowmelt and Stormwater Runoff in Urban Areas

Form of Runoff	EMCs (mg/l) Mean	Number of Events	Sources	Location
Snowmelt	116*	49	Oberts, 1994	MN
	2119	N/R	Sherman, 1998	Ontario
	1267 **R** 474 **U**	N/R	Novotny *et al.*, 1999	NY
	1612	N/R	Masterson and Bannerman, 1994	WI
	397	282	Environment Canada, 2001	Ontario, Canada
Non-winter Storm Event	42	61	Brush *et al.*, 1995	TX
	45	N/R	Sherman, 1998	Ontario
	40.5	N/R	Masterson and Bannerman, 1994	WI

*N/R = Not Reported, R = residential, U = urban, * = Median*

Chloride is a concern in surface drinking water systems because it can interfere with some of the treatment processes and can cause taste problems at concentrations as low as 250 mg/l. Chloride is also extremely difficult to remove once it enters the water.

Glycol-based deicers have been shown to be highly toxic at relatively low concentrations in streams receiving airport runoff. These deicers contain many proprietary agents, which may increase their toxicity and also make it very difficult to set standards for their use (Hartwell *et al.*, 1995). Corsi *et al.* (2001) observed acute toxicity of *Ceriodaphnia dubia*, *Pimephelas promelax*, *Hyalela azteca*, and *Chironimus tentans* in Wisconsin streams that experienced propylene glycol concentrations of 5,000 mg/l or more. Chronic toxicity was observed for *Ceriodaphnia dubia* and *Pimephelas promelax* at propylene glycol concentrations of 1,500 mg/l in the same study. In addition, glycol exerts an extremely high BOD on receiving waters, which can quickly reduce or eliminate dissolved oxygen. Glycol can also be toxic to small animals that are attracted by its sweet taste (Novotny *et al.*, 1999).

As with many urban pollutants, the effects of chloride can be diluted in larger waterbodies. In general, small streams are more likely to experience chloride effects, compared to rivers, which have a greater dilution ability.

4.12.3 Sources and Source Areas of Deicers

The main sources for deicers in urban watersheds include highway maintenance crews, airport deicing operations, and homeowner applications. Direct road application is the largest source of chloride, by far. Source areas include roads, parking lots, sidewalks, storm drains, airport runways, and snow collection areas. Because deicers are applied to paved surfaces, the primary means of transport to streams is through stormwater and meltwater runoff. Therefore, concentrations of deicer compounds are typically associated with factors such as road density or traffic patterns.

Table 45: Summary of State Standards for Salinity of Receiving Waters (USEPA, 1988)

State	Limiting Concentration (mg/l)	Beneficial Use
CO	250*	Drinking water
IL	500	General water supply
	250	Drinking water
IN	500	Drinking water
MA	250	Class A waters
MN	250	Drinking water
	500	Class A fishing and recreation
OH	250	Drinking water
SD	250	Drinking water
	100	Fish propagation
VA	250	Drinking water

** Monthly average*

4.13 Conclusion

IC collects and accumulates pollutants deposited from the atmosphere, leaked from vehicles, or derived from other sources. The pollutants build up over time but are washed off quickly during storms and are often efficiently delivered to downstream waters. This can create water quality problems for downstream rivers, lakes and estuaries.

As a result of local and national monitoring efforts, we now have a much better understanding of the nature and impacts of stormwater pollution. The typical sample of urban stormwater is characterized by high levels of many common pollutants such as sediment, nutrients, metals, organic carbon, hydrocarbons, pesticides, and fecal coliform bacteria. Other pollutants that have more recently become a concern in urban areas include MTBE, deicers, and the pathogens *Cryptosporidium* and *Giardia*. Concentrations of most stormwater pollutants can be characterized, over the long run, by event mean storm concentrations. Monitoring techniques have also allowed researchers to identify source areas for pollutants in the urban environment, including stormwater hotspots, which generate higher pollutant loads than normal development.

In general, most monitoring data shows that mean pollutant storm concentrations are higher in urban watersheds than in non-urban ones. For many urban pollutants, EMCs can be used to predict stormwater pollutant loads for urban watersheds, using IC as the key predictive variable. While a direct relationship between IC and pollutant concentrations does not usually exist, IC directly influences the volume of stormwater and hence, the total load. A few exceptions are worth noting. MTBE, deicers, and PAH appear to be related more to traffic or road density than IC. Additionally, MTBE and PAH concentrations may be greater at hotspot source areas, which are not always widely or uniformly distributed across a watershed. Pesticides, bacteria and pathogens are often associated with turf areas rather than IC. Bacteria and pathogen sources also include direct inputs from wildlife and inappropriate sewage discharges that are not uniformly distributed across a watershed and are not directly related to IC.

Further research into the relationship between stormwater pollutant loads and other watershed indicators may be helpful. For example, it would be interesting to see if turf cover is a good indicator of stream quality for impacted streams. Other important watershed indicators worth studying are the influence of watershed treatment practices, such as stormwater practices and stream buffers.

The direct effects of stormwater pollutants on aquatic systems appears to be a function of the size of the receiving water and the initial health of the aquatic community. For example, a small urban stream receiving high stormwater pollutant concentrations would be more likely to experience impacts than a large river, which is diluted by other land uses. Likewise, organisms in sensitive streams should be more susceptible to stormwater pollutants than pollution-tolerant organisms found in non-supporting streams.

Overall, the following conclusions can be made:

- Sediment, nutrient and trace metal loads in stormwater runoff can be predicted as a function of IC, although concentrations are not tightly correlated with watershed IC.
- Violations of bacteria standards are indirectly associated with watershed IC.
- It is not clear whether loads of hydrocarbons, pesticides or chlorides can be predicted on the basis of IC at the small watershed level.
- More research needs to be conducted to evaluate the usefulness of other watershed indicators to predict stormwater pollutant loads. For example, traffic, road density or hotspots may be useful in predicting MTBE, deicer and hydrocarbon loads. Also, watershed turf cover may be useful in predicting pesticide and bacterial loads.

- Most research on pollutants in stormwater runoff has been conducted at the small watershed level. Additional research is needed to evaluate the impact of watershed treatment, such as stormwater and buffer practices to determine the degree to which these may change stormwater concentrations or loads.
- Regional differences are evident for many stormwater pollutants, and these appear to be caused by either differences in rainfall frequency or snowmelt.



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Chapter 5: Biological Impacts of Impervious Cover

This chapter reviews research on the impact of urbanization on the aquatic community, focusing on aquatic insects, fish, amphibians, freshwater mussels, and freshwater wetlands. Specifically, the relationship between the health of the aquatic community and the amount of watershed IC is analyzed within the context of the Impervious Cover Model (ICM).

The chapter is organized as follows:

5.1 Introduction
5.2 Indicators and General Trends
5.3 Effects on Aquatic Insect[1] Diversity
5.4 Effects on Fish Diversity
5.5 Effects on Amphibian Diversity
5.6 Effects on Wetland Diversity
5.7 Effects on Freshwater Mussel Diversity
5.8 Conclusion

5.1 Introduction

A number of studies, crossing different ecoregions and utilizing various techniques, have examined the link between watershed urbanization and its impact on stream and wetland biodiversity. These studies reveal that a relatively small amount of urbanization has a negative effect on aquatic diversity, and that as watersheds become highly urban, aquatic diversity becomes extremely degraded. As documented in prior chapters, hydrologic, physical, and water quality changes caused by watershed urbanization all stress the aquatic community and collectively diminish the quality and quantity of available habitat. As a result, these stressors generally cause a decline in biological diversity, a change in trophic structure, and a shift towards more pollution-tolerant organisms.

Many different habitat conditions are critical for supporting diverse aquatic ecosystems. For example, streambed substrates are vulnerable to deposition of fine sediments, which affects spawning, egg incubation and fry-rearing. Many aquatic insect species shelter in the large pore spaces among cobbles and boulders, particularly within riffles. When fine sediment fills these pore spaces, it reduces the quality and quantity of available habitat. The aquatic insect community is typically the base of the food chain in streams, helps break down organic matter and serves as a food source for juvenile fish.

Large woody debris (LWD) plays a critical role in the habitat of many aquatic insects and fish. For example, Bisson *et al.* (1988) contend that no other structural component is more important to salmon habitat than LWD, especially in the case of juvenile coho salmon. Loss of LWD due to the removal of stream side vegetation can significantly hinder the survival of more sensitive aquatic species. Since LWD creates different habitat types, its quality and quantity have been linked to salmonid rearing habitat and the ability of multiple fish species to coexist in streams.

The number of stream crossings (e.g., roads, sewers and pipelines) has been reported to increase directly in proportion to IC (May *et al*., 1997). Such crossings can become partial or total barriers to upstream fish migration, particularly if the stream bed downcuts below the fixed elevation of a culvert or pipeline. Fish barriers can prevent migration and recolonization of aquatic life in many urban streams.

Urbanization can also increase pollutant levels and stream temperatures. In particular, trace metals and pesticides often bind to sediment particles and may enter the food chain, particularly by aquatic insects that collect and filter particles. While in-stream data is rare, some data are available for ponds. A study of trace

[1] *Throughout this chapter, the term "aquatic insects" is used rather than the more cumbersome but technically correct "benthic macroinvertebrates."*

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metal bioaccumulation of three fish species found in central Florida stormwater ponds discovered that trace metal levels were significantly higher in urban ponds than in non-urban control ponds, often by a factor of five to 10 (Campbell, 1995; see also Karouna-Renier, 1995). Although typical stormwater pollutants are rarely acutely toxic to fish, the cumulative effects of sublethal pollutant exposure may influence the stream community (Chapter 4).

Table 46 summarizes some of the numerous changes to streams caused by urbanization that have the potential to alter aquatic biodiversity. For a comprehensive review of the impacts of urbanization on stream habitat and biodiversity, the reader should consult Wood and Armitage (1997) and Hart and Finelli (1999).

Table 46: Review of Stressors to Urban Streams and Effects on Aquatic Life

Stream Change	Effects on Organisms
Increased flow volumes/ Channel forming storms	Alterations in habitat complexity Changes in availability of food organisms, related to timing of emergence and recovery after disturbance Reduced prey diversity Scour-related mortality Long-term depletion of LWD Accelerated streambank erosion
Decreased base flows	Crowding and increased competition for foraging sites Increased vulnerability to predation Increased fine sediment deposition
Increase in sediment transport	Reduced survival of eggs and alevins, loss of habitat due to deposition Siltation of pool areas, reduced macroinvertebrate reproduction
Loss of pools and riffles	Shift in the balance of species due to habitat change Loss of deep water cover and feeding areas
Changes in substrate composition	Reduced survival of eggs Loss of inter-gravel fry refugial spaces Reduced aquatic insect production
Loss of LWD	Loss of cover from predators and high flows Reduced sediment and organic matter storage Reduced pool formation and organic substrate for aquatic insects
Increase in temperature	Changes in migration patterns Increased metabolic activity, increased disease and parasite susceptibility Increased mortality of sensitive fish
Creation of fish blockages	Loss of spawning habitat for adults Inability to reach overwintering sites Loss of summer rearing habitat, Increased vulnerability to predation
Loss of vegetative rooting systems	Decreased channel stability Loss of undercut banks Reduced streambank integrity
Channel straightening or hardening	Increased stream scour Loss of habitat complexity
Reduction in water quality	Reduced survival of eggs and alevins Acute and chronic toxicity to juveniles and adult fish Increased physiological stress
Increase in turbidity	Reduced survival of eggs Reduced plant productivity Physiological stress on aquatic organisms
Algae blooms	Oxygen depletion due to algal blooms, increased eutrophication rate of standing waters

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5.2 Indicators and General Trends

Stream indicators are used to gauge aquatic health in particular watersheds. The two main categories of stream indicators are **biotic** and **development** indices. **Biotic** indices use stream diversity as the benchmark for aquatic health and use measures, such as species abundance, taxa richness, EPT Index, native species, presence of pollution-tolerant species, dominance, functional feeding group comparisons, or proportion with disease or anomalies. **Development** indices evaluate the relationship between the degree of watershed urbanization and scores for the biotic indices. Common development indices include watershed IC, housing density, population density, and percent urban land use.

5.2.1 Biological Indicators

Biotic indices are frequently used to measure the health of the aquatic insect or fish community in urban streams. Because many aquatic insects have limited migration patterns or a sessile mode of life, they are particularly well-suited to assess stream impacts over time. Aquatic insects integrate the effects of short-term environmental variations, as most species have a complex but short life cycle of a year or less. Sensitive life stages respond quickly to environmental stressors, but the overall community responds more slowly. Aquatic insect communities are comprised of a broad range of species, trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects. Unlike fish, aquatic insects are abundant in most small, first and second order streams. Individuals are relatively easy to identify to family level, and many "intolerant" taxa can be identified to lower taxonomic levels with ease.

Fish are good stream indicators over longer time periods and broad habitat conditions because they are relatively long-lived and mobile. Fish communities generally include a range of species that represents a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, and piscivores). Fish tend to integrate the effects of lower trophic levels; thus, their community structure reflects the prevailing food sources and habitat conditions. Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field by experienced fisheries scientists and subsequently released unharmed.

A review of the literature indicates that a wide variety of metrics are used to measure the aquatic insect and fish community. Community indices, such as the Index of Biotic Integrity (IBI) for fish and the Benthic Index of Biotic Integrity (B-IBI) for the aquatic insect community are a weighted combination of various metrics that typically characterize the community from "excellent" to "poor." Common metrics of aquatic community are often based on a composite of measures, such as species richness, abundance, tolerance, trophic status, and native status. Combined indices (C-IBI) measure both fish and aquatic insect metrics and a variety of physical habitat conditions to classify streams. Table 47 lists several common metrics used in stream assessments. It should be clearly noted that community and combined indices rely on different measurements and cannot be directly compared. For a comprehensive review of aquatic community indicators, see Barbour *et al.*(1999).

5.2.2 Watershed Development Indices

Watershed IC, housing density, population density, and percent urban land have all been used as indices of the degree of watershed development. In addition, reverse indicators such as percent forest cover and riparian continuity have also been used. The majority of studies so far have used IC to explore the relationship between urbanization and aquatic diversity. Percent urban land has been the second most frequently used indicator to describe the impact of watershed development. Table 48 compares the four watershed development indices and the thresholds where significant impacts to aquatic life are typically observed.

Table 47: Examples of Biodiversity Metrics Used to Assess Aquatic Communities		
Measurement	**Applied to:**	**Definition of Measurement**
Abundance	Fish, Aquatic Insects	Total number of individuals in a sample; sometimes modified to exclude tolerant species.
Taxa Richness	Fish, Aquatic Insects	Total number of unique taxa identified in a sample. Typically, an increase in taxa diversity indicates better water and habitat quality.
EPT Index	Aquatic Insects	Taxa belonging to the following three groups: *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies). Typically, species in these orders are considered to be pollution-intolerant taxa and are generally the first to disappear with stream quality degradation.
Native Status	Fish	Native vs. non-native taxa in the community.
Specific Habitat	Fish	Riffle benthic insectivorous individuals. Total number of benthic insectivores. Often these types of individuals, such as darters, sculpins, and dace are found in high velocity riffles and runs and are sensitive to physical habitat degradation.
		Minnow species Total number of minnow species present. Often used as an indicator of pool habitat quality. Includes all species present in the family Cyprinidae, such as daces, minnows, shiners, stonerollers, and chubs.
Tolerant Species	Fish, Aquatic Insects	The total number of species sensitive to and the number tolerant of degraded conditions. Typically, intolerant species decline with decreasing water quality and stream habitat. A common high pollution-tolerant species that is frequently used is Chironomids.
Dominance	Fish, Aquatic Insects	The proportion of individuals at each station from the single most abundant taxa at that particular station. Typically, a community dominated by a single taxa may be indicative of stream degradation.
Functional Feeding Group Comparisons	Fish	Omnivores/ Generalists: The proportion of individuals characterized as omnivores or generalists to the total number of individuals. Typically, there is a shift away from specialized feeding towards more opportunistic feeders under degraded conditions as food sources become unreliable.
		Insectivores: The proportion of individuals characterized as insectivores to the total number of individuals. Typically, the abundance of insectivores decreases relative to increasing stream degradation.
	Aquatic Insects	Others: The proportion of individuals characterized as shredders, scrapers, or filter feeders to the total number of individuals. Typically, changes in the proportion of functional feeders characterized as shredders can be reflective of contaminated leaf matter. In addition, an overabundance of scrapers over filterers can be indicative of increased benthic algae.
Disease/ Anomalies	Fish	Proportion of individuals with signs of disease or abnormalities. This is ascertained through gross external examination for abnormalities during the field identification process. Typically, this metric assumes that incidence of disease and deformities increases with increasing stream degradation.
** This table is not meant to provide a comprehensive listing of metrics used for diversity indices; it is intended to provide examples of types of measures used in biological stream assessments (see Barbour* et al.*, 1999).*		

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5.2.3 General Trends

Most research suggests that a decline in both species abundance and diversity begins at or around 10% watershed IC (Schueler, 1994a). However, considerable variations in aquatic diversity are frequently observed from five to 20% IC, due to historical alterations, the effectiveness of watershed management, prevailing riparian conditions, co-occurrence of stressors, and natural biological variation (see Chapter 1).

Figures 40 through 42 display the negative relationship commonly seen between biotic indices and various measures of watershed development. For example, stream research in the Maryland Piedmont indicated that IC was the best predictor of stream condition, based on a combined fish and aquatic insect IBI (MNCPPC, 2000). In general, streams with less than 6% watershed IC were in "excellent" condition, whereas streams in "good" condition had less than 12% IC, and streams in "fair" condition had less than 20%. Figure 40 shows the general boundaries and typical variation seen in MNCPPC stream research.

Figure 41 illustrates that B-IBI scores and Coho Salmon/Cutthroat Trout Ratio are a function of IC for 31 streams in Puget Sound, Washington. The interesting finding was that "good" to "excellent" B-IBI scores (greater than 25) were reported in watersheds that had less than 10% IC, with eight notable outliers. These outliers had greater IC (25 to 35%) but similar B-IBI scores. These outliers are unique in that they had a large upstream wetland and/or a large, intact riparian corridor upstream (i.e. >70% of stream corridor had buffer width >100 feet).

Figure 42 depicts the same negative relationship between watershed urbanization and fish-IBI scores but uses population density as the primary metric of development (Dreher, 1997). The six-county study area included the Chicago metro area and outlying rural watersheds. Significant declines in fish-IBI scores were noted when population density exceeded 1.5 persons per acre.

The actual level of watershed development at which an individual aquatic species begins to decline depends on several variables, but may be lower than that indicated by the ICM. Some researchers have detected impacts for individual aquatic species at watershed IC levels as low as 5%. Other research has suggested that the presence of certain stressors, such as sewage treatment plant discharges (Yoder and Miltner, 2000) or construction sites (Reice, 2000) may alter the ICM and lower the level of IC at which biodiversity impacts become evident.

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Table 48: Alternate Land Use Indicators and Significant Impact Levels (Brown, 2000; Konrad and Booth, 2002)			
Land Use Indicator	**Level at which Significant Impact Observed**	**Typical Value for Low Density Residential Use**	**Comments**
% IC	10-20%	10%	Most accurate; highest level of effort and cost
Housing Density	>1 unit/acre	1 unit/acre	Low accuracy in areas of substantial commercial or industrial development; less accurate at small scales
Population Density	1.5 to 8+ people/acre	2.5 people/acre	Low accuracy in areas of substantial commercial or industrial development; less accurate at small scales
% Urban Land Use	33% (variable)	10-100%	Does not measure intensity of development; moderately accurate at larger watershed scales
Road Density	5 miles/square mile	2 miles/square mile	Appears to be a potentially useful indicator

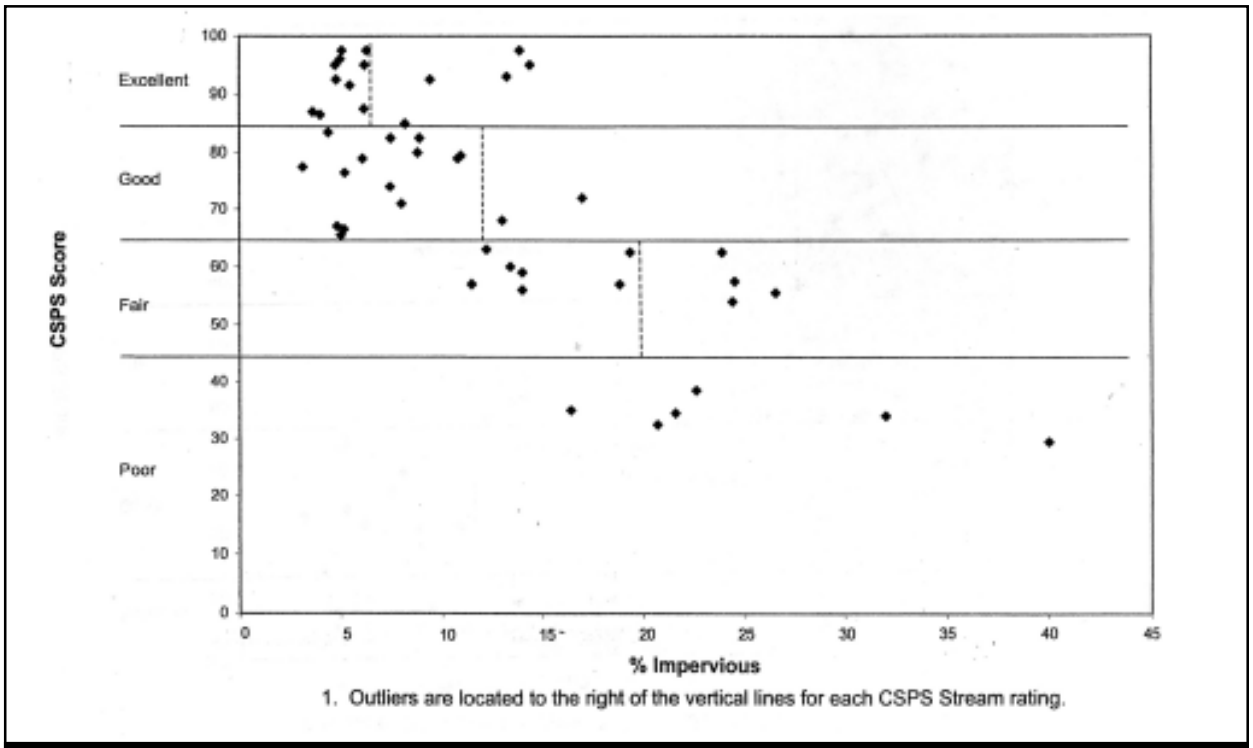

Figure 40: Combined Fish and Benthic IBI vs. IC in Maryland Piedmont Streams (MNCPPC, 2000)

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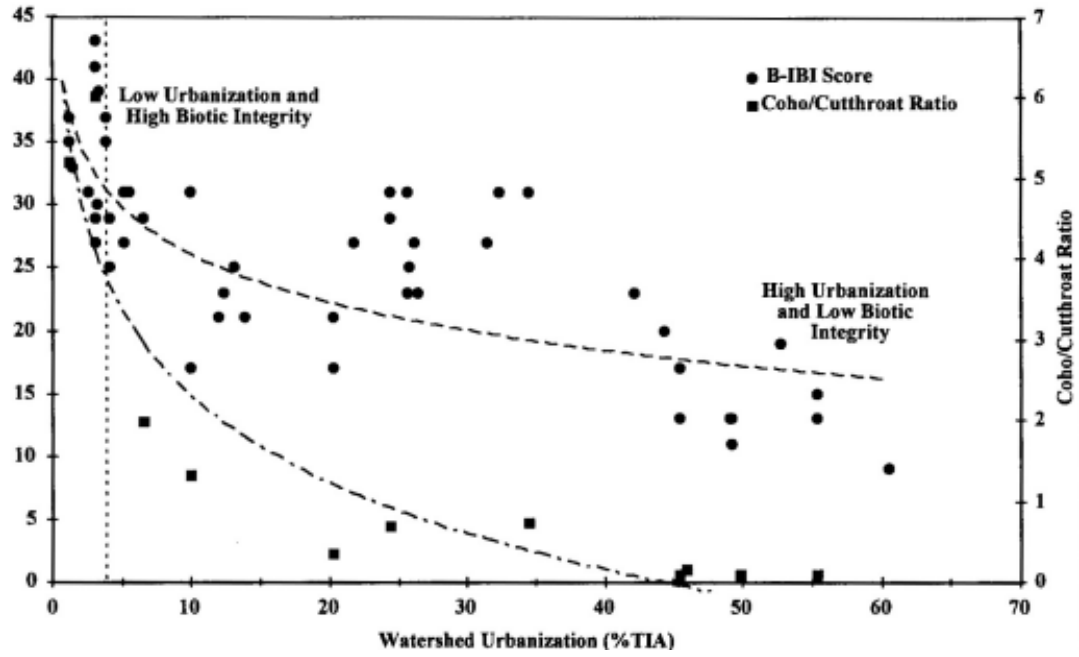

Figure 41: Relationship Between B-IBI, Coho/Cutthroat Ratios, and Watershed IC in Puget Sound Streams (Horner *et al.*, 1997)

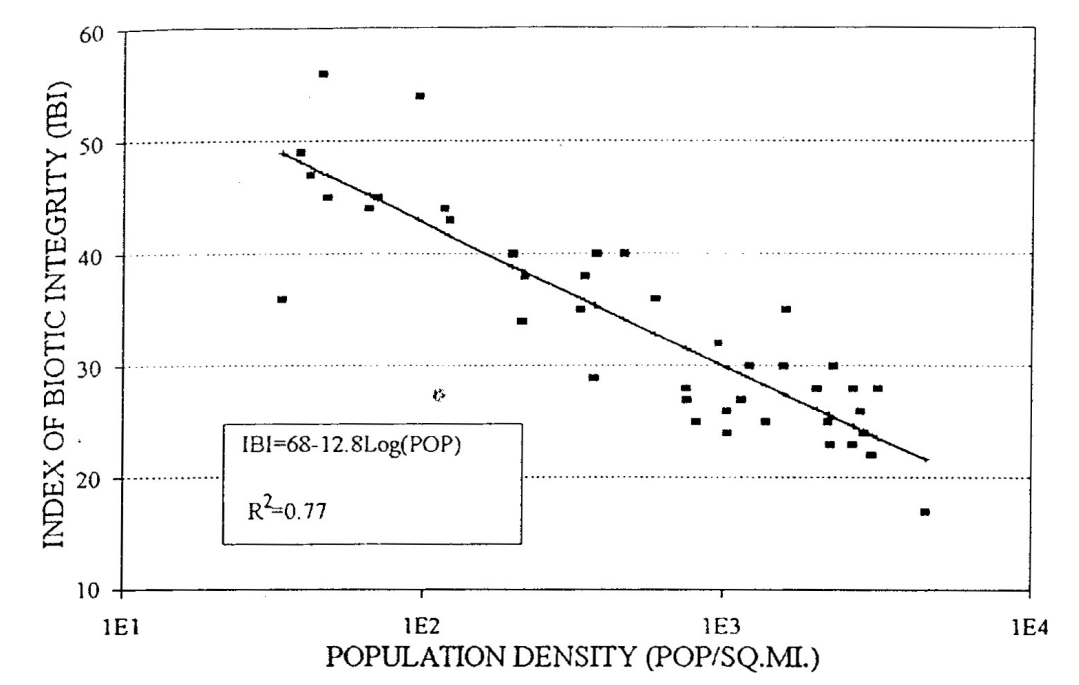

Figure 42: Index for Biological Integrity as a Function of Population Density in Illinois (Dreher, 1997)

5.3 Effects on Aquatic Insect Diversity

The diversity, richness and abundance of the aquatic insect community is frequently used to indicate urban stream quality. Aquatic insects are a useful indicator because they form the base of the stream food chain in most regions of the country. For this reason, declines or changes in aquatic insect diversity are often an early signal of biological impact due to watershed development. The aquatic insect community typically responds to increasing development by losing species diversity and richness and shifting to more pollution-tolerant species. More than 30 studies illustrate how IC and urbanization affect the aquatic insect community. These are summarized in Tables 49 and 50.

5.3.1 Findings Based on IC Indicators

Klein (1979) was one of the first researchers to note that aquatic insect diversity drops sharply in streams where watershed IC exceeded 10 to 15%. While "good" to "fair" diversity was noted in all headwater streams with less than 10% IC, nearly all streams with 12% or more watershed IC recorded "poor" diversity. Other studies have confirmed this general relationship between IC and the decline of aquatic insect species diversity. Their relationships have been an integral part in the development of the ICM. The sharp drop in aquatic insect diversity at or around 12 to 15% IC was also observed in streams in the coastal plain and Piedmont of Delaware (Maxted and Shaver, 1997).

Impacts at development thresholds lower than 10% IC have also been observed by Booth (2000), Davis (2001), Horner *et al.* (1997) and Morse (2001). There seems to be a general recognition that the high levels of variability observed below 10% IC indicate that other factors, such as riparian condition, effluent discharges, and pollution legacy may be better indicators of aquatic insect diversity (Horner and May, 1999; Kennen, 1999; Steedman, 1988; Yoder *et al.*, 1999).

The exact point at which aquatic insect diversity shifts from fair to poor is not known with absolute precision, but it is clear that few, if any, urban streams can support diverse aquatic insect communities with more than 25% IC. Indeed, several researchers failed to find aquatic insect communities with good or excellent diversity in any highly urban stream (Table 52). Indeed, MNCPPC (2000) reported that all streams with more than 20% watershed IC were rated as "poor."

Several good examples of the relationship between IC and B-IBI scores are shown in Figures 43 through 45. Figure 43 depicts the general trend line in aquatic insect diversity as IC increased at 138 stream sites in Northern Virginia (Fairfax County, 2001). The survey study concluded that stream degradation occurred at low levels of IC, and that older developments lacking more efficient site design and stormwater controls tended to have particularly degraded streams. Figures 44 and 45 show similar trends in the relationship between IC and aquatic insect B-IBI scores in Maryland and Washington streams. In particular, note the variability in B-IBI scores observed below 10% IC in both research studies.

Often, shift in the aquatic insect community from pollution-sensitive species to pollution-tolerant species occurs at relatively low IC levels (<10%). This shift is often tracked using the EPT metric, which evaluates sensitive species found in the urban stream community in the orders of *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies). EPT species frequently disappear in urban streams and are replaced by more pollution-tolerant organisms, such as chironomids, tubificid worms, amphipods and snails.

In undisturbed streams, aquatic insects employ specialized feeding strategies, such as shredding leaf litter, filtering or collecting organic matter that flows by, or preying on other insects. These feeding guilds are greatly reduced in urban streams and are replaced by grazers, collectors and deposit feeders. Maxted and Shaver (1997) found that 90% of sensitive

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Table 49: Recent Research Examining the Relationship Between IC and Aquatic Insect Diversity in Streams

Index	Key Finding (s)	Source	Location
Community Index	Three years stream sampling across the state at 1000 sites found that when IC was >15%, stream health was never rated good based on a C-IBI.	Boward *et al.*, 1999	MD
Community Index	Insect community and habitat scores were all ranked as poor in five subwatersheds that were greater than 30% IC.	Black and Veatch, 1994	MD
Community Index	Puget sound study finds that some degradation of aquatic invertebrate diversity can occur at any level of human disturbance (at least as measured by IC). 65% of watershed forest cover usually indicates a healthy aquatic insect community.	Booth, 2000	WA
Community Index	In a Puget Sound study, the steepest decline of B-IBI was observed after 6% IC. There was a steady decline, with approximately 50% reduction in B-IBI at 45% IC.	Horner *et al.*, 1997	WA
Community Index	B-IBI decreases with increasing urbanization in study involving 209 sites, with a sharp decline at 10% IC. Riparian condition helps mitigate effects.	Steedman, 1988	Ontario
Community Index	Wetlands, forest cover and riparian integrity act to mitigate the impact of IC on aquatic insect communities.	Horner *et al.*, 2001	WA, MD, TX
Community Index	B-IBI declines for aquatic insect with increasing IC at more than 200 streams.	Fairfax Co., 2001	VA
Community Index	Two-year stream study of eight Piedmont watersheds reported B-IBI scores declined sharply at an IC threshold of 15-30%.	Meyer and Couch,2000	GA
Community Index	Montgomery County study; subwatersheds with <12% IC generally had streams in good to excellent condition based on a combined fish and aquatic insect IBI. Watersheds with >20% IC had streams in poor condition.	MNCPPC, 2000	MD
Community Index	Study of 1st, 2nd, and 3rd order streams in the Patapsco River Basin showed negative relationship between B-IBI and IC.	Dail *et al.*, 1998	MD
Community Index	While no specific threshold was observed, impacts were seen at even low levels of IC. B-IBI values declined with increasing IC, with high scores observed only in reaches with <5% IC or intact riparian zones or upstream wetlands.	Horner and May, 1999	WA
Community Index	The C-IBI also decreased by 50% at 10-15% IC. These trends were particularly strong at low-density urban sites (0-30% IC).	Maxted and Shaver, 1997	DE
Diversity	In both coastal plain and Piedmont streams, a sharp decline in aquatic insect diversity was found around 10-15% IC.	Shaver *et al.*, 1995	DE
Diversity	In a comparison of Anacostia subwatersheds, there was significant decline in the diversity of aquatic insects at 10% IC.	MWCOG, 1992	DC
Diversity	In several dozen Piedmont headwater streams, aquatic diversity declined significantly beyond 10-12% IC.	Klein, 1979	MD
EPT Value	In a 10 stream study with watershed IC ranging from three to 30%, a significant decline in EPT values was reported as IC increased (r2 = 0.76).	Davis, 2001	MO
Sensitive Species	In a study of 38 wadeable, non-tidal streams in the urban Piedmont, 90% of sensitive organisms were eliminated from the benthic community after watershed IC reaches 10-15%.	Maxted and Shaver, 1997	DE
Species Abundance EPT values	For streams draining 20 catchments across the state, an abrupt decline in species abundance and EPT taxa was observed at approximately 6% IC.	Morse, 2001	ME

Table 50: Recent Research Examining the Relationship of Other Indices of Watershed Development on Aquatic Insect Diversity in Streams			
Biotic	**Key Finding (s)**	**Source**	**Location**
Percent Urban Land use			
Community Index	Study of 700 streams in 5 major drainage basins found that the amount of urban land and total flow of municipal effluent were the most significant factors in predicting severe impairment of the aquatic insect community. Amount of forested land in drainage area was inversely related to impairment severity.	Kennen, 1999	NJ
Community Index	All 40 urban sites sampled had fair to very poor B-IBI scores, compared to undeveloped reference sites.	Yoder, 1991	OH
Community Index	A negative correlation between B-IBI and urban land use was noted. Community characteristics show similar patterns between agricultural and forested areas the most severe degradation being in urban and suburban areas.	Meyer and Couch, 2000	GA
EPT Value, Diversity, Community Index	A comparison of three stream types found urban streams had lowest diversity and richness. Urban streams had substantially lower EPT scores (22% vs 5% as number of all taxa, 65% vs 10% as percent abundance) and IBI scores in the poor range.	Crawford and Lenat, 1989	NC
Sensitive Species	Urbanization associated with decline in sensitive taxa, such as mayflies, caddisflies and amphipods while showing increases in oligochaetes.	Pitt and Bozeman, 1982	CA
Sensitive Species	Dramatic changes in aquatic insect community were observed in most urbanizing stream sections. Changes include an abundance of pollution-tolerant aquatic insect species in urban streams.	Kemp and Spotila, 1997	PA
Diversity	As watershed development levels increased, the aquatic insect diversity declined.	Richards *et al.*, 1993	MN
Diversity	Significant negative relationship between number of aquatic insect species and degree of urbanization in 21 Atlanta streams.	Benke *et al.*, 1981	GA
Diversity	Drop in insect taxa from 13 to 4 was noted in urban streams.	Garie and McIntosh, 1986	NJ
Diversity	Aquatic insect taxa were found to be more abundant in non-urban reaches than in urban reaches of the watershed.	Pitt and Bozeman, 1982	CA
Diversity	A study of five urban streams found that as watershed land use shifted from rural to urban, aquatic insect diversity decreased.	Masterson and Bannerman, 1994	WI
Other Land Use Indicators			
Community Index	Most degraded streams were found in developed areas, particularly older developments lacking newer and more efficient stormwater controls.	Fairfax Co., 2001	VA
Diversity	Urban streams had sharply lower aquatic insect diversity with human population above four persons/acre in northern VA.	Jones and Clark, 1987	VA
EPT Value	Monitoring of four construction sites in three varying regulatory settings found that EPT richness was related to enforcement of erosion and sediment controls. The pattern demonstrated that EPT richness was negatively affected as one moved from upstream to at the site, except for one site.	Reice, 2000	NC
Sensitive Species	In a Seattle study, aquatic insect community shifted to chironomid, oligochaetes and amphipod species that are pollution-tolerant and have simple feeding guild.	Pedersen and Perkins,1986	WA

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species (based on EPT richness, % EPT abundance, and Hilsenhoff Biotic Index) were eliminated from the aquatic insect community when IC exceeded 10 to 15% in contributing watersheds of Delaware streams (Figure 46). In a recent study of 30 Maine watersheds, Morse (2001) found that reference streams with less than 5% watershed IC had significantly more EPT taxa than more urban streams. He also observed no significant differences in EPT Index values among streams with six to 27% watershed IC (Figure 47).

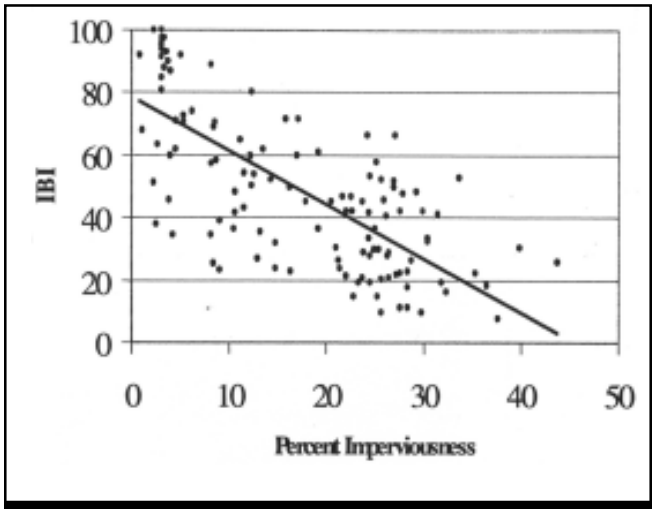

Figure 43: Trend Line Indicating Decline in Benthic IBI as IC Increases in Northern VA Streams (Fairfax County, 2001)

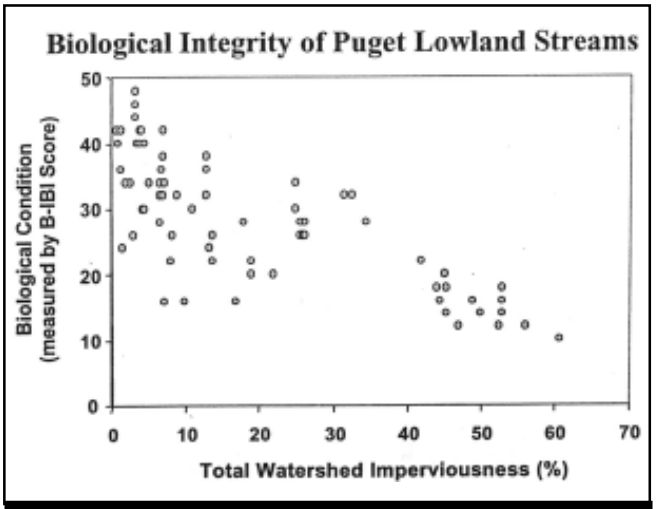

Figure 44: Relationship Between IC and B-IBI Scores in Aquatic Insects in Streams of the Puget Sound Lowlands (Booth, 2000)

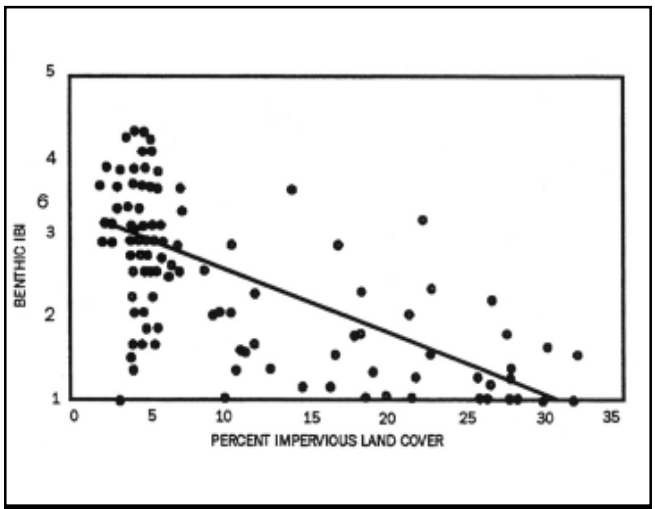

Figure 45: IC and B-IBI at Stream Sites in the Patapsco River Basin, MD (Dail *et al.*, 1998)

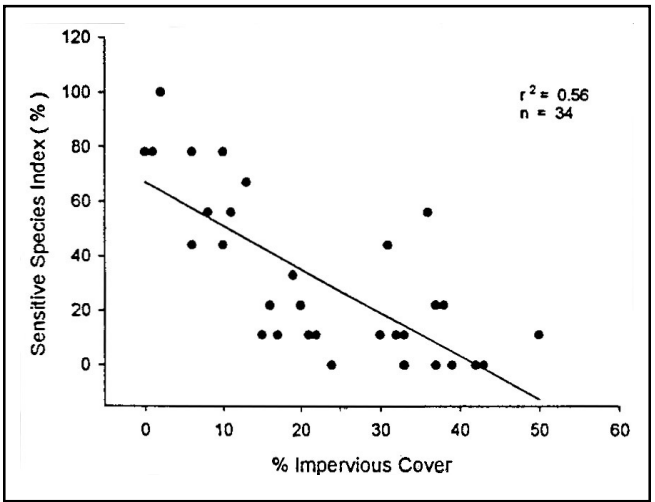

Figure 46: IC vs. Aquatic Insect Sensitivity - EPT Scores in Delaware Streams (Maxted and Shaver, 1997)

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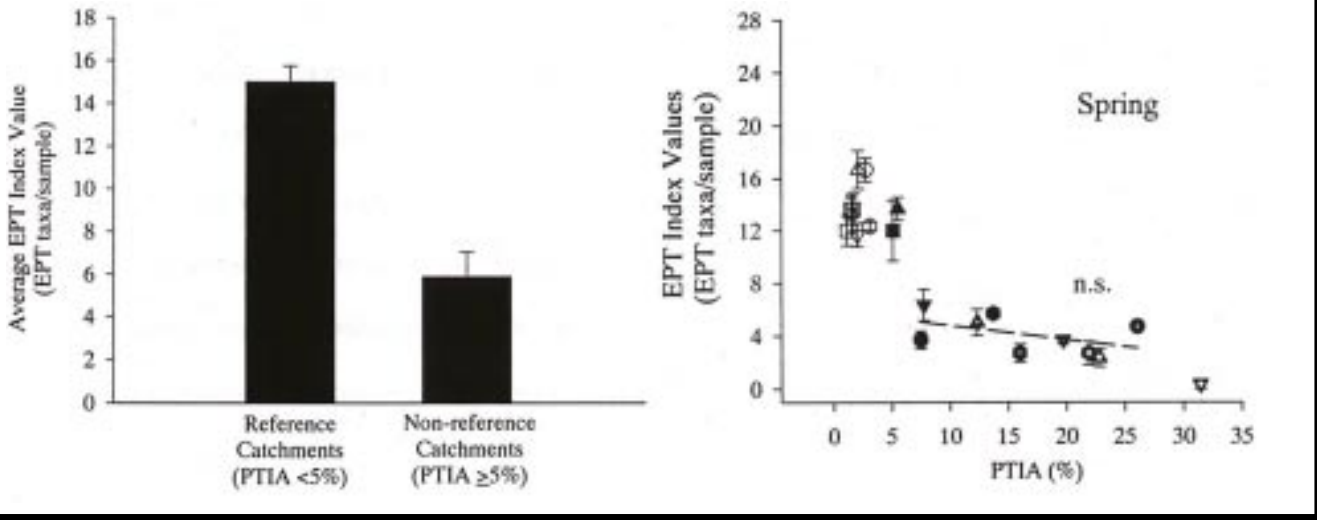

Figure 47: Average and Spring EPT Index Values vs.% IC in 20 Small Watersheds in Maine (Morse, 2001)

5.3.2 Findings Based on Other Development Indicators

Development indices, such as percent urban land use, population density, and forest and riparian cover have also been correlated with changes in aquatic insect communities in urban streams. Declines in benthic IBI scores have frequently been observed in proportion to the percent urban land use in small watersheds (Garie and McIntosh, 1986; Kemp and Spotila, 1997; Kennen, 1999; Masterson and Bannerman, 1994; Richards *et al.*, 1993; USEPA, 1982).

A study in Washington state compared a heavily urbanized stream to a stream with limited watershed development and found that the diversity of the aquatic insect community declined from 13 taxa in reference streams to five taxa in more urbanized streams (Pedersen and Perkins, 1986). The aquatic insect taxa that were lost were poorly suited to handle the variable erosional and depositional conditions found in urban streams. Similarly, a comparison of three North Carolina streams with different watershed land uses concluded the urban watershed had the least taxa and lowest EPT scores and greatest proportion of pollution-tolerant species (Crawford and Lenat, 1989).

Jones and Clark (1987) monitored 22 streams in Northern Virginia and concluded that aquatic insect diversity diminished markedly once watershed population density exceeded four or more people per acre. The population density roughly translates to ½ - 1 acre lot residential use, or about 10 to 20 % IC. Kennen (1999) evaluated 700 New Jersey streams and concluded that the percentage of watershed forest was positively correlated with aquatic insect density. Meyer and Couch (2000) reported a similar cover relationship between aquatic insect diversity and watershed and riparian forest cover for streams in the Atlanta, GA region. A study in the Puget Sound region found that aquatic insect diversity declined in streams once forest cover fell below 65% (Booth, 2000).

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5.4 Effects on Fish Diversity

Fish communities are also excellent environmental indicators of stream health. In general, an increase in watershed IC produces the same kind of impact on fish diversity as it does for aquatic insects. The reduction in fish diversity is typified by a reduction in total species, loss of sensitive species, a shift toward more pollution-tolerant species, and decreased survival of eggs and larvae. More than 30 studies have examined the relationship between watershed development and fish diversity; they are summarized in Tables 51 and 52. About half of the research studies used IC as the major index of watershed development, while the remainder used other indices, such as percent urban land use, population density, housing density, and forest cover.

5.4.1 Findings Based on IC Indicators

Recent stream research shows a consistent, negative relationship between watershed development and various measures of fish diversity, such as diversity metrics, species loss and structural changes.

Typically, a notable decline in fish diversity occurs around 10 to 15% watershed IC (Boward *et al.*, 1999; Galli, 1994; Klein, 1979; Limburg and Schmidt, 1990; MNCPPC, 2000; MWCOG, 1992; Steward, 1983). A somewhat higher threshold was observed by Meyer and Couch (2000) for Atlanta streams with 15 to 30% IC; lower thresholds have also been observed (Horner *et al.*, 1997 and May *et al.*, 1997). A typical relationship between watershed IC and fish diversity is portrayed in Figure 48, which shows data from streams in the Patapsco River Basin in Maryland (Dail *et al.*, 1998). Once again, note the variability in fish-IBI scores observed below 10% IC.

Wang *et al.* (1997) evaluated 47 Wisconsin streams and found an apparent threshold around 10% IC. Fish-IBI scores were "good" to "excellent" below this threshold, but were consistently rated as "fair" to "poor." Additionally, Wang documented that the total number of fish species drops sharply when IC increases (Figure 49). Often, researchers also reported that increases in IC were strongly correlated with several fish metrics, such as increases in non-native and pollution-tolerant species in streams in Santa Clara, California (EOA, Inc., 2001).

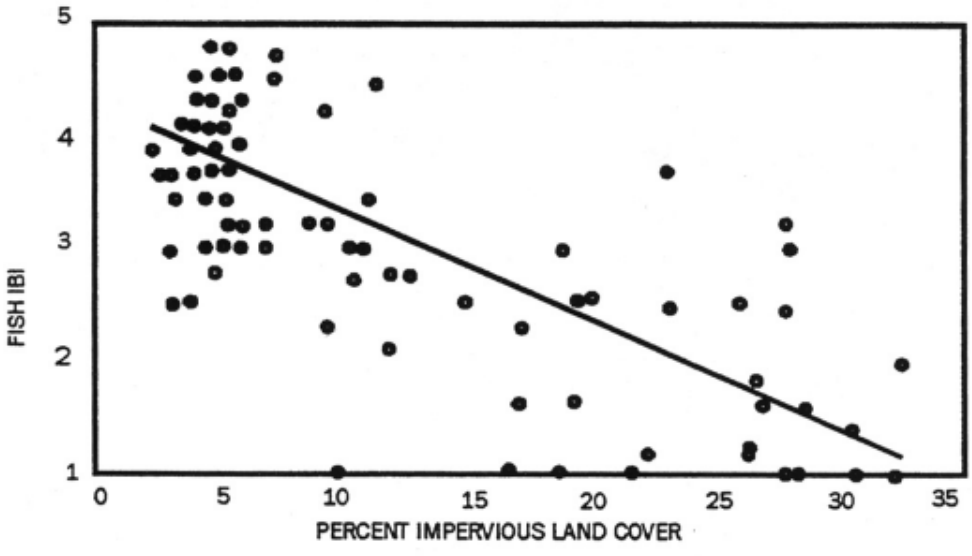

Figure 48: Fish-IBI vs. Watershed IC for Streams in the Patapsco River Basin, MD (Dail *et al.*, 1998)

Table 51: Recent Research Examining the Relationship Between Watershed IC and the Fish Community

Biotic	Key Finding (s)	Source	Location
Abundance	Brown trout abundance and recruitment declined sharply at 10-15% IC.	Galli, 1994	MD
Salmonids	Seattle study showed marked reduction in coho salmon populations noted at 10-15% IC at nine streams.	Steward, 1983	WA
Anadromous Fish Eggs	Resident and anadromous fish eggs and larvae declined in 16 subwatersheds draining to the Hudson River with >10% IC area.	Limburg and Schmidt, 1990	NY
Community Index	1st, 2nd, and 3rd order streams in the Patapsco River Basin showed negative relationship between IBI and IC.	Dail *et al.*, 1998	MD
Community Index	Fish IBI and habitat scores were all ranked as poor in five subwatersheds that were greater than 30% IC.	Black and Veatch, 1994	MD
Community Index	In the Potomac subregion, subwatersheds with < 12% IC generally had streams in good to excellent condition based on a combined fish and aquatic insect IBI. Watersheds with >20% IC had streams in poor condition.	MNCPPC, 2000	MD
Community Index	In a two-year study of Piedmont streams draining eight watersheds representing various land uses in Chattahochee River Basin, fish community quality dropped sharply at an IC threshold of 15-30%.	Meyer and Couch, 2000	GA
Diversity	Of 23 headwater stream stations, all draining <10% IC areas, rated as good to fair; all with >12% were rated as poor. Fish diversity declined sharply with increasing IC between 10-12%.	Schueler and Galli, 1992	MD
Diversity, Sensitive Species	Comparison of 4 similar subwatersheds in Piedmont streams, there was significant decline in the diversity of fish at 10% IC. Sensitive species (trout and sculpin) were lost at 10-12%.	MWCOG, 1992	MD
Diversity, Community Index	In a comparison of watershed land use and fish community data for 47 streams between the 1970s and 1990s, a strong negative correlation was found between number species and IBI scores with effective connected IC. A threshold of 10% IC was observed with community quality highly variable below 10% but consistently low above 10% IC.	Wang *et al.*, 1997	WI
Diversity	In several dozen Piedmont headwater streams fish diversity declined significantly in areas beyond 10-12% IC.	Klein, 1979	MD
Diversity , Abundance, Non-native Species	IC strongly associated with several fisheries species and individual-level metrics, including number of pollution-tolerant species, diseased individuals, native and non-native species and total species present	EOA, Inc., 2001	CA
Juvenile Salmon Ratios	In Puget Sound study, the steepest decline of biological functioning was observed after six percent IC. There was a steady decline, with approximately 50% reduction in initial biotic integrity at 45% IC area.	Horner *et al.*, 1997	WA
Juvenile Salmon Ratio	Physical and biological stream indicators declined most rapidly during the initial phase of the urbanization process as total IC area exceeded the five to 10% range.	May *et al.*, 1997	WA
Salmonoid	Negative effects of urbanization (IC) with the defacto loss of non-structural BMPs (wetland forest cover and riparian integrity) on salmon ratios	Horner *et al.*, 2001	WA, MD, TX
Salmonoid, Sensitive Species	While no specific threshold was observed (impacts seen at even low levels of IC), Coho/cutthroat salmon ratios >2:1 were found when IC was < 5%. Ratios fell below one at IC levels below 20 %.	Horner and May, 1999	WA
Sensitive species, Salmonid	Three years stream sampling across the state (approximately 1000 sites), MBSS found that when IC was >15%, stream health was never rated good based on CBI, and pollution sensitive brook trout were never found in streams with >2% IC.	Boward *et al.*, 1999	MD
Sensitive Species, Salmonids	Seattle study observed shift from less tolerant coho salmon to more tolerant cutthroat trout population between 10 and 15% IC at nine sites.	Luchetti and Feurstenburg 1993	WA

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Sensitive fish are defined as species that strongly depend on clean and stable bottom substrates for feeding and/or spawning. Sensitive fish often show a precipitous decline in urban streams. The loss of sensitive fish species and a shift in community structure towards more pollution-tolerant species is confirmed by multiple studies. Figure 50 shows the results of a comparison of four similar subwatersheds in the Maryland Piedmont that were sampled for the number of fish species present (MWCOG, 1992). As the level of watershed IC increased, the number of fish species collected dropped. Two sensitive species, including sculpin, were lost when IC increased from 10 to 12%, and four more species were lost when IC reached 25%. Significantly, only two species remained in the fish community at 55% watershed IC.

Salmonid fish species (trout and salmon) and anadromous fish species appear to be particularly impacted by watershed IC. In a study in the Pacific Northwest, sensitive coho salmon were seldom found in watersheds above 10 or 15% IC (Luchetti and Feurstenburg, 1993 and Steward, 1983). Key stressors in urban streams, such as higher peak flows, lower dry weather flows, and reduction in habitat complexity (e.g. fewer pools, LWD, and hiding places) are believed to change salmon species composition, favoring cutthroat trout populations over the natural coho populations (WDFW, 1997).

A series of studies from the Puget Sound reported changes in the coho/cutthroat ratios of juvenile salmon as watershed IC increased (Figure 51). Horner *et al*. (1999) found Coho/ Cutthroat ratios greater than 2:1 in watersheds with less than 5 % IC. Ratios fell below 1:1 when IC exceeded 20%. Similar results were reported by May *et al.* (1997). In the mid-Atlantic region, native trout have stringent temperature and habitat requirements and are seldom present in watersheds where IC exceeds 15% (Schueler, 1994a). Declines in trout spawning success are evident above 10% IC. In a study of over 1,000 Maryland streams, Boward *et al.* (1999) found that sensitive brook trout were never found in streams that had more than 4% IC in their contributing watersheds.

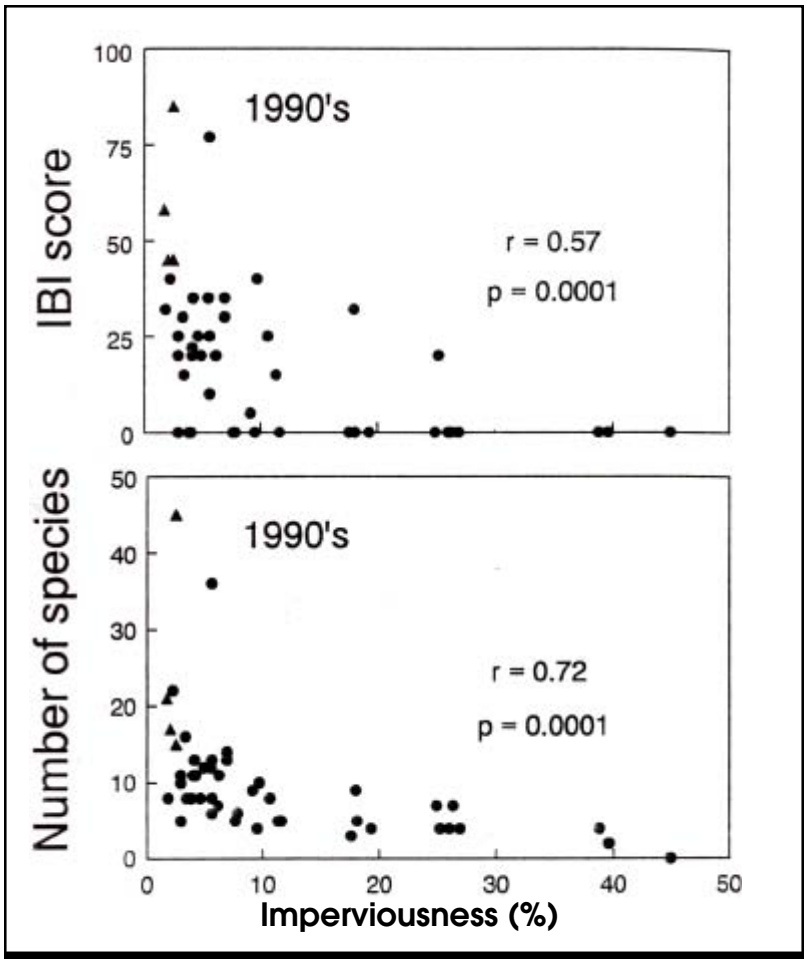

Figure 49: Fish-IBI and Number of Species vs. % IC in Wisconsin Streams (Wang *et al.*, 1997)

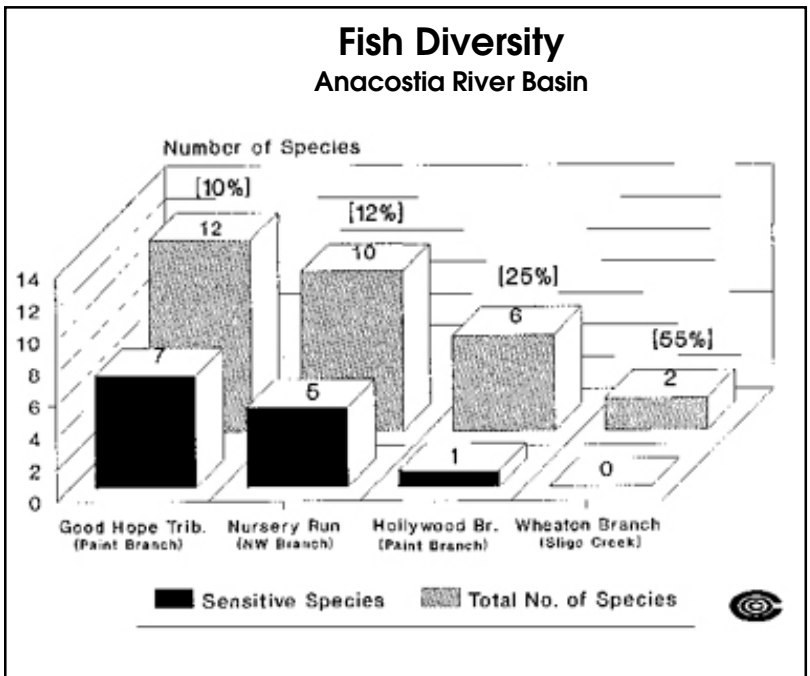

Figure 50: IC and Effects on Fish Species Diversity in Four Maryland Subwatersheds (MWCOG, 1992)

Table 52: Recent Research Examining Urbanization and Freshwater Fish Community Indicators			
Biotic	**Key Finding (s)**	**Source**	**Location**
Urbanization			
Community Index	All 40 urban sites sampled had fair to very poor IBI scores, compared to undeveloped reference sites.	Yoder, 1991	OH
Community Index	Negative correlations between biotic community and riparian conditions and forested areas were found. Similar levels of fish degradation were found between suburban and agricultural; urban areas were the most severe.	Meyer and Couch, 2000	GA
Community Index	Residential urban land use caused significant decrease in fish-IBI scores at 33%. In more urbanized Cuyahoga, a significant drop in IBI scores occurred around 8% urban land use in the watershed. When watersheds smaller than 100mi^2 were analyzed separately, the level of urban land associated with a significant drop in IBI scores occurred at around 15%. Above one du/ac, most sites failed to attain biocriteria regardless of degree of urbanization.	Yoder *et al.*, 1999	OH
Community Index, Abundance	As watershed development increased to about 10%, fish communities simplified to more habitat and trophic generalists and fish abundance and species richness declined. IBI scores for the urbanized stream fell from the good to fair category.	Weaver, 1991	VA
Diversity	A study of five urban streams found that as land use shifted from rural to urban, fish diversity decreased.	Masterson and Bannerman, 1994	WI
Diversity, Community Index	A comparison of three stream types found urban streams had lowest diversity and richness. Urban streams had IBI scores in the poor range.	Crawford and Lenat, 1989	NC
Salmon Spawning, Flooding Frequency	In comparing three streams over a 25-year period (two urbanizing and one remaining forested), increases in flooding frequencies and decreased trends in salmon spawning were observed in the two urbanizing streams, while no changes in flooding or spawning were seen in the forested system.	Moscript and Montgomery, 1997	WA
Sensitive Species	Observed dramatic changes in fish communities in most urbanizing stream sections, such as absence of brown trout and abundance of pollution-tolerant species in urban reaches.	Kemp and Spotila, 1997	PA
Sensitive Species, Diversity	Decline in sensitive species diversity and composition and changes in trophic structure from specialized feeders to generalists was seen in an urbanizing watershed from 1958 to 1990. Low intensity development was found to affect warm water stream fish communities similarly as more intense development.	Weaver and Garman, 1994	VA
Warm Water Habitat Biocriteria	25-30% urban land use defined as the upper threshold where attainment of warm water habitat biocriterion is effectively lost. Non-attainment also may occur at lower thresholds given the co-occurrence of stressors, such as pollution legacy, WTPs and CSOs.	Yoder and Miltner, 2000	OH
Community Index, Habitat	The amount of urban land use upstream of sample sites had a strong negative relationship with biotic integrity, and there appeared to be a threshold between 10 and 20% urban land use where IBI scores declined dramatically. Watersheds above 20% urban land invariably had scores less than 30 (poor to very poor). Habitat scores were not tightly correlated with degraded fish community attributes.	Wang *et al.*, 1997	WI
Community Index	A study in the Patapsco Basin found significant correlation of fish IBI scores with percent urbanized land over all scales (catchment, riparian area, and local area).	Roth *et al.*, 1998	MD

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Table 52 (continued): Recent Research Examining Urbanization and Freshwater Fish Community Indicators			
Biotic	**Key Finding (s)**	**Source**	**Location**
Urbanization			
Sensitive Species	Evaluated effects of runoff in both urban and non-urban streams; found that native species dominated the non-urban portion of the watershed but accounted for only seven percent of species found in the urban portions of the watershed.	Pitt, 1982	CA
Other Land Use Indicators			
Community Index, Habitat	Atlanta study found that as watershed population density increased, there was a negative impact on urban fish and habitat. Urban stream IBI scores were inversely related to watershed population density, and once density exceeded four persons/acre, urban streams were consistently rated as very poor.	Couch *et al.*, 1997	GA
Community Index	In an Atlanta stream study, modified IBI scores declined once watershed population density exceeds four persons/acre in 21 urban watersheds	DeVivo *et al.*, 1997	GA
Community Index	In a six-county study (including Chicago, its suburbs and outlying rural/agricultural areas), streams showed a strong correlation between population density and fish community assessments such that as population density increased, community assessment scores went from the better - good range to fair - poor. Significant impacts seen at 1.5 people/acre.	Dreher, 1997	IL
Community Index	Similarly, negative correlations between biotic community and riparian conditions and forested areas were also found. Similar levels of fish degradation were found between suburban and agricultural; urban areas were the most severe.	Meyer and Couch, 2000	GA
Community Index	Amount of forested land in basin directly related to IBI scores for fish community condition.	Roth *et al.*, 1996	MD
Salmonid, Sensitive Species	Species community changes from natural coho salmon to cutthroat trout population with increases in peak flow, lower low flow, and reductions in stream complexity.	WDFW, 1997	WA

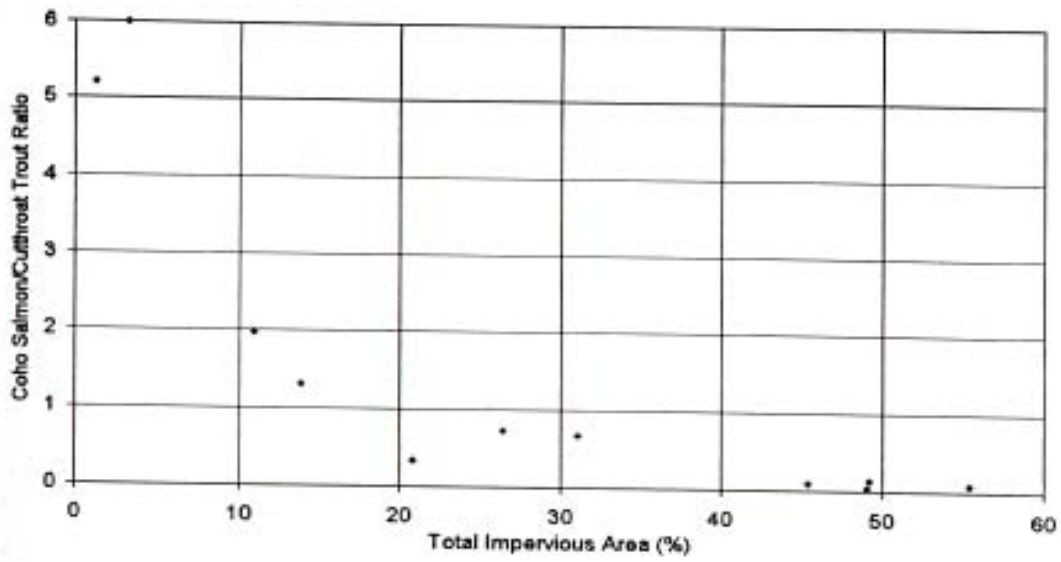

Figure 51: Coho Salmon/Cutthroat Trout Ratio for Puget Sound Streams (Horner *et al.*, 1997)

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Many fish species have poor spawning success in urban streams and poor survival of fish eggs and fry. Fish barriers, low intragravel dissolved oxygen, sediment deposition and scour are all factors that can diminish the ability of fish species to successfully reproduce. For example, Limburg and Schmidt (1990) discovered that the density of anadromous fish eggs and larvae declined sharply in subwatersheds with more than 10% IC.

5.4.2 Findings Based on Other Development Indicators

Urban land use has frequently been used as a development indicator to evaluate the impact on fish diversity. Streams in urban watersheds typically had lower fish species diversity and richness than streams located in less developed watersheds. Declines in fish diversity as a function of urban land cover have been documented in numerous studies (Crawford and Lenat, 1989; Masterson and Bannerman, 1994; Roth *et al., 1998;* Yoder, 1991, and Yoder *et al.*, 1999). USEPA (1982) found that native fish species dominated the fish community of non-urban streams, but accounted for only 7% of the fish community found in urban streams. Kemp and Spotila (1997) evaluated streams in Pennsylvania and noted the loss of sensitive species (e.g. brown trout) and the increase of pollution-tolerant species, such as sunfish and creek chub (Figure 52).

Wang *et al.* (1997) cited percentage of urban land in Wisconsin watersheds as a strong negative factor influencing fish-IBI scores in streams and observed strong declines in IBI scores with 10 to 20% urban land use. Weaver and Garman (1994) compared the historical changes in the warm-water fish community of a Virginia stream that had undergone significant urbanization and found that many of the sensitive species present in 1958 were either absent or had dropped sharply in abundance when the watershed was sampled in 1990. Overall abundance had dropped from 2,056 fish collected in 1958 to 417 in 1990. In addition, the 1990 study showed that 67% of the catch was bluegill and common shiner, two species that are habitat and trophic "generalists." This shift in community to more habitat and trophic generalists was observed at 10% urban land use (Weaver, 1991).

Yoder *et al.* (1999) evaluated a series of streams in Ohio and reported a strong decrease in warm-water fish community scores around 33% residential urban land use. In the more urbanized Cuyahoga streams, sharp drops in

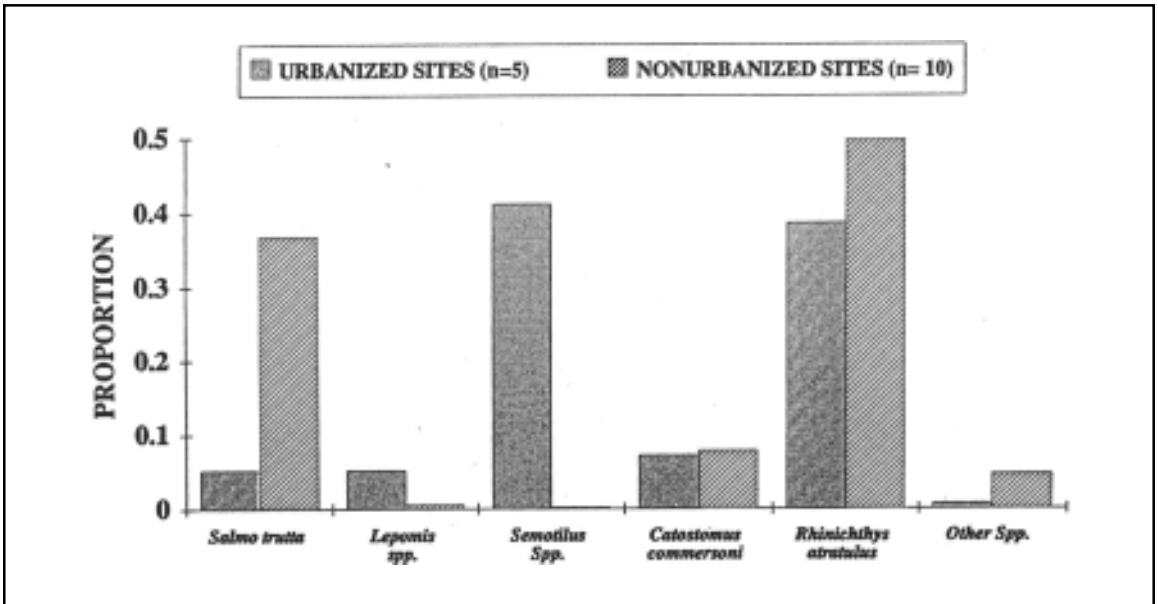

Figure 52: Mean Proportion of Fish Taxa in Urban and Non-Urban Streams, Valley Forge Watershed, PA (Kemp and Spotila, 1997)

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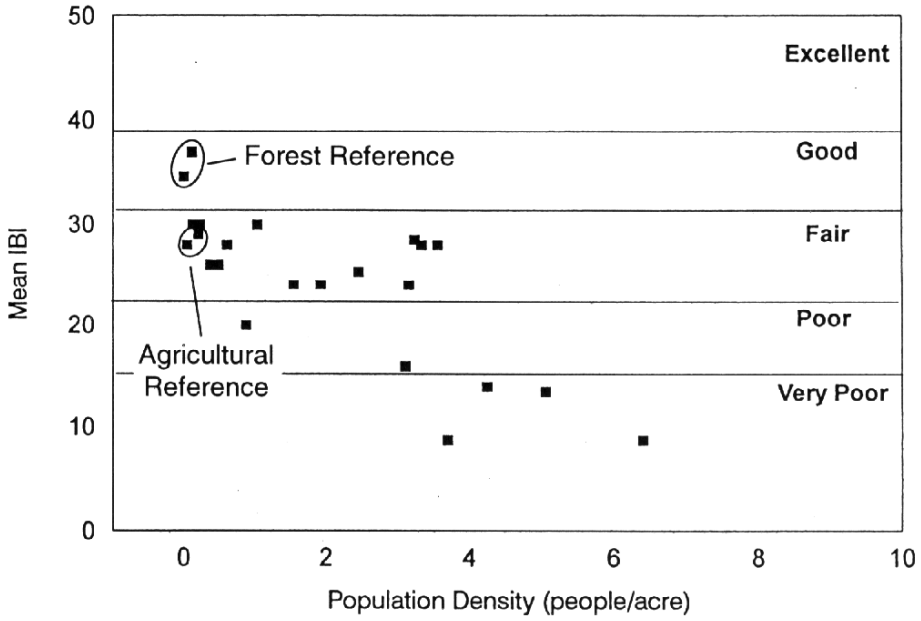

Figure 53: Relationship Between Watershed Population Density and Stream IBI Scores in Georgia Streams (DeVivo *et al.*, 1997)

fish-IBI scores occurred around 8% urban land use, primarily due to certain stressors which functioned to lower the non-attainment threshold. When watersheds smaller than 100mi^2 were analyzed separately, the percentage of urban land use associated with a sharp drop in fish-IBI scores was around 15%. In a later study, Yoder and Miltner (2000) described an upper threshold for quality warm-water fish habitat at 25 to 30% urban land use.

Watershed population and housing density have also been used as indicators of the health of the fish community. In a study of 21 urban watersheds in Atlanta, DeVivo *et al.* (1997) observed a shift in mean fish-IBI scores from "good to fair" to "very poor" when watershed population density exceeded four people/acre (Figure 53). A study of Midwest streams in metropolitan Illinois also found a negative relationship between increase in population density and fish communities, with significant impacts detected at population densities of 1.5 people or greater per acre (Dreher, 1997). In the Columbus and Cuyahoga watersheds in Ohio, Yoder *et al*. (1999) concluded that most streams failed to attain fish biocriteria above one dwelling unit/acre.

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5.5 Effects on Amphibian Diversity

Amphibians spend portions of their life cycle in aquatic systems and are frequently found within riparian, wetland or littoral areas. Relatively little research has been conducted to directly quantify the effects of watershed development on amphibian diversity. Intuitively, it would appear that the same stressors that affect fish and aquatic insects would also affect amphibian species, along with riparian wetland alteration. We located four research studies on the impacts of watershed urbanization on amphibian populations; only one was related to streams (Boward *et al.,* 1999), while others were related to wetlands (Table 53).

A primary factor influencing amphibian diversity appears to be water level fluctuations (WLF) in urban wetlands that occur as a result of increased stormwater discharges. Chin (1996) hypothesized that increased WLF and other hydrologic factors affected the abundance of egg clutches and available amphibian breeding habitat, thereby ultimately influencing amphibian richness. Increased WLF can limit reproductive success by eliminating mating habitat and the emergent vegetation to which amphibians attach their eggs.

Taylor (1993) examined the effect of watershed development on 19 freshwater wetlands in King County, WA and concluded that the additional stormwater contributed to greater annual WLF. When annual WLF exceeded about eight inches, the richness of both the wetland plant and amphibian communities dropped sharply. Large increases in WLF were consistently observed in freshwater wetlands when IC in upstream watersheds exceeded 10 to 15%. Further research on streams and wetlands in the Pacific northwest by Horner *et al.* (1997) demonstrated the correlation between watershed IC and diversity of amphibian species. Figure 54 illustrates the relationship between amphibian species abundance and watershed IC, as documented in the study.

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Table 53: Recent Research on the Relationship Between Percent Watershed Urbanization and the Amphibian Community

Indicator	Key Finding(s)	Reference Year	Location
% IC			
Reptile and Amphibian Abundance	In a three-year stream sampling across the state (approximately 1000 sites), MBSS found only hardy pollution-tolerant reptiles and amphibians in stream corridors with >25% IC drainage area.	Boward *et al.*, 1999	MD
Amphibian Density	Mean annual water fluctuation inversely correlated to amphibian density in urban wetlands. Declines noted beyond 10% IC.	Taylor, 1993	WA
Other Studies			
Species Richness	In 30 wetlands, species richness of reptiles and amphibians was significantly related to density of paved roads on lands within a two kilometer radius.	Findlay and Houlahan, 1997	Ontario
Species Richness	Decline in amphibian species richness as wetland WLF increased. While more of a continuous decline rather than a threshold, WLF = 22 centimeters may represent a tolerance boundary for amphibian community.	Horner *et al.*, 1997	WA
Amphibian Density	Mean annual water fluctuation inversely correlated to amphibian density in urban wetlands.	Taylor, 1993	WA

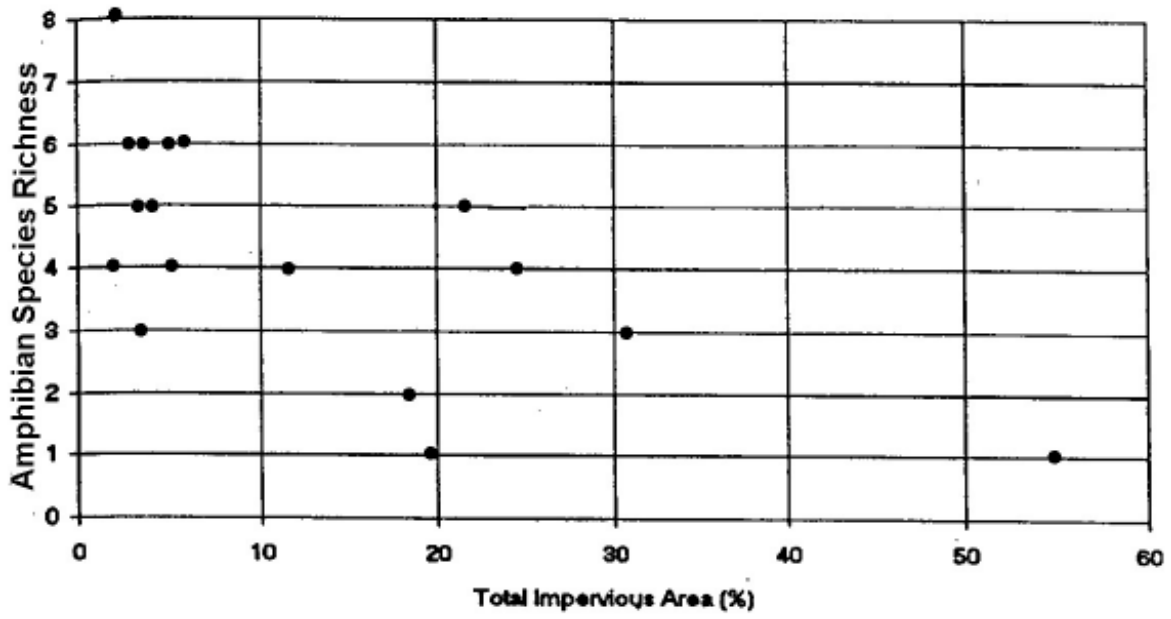

Figure 54: Amphibian Species Richness as a Function of Watershed IC in Puget Sound Lowland Wetlands (Horner *et al.*, 1997)

5.6 Effects on Wetland Diversity

We found a limited number of studies that evaluated the impact of watershed urbanization on wetland plant diversity (Table 54). Two studies used IC as an index of watershed development and observed reduced wetland plant diversity around or below 10% IC (Hicks and Larson, 1997 and Taylor, 1993). WLF and road density were also used as indicators (Findlay and Houlahan, 1997; Horner *et al.*, 1997; Taylor, 1993).

Horner *et al.* (1997) reported a decline in plant species richness in emergent and scrub-shrub wetland zones of the Puget Sound region as WLF increased. They cautioned that species numbers showed a continuous decline rather than a threshold value; however, it was indicated that WLF as small as 10 inches can represent a tolerance boundary for wetland plant communities. Horner further stated that in 90% of the cases where WLF exceeded 10 inches, watershed IC exceeded 21%.

Table 54: Recent Research Examining the Relationship Between Watershed Development and Urban Wetlands

Watershed Indicator Biotic	Key Finding(s)	Reference	Location
% IC			
Insect Community	Significant declines in various indicators of wetland aquatic macro-invertebrate community health were observed as IC increased to 8-9%.	Hicks and Larson, 1997	CT
WLF, Water Quality	There is a significant increase in WLF, conductivity, fecal coliform bacteria, and total phosphorus in urban wetland as IC exceeds 3.5%.	Taylor *et al.*, 1995	WA
Plant Density	Declines in urban wetland plant density noted in areas beyond 10% IC.	Taylor, 1993	WA
Other Watershed Indicators			
Plant Density	Mean annual water fluctuation inversely correlated to plant density in urban wetlands.	Taylor, 1993	WA
Plant Species Richness	Decline in plant species richness in emergent and scrub-shrub wetland zones as WLF increased. While more of a continuous decline, rather than a threshold, WLF=22 centimeters may represent a tolerance boundary for the community	Horner *et al.*, 1997	WA
Plant Species Richness	In 30 wetlands, species richness was significantly related to density of paved roads within a two kilometer radius of the wetland. Model predicted that a road density of 2kilometers per hectare in paved road within 1000 meters of wetland will lead to a 13% decrease in wetland plant species richness.	Findlay and Houlahan,1997	Ontario

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5.7 Effects on Freshwater Mussel Diversity

Freshwater mussels are excellent indicators of stream quality since they are filter-feeders and essentially immobile. The percentage of imperiled mussel species in freshwater ecoregions is high (Williams *et al.*, 1993). Of the 297 native mussel species in the United States, 72% are considered endangered, threatened, or of special concern, including 21 mussel species that are presumed to be extinct. Seventy mussel species (24%) are considered to have stable populations, although many of these have declined in abundance and distribution. Modification of aquatic habitats and sedimentation are the primary reasons cited for the decline of freshwater mussels (Williams *et al.,* 1993).

Freshwater mussels are very susceptible to smothering by sediment deposition. Consequently, increases in watershed development and sediment loading are suspected to be a factor leading to reduced mussel diversity. At sublethal levels, silt interferes with feeding and metabolism of mussels in general (Aldridge *et al.*, 1987). Major sources of mortality and loss of diversity in mussels include impoundment of rivers and streams, and eutrophication (Bauer, 1988). Changes in fish diversity and abundance due to dams and impoundments can also influence the availability of mussel hosts (Williams *et al.*, 1992).

Freshwater mussels are particularly sensitive to heavy metals and pesticides (Keller and Zam, 1991). Although the effects of metals and pesticides vary from one species to another, sub-lethal levels of PCBs, DDT, Malathion, Rotenone and other compounds are generally known to inhibit respiratory efficiency and accumulate in tissues (Watters, 1996). Mussels are more sensitive to pesticides than many other animals tested and often act as “first-alerts” to toxicity long before they are seen in other organisms.

We were unable to find any empirical studies relating impacts of IC on the freshwater mussel communities of streams.

5.8 Conclusion

The scientific record is quite strong with respect to the impact of watershed urbanization on the integrity and diversity of aquatic communities. We reviewed 35 studies that indicated that increased watershed development led to declines in aquatic insect diversity and about 30 studies showing a similar impact on fish diversity. The scientific literature generally shows that aquatic insect and freshwater fish diversity declines at fairly low levels of IC (10 to 15%), urban land use (33%), population density (1.5 to eight people/acre) and housing density (>1 du/ac). Many studies also suggest that sensitive elements of the aquatic community are affected at even lower levels of IC. Other impacts include loss of sensitive species and reduced abundance and spawning success. Research supports the ICM, although additional research is needed to establish the upper threshold at which watershed development aquatic biodiversity can be restored.

One area where more research is needed involves determining how regional and climatic variations affect aquatic diversity in the ICM. Generally, it appears that the 10% IC threshold applies to streams in the East Coast and Midwest, with Pacific Northwest streams showing impacts at a slightly higher level. For streams in the arid and semi-arid Southwest, it is unclear what, if any, IC threshold exists given the naturally stressful conditions for these intermittent and ephemeral streams (Maxted, 1999). Southwestern streams are characterized by seasonal bursts of short but intense rainfall and tend to have aquatic communities that are trophically simple and relatively low in species richness (Poff and Ward, 1989).

Overall, the following conclusions can be drawn:

- IC is the most commonly used index to assess the impacts of watershed urbanization on aquatic insect and fish diversity. Percent urban land use is also a common index.

- The ICM may not be sensitive enough to predict biological diversity in watersheds with low IC. For example, below 10% watershed IC, other watershed variables such as riparian continuity, natural forest cover, cropland, ditching and acid rain may be better for predicting stream health.

- More research needs to be done to determine the maximum level of watershed development at which stream diversity can be restored or maintained. Additionally, the capacity of stormwater treatment practices and stream buffers to mitigate high levels of watershed IC warrants more systematic research.

- More research is needed to test the ICM on amphibian and freshwater mussel diversity.

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Glossary

1st order stream: The smallest perennial stream. A stream that carries water throughout the year and does not have permanently flowing tributaries.

2nd order stream: Stream formed by the confluence of two 1st order streams.

3rd order stream: Stream formed by the confluence of two 2nd order streams.

Acute toxicity: Designates exposure to a dangerous substance or chemical with sufficient dosage to precipitate a severe reaction, such as death.

Alluvial: Pertaining to processes or materials associated with transportation or deposition by running water.

Anadromous: Organisms that spawn in freshwater streams but live most of their lives in the ocean.

Annual Pollutant Load: The total mass of a pollutant delivered to a receiving water body in a year.

Bankfull: The condition where streamflow just fills a stream channel up to the top of the bank and at a point where the water begins to overflow onto a floodplain.

Baseflow: Stream discharge derived from ground water that supports flow in dry weather.

Bedload: Material that moves along the stream bottom surface, as opposed to suspended particles.

Benthic Community: Community of organisms living in or on bottom substrates in aquatic habitats, such as streams.

Biological Indicators: A living organism that denotes the presence of a specific environmental condition.

Biological Oxygen Demand (BOD): An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by bacterial processes breaking down organic waste.

Carcinogen: A cancer-causing substance or agent.

Catchment: The smallest watershed management unit. Defined as the area of a development site to its first intersection with a stream, usually as a pipe or open channel outfall.

Chemical Oxygen Demand (COD): A chemical measure of the amount of organic substances in water or wastewater. Non-biodegradable and slowly degrading compounds that are not detected by BOD are included.

Chronic Toxicity: Showing effects only over a long period of time.

Combined Sewer Overflow (CSO): Excess flow (combined wastewater and stormwater runoff) discharged to a receiving water body from a combined sewer network when the capacity of the sewer network and/or treatment plant is exceeded, typically during storm events.

Combined Indices (C-IBI or CSPS): Combined indices that use both fish and aquatic insect metrics and a variety of specific habitat scores to classify streams.

Cryptosporidium parvum: A parasite often found in the intestines of livestock which contaminates water when animal feces interacts with a water source.

Deicer: A compound, such as ethylene glycol, used to melt or prevent the formation of ice.

Dissolved Metals: The amount of trace metals dissolved in water.

Dissolved Phosphorus: The amount of phosphorus dissolved in water.

Diversity: A numerical expression of the evenness and distribution of organisms.

Ecoregion: A continuous geographic area over which the climate is uniform to permit the development of similar ecosystems on sites with similar geophysical properties.

Embeddedness: Packing of pebbles or cobbles with fine-grained silts and clays.

EPT Index: A count of the number of families of each of the three generally pollution-sensitive orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Escherichia coli (E. coli): A bacteria that inhabits the intestinal tract of humans and other warm-blooded animals. Although it poses no threat to human health, its presence in drinking water does indicate the presence of other, more dangerous bacteria.

Eutrophication: The process of over-enrichment of water bodies by nutrients, often typified by the presence of algal blooms.

Fecal coliform: Applied to E. coli and similar bacteria that are found in the intestinal tract of humans and animals. Coliform bacteria are commonly used as indicators of the presence of pathogenic organisms. Their presence in water indicates fecal pollution and potential contamination by pathogens.

Fecal streptococci: Bacteria found in the intestine of warm-blooded animals. Their presence in water is considered to verify fecal pollution.

Fish Blockages: Infrastructures associated with urbanization, such as bridges, dams, and culverts, that affect the ability of fish to move freely upstream and downstream in watersheds. Can prevent re-colonization of resident fish and block the migration of anadromous fish.

Flashiness: Percent of flows exceeding the mean flow for the year. A flashy hydrograph would have larger, shorter-duration hydrograph peaks.

Geomorphic: The general characteristic of a land surface and the changes that take place in the evolution of land forms.

Giardia lamblia: A flagellate protozoan that causes severe gastrointestinal illness when it contaminates drinking water.

Herbicide: Chemicals developed to control or eradicate plants.

Hotspot: Area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydrograph: A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

Illicit discharge: Any discharge to a municipal separate storm sewer system that is not composed entirely of storm water, except for discharges allowed under an NPDES permit.

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Impervious Cover: Any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall.

Impervious Cover Model (ICM): A general watershed planning model that uses percent watershed impervious cover to predict various stream quality indicators. It predicts expected stream quality declines when watershed IC exceeds 10% and severe degradation beyond 25% IC.

Incision: Stream down-cuts and the channel expands in the vertical direction.

Index of Biological Integrity (IBI): Tool for assessing the effects of runoff on the quality of the aquatic ecosystem by comparing the condition of multiple groups of organisms or taxa against the levels expected in a healthy stream.

Infiltration: The downward movement of water from the surface to the subsoil. The infiltration capacity is expressed in terms of inches per hour.

Insecticide: Chemicals developed to control or eradicate insects.

Large Woody Debris (LWD): Fundamental to stream habitat structure. Can form dams and pools; trap sediment and detritus; provide stabilization to stream channels; dissipate flow energy and promote habitat complexity.

Mannings N: A commonly used roughness coefficient; actor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water.

Methyl Tertiary-Butyl Ether: An oxygenate and gasoline additive used to improve the efficiency of combustion engines in order to enhance air quality and meet air pollution standards. MTBE has been found to mix and move more easily in water than many other fuel components, thereby making it harder to control, particularly once it has entered surface or ground waters.

Microbe: Short for microorganism. Small organisms that can be seen only with the aid of a microscope. Most frequently used to refer to bacteria. Microbes are important in the degradation and decomposition of organic materials.

Nitrate: A chemical compound having the formula NO_3. Excess nitrate in surface waters can lead to excessive growth of aquatic plants.

Organic Matter: Plant and animal residues, or substances made by living organisms. All are based upon carbon compounds.

Organic Nitrogen: Nitrogen that is bound to carbon-containing compounds. This form of nitrogen must be subjected to mineralization or decomposition before it can be used by the plant community.

Overbank Flow: Water flow over the top of the bankfull channel and onto the floodplain.

Oxygenate: To treat, combine, or infuse with oxygen.

Peak Discharge: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Pesticides: Any chemical agent used to control specific organisms, for example, insecticides, herbicides, fungicides and rodenticides.

Piedmont: Any plain, zone or feature located at the foot of a mountain. In the United States, the Piedmont (region) is a plateau extending from New Jersey to Alabama and lying east of the Appalachian Mountains.

Pool: A stream feature where there is a region of deeper, slow-moving water with fine bottom materials. Pools are the slowest and least turbulent of the riffle/run/pool category.

Protozoan: Any of a group of single-celled organisms.

Rapid Bioassessment Protocols (RBP): An integrated assessment, comparing habitat, water quality and biological measures with empirically defined reference conditions.

Receiving Waters: Rivers, lakes, oceans, or other bodies of water that receive water from another source.

Riffle: Shallow rocky banks in streams where water flows over and around rocks disturbing the water surface; often associated with whitewater. Riffles often support diverse biological communities due to their habitat niches and increased oxygen levels created by the water disturbance. Riffles are the most swift and turbulent in the riffle/run/pool category.

Roughness: A measurement of the resistance that streambed materials, vegetation, and other physical components contribute to the flow of water in the stream channel and flood-plain. It is commonly measured as the Manning's roughness coefficient (Manning's N).

Run: Stream feature characterized by water flow that is moderately swift flow, yet not particularly turbulent. Runs are considered intermediate in the riffle/run/pool category.

Runoff Coefficient: A value derived from a site impervious cover value that is applied to a given rainfall volume to yield a corresponding runoff volume.

Salmonid: Belonging to the family Salmonidae, which includes trout and salmon.

Sanitary Sewer Overflow (SSO): Excess flow of wastewater (sewage) discharged to a receiving water body when the capacity of the sewer network and/or treatment plant is exceeded, typically during storm events.

Semi-arid: Characterized by a small amount of annual precipitation, generally between 10 and 20 inches.

Simple Method: Technique used to estimate pollutant loads based on the amount of IC found in a catchment or subwatershed.

Sinuosity: A measure of channel curvature, usually quantified as the ratio of the length of the channel to the length of a straight line along the valley axis. It is, in essence, a ratio of the stream's actual running length to its down-gradient length.

Soluble Phosphorus: The amount of phosphorus available for uptake by plants and animals.

Stormwater: The water produced as a result of a storm.

Subwatershed: A smaller geographic section of a larger watershed unit with a drainage area of between two to 15 square miles and whose boundaries include all the land area draining to a point where two 2nd order streams combine to form a 3rd order stream.

Total Dissolved Solids (TDS): A measure of the amount of material dissolved in water (mostly inorganic salts).

Total Kjeldhal Nitrogen (TKN): The total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.

Total Recoverable Metals: The amount of a metal that is in solution after a representative suspended sediment sample has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances).

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Total Maximum Daily Load (TMDL): The maximum quantity of a particular water pollutant that can be discharged into a body of water without violating a water quality standard.

Total Nitrogen (Total N): A measure of the total amount of nitrate, nitrite and ammonia concentrations in a body of water.

Total Organic Carbon (TOC): A measure of the amount of organic material suspended or dissolved in water.

Total Phosphorous (Total P): A measure of the concentration of phosphorus contained in a body of water.

Total Suspended Solids (TSS): The total amount of particulate matter suspended in the water column.

Trophic Level: The position of an organism in a food chain or food pyramid.

Turbidity: A measure of the reduced transparency of water due to suspended material which carries water quality and aesthetic implications. Applied to waters containing suspended matter that interferes with the passage of light through the water or in which visual depth is restricted.

Volatile Organic Compounds (VOC): Chemical compounds which are easily transported into air and water. Most are industrial chemicals and solvents. Due to their low water solubility they are commonly found in soil and water.

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CHAPTER 2

The Causes of Urban Stormwater Pollution

Runoff pollution occurs every time rain or snowmelt flows across the ground and picks up contaminants. It occurs on farms or other agricultural sites, where the water carries away fertilizers, pesticides, and sediment from cropland or pastureland. It occurs during forestry operations (particularly along timber roads), where the water carries away sediment, and the nutrients and other materials associated with that sediment, from land which no longer has enough living vegetation to hold soil in place.

This report, however, focuses on runoff pollution from developed areas, which occurs when stormwater carries away a wide variety of contaminants as it runs across rooftops, roads, parking lots, baseball diamonds, construction sites, golf courses, lawns, and other surfaces in our cities and suburbs. The oily sheen on rainwater in roadside gutters is but one common example of urban runoff pollution.

This chapter discusses some of the causes of stormwater runoff and pollution, which are important to understand before adopting management strategies.

The United States Environmental Protection Agency (EPA) now considers pollution from all diffuse sources, including urban stormwater pollution, to be the most important source of contamination in our nation's waters.[1] While polluted runoff from agricultural sources may be an even more important source of water pollution than urban runoff, urban runoff is still a critical source of contamination, particularly for waters near cities—and thus near most people. EPA ranks urban runoff and storm-sewer discharges as the second most prevalent source of water quality impairment in our nation's estuaries, and the fourth most prevalent source of impairment of our lakes.[2] Most of the U.S. population lives in urban and coastal areas where the water resources are highly vulnerable to and are often severely degraded by urban runoff.



Diane Cameron

Pollutants including oil and grease from cars that collect on street and parking lots during dry weather run off when it rains.

Urban stormwater continues to impair the nation's waterways, 27 years after passage in 1972 of the law now known as the Clean Water Act. The main reason why urban stormwater remains

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Over the past 27 years, water pollution control efforts have focused primarily on water discharges from facilities such as factories and sewage treatment plants. New efforts are needed to address the remaining sources of water pollution, including urban runoff.

such an important contributor to water pollution is the fact that in most areas, stormwater receives no treatment before entering waterbodies. The storm-sewer system merely collects the urban runoff and discharges it directly to the nearest river, lake, or bay.

Over the past 27 years, water pollution control efforts have focused primarily on certain process water discharges from facilities such as factories and sewage treatment plants, with less emphasis on diffuse sources. While these efforts have led to many water quality improvements, new efforts are now needed to address the remaining sources of water pollution, including urban runoff pollution.

Comprehensive stormwater regulation has been slow to develop (see box: "History of Stormwater Regulation in the United States"). Since 1992, cities with a population over 100,000, certain industries, and construction sites over 5 acres have had to develop and implement stormwater plans under Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater regulations. To date, states and the EPA have issued more than 260 permits affecting some 850 operators, including larger cities operating separate storm sewer systems, which requires them to develop stormwater management plans. A number of stormwater discharges from industrial activities are also subject to NPDES stormwater permit requirements.

In October 1999, EPA is expected to promulgate a rule requiring smaller municipalities, those with populations of fewer than 100,000 people located in urbanized areas (where population density is greater than 1,000 persons per square mile) to develop stormwater plans. Municipalities not in urbanized areas that have more than 10,000 residents and a population density greater than 1,000 persons per square mile will also have to develop stormwater plans if the state so designates. Under this so-called "Phase II" rule, the EPA and states will develop "tool boxes" from which the smaller local governments can choose particular stormwater strategies, including the strategies presented in this report, to develop their stormwater plans.

Stormwater must be distinguished from other urban sources of pollution largely caused by wet weather since each separate source is regulated differently. In addition to stormwater runoff, which is the focus of this study, there are two other significant sources of urban wet weather pollution: sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs). SSOs occur when sanitary sewers, often because of leaks and cracks, become surcharged in wet weather and overflow, often through manholes or into basements. CSOs occur when flows into combined sewer system (systems that receive stormwater, sanitary sewer discharges from residences and businesses, and wastewater discharges from industrial facilities and transport it all through a single pipe) exceed the treatment and storage capacity of the sewer system and waste treatment facility. At that point, this combined waste stream overflows into creeks, rivers, lakes or estuaries through designated outfalls usually without treatment. CSOs and SSOs are more of a problem with older systems while stormwater is an issue for all metropolitan areas, especially growing areas. Moreover, while prevention programs can be very important to efforts to reduce CSOs and SSOs, structural changes are usually necessary. By contrast, much stormwater pollution can be *prevented* with proper planning in growing or redevelopment areas.

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History of Stormwater Regulation in the United States

The history of stormwater regulation began over 25 years ago. It has been in and out of the courts, Congress, EPA and is now in the hands of states and local governments.

1972: EPA issues exemptions from the federal Clean Water Act NPDES permit program for most sources of stormwater. NRDC sues EPA to require permits for all point sources, including urban storm sewers (applications by 1973 and permits by 1974).

1975–1977: The U.S. District Court finds that EPA exemptions are contrary to the Clean Water Act (*NRDC v. Train*).[a] This decision is upheld by U.S. Court of Appeals in 1977 (*NRDC v. Costle*).[b]

1980: EPA issues rules responding to the court's decision that exempt cities outside "urbanized areas from needing NPDES permits for their storm sewers." NRDC and industry sue EPA over the rules (*NRDC v. EPA*).[c]

1980–1990: During this period, EPA struggled with developing stormwater rules, and extends the stormwater permit deadlines for large cities until 1987 and 1989. EPA also issues "nonenforcement letters" informing cities that EPA would not take enforcement actions against cities with permit applications and proposes narrowing the definition of stormwater discharges. In 1983, EPA issues a final report on the Nationwide Urban Runoff Program. In 1984, NRDC and the states negotiated with EPA to reject narrowing coverage and revoke letters.

1987: In Clean Water Act amendments, Congress requires EPA to issue by 1989 "Phase I" rules addressing stormwater from cities with a population over 100,000 and from industrial sites, and to issue by 1992 "Phase II" rules for other significant sources of stormwater pollution.

1990: EPA promulgates "Phase I" NPDES stormwater regulations and extends compliance beyond those dates in the 1987 law. NRDC sues EPA for illegally extending deadlines and excluding certain sources from regulations (*NRDC v. EPA*).[d]

1992: A U.S. Court of Appeals ruling prohibits further stormwater deadline extensions (*NRDC v. EPA*)[e] and invalidates certain provisions of the Phase I rule. EPA and the states issued initial general permits for stormwater discharges.

1992: Congress provides an additional extension to small cities for stormwater permit applications.

1995: EPA is sued for its failure to conduct study, file report, and issue regulations concerning Phase II stormwater pollutant sources (*NRDC v. Browner*).[f] EPA issues Report to Congress on "Storm Water Discharges Potentially Addressed by Phase II of the NPDES Storm Water Program." NRDC and EPA enter into consent decree requiring EPA to issue a final rule by March 1999 (later extended to October 1999) addressing both Phase II stormwater and Phase I issues remanded by the court. In 1996, EPA convenes a federal advisory committee.

1997: EPA issues draft Phase II stormwater rules.

[a] 396 F.Supp. 1393 (D.D.C. 1975), *aff'd* by *NRDC v. Costle*, 568 F.2d 1369 (D.C. Cir. 1972).
[b] 568 F.2d 1369 (D.C. Cir. 1972).
[c] 673 F.2d 392 (D.C. Cir. 1980) (per curiam).
[d] 915 F.2d 1314 (9th Cir. 1990).
[e] 966 F.2d 1292 (9th Cir. 1992).
[f] No. 95-634 PLF (D.D.C.) (consent order signed April 6, 1995).

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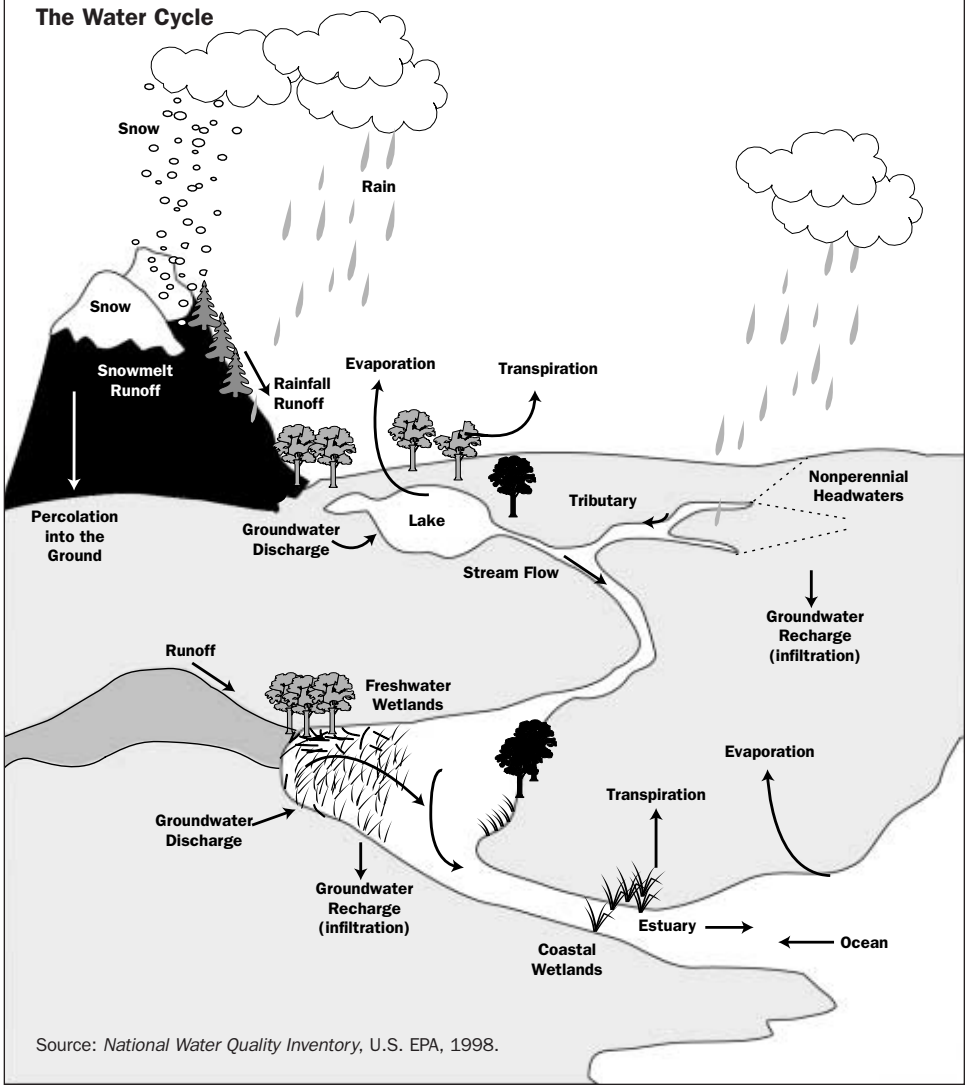
Remarkably, studies have shown that stormwater alone can be almost as contaminated as these sewage/stormwater mixtures.[3] Yet stormwater runoff remains to be regulated in most of the nation's populated areas. While many CSO and SSO control measures may overlap with stormwater pollution control measures, strategies that deal with stormwater specifically must be implemented if the quality of America's waterbodies is to improve. These strategies are the focus of this report.

THE WATER CYCLE

To fully understand the stormwater pollution problem, it is helpful to step back and review the water cycle, also known as the hydrologic cycle. The water cycle is simply the constant movement of water from the sky to the ground and back again. The main components of the water cycle are precipitation, infiltration, evapotranspiration

FIGURE 2-1
The Water Cycle



Source: *National Water Quality Inventory*, U.S. EPA, 1998.

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(evaporation and transpiration, the process by which plants release water they have absorbed into the atmosphere), surface and channel storage, and groundwater storage. As part of that cycle, when rainwater falls to the ground, or when snow or hail on the ground melt, that water may take several paths, as illustrated in Figure 2-1.

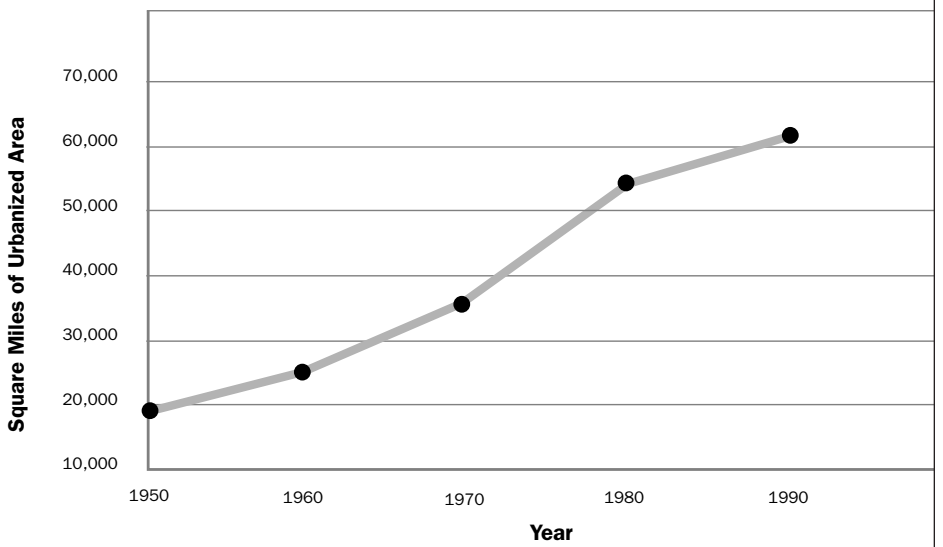
While the magnitude of these effects varies across the country depending on the precipitation patterns, soil types and other factors, the underlying principles remain the same.[4] In a typical Midwestern undeveloped area, for example, with natural ground cover such as forests or meadows, a large fraction—perhaps 50 percent—of the water infiltrates the soil. Much of this water may remain near the surface from which it often resurfaces into lakes or streams. Other infiltrated water descends to a deeper level, perhaps recharging an underground aquifer used for drinking water. A significant share—40 percent in this example—of the water returns to the atmosphere through evapotranspiration. Only a small amount of the water—the remaining 10 percent, in this example—typically remains on the surface of undeveloped land to run off into streams and other waterbodies.

Urbanization can dramatically alter this water cycle, increasing runoff and reducing, at times to almost zero, infiltration. This can completely alter the physical and chemical character of the receiving waterbody.

THE CAUSES OF STORMWATER POLLUTION

The stormwater pollution problem has two main components: the increased volume and velocity of surface runoff and the concentration of pollutants in the runoff. Both components are directly related to development in urban and urbanizing areas.

FIGURE 2-2
Growth of Urbanized Areas, United States



Source: Bureau of the Census, U.S. Department of Commerce.

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Table 2-1
Impacts from Increases in Impervious Surfaces

Increased Imperviousness Leads to:	RESULTING IMPACTS				
	Flooding	Habitat Loss (e.g., inadequate substrate, loss of riparian areas, etc.)	Erosion	Channel Widening	Streambed Alteration
Increased Volume	•	•	•	•	•
Increased Peak Flow	•	•	•	•	•
Increased Peak Flow Duration	•	•	•	•	•
Increased Stream Temperature		•			
Decreased Base Flow		•			
Changes in Sediment Loadings	•	•	•	•	•

Source: *Urbanization of Streams: Studies of Hydrologic Impacts*, EPA 841-R-97-009, 1997.

Together, these components cause changes in hydrology and water quality that result in a variety of problems including habitat loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion, as well as affects on our health, economy, and social well-being. These consequences will be discussed in Chapter 3; the following is a discussion of the sources of these problems.

Increased Volume and Velocity: The Impervious Cover Factor

Types of impervious cover. Some impervious cover, such as exposed rock or hardpan soil, is natural. Land development, however, greatly increases it. Human-made impervious cover comes in three varieties: rooftop imperviousness from buildings and other structures; transport imperviousness from roadways, parking lots, and other transportation-related facilities; and impaired pervious surfaces, also known as urban soils, which are natural surfaces that become compacted or otherwise altered and less pervious through human action. Examples of the hard soils include the base paths on a baseball diamond or a typical suburban lawn.

Transport imperviousness generally exceeds rooftop imperviousness in urban areas of the United States.[5] "Cumulative figures show that, worldwide, at least one third of all developed urban land is devoted to roads, parking lots, and other motor vehicle infrastructure. In the urban United States, the automobile consumes close to half the land area of cities; in Los Angeles the figure approaches two thirds."[6] The city of Olympia, Washington, also found that transport imperviousness constituted approximately two-thirds of total imperviousness in several residential and commercial areas.[7] This distinction is important because rainfall on transportation surfaces drains directly to a stream or stormwater collection system that discharges to a waterbody usually without treatment, whereas some roofs drain into seepage pits or other infiltration devices. Research has also found a strong relationship between curb density and overall imperviousness in residential areas suggesting that roads lead to the creation of other impervious surfaces.[8]

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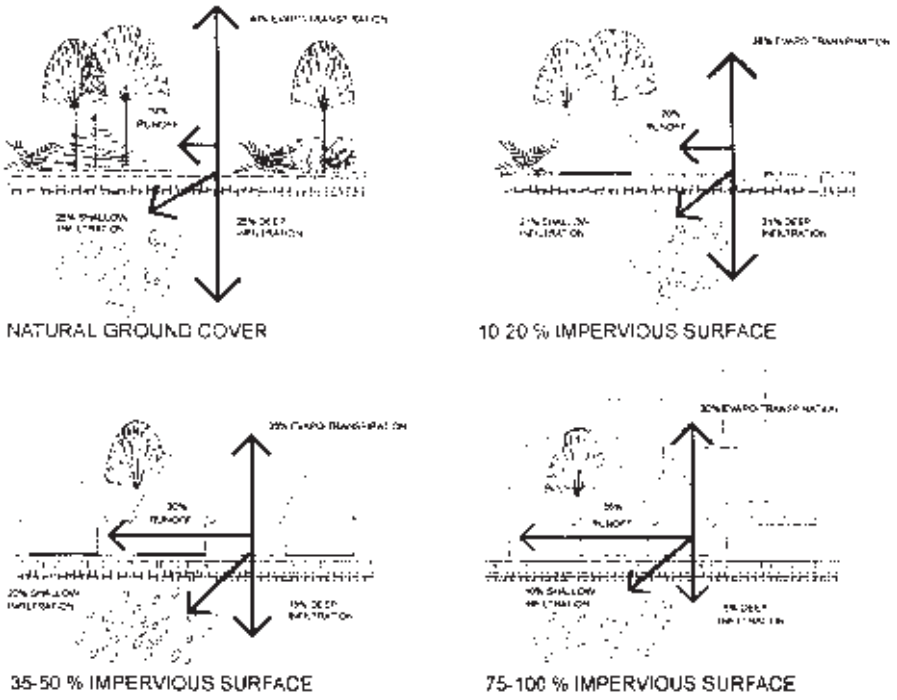
FIGURE 2-3
Water Cycle Changes Associated with Urbanization



Source: Environmental Protection Agency, *Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters*, #840-B-92-002, 1993.

The creation of additional impervious cover also reduces vegetation, which magnifies the effect of the reduced infiltration. Trees, shrubs, meadows, and wetlands, like most soil, intercept and store significant amounts of precipitation. Vegetation is also important in reducing the erosional forces of rain and runoff. In one study, conversion of forest to impervious cover resulted in an estimated 29 percent increase in runoff during a peak storm event.[9]

Imperviousness thresholds. Research has shown that when impervious cover reaches between 10 and 20 percent of the area of a watershed, ecological stress becomes clearly apparent.[10] After this point, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases. Figure 2-3 shows that as the amount of impervious surface in a watershed increases infiltration and evapotranspiration both drop substantially. As a result, more water, having nowhere else to go, runs off the surface picking up pollutants from activities occurring on the impervious surfaces.

To put these numbers into perspective, typical total imperviousness in medium-density, single-family home residential areas ranges from 25 percent to nearly 60 percent.[11] Total imperviousness at strip malls or other commercial sites can approach 100 percent.

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Center for Watershed Protection

Parking lots and roads increase the volume and velocity of runoff.

Increased volume of runoff. The effect of impervious surfaces on the volume of stormwater runoff can be dramatic. For example, a 1-inch rainstorm on a 1-acre natural meadow would typically produce 218 cubic feet of runoff, enough to fill a standard size office to a depth of about 2 feet. The same storm over a 1-acre paved parking lot would produce 3,450 cubic feet of runoff, nearly 16 times more than the natural meadow, and enough to fill three standard size offices completely.[12]

On a larger scale, the effect is even greater. In a 620-square-mile portion of the watershed of the Des Plaines River in Illinois, in 1886, when agricultural or urban development covered 10 percent of the land area, the river's median annual discharge was 4 cubic feet per second. Today, when development covers approximately 70 to 80 percent of that same area, the median annual discharge has been 700 to 800 cubic feet per second, 175 to 200 times the earlier discharge level.[13]

Greater stream and runoff velocity during storm events. Impervious surfaces increase the speed of runoff as it drains off the land. Unlike grassy meadows or forests, hard, impervious cover, such as parking lots and rooftops, offers little resistance to water flowing downhill, allowing it to travel faster across these surfaces.[14] In addition, the faster rate of runoff delivers more water in a shorter time to receiving waters than would occur under natural conditions. The increased velocity and delivery rate greatly magnifies the erosive power of water as it flows across the land surface and once it enters a stream.

Increased peak discharges. Increased imperviousness not only changes the volume of stormwater flows, but also the distribution of flows over time. When land is undeveloped, the initial stormwater flow following a rain event is relatively small, since the land absorbs and infiltrates much of the water. However, impervious cover forces rainwater or snowmelt to run off the land immediately, causing a sharp peak in runoff immediately following the rain event, as illustrated in Figure 1-5. Impervious cover can double, triple, quadruple or even quintuple peak discharge.[15] Streams receiving these increased urban peak flows are described as "flashy," meaning that they are prone to sporadic and unstable discharges including flash floods or sudden high pulses of storm flows. An increase in peak flow can have significant impacts on the human and natural environment. Greater peak flows lead to increased flooding, channel erosion and widening, sediment deposition, bank cutting, and general habitat loss as discussed in Chapter 3.

Reduced stream base flow. Because impervious cover reduces infiltration and forces stormwater to run off the land immediately, it also typically reduces the amount of

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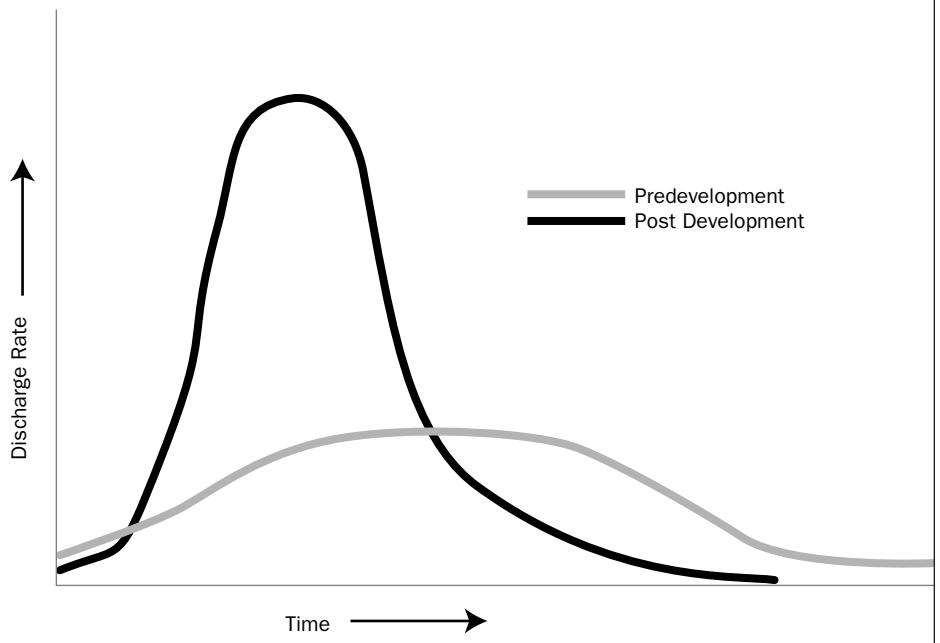
FIGURE 2-4
Pre- and Postdevelopment Hydraulics



Source: *Urban Runoff Pollution Prevention and Control Planning*, EPA 625-R-93-004, 1993, p. 4.

groundwater available to recharge streams when there is no rain.[16] Hydrologists often refer to groundwater zones under urban areas as "starved" since they are not replenished. This groundwater-charged stream flow, known as base flow, can fall to 10 percent of the regional average when the level of imperviousness in the stream watershed reaches 65 percent.[17] Prolonged low flow can have a significant impact on aquatic life and, in some cases, a greater impact than extreme peak flows.[18] Reduced infiltration can also lead to shortages of drinking water supplies.

Decreased natural stormwater purification functions. Government flood control agencies often replace the beds of creeks, streams, and other drainage ways with concrete open channels, or completely replace those drainage ways with subsurface concrete storm drain lines. These changes degrade or eliminate habitat and dramatically alter hydrology. Channelizing, diking, and levying disconnects a river from its floodplain and reduces its ability to modify floods naturally. Similarly, this and other development fills, converts, or otherwise eliminates swamps, marshes and other wetlands. Eliminating these natural drainage ways reduces flow storage and detention and soil moisture maintenance and can increase overall flooding and erosion. In addition, natural streambeds and floodplains provide a hydrologic link between groundwater and surface water and can naturally clean waters. By capturing and slowing stormwater, these areas trap sediment, trace metals, and soluble forms of nutrients.[19] Studies have shown that wetlands can retain up to 100 percent of the metals present in water.[20] Wetlands reduce

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Nicole Dupaix/OmniPhoto Communication (research and representation)

Preserving natural features such as wetlands, floodplains, and forested headwater streams helps prevent stormwater impacts.

nitrogen discharges, both through the process of bacterial denitrification and through plant uptake, but less effectively reduce phosphorous when soils are saturated.

Similarly, other natural areas can reduce pollutant loads. One riparian forest in the Chesapeake Bay region removed 89 percent of the nitrogen and 80 percent of the phosphorus from runoff.[21] Forests also typically absorb 70 to 80 percent of atmospherically deposited nitrogen.[22] Trees and other plants stabilize the soil, giving it structure that prevents erosion, and reduce runoff by intercepting and storing precipitation. When rapid stormwater flows have already created erosion on bare soils, plants on downhill slopes slow those flows and allow sediment, as well as other pollutants, to settle onto the land rather than in a waterbody.

However, use of wetlands, streams, and other natural systems is not desirable unless stormwater is delivered at a rate at which pollutants can be assimilated. Natural wetlands, while playing an important role in managing the quality and quantity of runoff, should not be viewed as a sink for polluted runoff. While wetlands help remove pollutants from runoff, some pollutants can accumulate in wetlands or be converted to more potent forms, thereby degrading the natural ecosystem functions and values of these systems and impact the organisms living there.[23] Furthermore, the US EPA recommends protection for any wetland or riparian area which removes pollutants from runoff to coastal waters.[24] Therefore, use of these systems for stormwater management should be carefully considered, realizing that these systems need quality water delivered at an appropriate rate to function properly.

Increased Deposition of Pollutants

The second aspect of urbanization that contributes to urban stormwater pollution is the increased discharge of pollutants. As human activity increases in a given area, the amount of waste material deposited on the land and in drainage systems increases. The principal contaminants of concern for stormwater fall into seven categories. The following table lists these categories and provides examples.

While all activities can be a source of some contaminants, certain activities are particularly large contributors. Industrial sites can be major sources of metals and organic chemicals. Feedlots are a large source of pathogens, nutrients, and BOD. Agricultural and timber operations discharge high quantities of sediment. This report focuses on those activities in urbanized and urbanizing areas, practices of homeowners, businesses, and government agencies that also contribute many of these contaminants.

Vehicle use. Driving a car or truck contributes a number of different types of pollutants to urban runoff. Pollutants are derived from automotive fluids, deterioration of parts, and vehicle exhaust. Once these pollutants are deposited onto road

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TABLE 2-2
Categories of Principal Contaminants in Stormwater

Category	Examples
Metals	zinc, cadmium, copper, chromium, arsenic, lead
Organic chemicals	pesticides, oil, gasoline, grease
Pathogens	viruses, bacteria, protozoa
Nutrients	nitrogen, phosphorus
Biochemical oxygen demand (BOD)	grass clippings, fallen leaves, hydrocarbons, human, and animal waste
Sediment	sand, soil, and silt
Salts	sodium chloride, calcium chloride

and parking surfaces, they are available for transport in runoff to receiving waters during storm events. One landmark study estimated that cars and other vehicles contributed 75 percent of the total copper load to the lower San Francisco Bay through runoff.[25] Brake pad wear contributed 50 percent of the total load, and 25 percent came from atmospheric deposition—the eventual settling of metals from tailpipe emissions onto the ground. Other car- and truck-related sources of metals include tire wear, used motor oil and grease, diesel oil, and vehicle rust.[26] Tire ware is a substantial source of cadmium and zinc; concentrations at outfalls often exceed acute toxicity levels. Engine coolants and antifreeze containing ethylene glycol and propylene glycol can be toxic and contribute high BOD to receiving waters.

Vehicle exhaust contributes the nutrient nitrogen to our nation's waters. Studies estimate that deposition of nitrogen from power plant and vehicle exhaust contributes 17 pounds per year of nitrogen and 0.7 pounds per year of phosphorus to a typical acre of land in the metropolitan Washington, DC, area.[27] In general, fossil fuel

TABLE 2-3
Sources of Heavy Metals from Transportation

Source	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Gasoline	•			•				•	•
Exhaust							•	•	
Motor Oil & Grease		•			•		•	•	•
Antifreeze					•				•
Undercoating								•	•
Brake Linings				•	•		•	•	•
Rubber	•			•				•	•
Asphalt				•			•		•
Concrete				•			•		•
Diesel Oil	•								
Engine Wear					•	•	•	•	•

Source: *Local Ordinances: A Users Guide*, Terrene Institute and EPA, Region 5, 1995.

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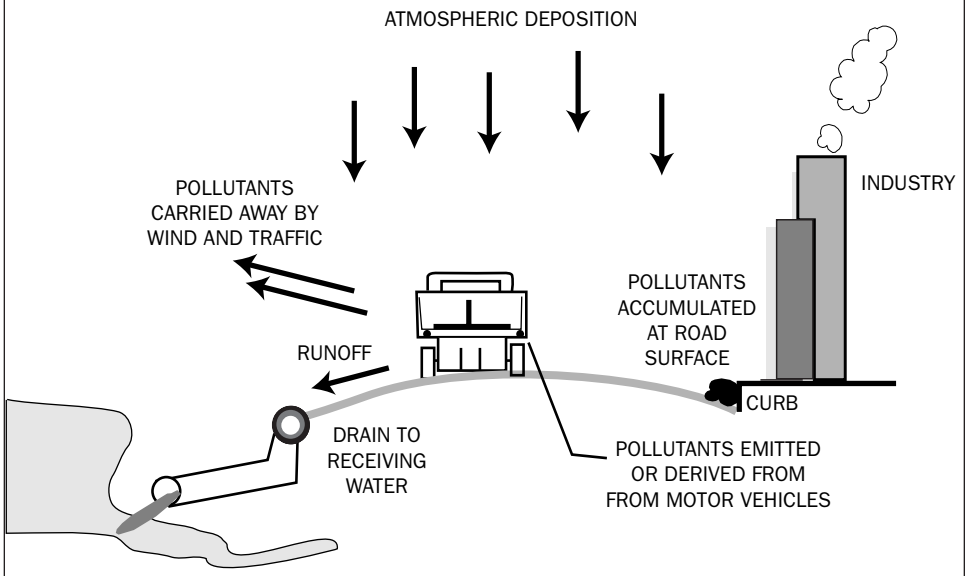
FIGURE 2-5
Pollutant Accumulation on Impervious Street and Highway Surfaces



Source: Based on Novotny and Olem, *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*, 1994.

combustion is the largest contributor of nitrogen to the waters of the northeastern United States, and is a very large contributor elsewhere.[28]

Oil, grease, and other hydrocarbons related to vehicle use and maintenance also contaminate our waters. These come from disposal of used oil and other fluids on the ground or into storm drains, spills of gasoline or oil, and leaks from transmissions or other parts of automobiles and trucks. The stormwater discharge from one square mile of roads and parking lots can yield approximately 20,000 gallons of residual oil per year.[29] Runoff from residential car washing also contributes oil, grease, grit, and detergents to the stormwater system. Even gas vapor emitted when filling tanks can subsequently mix with rain, contributing significantly to polluted runoff.[30]

Roads and parking lots. In many communities, most impervious cover is related to the transportation system.[31] Material accumulates on these surfaces during dry weather conditions, only to form a highly concentrated first flush during storm events. One study found streets to be the impervious surface with the highest pollutant loads in most land use categories.[32] Another found that transportation related land uses have the second highest level of pollutant concentrations; only piped industrial sources were higher.[33]

Home landscaping and public grounds maintenance. Landscaping practices are another potential source of pollutants in urban runoff. Turf management chemicals including fertilizers used at home and on golf courses, cemeteries, and public parks

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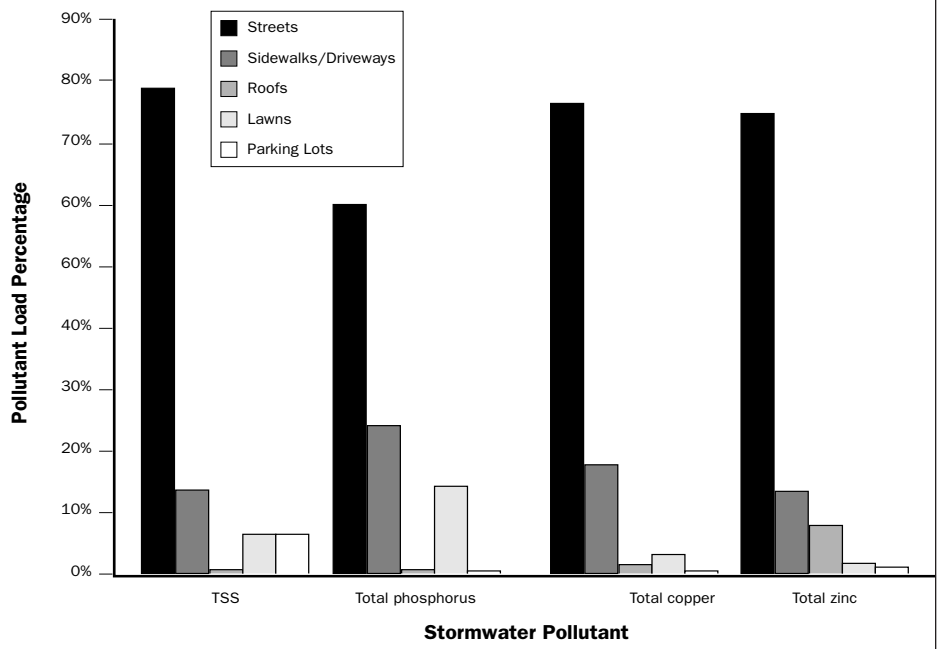
FIGURE 2-6
Key Pollutant Sources in Residential Areas



Source: *Better Site Design: A Handbook for Changing Development Rules in Your Community*, Center for Watershed Protection, 1998 (based on research by Roger Bannerman and Richard Dodds, 1992).

can add nutrients to runoff.[34] Monitoring has shown a direct link between the chemicals found in lawn care products and urban water quality.[35] While there remain questions on some details of the contribution of turf management to receiving water quality, it is clear that the type, quantity, and timing of materials used make a significant difference.

One important variable is the quantity of chemicals being applied. Over or improper application at homes and other places is far too common.[36] Experts estimate that residential fertilizer use accounts for one-third of the excess nitrogen entering the Sarasota Bay watershed in southwest Florida.[37] Of particular concern is the application of fertilizers and pesticides just before an intense storm event, since they may not have had time to become fixed in the soil and thatch.

Similarly, harmful pesticides found in stormwater, such as chloropyrifos, 2,4-D, and diazinon come from golf courses, municipal parks, highway medians and roadsides, and residential lawns and gardens.[38] The percentage of pesticide lost in runoff can be large; one study

The use of fertilizer and pesticides around the home can lead to water quality impacts.



Natural Resources Conservation Service, Shawnee County, KS

SARB_016398

TABLE 2-4
Six Pesticides Found Frequently in Stormwater Samples

Pesticide Name	Human Health and/or Environmental Effects
2,4-D	Associated with lymphoma in humans; testicular toxicant in animals.
Chlorpyrifos	Moderately toxic to humans; neurotoxicant; can be highly toxic to birds, aquatic organisms, and wildlife.
Diazinon	Moderately toxic to humans; neurotoxicant; can be highly toxic to birds, aquatic organisms, and wildlife.
Dicamba	Neurotoxicant; reproductive toxicity in animals; association with lymphoma in some human studies.
MCPA (Methoxane)	Low toxicity to non-toxic in test animals, birds, and fish; suspected gastrointestinal, liver, and kidney toxicant.
MCPP (Mecoprop)	Slightly to moderately toxic; some reproductive effects in dogs; suspected cardiovascular, blood, gastrointestinal, liver, kidney, and neurotoxicant.

Sources: T.R. Schueler, "Urban Pesticides: From the Lawn to the Stream," *Watershed Protection Techniques*, vol. 2, no. 1, Fall 1995, pp. 247, 250 and *Extoxnet: Extension Toxicology Network Pesticide Information Profiles* <http://ace/orst.edu/info/extoxnet> and Environmental Defense Fund, *Scorecard Chemical Profiles* <http://www.scorecard.org/chemical-profiles>.

found up to 90 percent of the herbicide 2,4-D was lost in runoff after being applied a few hours before a storm event.[39]

Since organic matter contains nutrients, raking autumn leaves or grass clippings into gutters or streets for municipal collection or otherwise facilitating the entry of these materials into the storm-sewer system also adds nutrient loads and oxygen-demanding substances to stormwater. Poorly maintained garden beds or lawns can be a source of sediment as well.

Construction sites. Construction activity is the largest direct source of human-made sediment loads.[40] "Results from both field studies and erosion models indicate that erosion rates from construction sites are typically an order of magnitude larger than row crops and several orders of magnitude greater than rates from well-vegetated areas, such as forest or pastures."[41] Since erosion rates are much higher for construction sites relative to other land uses, the total yield of sediment and nutrients is higher.[42] Studies indicate that poorly managed construction sites can release 7 to 1,000 tons of sediment per acre during a year, compared to 1 ton or less from undeveloped forest or prairie land.[43] Construction activity can also result in soil compaction and increased runoff.

Construction activities result in increased runoff, erosion, and sediment transport.



Like nutrients, soil and sediment are, to a certain degree, a naturally occurring and functional component of all waterbodies. Yet human activities usually increase the amount of sediment entering our waterbodies to such an extent as to turn sediment into a water quality problem.

Natural Resources Conservation Service, Shawnee County, KS

SARB_016399

Illicit sanitary connections to storm sewers from homes and businesses. Illicit connections from toilets to storm sewer pipes can add pathogens to stormwater.[44] [45] Pathogens are viruses, bacteria, and protozoa harmful to human health. Coliform bacteria, which come from human waste, is commonly used as an indicator that harmful pathogens may be present in the water.[46] Studies have found high levels of coliform bacterial in stormwater.[47]

Illicit sanitary connections can also add nutrients such as nitrogen and phosphorus to stormwater. Human waste also contributes to BOD. Leaking sanitary sewer lines located near storm sewer lines can pose the same problems as illicit connections.[48]



J. Kirk Condyles

Shellfish beds are frequently closed because of illicit sanitary connections to storm sewers and other stormwater sources.

Septic systems. Effluent from poorly maintained or failing septic systems can rise to the surface and contaminate stormwater.[49] Septic systems can be important sources of pathogens and nutrients, especially nitrogen, that are not effectively removed from the waste stream. Bathing beach and shellfish bed closures are frequently the result of septic system effluent. One study found that 74 percent of the nitrogen entering the Buttermilk Bay estuary in Massachusetts originated from septic systems.[50] Fecal coliform and BOD can be present in stormwater if the system is improperly sited, designed, installed, or maintained.

Illicit industrial connections to storm sewers. Businesses that illicitly connect pipes containing wastewater from industrial processes to the storm sewer system rather than to the sanitary sewers can add metals, solvents or other contaminants to stormwater. In Seattle, one industrial facility's discharge of lead to the storm sewer system resulted in sediment so contaminated that it could be sent to a smelter to be refined.[51] Floor drains, dry wells, and cesspools are also frequent sources of illicit industrial discharges and connections.

Uncovered materials stored outside. Rain or melting snow can erode piles of bulk material, such as sand, loose topsoil, or road salt if left uncovered, adding sediment, salts or other pollutants to nearby waterbodies. Likewise, precipitation can wash contaminants off leaking or dirty objects left outdoors. For example, water quality monitoring showed that untreated runoff collected from auto recycling facilities near Los Angeles frequently exceeded EPA benchmark figures, for biochemical oxygen demand, nitrogen, oil and grease, phosphorus, and sediment.[52]

Street, sidewalk, and airport de-icing. In colder parts of the country, salts used to keep roads, parking lots and sidewalks free of ice often drain into our waterbodies as snow and ice melt and spring rain falls. While some salt and ice treatment is necessary to keep roads safe in winter, measures can be taken to reduce or prevent

SARB_016400



J. Kirk Condyles

Leaking automotive fluids and other pollutants from auto recycling facilities can lead to contaminated runoff.

the impacts from de-icing. The principal salts used are sodium chloride and calcium chloride, although materials such as calcium magnesium acetate and other commercial products are also used.[53] Some municipalities spread sand to maintain road traction on snow and ice, and this sand eventually may increase sediment loads. Airports de-ice runways and planes, usually with glycol mixtures that can be both toxic to fish, wildlife, and humans and exert high BOD on receiving streams.

Landfills. Because the soil cover on landfills is not stabilized with vegetation or other retaining cover while the landfill is operational, soil can erode from landfills as it does from construction sites. Additionally, improperly maintained hazardous-waste landfills can allow toxic contaminants to reach or stay on the surface of the landfill, allowing stormwater to carry these pollutants to nearby waterbodies.

Pets and wild animals. Waste from domestic and wild animals is a source of pathogens, nutrients and BOD in stormwater.[54] The Northern Virginia Soil and Water Conservation District estimates that each day, dogs leave 180,000 pounds of waste on the ground in Fairfax County, Virginia, alone.[55] Waste from birds such as pigeons, geese, and gulls that are attracted to human activity can also be a problem. Wild geese that congregate in large numbers on cultivated turf adjacent to bodies of water also contribute to pathogen, nutrient and BOD loadings.[56]

Littering. Not only does stormwater frequently receive no treatment, it also often does not even have the benefit of simple filtering or screening for visible objects. As a result, paper cups, cigarette butts, virtually anything made of styrofoam, newspaper, and other materials that people toss on the ground are carried into storm sewer systems—and eventually into lakes, streams, and oceans.

An advertisement from the Water Quality Consortium in Puget Sound, Washington informs citizens that pet waste is a threat to water quality.



Washington State Department of Ecology Water Quality Consortium

This list, exhaustive as it is, is incomplete. Galvanized roofs, unpaved roads, the dust that collects on paved streets, and countless other aspects of daily life in urban areas contribute to polluted runoff. The first step in stormwater management is not to memorize any particular list, but rather to recognize the breadth of opportunities for pollution prevention and the need to think holistically about the entire chain of human activities that affect runoff quantity and quality. The case studies presented in this report demonstrate a wide variety of effective and efficient strategies for addressing stormwater runoff at the source.

SARB_016401

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

ORDER: WQ 99 - 05

Own Motion Review of the Petition of
Environmental Health Coalition
to Review Waste Discharge Requirements Order No. 96-03,
NPDES Permit No. CAS0108740
for Storm Water and Urban Runoff from the
Orange County Flood Control District
and the
Incorporated Cities of Orange County
Within the San Diego Region,
Issued by the
California Regional Water Quality Control Board,
San Diego Region.

SWRCB/OCC File A-1041

BY THE BOARD:

In Order WQ 98-01, the State Water Resources Control Board (State Water Board) ordered that certain receiving water limitation language be included in future municipal storm water permits. Following inclusion of that language in permits issued by the San Francisco Bay and San Diego Regional Water Quality Control Boards (Regional Water Boards) for Vallejo and Riverside respectively, the United States Environmental Protection Agency (EPA) objected to the permits. The EPA objection was based on the receiving water limitation language. The EPA has now issued those permits itself and has included receiving water limitation language it deems appropriate.

SARB_016402

In light of EPA's objection to the receiving water limitation language in Order WQ 98-01 and its adoption of alternative language, the State Water Board is revising its instructions regarding receiving water limitation language for municipal storm water permits. It is hereby ordered that Order WQ 98-01 will be amended to remove the receiving water limitation language contained therein and to substitute the EPA language. Based on the reasons stated here, and as a precedent decision,[1] the following receiving water limitation language shall be included in future municipal storm water permits.[2]

RECEVING WATER LIMITATIONS

The permittees shall comply with Discharge Prohibitions [ ][3] and Receiving Water Limitations [ ] through timely implementation of control measures and other actions to reduce pollutants in the discharges in accordance with the SWMP and other requirements of this permit including any modifications. The SWMP shall be designed to achieve compliance with Receiving Water Limitations [ ]. If exceedance(s) of water quality objectives or water quality standards (collectively, WQS) persist notwithstanding implementation of the SWMP and other requirements of this permit, the permittees shall assure compliance with Discharge Prohibitions [ ] and Receiving Water Limitations [ ] by complying with the following procedure:

---

[1] In SWRCB Order WR 96-1, the State Water Board determined that water quality orders are precedent decisions. (See Gov. Code §11425.60.)

[2] This language may be revised as necessary to ensure that terminology conforms with the rest of the permit.

[3] Insert appropriate numbers for prohibitions and limitations that implement water quality objectives and water quality standards.

a. Upon a determination by either the permittees or the Regional Water Board that discharges are causing or contributing to an exceedance of an applicable WQS, the permittees shall promptly notify and thereafter submit a report to the Regional Water Board that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of WQSs. The report may be incorporated in the annual update to the SWMP unless the Regional Water Board directs an earlier submittal. The report shall include an implementation schedule. The Regional Water Board may require modifications to the report.

b. Submit any modifications to the report required by the Regional Water Board within 30 days of notification.

c. Within 30 days following approval of the report described above by the Regional Water Board, the permittees shall revise the SWMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, implementation schedule, and any additional monitoring required.

d. Implement the revised SWMP and monitoring program in accordance with the approved schedule.

So long as the permittees have complied with the procedures set forth above and are implementing the revised SWMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless directed by the Regional Water Board to develop additional BMPs.

///

///

ORDER

IT IS ORDERED that Order WQ 98-01 is revised as discussed above.

CERTIFICATION

The undersigned, Administrative Assistant to the Board, does hereby certify that the foregoing is a full, true, and correct copy of an order duly and regularly adopted at a meeting of the State Water Resources Control Board held on June 17, 1999.

AYE: James M. Stubchaer
Mary Jane Forster
John W. Brown
Arthur G. Baggett, Jr.

NO: None

ABSENT: None

ABSTAIN: None

Maureen Marché
Administrative Assistant to the Board

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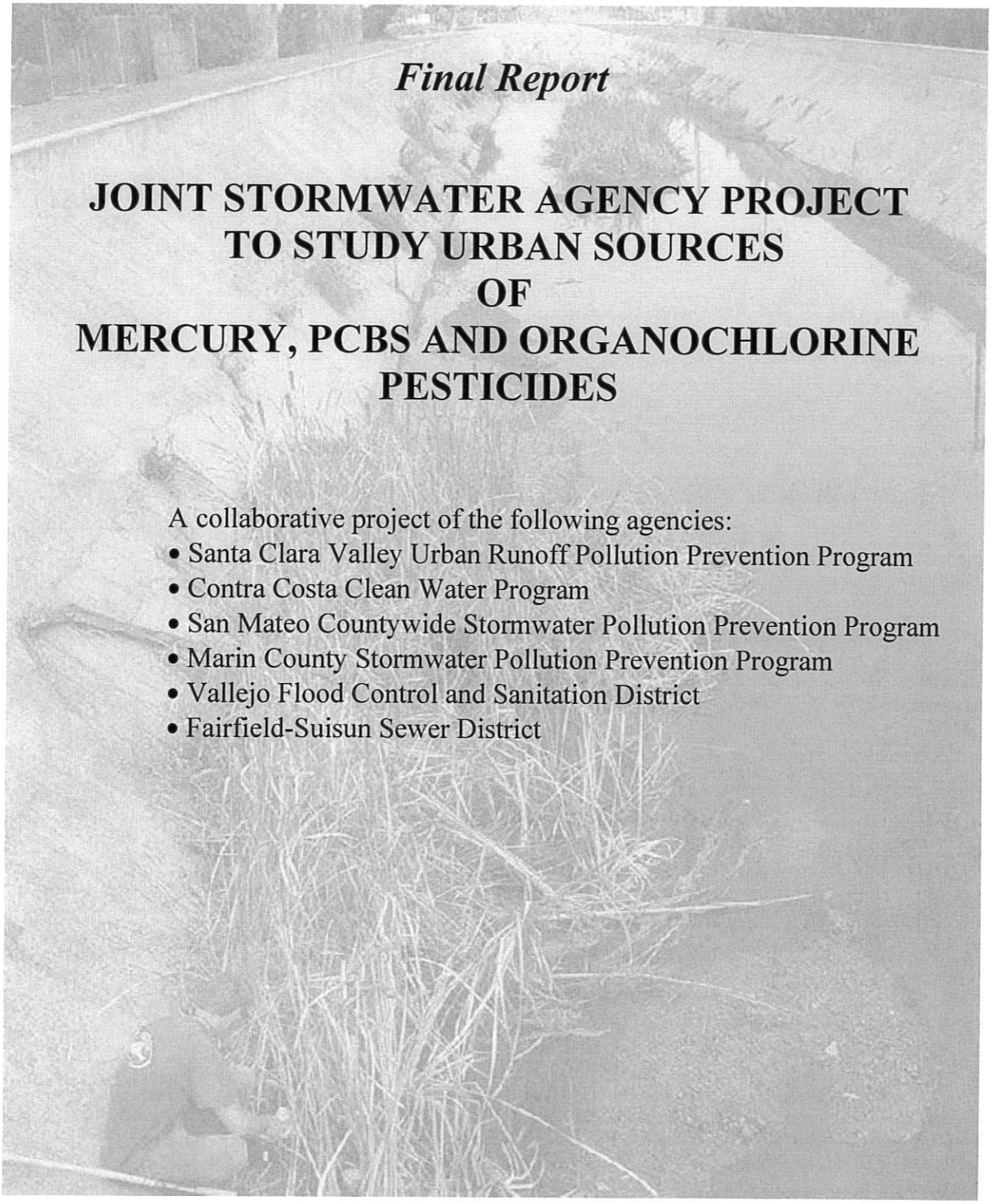

Final Report

JOINT STORMWATER AGENCY PROJECT TO STUDY URBAN SOURCES OF MERCURY, PCBS AND ORGANOCHLORINE PESTICIDES

A collaborative project of the following agencies:

- Santa Clara Valley Urban Runoff Pollution Prevention Program
- Contra Costa Clean Water Program
- San Mateo Countywide Stormwater Pollution Prevention Program
- Marin County Stormwater Pollution Prevention Program
- Vallejo Flood Control and Sanitation District
- Fairfield-Suisun Sewer District

KINNETIC LABORATORIES INCORPORATED

April 2002

EOA, Inc.
Eisenberg, Olivieri & Associates
Environmental and Public Health Engineering

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Final Report

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- Fairfield-Suisun Sewer District

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KINNETIC LABORATORIES INCORPORATED

April 2002

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EXECUTIVE SUMMARY

This report summarizes the results from two years of sampling conducted to document the presence and distribution of contaminants of concern in sediments collected from storm drains. During the first year of the program sediments were collected from 61 sites from Marin, San Mateo, Santa Clara Valley, Contra Costa and Solano Counties. Sampling locations were selected to characterize the average, range and variability of mercury and PCB concentrations in urban residential/commercial catchments, urban industrial catchments, open space, and downstream sites representative of entire watersheds. Sediments from the first year were tested to determine particle size distributions, total organic carbon (TOC), percent moisture, PCB congeners, total mercury, and methyl mercury. During the second year, field surveys were designed to emphasize industrial catchments. Organochlorine pesticides, including chlordane and DDTs, were added to the tests conducted on the sediment and methyl mercury was eliminated from the analytical suite.

During the second year's survey, samples from 70 sites were submitted to the laboratory for analysis. Approximately two-thirds of the sampling locations were from areas dominated by industrial land use activities. Sediment sampling procedures were based on those in use by the Regional Monitoring Program for Trace Substances in the San Francisco Estuary and the USGS National Water Quality Assessment Program. To assure comparability of results, these procedures were coordinated with complimentary work being conducted by the Alameda Countywide Clean Water Program. Seven field replicates, submitted blind to the laboratories performing the analyses, were included to assess the extent of field variability since this could have a strong influence on data interpretation. In addition, a thorough laboratory control program included the use of method blanks, matrix spike/spike duplicates, surrogate spikes, laboratory control samples (LCS), certified reference materials (CRM), and laboratory replicates.

Summary statistics were developed for major land use classifications including the number of samples, the percentage of the samples with values above project reporting limits, minimum and maximum detected values, the median, 25th and 75th percentiles, mean, standard deviation and coefficient of variation. In the previous year, statistics were developed based upon natural logarithm transformations and evaluation was based upon characteristics of the lognormal distribution. Upon normalization to fines of the data for both years, portions of the data set were found to depart substantially from the lognormal distribution. In addition, handling of below detection limit data was becoming an issue for a few of the target analytes. In order to allow inclusion of the censored (below detection limit) data, a method known as regression on order statistics was used to obtain estimates of the distribution of data below project detection limits.

Two hypotheses were established to address objectives established for the second year of the sediment testing program. These included:

H_o: *There was no difference in storm drain sediment contaminant levels among residential/commercial and industrial land use sites.*

H_1: *There was no difference in storm drain sediment contaminant levels among urban (industrial, residential/commercial and mixed) and nonurban (open) land use classifications.*

The combined two-year data set of this sampling project together with data provided by the Alameda Countywide Clean Water Program and appropriate sites from separate PCB case studies resulted in 164 sampling units for PCBs consisting of 68 industrial sites, 31 residential/commercial sites, 44 mixed land

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use sites, and 21 open space sites. Slightly fewer sites (152) were tested for mercury. Organochlorine pesticide data were available from 73 locations.

All data analysis was based upon measured concentrations normalized to the sediment particles less than 62.5 microns (fine fraction).

A nonparametric analysis of variance, the Kruskal Wallis test, indicated that concentrations of total PCBs, total mercury and total chlordane were all significantly different among the four land use classifications. No significant differences ($p=0.134$) were found in the concentration of DDT in storm drain sediments from different land use classifications. A Bonferonni Inequality test indicated that concentrations of total PCB and total mercury in open land use sites were significantly lower than the remaining three categories. No significant differences were evident in the concentrations of total PCBs and mercury measured from industrial and residential/commercial land use sites. Chlordane was found to be significantly higher in sediments from residential/commercial land use sites.

Similar tests were conducted after reclassification of sampling sites to urban and nonurban (open) sites. Mann-Whitney tests indicated that samples taken from urban environments had significantly higher levels of total PCBs, total mercury, chlordane, and DDT. Median concentrations of constituents in samples collected from urban sites vs. nonurban sites were over 100 times greater for total PCBs, three times greater for total mercury, 40 times greater for chlordane and 100 times greater for DDT compounds. In the case of both chlordane and DDT, representative coverage of open land use activities was not accomplished. Only four samples were taken from open land use areas since the emphasis was directed towards improving coverage of industrial land use areas for better characterization of PCB sources.

The concentrations of contaminants in sediments from Bay area storm drains were used as the basis to develop planning level estimates of loading to San Francisco Bay. Estimation procedures were generally based on the SIMPLE model. Several key assumptions were necessary to develop input parameters. The first assumption was that concentrations of contaminants present in sediments from storm drains were 100 percent associated with particles less than 62.5 microns in size (fine fraction). The second major assumption was that the concentration of contaminants associated with the embedded fine fraction was representative of the concentration of the contaminants in suspended sediments in stormwater discharges.

Load estimates were developed based upon the 25th percentile, 75th percentile and median concentrations in order to provide a framework for assessing the extent of uncertainty associated with estimates (Table ES.1). The overall load for PCBs was estimated to range from 19 to 228 pounds per year with a median estimate of 87 pounds per year. Over 99 percent of the PCBs are from urban sources. Mercury loads were estimated at 131 to 578 pounds per year with a median of 271 pounds per year. In the case of mercury, a substantial portion (12 to 22 percent) was estimated to come from open and agricultural land use portions of the watersheds. Estimates of mercury loads associated with stormwater discharges specifically do not include large point sources associated with historic mercury mines located within San Francisco Bay watersheds. These sources were not characterized in this study.

Far less information is currently available for chlordane and DDT. Although initial estimates of loads from agricultural and open land use areas are very low, they are only based upon measurements from four sites. Preliminary estimates were made for these two constituents based upon data from this year. Based upon this limited set of data it is estimated that 48 to 261 pounds of chlordane and 2.3 to 55 pounds of DDT are discharged to the Bay from both urban and nonurban areas on an annual basis (Table ES.1).

An evaluation of the possible effects of remediation at locations with PCB concentrations in the top 15 percent of all urban sites was conducted to examine sensitivity to such measures. Clean up to an objective equivalent to the 75th percentile reduced estimated high-end loads by 24%. Use of the median urban concentration as a cleanup objective reduced high-end load estimates by approximately 50%.

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Table ES.1 Summary of estimated stormwater loads to San Francisco Bay from 17 watersheds and portions contributed by urban sources

	San Francisco Bay Watersheds		Urban Sources	
	Pounds	Kilograms	Pounds	Kilograms
PCB, Median	87	39.5	87	39.5
PCB, High	228	103.6	227	103.2
PCB, Low	19	8.6	19	8.6
Total Hg, Median	271	123.2	210	95.5
Total Hg, High	578	262.7	497	225.9
Total Hg, Low	131	59.5	115	52.3
Chlordane, Median	85	38.6	84	38.2
Chlordane, High	261	118.6	260	118.2
Chlordane, Low	48	21.8	48	21.8
DDT, Median	23	10.5	23	10.5
DDT, High	51	23.2	50	22.7
DDT, Low	2.3	1.0	2.3	1.0

Ranking the data and comparing distributional characteristics identified sites with particularly high concentrations of the target constituents. Several sites were found to have high concentrations of several of the target constituents. The highest concentration of PCBs (124,198 ug/Kg fines) was encountered in sediments collected from a manhole in an industrial catchment in San Carlos (SMC020). This site receives runoff from an area that includes Delta Star, a former generator of PCBs and manufacturer of transformers. High levels of mercury (11.3 mg/Kg fines), total chlordane (11,971 ug/Kg fines), and DDT (24,541 ug/Kg fines) were also encountered at this site. HCHs[1] were also detected at this site in the highest concentrations encountered in the study (3,611 ug/Kg fines). PCBs and other pollutants have been found in soil samples from the Delta Star site. The Regional Board has adopted site cleanup requirements (Order No. 99-062).

The second highest concentration of PCBs (28,003 ug/Kg fines) was found in sediments collected from Colma Creek (SMC024). An oil and grease sheen has been observed at this site and at previous sites downstream of this sampling location. The sampling point is located inside a culvert under Collins Road. Several sources appear to converge at this point. All conveyances go underground at this point and mapping information was limited. The catchment includes a number of automobiles sales and maintenance activities. This site also had elevated levels of total chlordane (1,633 ug/Kg fines).

Sediments collected from the Pulgas Creek Pump Station (SMC023) in San Carlos contained the third highest concentration of PCBs (25,044 ug/Kg fines). This pump station drains an industrial catchment. Sediments at this site were anoxic. The composition of the PCBs at this site showed signs of weathering typical of anoxic conditions. Congeners with three to four chlorine atoms were more abundant than expected in typical Arochlor formulations. Sediments from this pump station also contained high levels of chlordane (902 ug/Kg fines) and DDT (1,410 ug/Kg fines).

[1] HCH refers to the sum of the alpha, beta, gamma (lindane) and delta isomers of hexachlorocyclohexane.

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Sediments collected from a manhole near Nebraska Street in Vallejo (VFC006) contained the fourth highest concentrations of PCBs (21,231 ug/Kg fines) encountered this year. This is primarily a residential catchment that ultimately discharges through Austin Creek. Unlike some of the other sites with high levels of PCBs, other target constituents were not present at elevated levels at this site.

Sediments sampled for CCC032 in Richmond was comprised of a composite of four catch basins located on the north side of West Cutting Boulevard near South 1st Street. PCBs in this composite sample were measured at 12,538 ug/Kg fines. Composite samples came from catch basins in front of the Richmond Distribution Center, a PG&E substation, and a machine shop. Measurements of mercury, chlordane, and DDT were all within the top 15 percent at this site.

The highest concentrations of mercury were measured in sediments from three sites in Marin County (MCS007, MCS011, and MCS010), three in San Mateo County (SMC025, SMC030, and SMC020) and one Santa Clara Valley site (SCV028). The Marin County sites were all located in the lower portions of the Pacheco and Arroyo San Jose watersheds. Both ultimately discharge through Pacheco Pond to San Francisco Bay. The San Mateo sites include SMC020 where high PCBs were also encountered. Other San Mateo sites included (SMC025) which is an industrial area where sediments were collected from a manhole located at the eastern end of Beatty Avenue. SMC030 is located in the Jefferson Branch of Redwood Creek just northwest of Harrison Street where it runs underneath Duane Street. Drainage for this branch of the Creek includes Stulsaft Park on Farm Hill Boulevard. During redevelopment of the Park, it was discovered that the Park was the site of a mercury mine in the 1950's. San Mateo County Health Service Agency and Redwood City discovered residual mercury contamination in the soils and have planned remediation efforts before continuing with the redevelopment process.

One Marin County site, MCS008, was found to have high levels of both chlordane (15,396 ug/Kg fines) and DDT (2,054 ug/Kg fines). Sediment was collected from a corrugated metal outfall near 31 Pamaron Way that flows into Pacheco Creek. A followup investigation was conducted by Marin County to evaluate potential sources.

SARB_016417

1.0 INTRODUCTION

1.1 Background and Overview

The Project Plan for the first year of this project, "Joint Stormwater Agency Project to Study Urban Sources of Mercury and PCBs," (EOA, Inc. 2000) was developed, approved, and submitted to the Regional Board on July 1, 2000 as a collaborative project of the following agencies:

- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
- Contra Costa Clean Water Program (CCCWP)
- San Mateo Countywide Stormwater Pollution Prevention Program (SMCSPPP)
- Marin County Stormwater Pollution Prevention Program (MCSPPP)
- Vallejo Flood Control and Sanitation District (VFCSD)
- Fairfield-Suisun Sewer District (FSSD).

The first year Project Plan (EOA, Inc. 2000) provided a summary of developments that lead to implementation of this project. The overall goal of the project was to provide data to support development of TMDLs for PCBs and mercury in San Francisco Bay. During the first year of this study, the Regional Board requested that three primary questions be addressed. These included:

1. Are PCBs distributed somewhat evenly throughout the landscape resulting in relatively similar PCB discharges from storm water conveyance systems?
2. Are storm drains or other surface drainage pathways sources of PCBs in themselves?
3. Are there specific locations within watersheds where prior or current use of PCBs result in land sources contributing to continued PCBs discharges through stormwater conveyance systems?"

During the first year, deposited sediments were collected from 61 monitoring stations located within jurisdictions of the six stormwater agencies funding this investigation. Data from an additional 22 sites sampled and analyzed by the Alameda Countywide Clean Water Program were used to augment the data set. All sediments were analyzed to determine particle size distributions, total organic carbon, percent moisture, PCB congeners, total mercury, and methyl mercury.

Sampling locations were selected to characterize the average, range and variability of mercury and PCB concentrations of each of the following four categories:

- Urban residential/commercial catchments.
- Urban industrial catchments.
- Open space.
- Downstream sites representative of entire watersheds.

Consideration was also given to providing adequate spatial coverage within the study area.

Based upon results from the first year's program, a work plan was developed to acquire further information on potential sources of contaminants in storm drainages in San Francisco Bay watersheds (EOA Inc., 2001). This work plan was based upon input from the Regional Board and various stormwater agencies. The new work plan called for scaling back on mercury investigation by elimination of methyl mercury, adding chlorinated pesticides to the analytical list, and focusing upon identification of smaller drainages with high industrial use as well as areas where PCBs were historically used, stored or released. In addition, the work plan called for case studies to be performed in areas where high concentrations of PCBs were encountered during the previous year. The case studies were intended to

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isolate and identify significant sources within the target drainages. In most situations, the case studies are being conducted independently by each discharger.

1.2 Project Objectives

The second year work was designed to augment and extend the initial data from the fall 2000 survey. The general goal was to continue to assist Regional Board staff in developing TMDLs. This second year of work focused on PCBs, but included gathering additional data on mercury and beginning to collect data on organochlorine pesticides (especially the "legacy" pesticides chlordane, DDT, and dieldrin).

The specific objectives of the work were:

- Gathering further data on the distribution of total mercury and PCBs homologs in different land uses in urbanized watersheds draining to San Francisco Bay,
- Beginning to gather data on the distribution of organochlorine pesticides in different land uses in urbanized watersheds draining to San Francisco Bay,
- Attempting to identify additional conveyance systems with elevated concentrations of PCBs in embedded sediments, and
- Calculating order–of–magnitude estimates of loadings of PCBs, mercury, and chlorinated pesticides to the Bay from urban runoff conveyance systems.

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2.0 METHODS

2.1 Selection of Sampling Sites

Stations were selected to characterize the average, range and variability of mercury and PCB concentrations within each of the following four categories:

- Urban residential/commercial catchments.
- Urban industrial catchments.
- Open space.
- Downstream sites representative of entire watersheds.

In addition, stations were initially apportioned to be within the participating agencies' jurisdiction as follows:

- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) – 34%
- Contra Costa Clean Water Program (CCCWP) – 24%
- San Mateo Countywide Stormwater Pollution Prevention Program (SMCSPPP) – 24%
- Marin County Stormwater Pollution Prevention Program (MCSPPP) – 6%
- Vallejo Flood Control and Sanitation District (VFCSD) – 6%
- Fairfield-Suisun Sewer District (FSSD). – 6%

The initial scope of work called for the selection of approximately 60 monitoring stations in all. The Vallejo Flood Control and Sanitation District opted to fund sampling at an additional five stations in lieu of conducting a case study investigation. This included resampling at one of the previous years sites where the highest concentrations of PCBs were encountered. The Marin County Stormwater Pollution Prevention Program also independently increased sampling sites by six to a total of nine in order to conduct an investigation of sources of contaminants in the two major watersheds flowing to Pacheco Pond. Fifty-eight monitoring stations were selected during the investigation and selection of stations (Table 1).

Table 1. Number of sampling locations by jurisdiction and drainage type.

DRAINAGE TYPE	SCVURPPP	SMCSPPP	CCCWP	MCSPPP	VFCSD	FSSD	TOTAL
Industrial	13	11	13	4	1	2	**44**
Res./Com.	1	4		2	4		**11**
Open	2		1		1		**4**
Mixed	4	1		3	2	1	**11**
Total	**20**	**16**	**14**	**9**	**8**	**3**	**70**

Final apportionment of stations within jurisdictions was close to target levels set for each jurisdiction (Table 2) when additional samples taken by the Marin and Vallejo programs are considered. As designed, the emphasis this year was on improving coverages in industrial land use areas.

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Table 2. Station location percentages by jurisdiction and drainage type.

DRAINAGE TYPE	SCVURPPP %	SMCSPPP %	CCCWP %	MCSPPP %	VFCSD %	FSSD %	TOTAL %
Industrial	18.1	15.3	18.1	5.6	1.4	2.8	**62.9**
Res./Com.	1.4	5.6	0	2.8	6.9	0	**15.7**
Open	2.8	0	1.4	0	2.8	0	**5.7**
Mixed	5.6	1.4	0	4.2	2.8	1.4	**15.7**
Total	**28.6**	**22.9**	**20.0**	**12.9**	**11.4**	**4.3**	**100**

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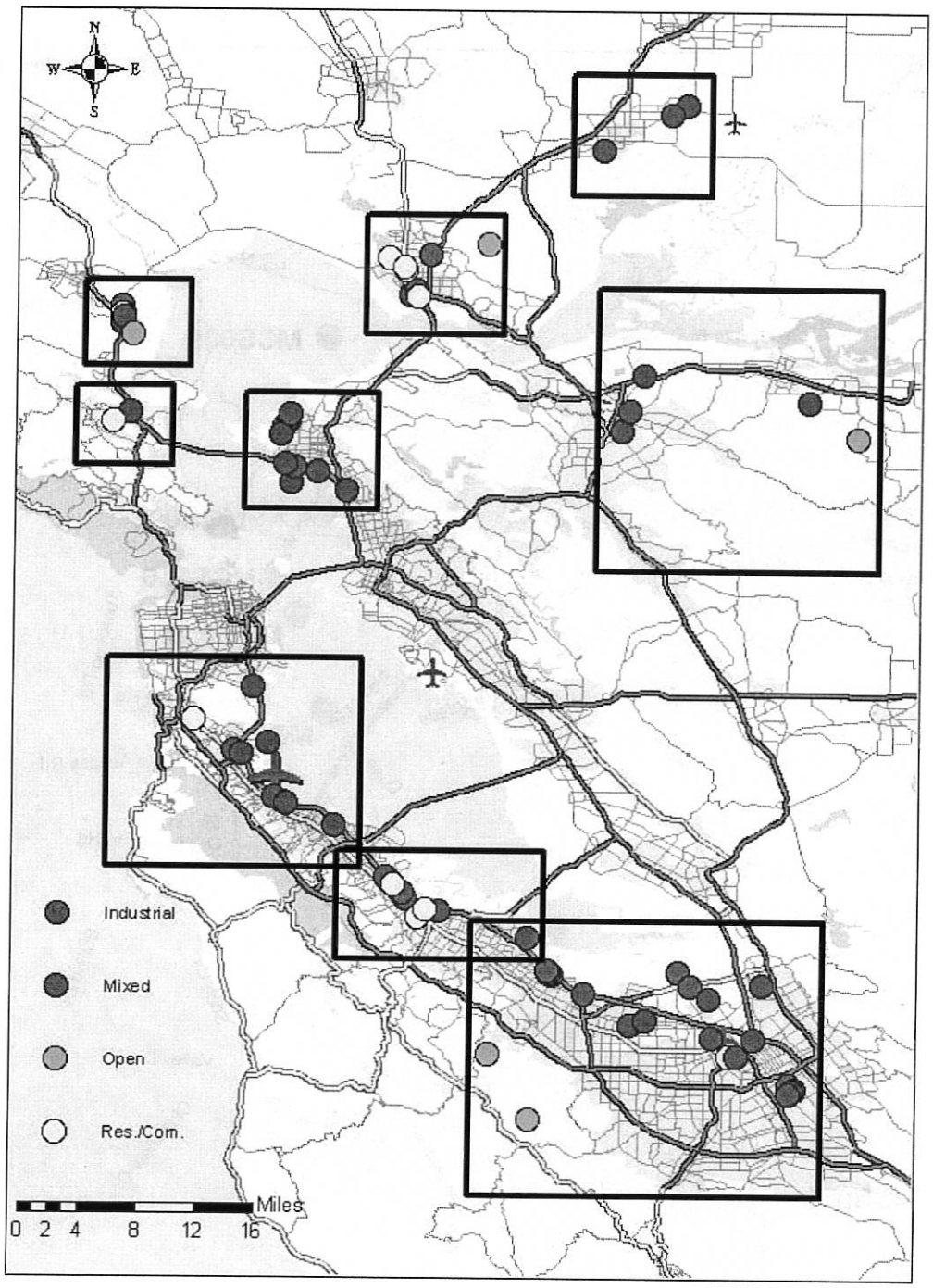

Figure 1. Sampling sites showing locations of detail maps

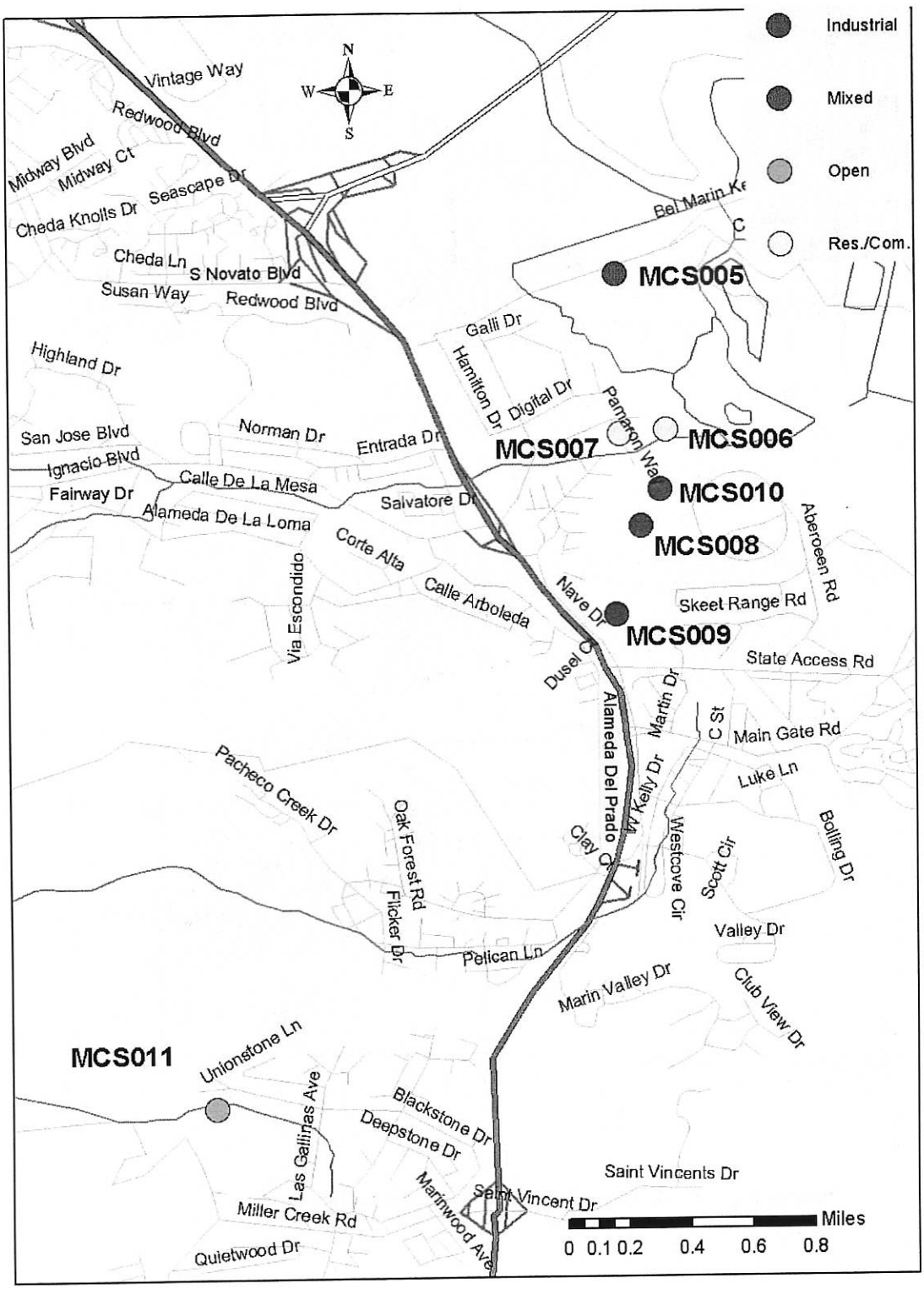

Figure 2. Sampling locations in northern Marin County

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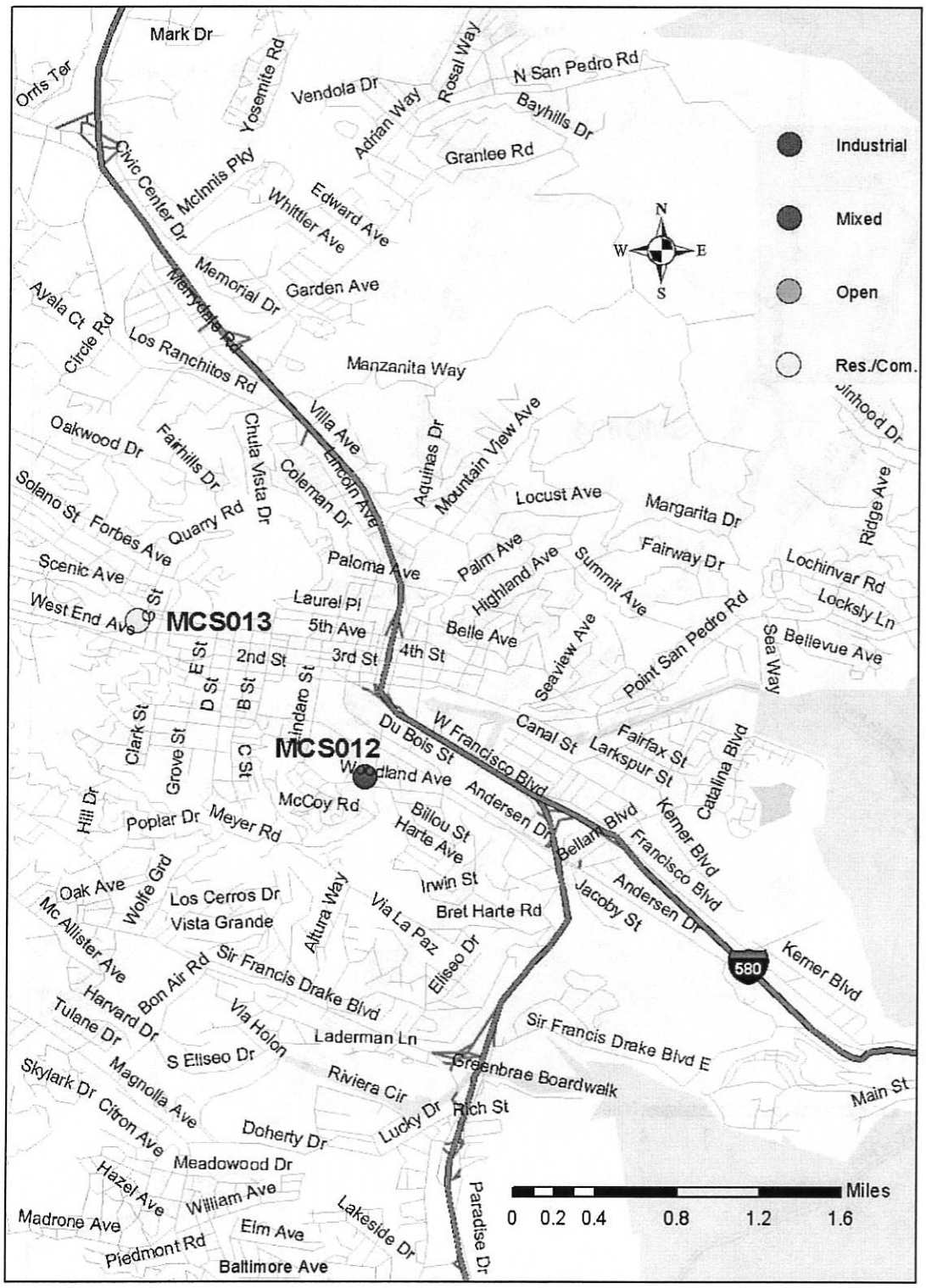

Figure 3. Sampling locations in southern Marin County.

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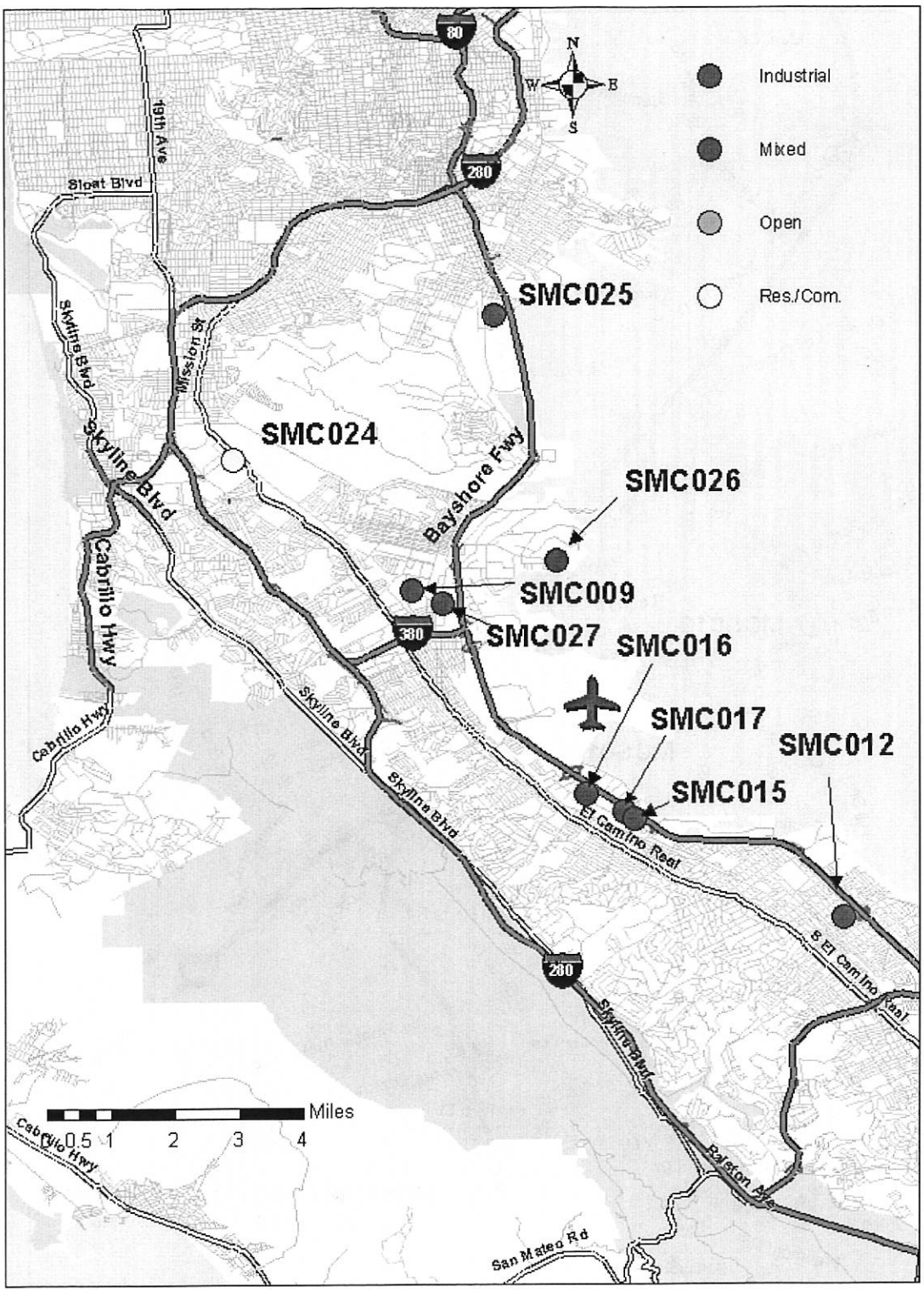

Figure 4. Sampling locations in northern San Mateo County.

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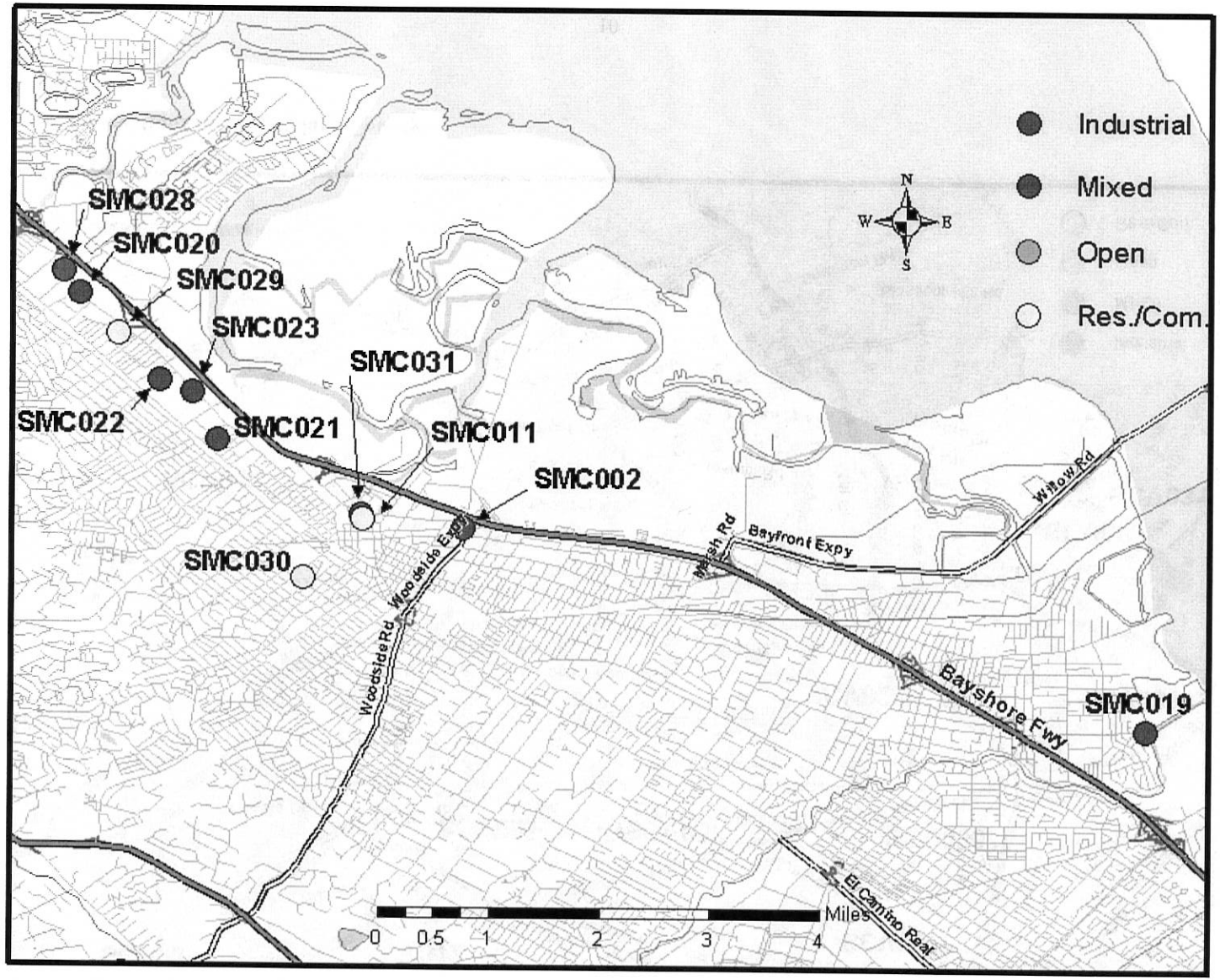

Figure 5. Sampling locations in southern San Mateo County

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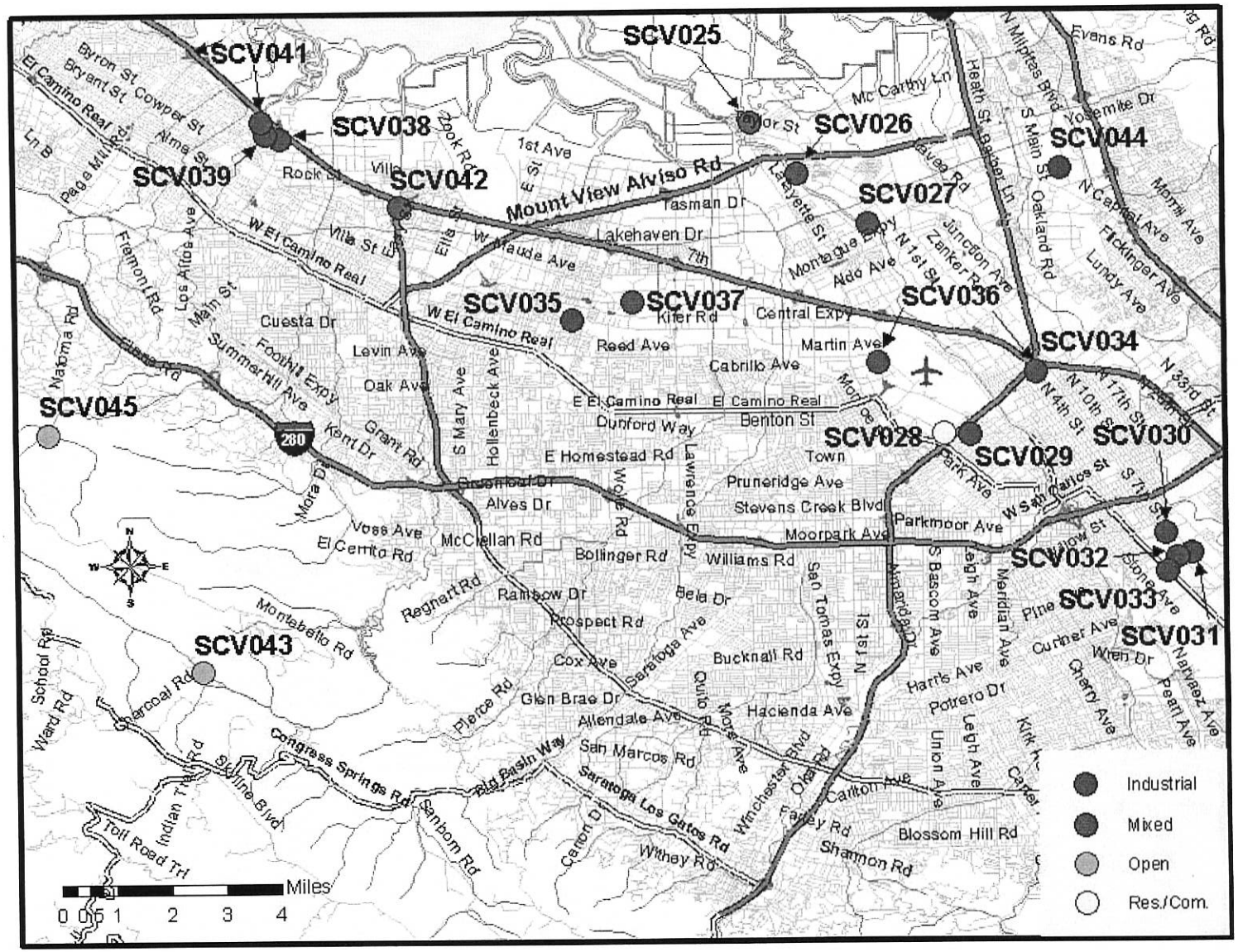

Figure 6. Sampling locations in Santa Clara County

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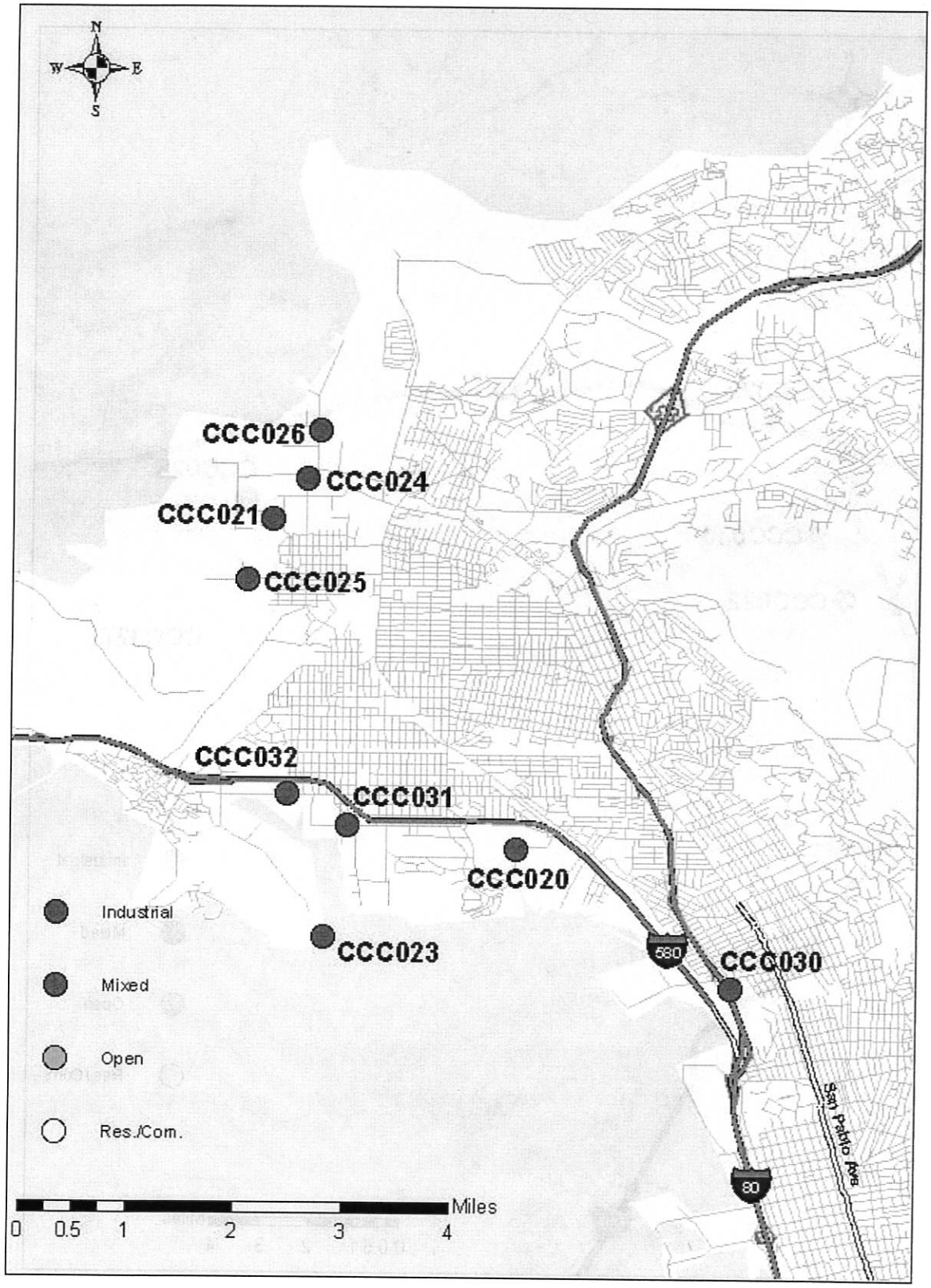

Figure 7. Sampling locations in western Contra Costa County.

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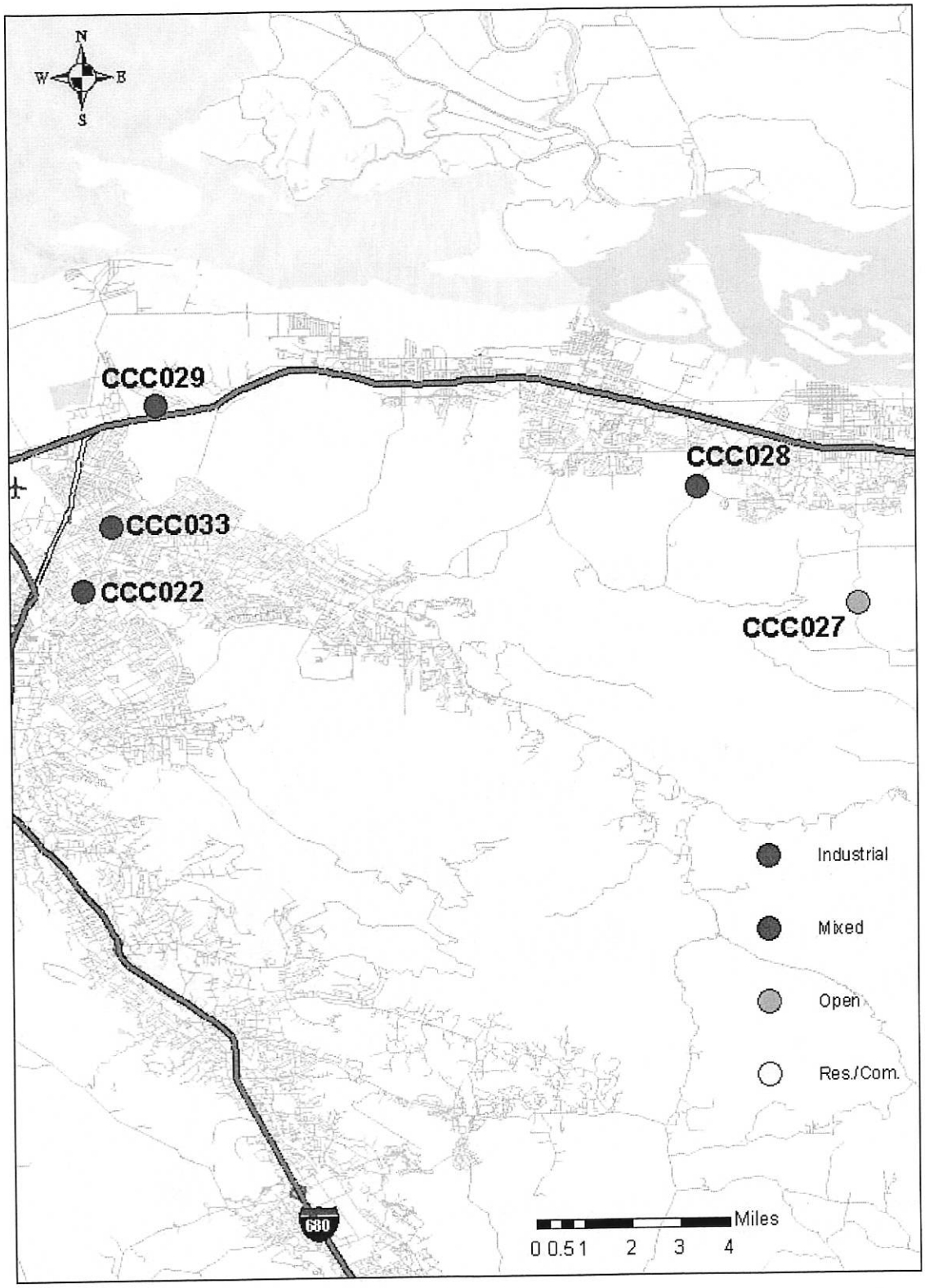

Figure 8. Sampling locations in eastern Contra Costa County.

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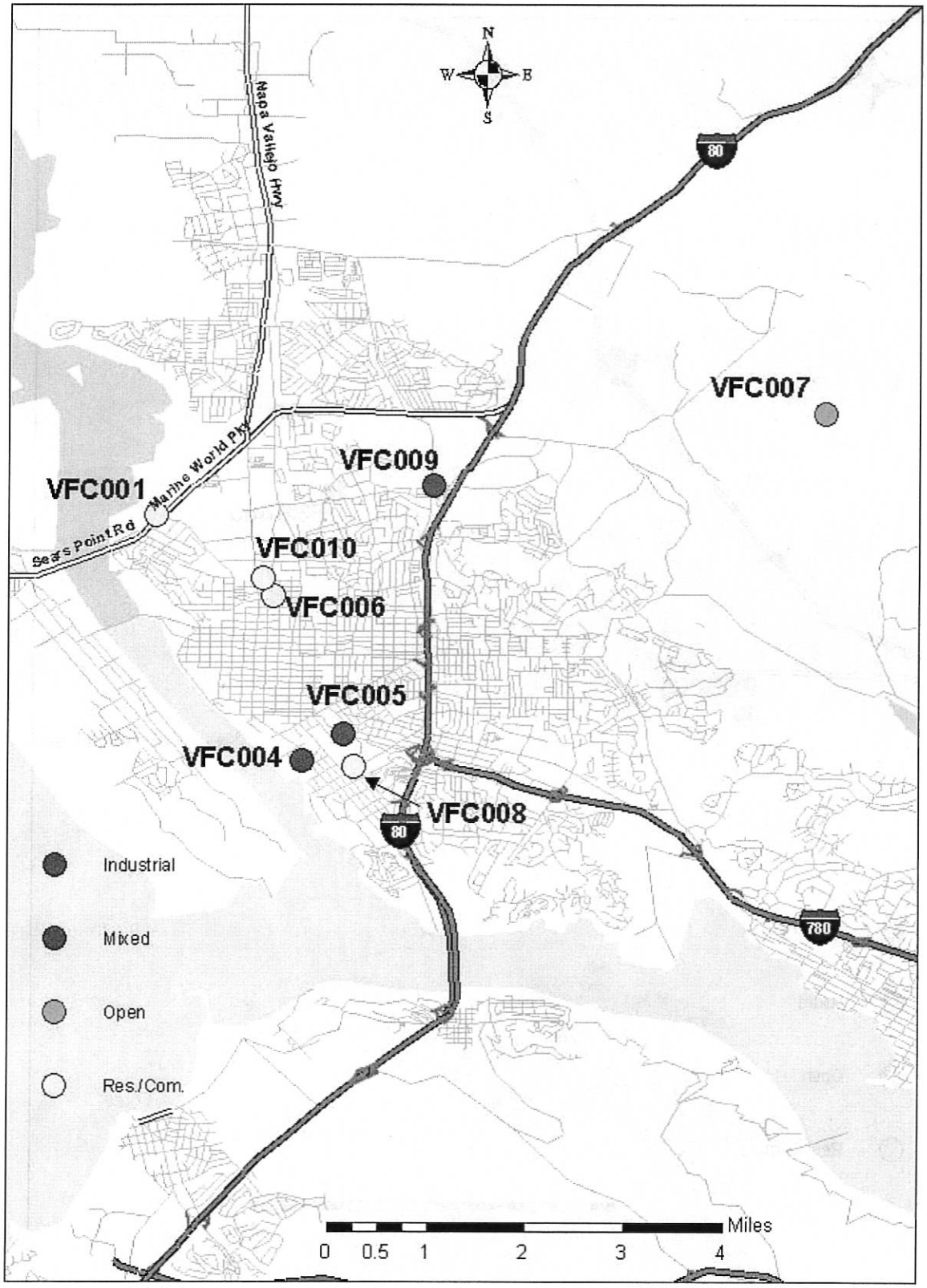

Figure 9. Sampling locations in the region of Vallejo.

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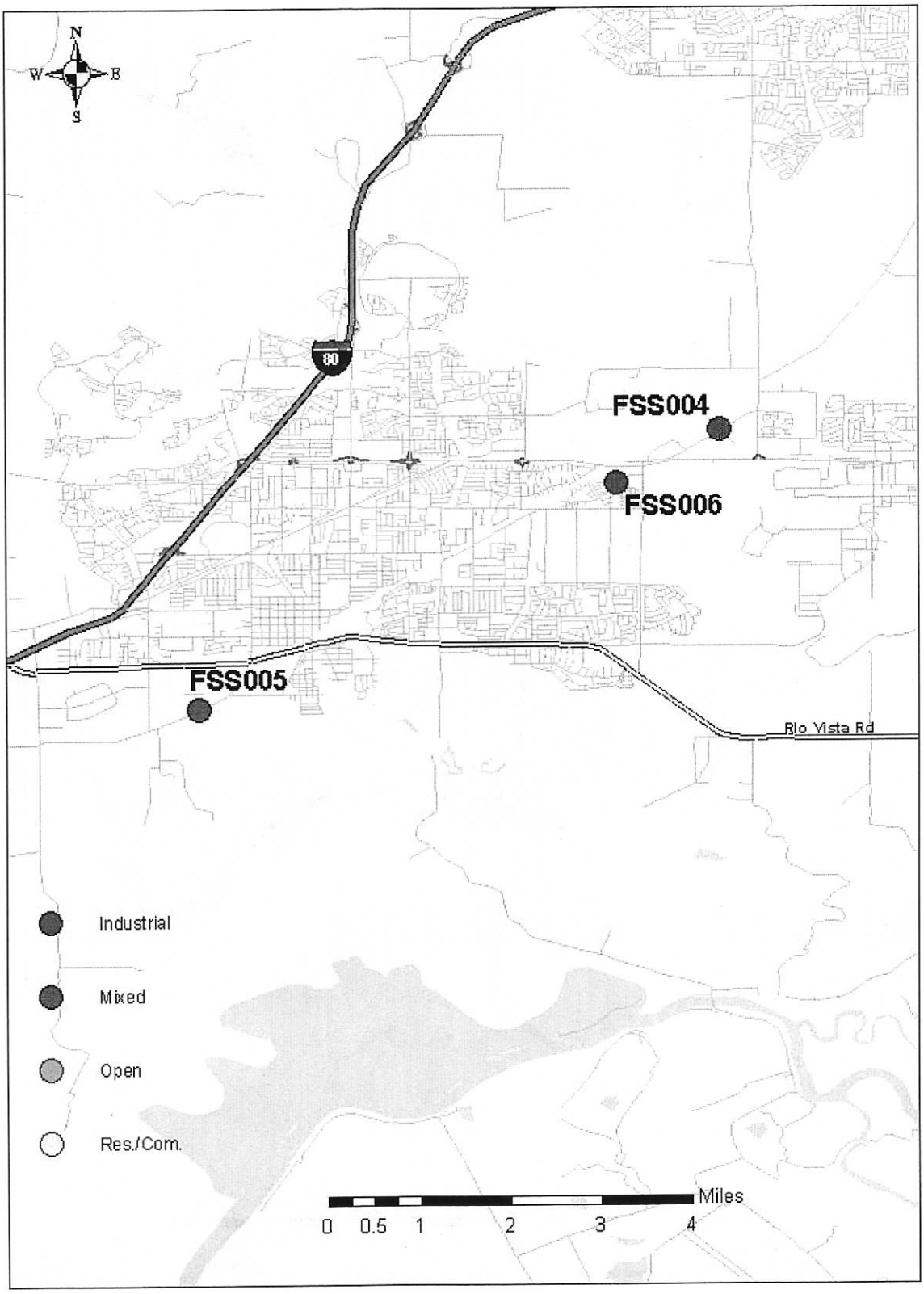

Figure 10. Sampling locations in the region of Fairfield.

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Table 3. Sampling Locations and Station Identifications 2000-2001.

STATION ID	GENERAL SITE LOCATION	SAMPLING DATE	LATITUDE	LONGITUDE	WATERSHED PROPERTIES	SAMPLING LOCATION
SCV001	555 Burke Street (San Jose)	30 Oct. 2000	37° 18.620'	121° 51.167'	Industrial	Manhole
	285 Leo Street (San Jose)		37° 18.668'	121° 51.860'		Manhole
SCV002	Sunol Street and Auzerais Avenue (San Jose)	30 Oct. 2000	37° 19.263'	121° 54.345'	Industrial	Catchbasin
	West Home Street near. Sunol Street (San Jose)		37° 19.207'	121° 54.253'		Catchbasin
SCV003	Fairchild Drive east of Ellis Street (Mountain View)	27 Oct. 2000	37° 24.195'	122° 03.032'	Industrial	Manhole
	Intersection of National Ave. and Fairchild Drive (Mountain View)		37° 24.248'	122° 03.213'		Manhole
SCV004	Intersection of Transport St. and Industrial Avenue (Palo Alto)	24 Oct. 2000	37° 25.455'	122° 05.900'	Industrial	Catchbasin
SCV005	Tahoe Ave. (near Lawrence Exp. And Kiefer, Santa Clara)	27 Oct. 2000	37° 22.545'	121° 59.875'	Industrial	Manhole
SCV006	601 Walsh Avenue (Santa Clara)	27 Oct. 2000	37° 22.210'	121° 56.792'	Industrial	Manhole
SCV007	Ringwood near Montegue Expressway (Milpitas)	27 Oct. 2000	37° 24.267'	121° 54.028'	Industrial	Outfall
SCV008	Charleston Retention Basin (Mountain View)	24 Oct. 2000	37° 25.308'	122° 04.322'	Industrial	Detention Basin
SCV009	Bellew Pump Station (Milpitas)	31 Oct. 2000	37° 25.087'	121° 55.785'	Industrial	Pump Station
SCV010	Murphy Ranch Pump Station (Milpitas)	31 Oct. 2000	37° 24.089'	121° 55.532'	Industrial	Pump Station
SCV011	Oak Creek Pump Station (Milpitas)	31 Oct. 2000	37° 24.395'	121° 55.248'	Industrial	Pump Station
SCV012	West Virginia Street and the Guadalupe River (San Jose)	30 Oct. 2000	37° 19.207'	121° 53.343'	Res./Com.	Outfall
SCV014	South Corner A Street and Knowles (Los Gatos)	30 Oct. 2000	37° 15.687'	121° 57.700'	Res./Com	Catchbasin
SCV015	Calabassas Creek near Mount Eden Road (Saratoga)	26 Oct. 2000	37° 16.132'	122° 03.638'	Open	Open Channel
SCV016	San Francisquito Creek near Alpine Road (Santa Clara County)	27 Oct. 2000	37° 24.758'	122° 11.655'	Open	Open Channel
SCV017	Coyote Creek at Gilroy Hot Springs (Santa Clara County)	26 Oct. 2000	37° 05.963'	121° 28.375'	Open	Open Channel
SCV018	Lincoln Ave & Savaker Street (San Jose)	30 Oct. 2000	37° 19.068'	121° 54.482'	Mixed	Catchbasin
	Northrup & Lincoln (San Jose)		37° 19.050'	121° 54.502'		Catchbasin
	La Fenetre Apartments on Parkmoor Avenue (San Jose)		37° 19.007'	121° 54.495'		Catchbasin
SCV019	Sunnyoaks Industrial Center (Campbell)	26 Oct. 2000	37° 16.307'	121° 57.148'	Mixed	Catchbasin
	1260 Dell Avenue (Campbell)		37° 16.063'	121° 57.210'		Catchbasin
SCV021	Cottle Road South (just south of Santa Teresa Blvd, San Jose.)	30 Oct. 2000	37° 14.088'	121° 48.232'	Mixed	Open Channel
SCV022	Old Oakland near Montegue Expressway (Milpitas)	27 Oct. 2000	37° 24.267'	121° 54.028'	Mixed	Outfall
SCV024	Calabassas Creek between Lakeside Dr. and Scott Blvd. (Sunnyvale)	31 Oct. 2000	37° 23.285'	121° 59.215'	Mixed	Open Channel
SCV025	Gold Street Pump Station (Alviso)	21 Sept. 2001	37° 25.694'	121° 58.551'	Mixed	Pump Station

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STATION ID	GENERAL SITE LOCATION	SAMPLING DATE	LATITUDE	LONGITUDE	WATERSHED PROPERTIES	SAMPLING LOCATION
SCV026	Oakmead Pump Station (San Jose)	21 Sept. 2001	37° 24.868'	121° 57.810'	Mixed	Pump Station
SCV027	River Oaks Pump Station (San Jose)	21 Sept. 2001	37° 24.082'	121° 56.691'	Industrial	Pump Station
SCV028	Newhall Street and Campbell Avenue (San Jose)	5 Oct. 2001	37° 20.743'	121° 55.535'	Res./Com.	Manhole
SCV029	McKendrie Street and Stockton Avenue (San Jose)	5 Oct. 2001	37° 20.730'	121° 55.110'	Industrial	Catchbasin
SCV030	Lorentz Barrel and Drum (San Jose)	10 Sept. 2001	37° 19.186'	121° 51.940'	Industrial	Catchbasin
SCV031	Needles Drive and 10th Street (San Jose)	10 Sept. 2001	37° 18.832'	121° 51.608'	Industrial	Catchbasin
SCV032	1850, 1854, and 1760 7th Street (San Jose)	10 Sept. 2001	37° 18.657'	121° 51.726'	Industrial	Catchbasin
SCV033	Stauffer Chemical/GE Datasonics (1887 Monterey Rd. San Jose)	10 Sept. 2001	37° 18.541'	121° 52.008'	Industrial	Manhole
SCV034	5th and 7th Streets (San Jose)	5 Oct. 2001	37° 21.722'	121° 54.060'	Industrial	Manhole
SCV035	Hendy Avenue (Sunnyvale)	25 Sept. 2001	37° 22.562'	122° 01.349'	Industrial	Catchbasin
SCV036	Robert Avenue (Santa Clara)	21 Sept. 2001	37° 21.881'	121° 56.567'	Industrial	Catchbasin
SCV037	Commercial Street and Arques Avenue	25 Sept. 2001	37° 22.853'	122° 00.453'	Industrial	Catchbasin
SCV038	Commercial Avenue (Sunnyvale)	25 Sept. 2001	37° 25.501'	122° 06.005'	Industrial	Catchbasin
	Independence Avenue (Sunnyvale)		37° 25.288'	122° 05.794'		Catchbasin
SCV039	Fabian Way (Palo Alto)	25 Sept. 2001	37° 25.563'	122° 06.249'	Industrial	Manhole
SCV041	Lower Adobe Creek (Palo Alto)	25 Sept. 2001	37° 25.773'	122° 06.319'	Mixed	Open Channel
SCV042	Lower Stevens Creek (Mountain View)	25 Sept. 2001	37° 24.389'	122° 04.135'	Mixed	Open Channel
SCV043	Upper Stevens Creek (Santa Clara County)	25 Sept. 2001	37° 17.019'	122° 07.334'	Open	Open Channel
SCV044	Wrigley Creek (North American Transformer, Milpitas)	25 Sept. 2001	37° 24.949'	121° 53.646'	Industrial	Open Channel
SCV045	Upper Adobe Creek (Santa Clara County)	2 Oct. 2001	37° 20.824'	122° 09.742'	Open	Open Channel
SMC001	Douglas Pump Station (Redwood City)	24 Oct. 2000	37° 29.230'	122° 12.392'	Industrial	Pump Station
SMC002	Broadway Pump Station (Redwood City)	24 Oct. 2000	37° 29.233'	122° 12.822'	Industrial	Pump Station
SMC003	Maple Ave. and South Canal (South San Francisco)	25 Oct. 2000	37° 39.027'	122° 24.833'	Res./Com.	Pump Station
SMC004	Veterans Pump Station (Redwood City)	24 Oct. 2000	37° 29.832'	122° 14.223'	Res./Com.	Pump Station
SMC005	Coyote Point Pump Station (San Mateo)	25 Oct. 2000	37° 35.213'	122° 19.918'	Res./Com.	Open Channel
SMC006	Cordilleras Creek at Edmunds (San Mateo County)	24 Oct. 2000	37° 28.513'	122° 16.972'	Open	Open Channel
SMC007	McGarvey Creek and West Union Confluence (San Mateo County)	25 Oct. 2000	37° 26.665'	122° 17.463'	Open	Open Channel
SMC008	Bear Gulch Creek nr. Woodside Road (Woodside)	24 Oct. 2000	37° 24.975'	122° 16.147'	Open	Open Channel
SMC009	South Maple Pump Station (South San Francisco)	25 Oct. 2000	37° 38.657'	122° 25.002'	Mixed	Pump Station
SMC010	Colma Creek near West Orange Avenue (South San Francisco)	25 Oct. 2000	37° 39.190'	122° 25.533'	Mixed	Open Channel

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STATION ID	GENERAL SITE LOCATION	SAMPLING DATE	LATITUDE	LONGITUDE	WATERSHED PROPERTIES	SAMPLING LOCATION
SMC011	Bradford Pump Station (Redwood City)	24 Oct. 2000	37° 29.332'	122° 13.622'	Mixed	Pump Station
SMC012	San Mateo Creek near South Grant Street (San Mateo)	25 Oct. 2000	37° 34.203'	122° 19.115'	Mixed	Open Channel
SMC013	Poplar Creek near N. Bayshore Blvd. and E. Poplar Ave. (San Mateo)	25 Oct. 2000	37° 34.857'	122° 19.407'	Mixed	Open Channel
SMC015	Adrian Road @ David Road Pump Station (Burlingame)	6 Sept. 2001	37° 35.633'	122° 22.095'	Industrial	Pump Station
SMC016	1740 Rollins Road Pump Station (Burlingame)	6 Sept. 2001	37° 35.875'	122° 22.627'	Industrial	Pump Station
SMC017	1592 Marsten @ Rollins Road Pump Station (Burlingame)	6 Sept. 2001	37° 35.529'	122° 21.955'	Industrial	Pump Station
SMC019	O'Connor Street Pump Station (East Palo Alto)	20 Sept. 2001	37° 27.659'	122° 07.455'	Industrial	Pump Station
SMC020	Delta Star (San Carlos)	20 Sept. 2001	37° 31.054'	122° 15.829'	Industrial	Manhole
SMC021	Bayport Avenue and Center Street (San Carlos)	20 Sept. 2001	37° 29.921'	122° 14.755'	Industrial	Manhole
SMC022	Bransten Road (San Carlos)	20 Sept. 2001	37° 30.378'	122° 15.213'	Industrial	Catchbasin
SMC023	Pulgas Creek Pump Station (San Carlos)	25 Sept. 2001	37° 30.290'	122° 14.949'	Industrial	Pump Station
SMC024	Colma Creek @ Collins Avenue (Colma)	6 Sept. 2001	37° 40.442'	122° 27.421'	Res./Com.	Open Channel
SMC025	Beatty Avenue (Brisbane)	20 Sept. 2001	37° 42.399'	122° 23.887'	Industrial	Manhole
SMC026	430 East Grand Avenue (South San Francisco)	6 Sept. 2001	37° 39.051'	122° 23.022'	Industrial	Manhole
SMC027	214 Shaw Road (South San Francisco)	6 Sept. 2001	37° 38.478'	122° 24.576'	Industrial	Manhole
SMC028	Belmont Creek (San Carlos)	20 Sept. 2001	37° 31.228'	122° 15.964'	Mixed	Open Channel
SMC029	Holly Street and Industrial Road (San Carlos)	20 Sept. 2001	37° 30.742'	122° 15.531'	Res./Com.	Open Channel
SMC030	Jefferson Branch of Redwood Creek (Redwood City)	4 Oct. 2001	37° 28.851'	122° 14.074'	Res./Com.	Open Channel
SMC031	Redwood Creek Main Branch (Redwood City)	4 Oct. 2001	37° 28.823'	122° 14.074'	Res./Com.	Open Channel
CCC001	Goodrich Ave and Richmond Parkway (Richmond)	27 Oct. 2000	37° 58.490'	122° 21.900'	Industrial	Open Channel
CCC002	Giant Street at Rheem Creek (Richmond)	27 Oct. 2000	37° 58.617'	122° 21.212'	Industrial	Catchbasin
CCC003	209 Parr Boulevard (Richmond)	27 Oct. 2000	37° 58.062'	122° 22.178'	Industrial	Manhole
CCC005	Parr Boulevard and Richmond Parkway (Richmond)	27 Oct. 2000	37° 58.068'	122° 22.512'	Industrial	Catchbasin
CCC006	Hensley Street and Castro Street (Richmond)	27 Oct. 2000	37° 56.803'	122° 22.008'	Industrial	Catchbasin
CCC007	Marina Vista Road (near Shell just west of I-680, Martinez)	27 Oct. 2000	38° 01.523'	122° 07.037'	Industrial	Catchbasin
CCC009	Willow Creek near private road to Tefler (Pittsburg)	25 Oct. 2000	38° 01.808'	121° 54.883'	Industrial	Open Channel
CCC010	Pine Creek near Castle Rock Road (Contra Costa County)	25 Oct. 2000	37° 53.605'	121° 59.630'	Open	Open Channel
CCC011	Bollinger Creek North of Crow Canyon (Contra Costa County)	27 Oct. 2000	37° 47.102'	122° 00.083'	Open	Open Channel
CCC012	San Ramon Creek near Sycamore Valley Road (Danville)	27 Oct. 2000	37° 48.673'	121° 59.037'	Res./Com.	Open Channel
CCC013	Tassajarra Creek near Finley and Old School Road (Contra Costa County)	27 Oct. 2000	37° 48.185'	121° 51.652'	Open	Open Channel

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STATION ID	GENERAL SITE LOCATION	SAMPLING DATE	LATITUDE	LONGITUDE	WATERSHED PROPERTIES	SAMPLING LOCATION
CCC014	Alhambra Creek near Brockwood Drive (Contra Costa County)	27 Oct. 2000	37° 57.622'	122° 07.490'	Open	Open Channel
CCC015	Kellogg Creek and Vasco (Contra Costa County)	25 Oct. 2000	37° 52.317'	121° 41.942'	Open	Open Channel
CCC016	Walnut Creek above Willow Pass Road (Concord)	27 Oct. 2000	37° 57.968'	122° 03.302'	Mixed	Open Channel
CCC017	Rheem Creek near Giant Highway (Richmond)	27 Oct. 2000	37° 58.632'	122° 21.208'	Mixed	Open Channel
CCC018	Wildcat Creek at 3rd Street (Richmond)	27 Oct. 2000	37° 57.623'	122° 22.005'	Mixed	Open Channel
CCC019	Gregory Lane at Contra Costa Blvd. (Pleasant Hill)	25 Oct. 2000	37° 56.863'	122° 03.618'	Res./Com.	Open Channel
CCC020	Stege Marsh (intersection of Regatta and open channel, Richmond)	1 Oct. 2001	37° 55.078'	122° 20.300'	Industrial	Open Channel
CCC021	Pittsburgh Avenue (Richmond)	1 Oct. 2001	37° 57.790'	122° 22.287'	Industrial	Catchbasin
CCC022	Landini Road and Erickson Road (Walnut Creek)	21 Sept. 2001	37° 57.484'	122° 02.241'	Industrial	Catchbasin
CCC023	End of Canal Road (Richmond)	1 Oct. 2001	37° 54.376'	122° 21.852'	Industrial	Catchbasin
CCC024	San Pablo Creek Outfall near Third Street (Richmond)	1 Oct. 2001	37° 58.048'	122° 22.010'	Industrial	Outfall
CCC025	West Gertrude (Richmond)	1 Oct. 2001	37° 57.240'	122° 22.486'	Industrial	Catchbasin
CCC026	Open Channel on Goodrick Avenue (Richmond)	1 Oct. 2001	37° 58.433'	122° 21.917'	Industrial	Open Channel
CCC027	Sand Creek at Empire Mine Road (Contra Costa County)	21 Sept. 2001	37° 57.107'	121° 48.271'	Open	Open Channel
CCC028	James Donlan Blvd. at Sommersville Road (Antioch)	3 Oct. 2001	37° 59.241'	121° 51.177'	Industrial	Outfall
CCC029	Mt. Diablo Creek downstream of US Naval Weapon Station (Concord)	3 Oct. 2001	38° 00.824'	122° 00.906'	Industrial	Open Channel
CCC030	Cerrito Creek at Pierce Road (Richmond)	2 Oct. 2001	37° 53.975'	122° 18.556'	Industrial	Open Channel
CCC031	Wright Avenue at Harbor Way (Richmond)	1 Oct. 2001	37° 55.274'	122° 21.664'	Industrial	Catchbasin
CCC032	West Cutting Blvd. Near South 1st Street (Richmond)	1 Oct. 2001	37° 55.523'	122° 22.146'	Industrial	Catchbasin
CCC033	2501 Concord Blvd. near PG&E Substation (Concord)	21 Sept. 2001	37° 58.648'	122° 01.735'	Industrial	Catchbasin
MCS001	Miller Creek at end of Marinwood (Marinwood)	30 Oct. 2000	38° 01.842'	122° 32.287'	Open	Open Channel
MCS002	Mahone Creek near intersection of E St. and First Street (Larkspur)	30 Oct. 2000	37° 58.257'	122° 32.007'	Mixed	Open Channel
MCS003	Novato Creek at Downtown Novato Center (Novato)	30 Oct. 2000	38° 06.437'	122° 34.732'	Mixed	Open Channel
MCS004	Arroyo Corte Madera Del Presidio at La Goma (Mill Valley)	30 Oct. 2000	37° 53.872'	122° 32.192'	Mixed	Open Channel
MCS005	Pacheco Pond (Novato)	25 June 2001	38° 04.670'	122° 31.879'	Mixed	Pond
MCS006	Mouth of Arroyo San Jose into Pacheco Pond (Novato)	25 June 2001	38° 04.230'	122° 31.737'	Mixed	Open Channel
MCS007	Outfall into Arroyo San Jose (Novato)	25 June 2001	38° 04.219'	122° 31.868'	Res./Com.	Outfall
MCS008	Outfall into Pacheco Creek (Novato)	25 June 2001	38° 03.962'	122° 31.808'	Industrial	Outfall
MCS009	Pacheco Creek downstream of Railroad Tracks (Novato)	25 June 2001	38° 03.713'	122° 31.641'	Industrial	Open Channel
MCS010	Outfall at the end of Commercial Boulevard (Novato)	25 June 2001	38° 04.063'	122° 31.755'	Industrial	Catchbasin

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STATION ID	GENERAL SITE LOCATION	SAMPLING DATE	LATITUDE	LONGITUDE	WATERSHED PROPERTIES	SAMPLING LOCATION
MCS011	Pacheco Creek at the end of Pacheco Creek Road (Novato)	25 June 2001	38° 03.033'	122° 33.245'	Mixed	Open Channel
MCS012	Unlined Drainage Ditch near Lovell (San Rafael)	25 June 2001	37° 57.989'	122° 31.349'	Industrial	Open Channel
MCS013	Open Ditch through the San Rafael Improvement Club (San Rafael)	25 June 2001	37° 58.495'	122° 32.334'	Res./Com.	Open Channel
VFC001	Austin Creek at Hwy 37 (Vallejo)	31 Oct. 2000	38° 07.590'	122° 16.153'	Res./Com.	Open Channel
VFC001	Austin Creek at Hwy 37 (Vallejo)	16 Oct. 2001	38° 07.585'	121° 16.155'	Res./Com.	Open Channel
VFC002	Stream bed below flume exiting Chabot Lake (Vallejo)	31 Oct. 2000	38° 08.467'	122° 14.790'	Res./Com.	Open Channel
VFC003	Hiddenbrooke (Vallejo)	31 Oct. 2000	38° 08.503'	122° 10.209'	Open	Detention Basin
VFC004	Midway Street (Vallejo)	16 Oct. 2001	38° 05.446'	121° 14.867'	Industrial	Open Channel
VFC005	Lake Dalwigk (Vallejo)	16 Oct. 2001	38° 05.676'	121° 14.512'	Mixed	Detention Basin
VFC006	Nebraska Street (Vallejo)	16 Oct. 2001	38° 06.880'	121° 15.128'	Res./Com.	Manhole
VFC007	Hiddenbrooke/Sky Valley (Vallejo)	16 Oct. 2001	38° 08.472'	122° 10.278'	Open	Detention Basin
VFC008	Lemon Street (Vallejo)	16 Oct. 2001	38° 05.392'	121° 14.415'	Res./Com.	Open Channel
VFC009	Fairgrounds Drive at Coach Lane (Vallejo)	16 Oct. 2001	38° 07.848'	121° 13.719'	Mixed	Open Channel
VFC010	Sonoma Boulevard at Couch Street (Vallejo)	16 Oct. 2001	38° 06.953'	121° 15.257'	Res./Com.	Open Channel
FSS001	Union Creek and Highway 12 (Solano County)	31 Oct. 2000	38° 13.777'	121° 58.547'	Industrial	Open Channel
FSS002	Suisun Creek and Cordelia (Fairfield)	31 Oct. 2000	38° 13.487'	122° 06.427'	Open	Open Channel
FSS003	Green Valley Creek and Cordelia (Cordelia)	3 Nov. 2000	38° 12.712'	122° 07.765'	Res./Com.	Open Channel
FSS004	Huntington Drive (Fairfield)	21 Sept. 2001	38° 16.651'	121° 58.523'	Industrial	Catchbasin
FSS005	Outfall into Ledgewood Creek at Cordelia Road (Solano County)	21 Sept. 2001	38° 14.012'	122° 03.478'	Mixed	Outfall
FSS006	McCoy Creek at Walters Court (Fairfield)	21 Sept. 2001	38° 16.148'	121° 59.498'	Industrial	Open Channel

SCV = Santa Clara Valley Urban Runoff Pollution Prevention Program

SMC = San Mateo Countywide Stormwater Pollution Prevention Program

CCC = Contra Costa Clean Water Program

MCS = Marin County Stormwater Pollution Prevention Program

VFC = Vallejo Flood Control and Sanitation District

FSS = Fairfield-Suisun Sewer District

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2.2 Sampling Procedures

General procedures used for sediment sampling were based on those in use by the Regional Monitoring Program for Trace Substances in the San Francisco Estuary (RMP) and the USGS National Water Quality Assessment Program (NAWQA). Development of sampling procedures was coordinated with complementary work being conducted by the Alameda Countywide Clean Water Program to assure comparability of results.

2.2.1 Initial Sampling Equipment Decontamination

Sediment sampling equipment was prepared in the laboratory a minimum of four days prior to sampling. Cleaning methods followed protocols adapted from the NOAA National Status and Trends Program for use by the Regional Monitoring Program (Bell *et al.*, 1999). Sampling equipment included:

- 6" x 6" Petite Ponar Grab (all 316 Stainless Steel)
- Tefzel-coated sampling scoops and spoons
- Tefzel-coated compositing buckets
- Wash bottles and storage containers for deionized water
- Wash bottles for hydrochloric acid and methanol

Prior to sampling, all equipment was thoroughly cleaned. Equipment was soaked (fully immersed) for three days in 2% Micro® solution and deionized water. Equipment was rinsed three times in deionized water and let dry in a clean place. Equipment was then rinsed with a 1.0% solution of hydrochloric acid, followed by a rinse with deionized water to eliminate the acid. A rinse was then conducted with petroleum ether, followed by another set of three rinses with deionized water. Equipment was then allowed to dry in a clean place.

The cleaned Ponar Grab and compositing buckets were wrapped in aluminum foil until used in the field. All other equipment was stored in clean Ziploc™ bags until used in the field.

2.2.2 Field Sampling Procedures

Final coordinates for sediment sampling were determined in the field using a Garmin GPS. Field log sheets were compiled for each site that recorded the sampling date, crew members names, narrative description of the sampling site (general location) and all specific substations (places where samples are collected for compositing, including whether sediment was under water or exposed), and the method used to collect sediment. To reduce variability within any sampling site, a minimum of three equal volume replicates were taken whenever possible. These replicates were mixed to produce a single site composite.

Similar to procedures established for NAWQA (Shelton and Capel, 1994), one of two sampling methods was used to collect sediments, depending upon the site-specific conditions:

1. Tefzel-coated spoons/scoops – This was the primary sampling method used at most open channel or catchbasin sites. Spoon/scoops were used to collect sediments adjacent to obstructions and other areas for which other sampling gear was inappropriate. Samples were then placed directly into the compositing bucket.

2. Stainless Steel Petite Ponar Grab – The Ponar Grab was used for collection in shallow and deeper open channels, and at pump stations. The Ponar Grab is a self-closing sampler using a spring-loaded Pinch-Pin™ that releases when the sampler impacts the bottom and the lowering cable or

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line becomes slack. The top of each scoop has a removable stainless steel screen (583 micron) to allow water to flow through the sampler during descent. This lessens the frontal shock wave created by descent and reduces surface disturbance. Both screens are covered with neoprene rubber flaps that open during descent for water flow through, and close during retrieval to prevent sample wash out. After the Ponar Grab was retrieved, the surface water was allowed to drain off, and sediment was removed with a Tefzel-coated spoon/scoop and placed in the compositing bucket.

In order to be considered acceptable, the grab samples were required to satisfy a set of quality criteria. Samples were rejected if the Ponar grab did not close fully allowing sample to wash out or if removal of the overlying water resulted in significant wash out of sediment fines.

The compositing bucket was covered with aluminum foil when not in use. No sieving of sediments was performed in the field, however, larger debris and cobble were removed from the samples using a Tefzel-coated spoon. Sieving was later performed by the laboratory to remove excess cobble and debris prior to their analysis. At the conclusion of sample collection at each site, all sediment was composited in the buckets and then subsampled for distribution to the appropriate laboratories. Disposable powder free nitrile gloves were worn while collecting and compositing samples to mitigate potential contamination. Gloves were changed between each location to reduce the potential for cross-contamination.

All sampling equipment was rinsed with native water, when possible, or deionized water between uses at different depositional areas. All sampling equipment used at a particular sampling location was field cleaned prior to use at a different sampling location. The field-cleaning protocol involved 1) removal of sediments using a scrub brush and native water or deionized water; 2) scrubbing of sampling gear and compositing equipment with a 2% Micro® solution and deionized water; 3) rinse with deionized water; 4) rinse with a 1.0% solution of HCl; 5) rinse with methanol; and 6) rinse with deionized water.

At the conclusion of sample processing at each sampling location, all samples were wrapped in protective material and stored on ice in the field. At the conclusion of a day's sampling, all samples were either stored overnight on dry ice or removed to a freezer for temporary storage prior to distribution to the analytical laboratories.

2.3 Analytical Methods and Reporting Limits

Analytical methods and detection limits for sediments are summarized in Tables 4 through 6. All detection limits were based upon dry weight with the assumption that sediments will contain no more than 20% water by weight. Laboratory method detection limits (MDL) and method reporting limits (MRL) are summarized in Table 5 for specific PCB congeners being analyzed. The list of PCB congeners analyzed included the 40 congeners listed in the Regional Monitoring Program QAPP (Lowe, Hoenicke, and Davis 1999), two extra congeners included in the Alameda County program (Applied Marine Science 2000), and 12 additional congeners. During the first year of the program, the laboratory inadvertently analyzed PCB199 rather than PCB201 due to minor differences in nomenclature between the IUPAC naming and number conventions utilized by this program and BZ (Ballschmiter and Zell 1980) conventions used by the laboratory. This was corrected during the second season of testing. Project detection limits for individual organochlorine pesticides analyzed during the second season of testing are summarized in Table 6.

Samples were collected in a single, 1-liter, widemouth glass container for transfer to the laboratory where the samples were homogenized, sieved through a 2 millimeter screen and then subsampled for each of the analyses in Tables 4 through 6. All samples were maintained at 2-4 degrees centigrade while being stored and during the shipping process.

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Table 4. Parameters, methods, and holding times for analysis of sediments

Parameter	Units (dry wt.)	Method	Method Reporting Limit	Holding Times
Individual PCB Congeners	ng/g	EPA 8082	0.5	14 days extract 40 days analysis
Organochlorine Pesticides	ng/g	EPA 8081 A	0.1	14 days extract 40 days analysis
Total Mercury	ng/g	EPA 7471a	2-4	28 days
Particle Size (Puget Sound Protocol with hydrogen peroxide digestion)	%	ASTM D422M/PSEP	NS[1]	6 months[2]
Percent Moisture	%	EPA 160.3/PSEP	0.1	6 months[2]
TOC	%	ASTM D4129-82/PSEP	0.1	14 days

ASTM=American Society for Testing and Materials, PSEP=Puget Sound Estuary Project

1. NS indicates that the Target Detection Limit is not specified.
2. Maximum recommended limits if samples are sealed and refrigerated during storage.

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Table 5. Comparison of Regional Monitoring Program target method detection limits (MDLs) for PCB congeners with project specific MDLs and method reporting limits (MRLs)

PCB Congener Number (IUPAC)	PCB Congener Name (IUPAC)	RMP Target MDL[1] ng/g	Laboratory MDL ng/g	Laboratory MRL ng/g
8	2,4'-Dichlorobiphenyl	1	0.5	0.5
18	2,2',5-Trichlorobiphenyl	1	0.2	0.5
28	2,4,4'-Trichlorobiphenyl	1	0.09	0.5
31	2,4',5-Trichlorobiphenyl	1		0.5
33	2,3',4'-Trichlorobiphenyl	1	0.1	0.5
44	2,2',3,5'-Tetrachlorobiphenyl	1	0.07	0.5
49	2,2',4,5'-Tetrachlorobiphenyl	1	0.1	0.5
52	2,2',5,5'-Tetrachlorobiphenyl	1	0.07	0.5
56	2,3,3',4'-Tetrachlorobiphenyl	1		0.5
60	2,3,4,4'-Tetrachlorobiphenyl	1	0.3	0.5
66	2,3',4,4'-Tetrachlorobiphenyl	1	0.09	0.5
70	2,3',4',5-Tetrachlorobiphenyl	1	0.5	0.5
74	2,4,4',5-Tetrachlorobiphenyl	1	0.5	0.5
77[2]	3,3',4,4'-Tetrachlorobiphenyl	NA		0.5
81[2]	3,4,4',5-Tetrachlorobiphenyl	NA		0.5
87	2,2',3,4,5'-Pentachlorobiphenyl	1	0.07	0.5
90[2]	2,2',3,4',5-Pentachlorobiphenyl	NA		0.5
95	2,2',3,5',6-Pentachlorobiphenyl	1	0.5	0.5
97	2,2',3,4',5'-Pentachlorobiphenyl	1	0.5	0.5
99	2,2',4,4',5-Pentachlorobiphenyl	1	0.5	0.5
101	2,2',4,5,5'-Pentachlorobiphenyl	1	0.2	0.5
105	2,3,3',4,4'-Pentachlorobiphenyl	1	0.4	0.5
110	2,3,3',4',6-Pentachlorobiphenyl	1	0.05	0.5
114[2]	2,3,4,4',5-Pentachlorobiphenyl	NA		0.5
118	2,3',4,4',5-Pentachlorobiphenyl	1	0.07	0.5
123[2]	2,3',4,4',5'-Pentachlorobiphenyl	NA		0.5
126[2]	3,3',4,4',5-Pentachlorobiphenyl	NA		0.5
128	2,2',3,3',4,4'-Hexachlorobiphenyl	1	0.2	0.5
132	2,2',3,3',4,6'-Hexachlorobiphenyl	1	0.5	0.5
138	2,2',3,4,4',5'-Hexachlorobiphenyl	1	0.3	0.5
141	2,2',3,4,5,5'-Hexachlorobiphenyl	1	0.5	0.5
149	2,2',3,4',5',6-Hexachlorobiphenyl	1	0.5	0.5
151	2,2',3,5,5',6-Hexachlorobiphenyl	1	0.5	0.5
153	2,2',4,4',5,5'-Hexachlorobiphenyl	1	0.2	0.5
156	2,3,3',4,4',5-Hexachlorobiphenyl	1	0.09	0.5
157[2]	2,3,3',4,4',5'-Hexachlorobiphenyl	NA		0.5
158	2,3,3',4,4',6-Hexachlorobiphenyl	1	0.3	0.5
166[2]	2,3,4,4',5,6-Hexachlorobiphenyl	NA		0.5
167[2]	2,3',4,4',5,5'-Hexachlorobiphenyl	NA		0.5
169[2]	3,3',4,4',5,5'-Hexachlorobiphenyl	NA		0.5
170	2,2',3,3',4,4',5-Heptachlorobiphenyl	1	0.3	0.5
174	2,2',3,3',4,5,6'-Heptachlorobiphenyl	1	0.5	0.5
177	2,2',3,3',4,5',6'-Heptachlorobiphenyl	1	0.5	0.5
180	2,2',3,4,4',5,5'-Heptachlorobiphenyl	1	0.3	0.5
183	2,2',3,4,4',5',6-Heptachlorobiphenyl	1	0.08	0.5
184[2]	2,2',3,4,4',6,6'-Heptachlorobiphenyl	NA		0.5
187	2,2',3,4',5,5',6-Heptachlorobiphenyl	1	0.2	0.5
189[2]	2,3,3',4,4',5,5'-Heptachlorobiphenyl	NA		0.5
194	2,2',3,3',4,4',5,5'-Octachlorobiphenyl	1	0.07	0.5
195	2,2',3,3',4,4',5,6-Octachlorobiphenyl	1	0.5	0.5
199[2]	2,2',3,3',4,5,5',6'-Octachlorobiphenyl	NA	0.5	0.5
201	2,2',3,3',4,5',6,6'-Octachlorobiphenyl	1		0.5
203	2,2',3,4,4',5,5',6-Octachlorobiphenyl	1		0.5
206[2]	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	NA	0.07	0.5
209[2]	2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl	NA	0.08	0.5

MDL=Method Detection Limit, MRL=Method Reporting Limit, NA= Not Applicable, not reported by the RMP.

1. Lowe, S., R. Hoenicke, and Jay Davis 1999. 1999 Quality Assurance Project Plan, Regional Monitoring Program for Trace Substances. RMP Contribution #33
2. Congeners not included in 1999 RMP QAPP.

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Table 6. Comparison of Regional Monitoring Program target method detection limits (MDLs) for organochlorine pesticides with project specific MDLs and method reporting limits (MRLs)

Organochlorine Pesticides	RMP Target MDL[1] ng/g	Approximate Laboratory MDL ng/g	Minimum Laboratory RL ng/g
alpha-BHC	1	0.1	1
beta-BHC	1	0.1	1
gamma-BHC (lindane)	1	0.2	1
delta-BHC	1	0.4	1
Heptachlor	1	0.1	1
Aldrin	1	0.2	1
Heptachlor Epoxide	1	0.1	1
gamma-Chlordane	1	0.1	1
Endosulfan I	1	0.1	1
alpha-Chlordane	1	0.1	1
Dieldrin	1	0.3	1
4,4'-DDE	1	0.2	1
Endrin	1	0.1	1
Endosulfan II	1	0.2	1
4,4'-DDD	1	0.2	1
Endrin Aldehyde	1	0.4	1
Endosulfan Sulfate	1	0.2	1
4,4'-DDT	1	0.2	1
Endrin Ketone	1	0.2	1
Methoxychlor	1	0.2	1
Hexachlorobenzene	1	0.05	1
Chlorpyrifos	1	0.06	1
Oxychlordane	1	0.1	1
2,4'-DDE	1	0.05	1
trans-Nonachlor	1	0.04	1
2,4'-DDD	1	0.04	1
cis-Nonachlor	1	0.04	1
2,4'-DDT	1	0.2	1
Mirex	1	0.06	1

2.4 Field and Laboratory Quality Control

2.4.1 Field Sampling Quality Control

Six field replicate samples were collected contemporaneously with an original sample and submitted blind to the laboratories performing the analyses. Identical recovery techniques were used for both the original and the replicate sample, and both samples were treated in an identical manner during storage, transportation, and analysis.

Data quality objectives are not established for field replicates. Replicates were included in this study to assess the extent of field variability since this could have a strong influence on data interpretation.

2.4.2 Laboratory Quality Control

A thorough laboratory quality control program was established in the 2000 Quality Assurance Project Plan (Kinnetic Laboratories, Inc. 2000) and the 2001 update (Kinnetic Laboratories, Inc. 2001). This

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program included use of method blanks, matrix spike/spike duplicates, surrogate spikes, laboratory control samples (LCS), certified reference materials (CRM) and laboratory replicates. Table 7 summarizes the frequency of each control check for each analyte and established data quality objectives.

Table 7. Summary of laboratory quality control performance measures and data quality objectives for measurement of mercury, PCBs, organochlorine pesticides, TOC and grain size in sediments.

QA Sample	QA Measure	Minimum Frequency	Criteria
Method Blank	**Contamination** by reagents, laboratory ware, etc.	One per batch (minimum of 1 for every 20 samples)	<MDL or <10% of lowest sample
Certified Reference Material	**Accuracy**	One per 20 field samples (TOC every 15 samples)	50-150 % recovery for NIST-1944
	Precision		RPD (if n=2) <35% RSD (if n>2) <35% RSD of last 7 CRMs <35%
Laboratory Replicates	**Precision**	One per 20 field samples	RPDs TOC <20% Hg <30% PCBs <40% OP Pest <40% RSD PSDs <20%
Laboratory Control Samples (LCS) (required for TOC and Grain Size, optional for PCBs and Hg)	**Accuracy and Precision**	One per 20 field samples	Within 20-25% consensus value
Matrix Spikes (Spike and Spike Duplicate)	**Accuracy**	One per 20 field samples	Percent Recoveries TOC 85-115% Hg 60-130% PCBs 30-150% OC Pest 30-150%
Surrogate Spikes	**% Recovery**	One per sample	Percent Recoveries PCBs 30-150% OC Pest 30-150%

1. Table based upon Tables 4a through 4c of the Regional Monitoring Program QAPP (Lowe, Heineke and Davis 1999). MDL=Method Detection Limit; RPD=Relative Percent Difference; RSD=Relative Standard Deviation

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2.5 Data Analysis

2.5.1 Descriptive Statistics

Summary statistics included the number of samples, the percentage of the samples with values above project reporting limits, minimum and maximum detected values, the median, 25th and 75th percentiles, mean, standard deviation and coefficient of variation. In the previous year, statistics were developed based upon natural logarithm transformations and evaluation based upon characteristics of the lognormal distribution. Upon normalization to fines of the data for both years, portions of the data set were found to depart substantially from the lognormal distribution. In addition, handling of below detection limit data was becoming an issue for a few of the target analytes. In order to allow inclusion of the censored (below detection limit) data, a method known as regression on order statistics (ROS) was used. An Excel add-in tool developed by Caltrans (Shumway andArzari, 2000) was used to determine descriptive statistics for each target analyte. This tool was developed based upon procedures described by Helsel and Cohn (1988) and Helsel (1980).

The ROS method is based upon mapping the ordered (both censored and uncensored), log transformed data onto a probability scale. A least squares line is then fit by regressing the log transformed concentrations to the uncensored data on the probability scale. Censored data points are then assigned values based upon the ordered plotting positions and the regression equation. Summary statistics are then developed based upon the complete data set including estimated values for censored data.

2.5.2 Hypothesis Testing

Two hypotheses were established to address the primary objectives of this study. These included:

H_o: *There was no difference in storm drain sediment contaminant levels among residential/commercial and industrial land use sites.*

H_1: *There was no difference in storm drain sediment contaminant levels among urban (industrial, residential/commercial and mixed) and nonurban (open) land use classifications.*

Data were first normalized to the organic-free, fine fraction (<62.5 micron) of the sediment samples. Data were first log transformed and examined graphically as an initial screening process to evaluate normality. In a few cases, data was noted to depart substantially from normality. Due to both normality issues and problems with addressing below detection limit data, nonparametric statistical tests were used to address the two hypotheses. The Kruskal-Wallis one-way analysis of variance test was used for comparison involving more than two land use categories. This was followed by Bonferonni's Inequality Test, a nonparametric, a posterior test. The Mann-Whitney test was used for two-sample comparisons. Statistical significance for all tests was based upon the probability of Type 1 or α-error being less than or equal to 0.05.

2.5.3 Stormwater Load Estimations

Estimates of contaminant loading to San Francisco Bay associated with stormwater were developed with the general procedures outlined in the Simple Method (Schueler 1987) since it requires a relatively modest amount of information to obtain rough, planning level estimates of loading. Many of the input values for the estimates were based upon Davis et al. (2000) in order to provide consistent structure. The

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Simple Method estimates loads for chemical constituents as the product of annual runoff volume and pollutant concentrations, as:

$$L=0.226*R*C*A$$

Where:
- L = Annual Load (lbs)
- R = Annual Runoff (inches)
- C = Land Use Specific Pollutant Concentration (mg/L)
- A = Area (acres)
- 0.226 = Unit Conversion Factor

Pollutant concentrations (C) were developed for each major land use category (residential, commercial, industrial, agriculture and open) based upon the assumption that the concentration of each constituent in suspended solids could be estimated from storm drain sediment concentrations that were normalized to the fine fraction. This was defined as the proportion of the sample consisting of sediments less than 62.5 microns after digestion by hydrogen peroxide to remove organic material.

The median was used as the best estimate of the concentration of each pollutant in the fine fraction. A range of concentrations was developed based upon use of the 25th and 75th percentile concentrations associated with each land use. For two constituents, only four measurements were available from open land use areas. In these special cases, the minimum and maximum values were used in lieu of the 25th and 75th percentile values and the average value was used in place of the median.

Pollutant concentrations (C) were calculated for each land use by the following formulas:

C_m = (Median Sediment Concentration, normalized to fines) * (Average TSS Concentration)
C_{25} = (25th Percentile Sediment Concentration, normalized to fines) * (Average TSS Concentration)
C_{75} = (75th Percentile Sediment Concentration, normalized to fines) * (Average TSS Concentration)

Annual Runoff was calculated as:

$$R=P*P_j*Rv$$

Where:
- R = Annual Runoff (inches)
- P = Annual Rainfall (inches)
- P_j = Fraction of annual rainfall events that produce runoff
- Rv = Runoff Coefficient

Estimates of runoff coefficients (Rv) were calculated for each major land use category based upon a linear relationship with the impervious fraction associated with each category. The following relationship established by Schueler (1987) was used to obtain estimates of runoff coefficients.

$$Rv=0.05+0.91Ia$$

Where: Ia = Impervious Fraction

Estimates of annual runoff (P) were obtained from long term rainfall records maintained by the National Climatic Data Center. A default value of 0.9 was used for the fraction of annual rainfall that is expected to produce runoff (P_j).

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2.5.3.1 Watersheds and Land Use

Watershed delineations were based upon CALWATER (Version 2.0) hydrologic areas (CDF&G 1999) used by the San Francisco Estuary Institute (SFEI; Davis et al. 2000) to estimate contaminant loads to coastal waters in the Bay area as part of a legislative mandate (AB 1429). The SFEI project elected to eliminate all areas of each watershed greater than 20 square miles that were located above a dam. The primary rationale for this approach was the assumption that significant proportions of particulates would be trapped in the reservoirs, substantially reducing transport of the particulates and associated contaminants to the receiving waters. For our purposes, only the seventeen watersheds entering San Francisco Bay were used to estimate contaminant loads (Figure 11).

Davis et al. (2000) also developed generalized land use within each watershed based upon the 1995 Association of Bay Area Governments (ABAG 1996) land use data set. The approximately 160 detailed classifications were reduced to five categories: residential, commercial, industrial, agriculture and open. Data from Davis et al were used to determine the total area of each watershed and the percentage of each major land use category (Table 8).

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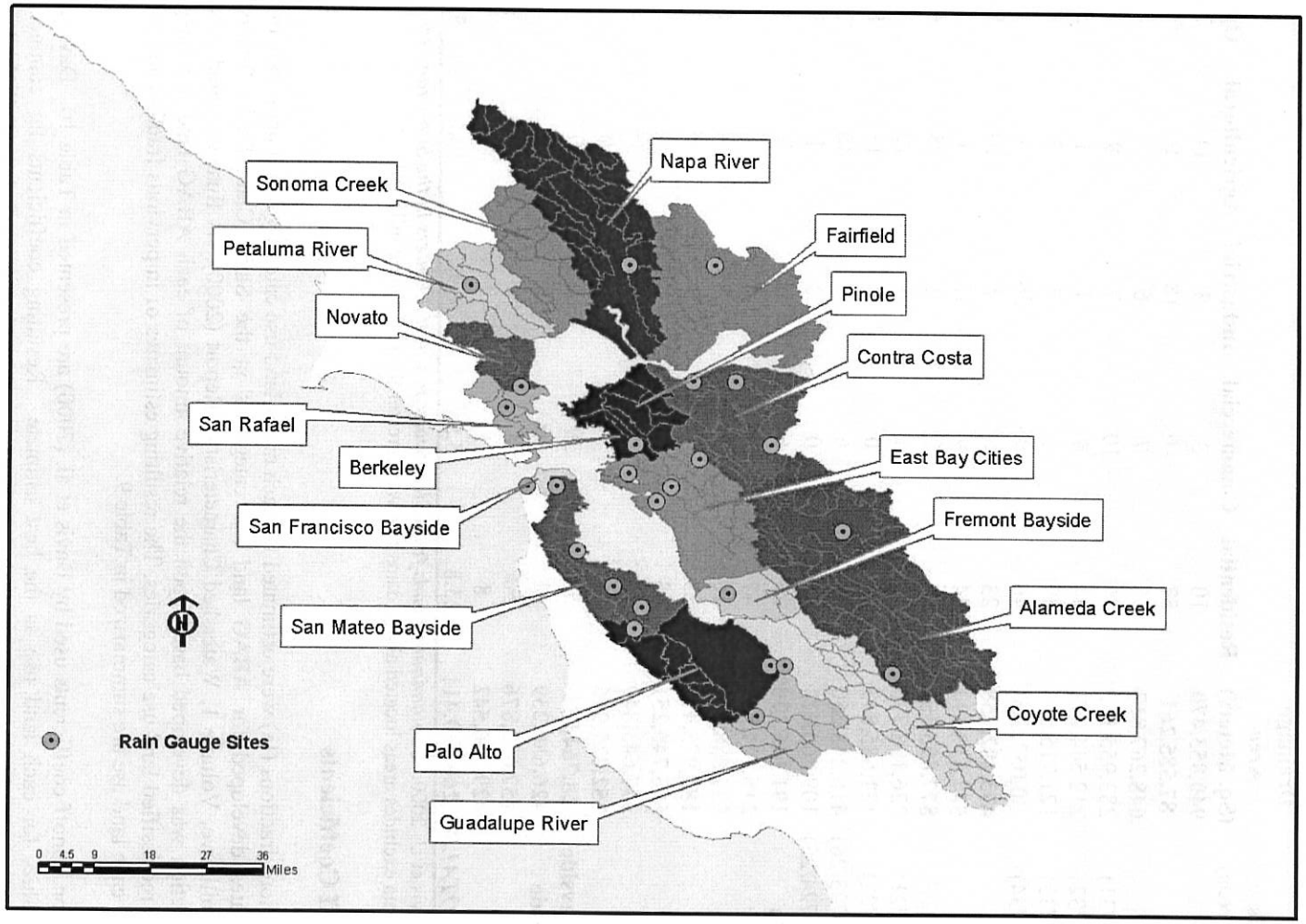

Figure 11. Hydrologic areas (HA) used to develop stormwater runoff loading estimates for San Francisco Bay . Hydrologic subareas shown for each HA. Rain gauge sites marked on the map were used to develop annual rainfall estimates for each HA.

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Table 8. Summary of drainage areas and land use within each hydrologic area tributary to San Francisco Bay[1]

Watersheds (Hydrologic Areas)	Drainage Area (Sq. Meters)	Residential	Commercial	Industrial	Agricultural	Open
Alameda Creek	**940,853,470**	10	3	3	11	73
Berkeley	**87,585,261**	57	16	18	0	9
Concord	**648,267,817**	35	7	6	5	47
Concord (220731)	283,955,162	25	10	7	9	49
Concord (220732)	212,544,012	44	4	1	1	50
Concord (220733)	121,715,016	39	6	7	0	47
Concord (220734)	30,053,627	46	9	26	6	12
Coyote Creek	**473,402,458**	23	6	7	10	53
East Bay Cities	**537,837,394**	44	9	12	1	34
Fairfield	**877,893,352**	7	3	2	28	60
Fairfield (220721)	226,198,776	12	1	5	12	70
Fairfield (220722)	131,685,843	0	0	0	13	86
Fairfield (220723/26)	410,248,260	8	6	2	48	36
Fairfield (220724/25)	109,760,473	0	0	0	1	99
Fremont Bayside	**191,146,170**	26	6	11	8	49
Guadalupe River	**215,171,511**	47	8	5	5	35
Napa River	**937,888,979**	10	3	1	24	62
Novato	**183,975,415**	23	7	1	13	56
Palo Alto	**593,745,251**	43	10	8	1	39
Petaluma River	**377,643,849**	14	1	2	35	48
Pinole	**152,427,916**	33	5	12	0	49
San Francisco Bayside	**28,764,911**	58	39	2	0	1
San Mateo Bayside	**426,680,239**	41	10	12	0	37
San Rafael	**157,659,876**	50	8	1	0	41
Sonoma Creek	**429,766,542**	8	1	1	36	54
GRAND TOTALS	**7,260,710,411**	**23.8**	**5.5**	**5.1**	**13.8**	**51.7**

1. Source: Davis et al. 2000. ***Contaminant Loads from Stormwater to Coastal Waters in the San Francisco Bay Region.*** (Data excludes areas located above dams that were greater than 20 square miles.)

2.5.3.2 Runoff Coefficients

Default impervious fractions (Ia) were estimated for each major land use category based upon impervious fraction estimates developed for ABAG land use categories in the Santa Clara Basin Watershed Management Initiative, Volume 1, Watershed Characteristics Report (2000). A final weighted average impervious fraction was developed based upon the relative amount of each ABAG land use category within the five reclassified land use categories. The resulting estimates of impervious fraction and runoff coefficients for each land use are summarized in Table 9.

As a comparison, runoff coefficients used by Davis et al. (2000) are presented in Table 10. Davis used the average values for each land use as the best estimate. Resulting coefficients for commercial, industrial and agricultural land use were very similar, however, our estimates are substantially higher for residential land use and substantially lower for open land use.

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Table 9. Estimates of impervious fraction and calculated runoff coefficients for each major land use category.

	Residential	Commercial	Industrial	Agricultural	Open
Ia (Impervious Fraction)	0.60	0.94	0.91	0.025	0.01
R_v (Runoff Coefficient)	0.60	0.91	0.89	0.07	0.06

Table 10. Runoff coefficients used by SFEI (2000)[1]

R_v (Runoff Coefficient)	Residential	Commercial	Industrial	Agricultural	Open
Low	0.20	0.60	0.60	0.05	0.10
Average (Best)	0.35	0.90	0.90	0.10	0.25
High	0.50	0.95	0.95	0.20	0.50

1.Values based upon BASMAA (1996) and SCCWRP (2000)

2.5.3.3 Rainfall

Estimates of annual average rainfall were developed for each hydrologic area based upon long-term records from National Climatic Data Center (NCDC) Cooperative rain gauges located throughout the region. Data were available from 25 stations (Table 11, Figure 12). Data from one to five stations were averaged to obtain the best estimate of rainfall within each hydrologic area (Table 12). In most cases, gauges are located in urban areas at lower elevations. This tends to result in a bias towards lower total rainfall for each watershed. This, in turn, may result in lower overall estimates of TSS loading. However, since the particular contaminants of concern in this study are most strongly associated with the urban environment, this approach is not likely to introduce a significant bias in estimates of contaminant loading.

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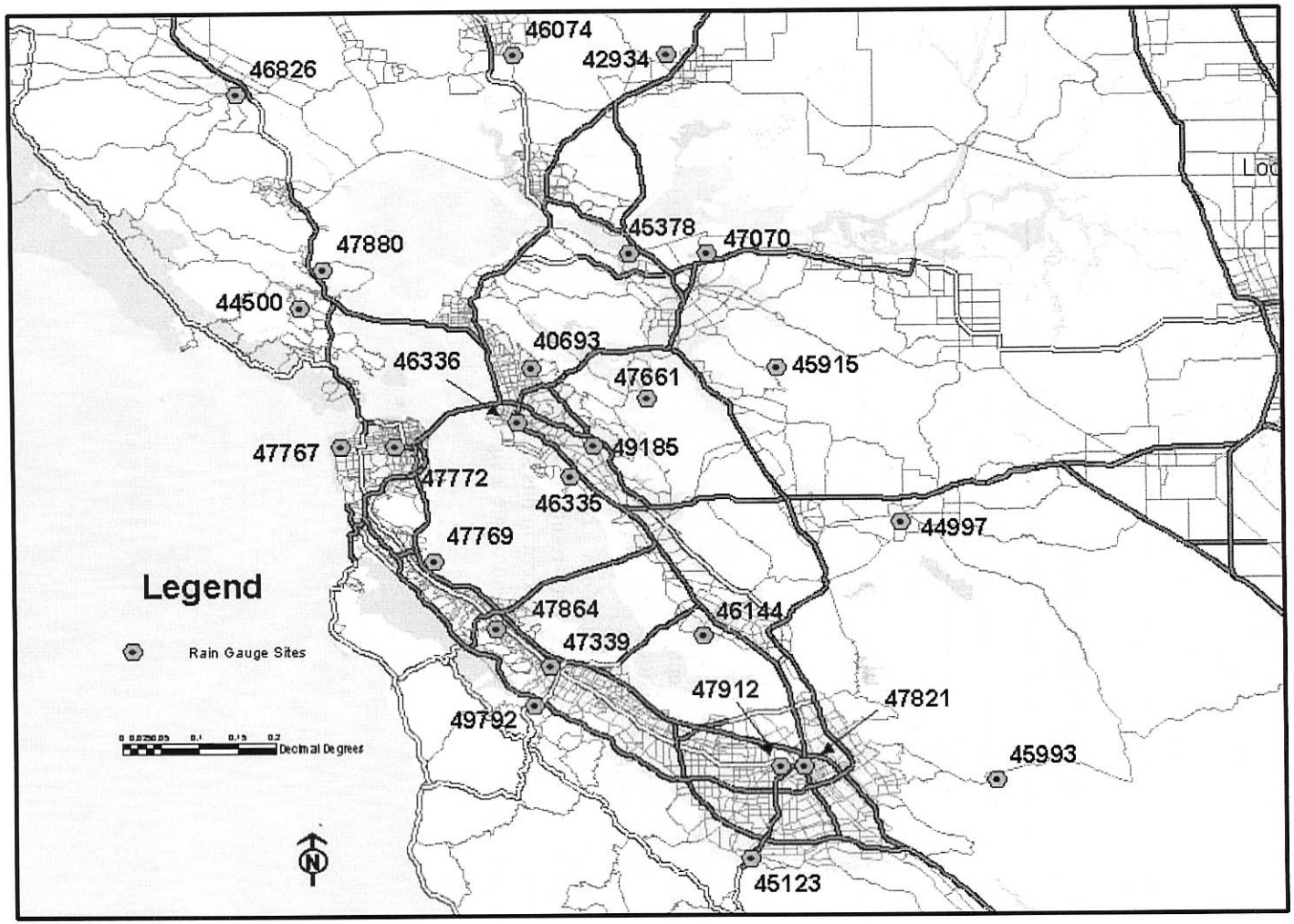

Figure 12. Location of rain gauges used for estimates of annual precipitation. Numbers refer to NCDC Coop designations.

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Table 11. Summary of data used to estimate average annual rainfall in each region.

NCDC COOP Station Number	Station Name	Record Start Date	Record End Date	Annual Average Rainfall (inches)	Latitude (deg:min)	Longitude (deg:min)
047880	San Rafael Civic Center	7/1/48	12/31/00	35.85	38:00	122:31
044500	Kentfield	7/1/48	12/31/00	48.70	37:57	122:33
046826	Petaluma Fire Station	7/1/48	12/31/00	25.24	38:14	122:38
047769	San Francisco WSO AP	7/1/48	12/31/00	20.07	37:37	122:23
047864	San Mateo	7/1/48	12/31/78	18.77	37:32	122:18
047339	Redwood City	7/1/48	12/31/00	19.96	37:29	122:14
049792	Woodside Fire Station	3/1/73	11/30/00	30.27	37:26	122:15
047912	Santa Clara University	1/3/31	5/31/76	14.04	37:21	121:56
047821	San Jose	7/1/48	12/31/00	14.49	37:21	121:54
045123	Los Gatos	7/1/48	12/31/00	24.78	37:14	121:58
046144	Newark	7/1/48	12/31/00	14.62	37:31	122:02
040693	Berkeley	1/1/19	12/31/00	23.34	37:52	122:15
045378	Martinez Water Plant	2/1/70	12/31/00	19.59	38:01	122:07
047070	Port Chicago Naval Depot	7/8/48	9/30/75	15.72	38:01	122:01
045915	Mount Diablo Junction	4/1/52	12/31/00	24.10	37:52	121:56
047661	St. Mary's College	7/1/48	7/31/81	28.20	37:50	122:06
046336	Oakland Museum	10/1/70	12/31/00	23.31	37:48	122:16
049185	Upper San Leandro Fltr	7/1/48	12/31/00	25.39	37:46	122:10
046335	Oakland WSO AP	7/1/48	9/30/00	18.03	37:44	122:12
044997	Livermore	4/1/30	12/31/00	14.48	37:40	121:46
045993	Mt. Hamilton	7/1/48	12/31/00	23.19	37:20	121:39
042934	Fairfield	12/4/50	12/31/00	22.44	38:17	122:04
046074	Napa State Hospital	2/1/17	12/31/00	24.64	38:17	122:16
047772	San Fran Mission Dolore	1/1/14	12/31/00	20.88	37:46	122:26
047767	San Francisco Richmond	7/1/48	12/31/00	19.90	37:46	122:30

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Table 12. Average annual rainfall values used for each hydrologic area.

Hydrologic Area	Average Rainfall
Alameda Creek	18.84
Berkeley	23.34
Concord	19.80
Coyote Creek	14.38
East Bay Cities	21.91
Fairfield	22.44
Fremont Bayside	14.62
Guadalupe River	24.78
Napa River	24.64
Novato	30.54
Palo Alto	20.74
Petaluma River	25.24
Pinole	21.47
San Francisco Bayside	20.39
San Mateo Bayside	22.27
San Rafael	48.70
Sonoma Creek	24.94

2.5.3.4 Contaminant Concentrations

Contaminant load concentrations for each constituent were based on the assumption that 100 percent of each contaminant was associated with the fine (less than 62.5 micron) fraction of the storm drain sediments. It was also assumed that concentration of contaminants in the fine fraction were representative of the concentration of the constituents in the suspended material in the stormwater discharges as measured by Total Suspended Solids (TSS). This requires the further assumption that TSS measures obtained by autosamplers in stormwater monitoring programs are limited to particles less than 62.5 microns. Data from regional programs conducted in the San Francisco Bay area were used as input for suspended sediment concentrations from each major land use category (Table 13). Since no information was available for sediment loads from agricultural activities in the Bay area, a generalized estimate for California developed by the Southern California Coastal Water Research Project (2000) was utilized. For our purposes, only the average TSS concentrations were used to develop load estimates. Variability was only evaluated by utilization of the 25th and 75th percentile concentrations of each specific contaminant. Additional variability introduced by estimates of TSS for each land use category (Table 13) and differences in annual rainfall were not included in the load estimates.

Table 13. Estimates of the range and average concentration of suspended solids in stormwater runoff from the five major land use classifications.

TSS (mg/L)	Residential[1]	Commercial[1]	Industrial[1]	Agricultural[2]	Open[1]
Low	28	30	49	646	27
Average (Best)	90	98	157	2068	85
High	286	312	502	6618	272

1. Data as summarized from BASMAA (1996) by Davis et al. (2000)
2. Data from SCCWRP (2000)

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3.0 RESULTS AND DISCUSSION

The field survey was conducted during two time periods. Initial sampling was completed at all Marin County sites on June 25, 2001. The remaining sites were sampled over a five-week period between September 6th and October 16th, 2001.

All surveys were completed before the occurrence of any substantial rainfall in the Bay area. A minor event yielding only 0.10 to 0.13 inches of rain occurred on September 25th, 2001. This event was not large enough to produce runoff of any significance.

As general reference, a summary of the results of 2000 survey is presented in Table 14. These summary data are limited to constituents that were also measured during the second year of the program.

Data from the 2001 survey are summarized in Tables 15 and 16. Bulk chemistry results are summarized in Table 15 for all major constituents analyzed during this year's program. Organic compounds are grouped into the major categories of PCBs, DDTs, chlordane, HCH[2], and endosulphan. Complete breakdown of chemical results for each of these categories is included in Appendix A. Table 16 provides of summary of all organic data normalized to the percent of organic-free, fines (silt/clay sized particles) present in the sediments. These data were used for all statistical comparisons and for estimation of contaminant loads.

Primary data (total PCBs, mercury, chlordane and DDT) are graphically summarized in Figures 13 through 16. All graphical summaries are based upon data that have been normalized to the fine fraction (particles less than 62.5 microns). In the case of total PCBs and mercury, the graphical summaries include results of both the 2000 and 2001 sediment testing programs. Alameda County data is limited to testing conducted during the 2000 program. The 2001 program in Alameda County consisted primarily of second round sampling at the same sites they investigated in the first year of the program.

[2] HCH refers to the sum of the alpha, beta, gamma (lindane) and delta isomers of hexachlorocyclohexane

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Table 14. Summary of first year (2000) data results from each sampling location

Site Name	Total PCBs (ug/Kg)	Total PCBs normalized to fines (ug/Kg fines)	Mercury, Total (mg/Kg)	Mercury, Total normalized to fines (mg/Kg fines)	% Fines[1]	Total Organic Carbon (%)	Solids, Total (%)
Contra Costa County							
CCC001	184.1	229	0.47	0.58	80.5	4.61	47.2
CCC002	194.6	1052	0.26	1.41	18.5	3.64	69.9
CCC003	174.9	723	0.36	1.49	24.2	2.08	68.1
CCC005	171.8	366	0.28	0.60	47.0	1.9	76.0
CCC006	165.0	2705	0.72	11.8	6.1	2.38	77.6
CCC007	15.7	121	0.68	5.23	13.0	3.25	73.5
CCC007FR[2]	23.3	197	0.31	2.63	11.8	3.26	71.3
CCC009	4.7	4.9	0.07	0.07	96.2	1.66	50.8
CCC010	4.6	7.0	0.04	0.06	65.4	4.38	24.0
CCC011	0.0	0.0	0.04	0.38	10.6	0.54	75.3
CCC012	4.3	23	0.03	0.16	18.5	0.93	85.1
CCC013	0.0	0.0	0.03	0.11	26.4	0.26	67.4
CCC014	0.0	0.0	0.03	0.07	43.6	1.17	76.9
CCC015	0.0	0.0	0.02	0.06	33.7	1.25	54.2
CCC016	19.7	55	0.15	0.42	35.9	4.69	34.0
CCC017	133.3	479	0.11	0.40	27.8	2.56	50.8
CCC018	5.6	9.1	0.1	0.16	61.5	1.03	60.4
CCC019	58.2	1293	0.19	4.22	4.5	4.24	65.1
Fairfield Suisun							
FSS001	114.1	161	0.06	0.08	70.9	2.71	58.7
FSS002	0.3	1.3	0.03	0.13	22.9	1.57	37.2
FSS003	0.2	1.0	0.02	0.10	19.7	0.69	59.7
Marin County							
MCS001	0.0	0.0	0.03	0.09	32.5	3.12	75.5
MCS002	72.3	1721	0.36	8.57	4.2	1.5	66.5
MCS003	0.0	0.0	0.05	1.39	3.6	0.38	73.8
MCS004	18.9	48	0.09	0.23	39.4	1.58	37.5
Santa Clara County							
SCV001	26746	61912	1.08	2.50	43.2	6.93	48.2
SCV002	654.4	1674	0.33	0.84	39.1	10.1	42.1
SCV002FR	132.6	285	0.29	0.62	46.5	7.85	37.3
SCV003	92.2	3179	0.1	3.45	2.9	1.33	71.9
SCV004	95.9	505	0.15	0.79	19.0	7.36	58.2
SCV005	66.3	102	0.68	1.05	64.8	15.9	36.9
SCV006	56.0	467	1.18	9.83	12.0	3.9	69.7
SCV007	12.2	321	0.1	2.63	3.8	2.36	71.2
SCV007FR	12.0	273	0.15	3.41	4.4	2.1	67.7
SCV008	34.2	44.3	0.13	0.17	77.2	4.08	34.9
SCV009	57.0	91.1	0.16	0.26	62.6	10.2	38.8
SCV009FR	17.6	28.1	0.16	0.26	62.7	5.55	41.8
SCV010	24.0	136	0.07	0.40	17.7	2.38	58.6
SCV011	14.1	371	0.13	3.42	3.8	11.2	69.2
SCV012	124.0	579	4.26	19.9	21.4	1.56	64.1
SCV014	30.5	258	0.18	1.53	11.8	3.78	71.3
SCV015	1.1	6.5	0.07	0.41	16.9	0.66	68.9

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Site Name	Total PCBs (ug/Kg)	Total PCBs normalized to fines (ug/Kg fines)	Mercury, Total (mg/Kg)	Mercury, Total normalized to fines (mg/Kg fines)	% Fines[1]	Total Organic Carbon (%)	Solids, Total (%)
SCV016	29.8	113	0.04	0.15	26.4	1.63	54.2
SCV017	0.2	7.7	0.03	1.15	2.6	0.51	62.7
SCV018	38.4	267	0.20	1.39	14.4	3.51	56.7
SCV018FR	50.3	359	0.21	1.50	14.0	3.51	54.1
SCV019	101.2	1281	0.31	3.92	7.9	5.59	57.2
SCV021	10.0	89	0.12	1.07	11.2	2.38	69.6
SCV022	328.0	8200	0.09	2.25	4.0	2.44	66.0
SCV024	13.9	1069	0.05	3.85	1.3	0.05U	69.9
San Mateo County							
SMC001	69.8	71	0.17	0.17	98.5	1.52	34.5
SMC002	116.2	2371	0.07	1.43	4.9	1.86	73.9
SMC003	225.3	711	0.17	0.54	31.7	5.91	49.3
SMC004	83.7	1947	0.11	2.56	4.3	1.44	73.4
SMC005	187.4	424	0.2	0.45	44.2	3.77	36.4
SMC006	5.8	43	0.04	0.30	13.4	0.79	76.8
SMC007	0.0	0.0	0.03	0.57	5.3	0.29	69.8
SMC008	3.6	4.6	0.04	0.05	77.7	2.35	36.4
SMC009	476.9	2110	0.24	1.06	22.6	3.83	56.0
SMC009FR	226.8	1187	0.21	1.10	19.1	2.94	65.8
SMC010	194.8	566	0.06	0.17	34.4	3.63	38.6
SMC011	338.8	360	0.44	0.47	94.1	4.4	24.5
SMC012	12.4	258	0.05	1.04	4.8	0.82	70.9
SMC013	89.5	1904	0.11	2.34	4.7	1.35	69.7
Vallejo							
VFC001	144.7	228	0.18	0.28	63.4	3.01	52.7
VFC002	0.8	1.1	0.15	0.21	70.3	2.57	35.6
VFC003	0.3	0.4	0.29	0.39	75.3	2.08	33.6

1. % Fines indicates the organic-free fraction of the sediment less than 62.5 microns.
2. The suffix "FR" indicates that the sample was a field replicate.

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Table 15. Summary of data results from 2001 survey at each sampling location.

Site Name	% Fines	TOC (%)	Total PCBs (ug/Kg)	Mercury, Total (mg/Kg)	Total DDT[1] (ug/Kg)	Total Chlordane[2] (ug/Kg)	HCH[3] (ug/Kg)	Endosulfan[4] (ug/Kg)	Aldrin (ug/Kg)	Dieldrin (ug/Kg)	Endrin (ug/Kg)	Chlorpyrifos (ug/Kg)	Mirex (ug/Kg)
Contra Costa County													
CCC020	22	5.0	145	0.14	18	47	ND	ND	ND	ND	ND	4.8	ND
CCC021	20	2.1	18	0.14	22	2.3	ND	ND	ND	ND	ND	ND	ND
CCC022	39	6.3	26	0.23	ND	53	ND	ND	ND	ND	ND	4.2	ND
CCC023	15	3.0	242	0.34	43	4.3	ND	ND	ND	ND	ND	ND	ND
CCC024	72	1.3	16	0.08	14	8.0	ND	ND	ND	6.5	ND	ND	ND
CCC024FR[5]	78	3.2	116	0.20	89	16	ND	ND	ND	5.9	ND	ND	ND
CCC025	25	3.5	144	0.27	66	41	ND	ND	ND	15	ND	ND	ND
CCC026	61	6.7	156	0.47	17	11	ND	ND	ND	6	ND	23	ND
CCC027	59	0.9	ND	0.03	0.16	0.42	0.19	ND	ND	ND	ND	ND	ND
CCC028	78	2.1	7	0.07	ND	1.3	ND	ND	ND	ND	ND	ND	ND
CCC029	24	1.8	ND	0.07	6	ND	ND	ND	ND	ND	ND	ND	ND
CCC030	77	7.7	297	0.63	74	203	ND	ND	ND	ND	ND	24	ND
CCC031	23	7.7	1153	0.41	215	ND	ND	ND	ND	ND	ND	ND	6.6
CCC032	16	2.7	1945	0.95	ND	ND	ND	ND	ND	ND	ND	ND	ND
CCC033	44	13	13	0.32	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fairfield Suisun													
FSS004	15	1.0	ND	0.08	ND	0.82	ND	ND	ND	ND	ND	ND	ND
FSS005	82	3.9	1	0.14	23	ND	ND	ND	ND	ND	ND	ND	ND
FSS006	90	3.6	ND	0.12	ND	ND	ND	ND	ND	ND	ND	ND	ND
Marin County													
MCS005	96	2.6	0.24	0.15	19	4.3	ND	ND	ND	ND	ND	ND	ND
MCS006	31	3.7	16	0.27	15	55	ND	ND	ND	3.4	ND	ND	ND
MCS007	1	1.6	2	0.38	1.8	8.6	ND	ND	ND	ND	ND	ND	ND
MCS008	4	1.8	4	0.24	83	622	ND	ND	ND	ND	ND	ND	ND
MCS009	50	4.8	13	0.22	132	25	ND	ND	ND	ND	ND	ND	ND
MCS009FR	53	3.0	6	0.14	102	20	ND	ND	ND	ND	ND	ND	ND
MCS010	4	2.1	36	0.33	22	14	2.4	ND	ND	ND	ND	46	ND
MCS011	2	1.7	ND	0.26	0.74	0.11	0.64	ND	ND	ND	ND	ND	ND

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Site Name	% Fines	TOC (%)	Total PCBs (ug/Kg)	Mercury, Total (mg/Kg)	Total DDT[1] (ug/Kg)	Total Chlordane[2] (ug/Kg)	HCH[3] (ug/Kg)	Endosulfan[4] (ug/Kg)	Aldrin (ug/Kg)	Dieldrin (ug/Kg)	Endrin (ug/Kg)	Chlorpyrifos (ug/Kg)	Mirex (ug/Kg)
MCS012	75	1.5	52	0.38	41	52	ND	ND	11	28	ND	3	ND
MCS013	9	6.7	14	0.21	38	47	ND	ND	ND	6.6	ND	ND	ND
Santa Clara County													
SCV025	49	1.5	42	0.32	23	12	ND	ND	ND	ND	ND	4.1	ND
SCV026	13	1.7	3	0.14	56	ND	ND	ND	ND	ND	ND	ND	ND
SCV027	13	2.9	ND	0.27	108	0.53	ND	ND	ND	ND	ND	ND	ND
SCV028	3	1.0	165	0.80	40	51	ND	ND	ND	ND	ND	ND	ND
SCV029	12	2.4	768	0.08	177	63	ND	ND	ND	ND	ND	ND	ND
SCV030	19	5.3	60	0.30	12	ND	ND	ND	ND	ND	ND	ND	ND
SCV031	31	6.5	47	1.9	6.8	9.1	ND	ND	ND	ND	ND	ND	ND
SCV032	23	5.3	294	0.29	23	23	ND	ND	ND	ND	ND	ND	ND
SCV033	17	2.1	1215	0.30	ND	86	ND	ND	ND	ND	ND	ND	ND
SCV034	47	11	135	3.04	ND	11300	ND	ND	ND	ND	ND	ND	ND
SCV035	26	7.1	338	0.14	55	14	ND	ND	ND	ND	ND	ND	ND
SCV036	17	6.3	84	0.18	ND	98	ND	ND	ND	ND	ND	ND	ND
SCV037	13	6.0	70	0.13	39	22	ND	ND	ND	ND	ND	ND	ND
SCV037FR	14	6.5	51	0.12	27	17	ND	ND	ND	ND	ND	ND	ND
SCV038	18	7.3	593	0.34	80	110	ND	ND	ND	ND	ND	6.1	ND
SCV039	10	53	312	0.05	ND	ND	ND	ND	ND	ND	ND	11	ND
SCV041	18	2.0	3	0.03	8.1	5.8	ND	ND	ND	ND	ND	1.3	ND
SCV041FR	26	2.2	1	0.04	2.1	15	ND	ND	ND	ND	ND	ND	ND
SCV042	17	2.2	33	0.06	3.8	6.9	ND	ND	ND	ND	ND	ND	ND
SCV043	13	1.0	ND	0.09	0.11	0.12	ND	ND	ND	ND	ND	ND	ND
SCV044	22	1.4	533	0.05	37	ND	ND	ND	ND	ND	ND	ND	ND
SCV045	6	0.5	0.44	0.02	ND	0.24	ND	ND	ND	ND	ND	ND	ND
San Mateo County													
SMC002[6]	11	2.2	61	NS[7]	47	13	ND	ND	ND	ND	ND	4.7	ND
SMC009[6]	4	0.8	70	NS	30	11	ND	ND	ND	ND	ND	ND	ND
SMC011[6]	78	2.3	124	NS	11	28	ND	ND	ND	ND	ND	25	ND
SMC015	53	7.6	63	0.12	1572	63	ND	ND	ND	ND	ND	18	ND
SMC016	4	1.3	81	0.10	18	45	ND	ND	ND	ND	ND	4.2	ND
SMC016FR	3	1.2	87	0.11	31	65	ND	ND	ND	ND	ND	ND	ND
SMC017	87	6.4	139	0.35	ND	21	ND	ND	ND	ND	ND	29	ND
SMC019	23	2.5	70	0.13	92	34	ND	ND	ND	6.8	ND	4.3	0.85
SMC020	16	7.5	20294	1.84	4010	1956	590	ND	ND	ND	ND	ND	ND
SMC021	40	11	1222	0.92	59	166	ND	ND	ND	ND	ND	ND	ND

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Site Name	% Fines	TOC (%)	Total PCBs (ug/Kg)	Mercury, Total (mg/Kg)	Total DDT[1] (ug/Kg)	Total Chlordane[2] (ug/Kg)	HCH[3] (ug/Kg)	Endosulfan[4] (ug/Kg)	Aldrin (ug/Kg)	Dieldrin (ug/Kg)	Endrin (ug/Kg)	Chlorpyrifos (ug/Kg)	Mirex (ug/Kg)
SMC022	11	3.7	291	0.07	24	10	ND	ND	ND	ND	ND	ND	ND
SMC023	9	4.8	2257	0.32	127	81	ND	ND	ND	ND	ND	ND	ND
SMC024	60	13	16810	1.31	ND	980	ND	ND	ND	ND	ND	1000	ND
SMC025	6	4.7	143	1.73	37	37	ND	ND	ND	4.4	ND	8.3	ND
SMC025FR	6	2.9	242	1.91	54	27	ND	ND	ND	ND	ND	7.2	ND
SMC026	27	2.3	115	0.35	ND	ND	ND	ND	ND	ND	ND	ND	ND
SMC027	7	1.7	33	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND
SMC028	8	0.6	4	0.05	11	12	ND	ND	ND	ND	ND	ND	ND
SMC029	68	8.8	421	0.63	96	221	ND	ND	ND	ND	ND	45	ND
SMC030	6	0.7	5	0.66	ND	25	ND	ND	ND	ND	ND	ND	ND
SMC031	21	4.0	135	0.18	33	176	ND	ND	ND	16	ND	ND	ND
Vallejo													
VFC001	86	6.0	369	0.94	6.2	58	ND	ND	ND	ND	ND	ND	ND
VFC004	67	3.0	12	0.33	ND	26	ND	ND	ND	ND	ND	ND	ND
VFC005	74	7.8	55	1.86	ND	25	ND	ND	ND	ND	ND	ND	ND
VFC006	6	2.7	1259	0.17	11	222	ND	ND	ND	29	ND	ND	ND
VFC007	39	1.8	ND	0.18	ND	ND	ND	ND	ND	ND	ND	ND	ND
VFC008	83	7.5	36	0.37	ND	45	ND	ND	ND	ND	ND	ND	ND
VFC009	61	2.7	3	0.42	ND	37	ND	ND	ND	ND	ND	6.1	ND
VFC009FR	42	2.6	12	0.37	ND	23	ND	ND	ND	ND	ND	ND	ND
VFC010	60	7.3	349	0.57	106	199	ND	ND	ND	70	ND	ND	ND

1. DDT indicates the sum of 4,4'DDT, 2,4'DDT, 4,4'DDE, 2,4'DDE, 4,4'DDD, and 2,4'DDD.
2. Total chlordane indicates the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide and oxychlordane.
3. HCH refers to the sum of the alpha, beta, gamma (lindane) and delta isomers of hexachlorocyclohexane.
4. Endosulfan refers to the sum of endosulfan I, endosulfan II, and endosulfan sulfate.
5. The suffix "FR" indicates that the sample was a field replicate.
6. Data from 2001 resampling at three San Mateo County pump stations in support of PCB case studies.
7. NS=Not Sampled These analyses not included with the case study.

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Table 16. Summary of 2001 data normalized to the fine fraction (<62.5 microns).

Site Name	Total PCBs (ug/Kg fines)	Mercury, Total (mg/Kg fines)	Total DDT[1] (ug/Kg fines)	Total Chlordane[2] (ug/Kg fines)	HCH[3] (ug/Kg fines)	Endosulfan[4] (ug/Kg fines)	Aldrin (ug/Kg fines)	Dieldrin (ug/Kg fines)	Endrin (ug/Kg fines)	Chlorpyrifos (ug/Kg fines)	Mirex (ug/Kg fines)
Contra Costa County											
CCC020	648	0.63	79	211	ND	ND	ND	ND	ND	22	ND
CCC021	91	0.70	109	12	ND	ND	ND	ND	ND	ND	ND
CCC022	68	0.59	ND	135	ND	ND	ND	ND	ND	11	ND
CCC023	1624	2.3	287	29	ND	ND	ND	ND	ND	ND	ND
CCC024	22	0.11	19	11	ND	ND	ND	9.0	ND	ND	ND
CCC024FR[5]	149	0.26	114	20	ND	ND	ND	7.5	ND	ND	ND
CCC025	568	1.1	261	163	ND	ND	ND	59	ND	ND	ND
CCC026	254	0.76	27	18	ND	ND	ND	10	ND	37	ND
CCC027	ND	0.05	ND	0.7	ND	ND	ND	ND	ND	ND	ND
CCC028	9	0.09	ND	1.7	ND	ND	ND	ND	ND	ND	ND
CCC029	ND	0.29	25	ND	ND	ND	ND	ND	ND	ND	ND
CCC030	386	0.82	96	264	ND	ND	ND	ND	ND	31	ND
CCC031	4915	1.7	916	ND	ND	ND	ND	ND	ND	ND	28
CCC032	12538	6.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
CCC033	29	0.72	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fairfield Suisun											
FSS004	ND	0.52	ND	5	ND	ND	ND	ND	ND	ND	ND
FSS005	1.5	0.17	28	ND	ND	ND	ND	ND	ND	ND	ND
FSS006	ND	0.13	ND	ND	ND	ND	ND	ND	ND	ND	ND
Marin County											
MCS005	0.25	0.16	20	4.5	ND	ND	ND	ND	ND	ND	ND
MCS006	52	0.88	49	179	ND	ND	ND	11	ND	ND	ND
MCS007	259	40	188	898	ND	ND	ND	ND	ND	ND	ND
MCS008	89	5.9	2054	15396	ND	ND	ND	ND	ND	ND	ND
MCS009	25	0.44	264	50	ND	ND	ND	ND	ND	ND	ND
MCS009FR	12	0.26	192	38	ND	ND	ND	ND	ND	ND	ND
MCS010	1006	9.3	604	399	67	ND	ND	ND	ND	1292	ND
MCS011	ND	14	40	5.9	34	ND	ND	ND	ND	ND	ND
MCS012	69	0.51	54	69	ND	ND	15	37	ND	4.0	ND
MCS013	166	2.5	441	550	ND	ND	ND	77	ND	ND	ND

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Site Name	Total PCBs (ug/Kg fines)	Mercury, Total (mg/Kg fines)	Total DDT[1] (ug/Kg fines)	Total Chlordane[2] (ug/Kg fines)	HCH[3] (ug/Kg fines)	Endosulfan[4] (ug/Kg fines)	Aldrin (ug/Kg fines)	Dieldrin (ug/Kg fines)	Endrin (ug/Kg fines)	Chlorpyrifos (ug/Kg fines)	Mirex (ug/Kg fines)
Santa Clara County											
SCV025	87	0.66	46	25	ND	ND	ND	ND	ND	8.4	ND
SCV026	27	1.1	450	ND	ND	ND	ND	ND	ND	ND	ND
SCV027	ND	2.0	813	4.0	ND	ND	ND	ND	ND	ND	ND
SCV028	5398	26	1307	1680	ND	ND	ND	ND	ND	ND	ND
SCV029	6306	0.66	1453	515	ND	ND	ND	ND	ND	ND	ND
SCV030	318	1.6	60	ND	ND	ND	ND	ND	ND	ND	ND
SCV031	155	6.2	22	30	ND	ND	ND	ND	ND	ND	ND
SCV032	1270	1.3	98	97	ND	ND	ND	ND	ND	ND	ND
SCV033	7082	1.7	ND	501	ND	ND	ND	ND	ND	ND	ND
SCV034	289	6.5	ND	24296	ND	ND	ND	ND	ND	ND	ND
SCV035	1315	0.54	214	54	ND	ND	ND	ND	ND	ND	ND
SCV036	480	1.0	ND	561	ND	ND	ND	ND	ND	ND	ND
SCV037	548	1.0	309	172	ND	ND	ND	ND	ND	ND	ND
SCV037FR	368	0.87	198	126	ND	ND	ND	ND	ND	ND	ND
SCV038	3381	1.9	456	627	ND	ND	ND	ND	ND	35	ND
SCV039	3125	0.50	ND	ND	ND	ND	ND	ND	ND	110	ND
SCV041	18	0.17	45	33	ND	ND	ND	ND	ND	7.3	ND
SCV041FR	2.7	0.15	8.1	58	ND	ND	ND	ND	ND	ND	ND
SCV042	197	0.36	23	41	ND	ND	ND	ND	ND	ND	ND
SCV043	ND	0.67	0.8	0.9	ND	ND	ND	ND	ND	ND	ND
SCV044	2443	0.23	171	ND	ND	ND	ND	ND	ND	ND	ND
SCV045	7.4	0.34	ND	4.0	ND	ND	ND	ND	ND	ND	ND
San Mateo County											
SMC002[6]	560	NS[7]	427	123	ND	ND	ND	ND	ND	43	ND
SMC009[6]	1735	NS	734	268	ND	ND	ND	ND	ND	ND	ND
SMC011[6]	159	NS	14	36	ND	ND	ND	ND	ND	32	ND
SMC015	119	0.23	2973	119	ND	ND	ND	ND	ND	34	ND
SMC016	1942	2.4	425	1074	ND	ND	ND	ND	ND	100	ND
SMC016FR	2695	3.4	969	2003	ND	ND	ND	ND	ND	ND	ND
SMC017	160	0.40	ND	24	ND	ND	ND	ND	ND	33	ND
SMC019	304	0.56	397	148	ND	ND	ND	29	ND	19	3.7
SMC020	124198	11	24541	11971	3611	ND	ND	ND	ND	ND	ND
SMC021	3018	2.3	146	410	ND	ND	ND	ND	ND	ND	ND
SMC022	2709	0.65	220	93	ND	ND	ND	ND	ND	ND	ND
SMC023	25044	3.6	1410	902	ND	ND	ND	ND	ND	ND	ND

SARB_016459

Site Name	Total PCBs (ug/Kg fines)	Mercury, Total (mg/Kg fines)	Total DDT[1] (ug/Kg fines)	Total Chlordane[2] (ug/Kg fines)	HCH[3] (ug/Kg fines)	Endosulfan[4] (ug/Kg fines)	Aldrin (ug/Kg fines)	Dieldrin (ug/Kg fines)	Endrin (ug/Kg fines)	Chlorpyrifos (ug/Kg fines)	Mirex (ug/Kg fines)
SMC024	28003	2.2	ND	1633	ND	ND	ND	ND	ND	1666	ND
SMC025	2376	29	607	616	ND	ND	ND	73	ND	138	ND
SMC025FR	4240	34	940	482	ND	ND	ND	ND	ND	126	ND
SMC026	432	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND
SMC027	458	0.56	ND	ND	ND	ND	ND	ND	ND	ND	ND
SMC028	47	0.64	147	158	ND	ND	ND	ND	ND	ND	ND
SMC029	624	0.93	142	327	ND	ND	ND	ND	ND	67	ND
SMC030	96	12	ND	456	ND	ND	ND	ND	ND	ND	ND
SMC031	655	0.88	161	857	ND	ND	ND	78	ND	ND	ND
Vallejo											
VFC001	431	1.1	7.2	68	ND	ND	ND	ND	ND	ND	ND
VFC004	18	0.49	ND	39	ND	ND	ND	ND	ND	ND	ND
VFC005	75	2.5	ND	34	ND	ND	ND	ND	ND	ND	ND
VFC006	21231	2.9	185	3744	ND	ND	ND	489	ND	ND	ND
VFC007	ND	0.46	ND	ND	ND	ND	ND	ND	ND	ND	ND
VFC008	44	0.45	ND	54	ND	ND	ND	ND	ND	ND	ND
VFC009	5.3	0.69	ND	61	ND	ND	ND	ND	ND	10	ND
VFC009FR	28	0.87	ND	53	ND	ND	ND	ND	ND	ND	ND
VFC010	583	0.95	177	333	ND	ND	ND	117	ND	ND	ND

1. DDT indicates the sum of 4,4'DDT, 2,4'DDT, 4,4'DDE, 2,4'DDE, 4,4'DDD, and 2,4'DDD.
2. Total chlordane indicates the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide and oxychlordane.
3. HCH refers to the sum of the alpha, beta, gamma (lindane) and delta isomers of hexachlorocyclohexane.
4. Endosulfan refers to the sum of endosulfan I, endosulfan II, and endosulfan sulfate.
5. The suffix "FR" indicates that the sample was a field replicate.
6. Data from 2001 resampling at three San Mateo County pump stations in support of PCB case studies
7. NS=Not Sampled These analyses not included with the case study..

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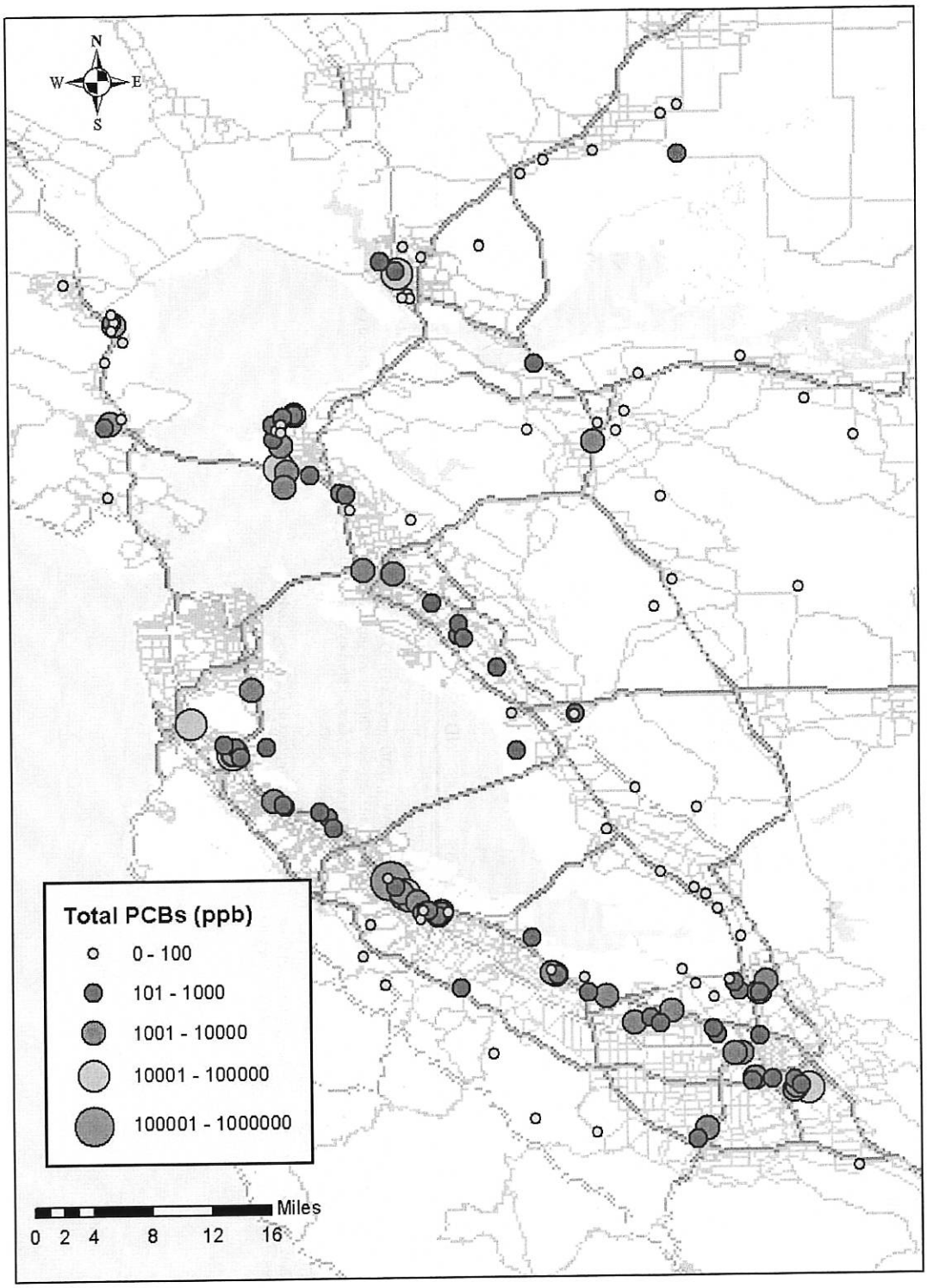

Figure 13. Concentrations of total PCBs measured in storm drains throughout the study area. All data normalized to the fine fraction (<62.5 micron). Includes all data from 2000 and 2001 surveys. Alameda data limited to 2000 survey.

SARB_016461

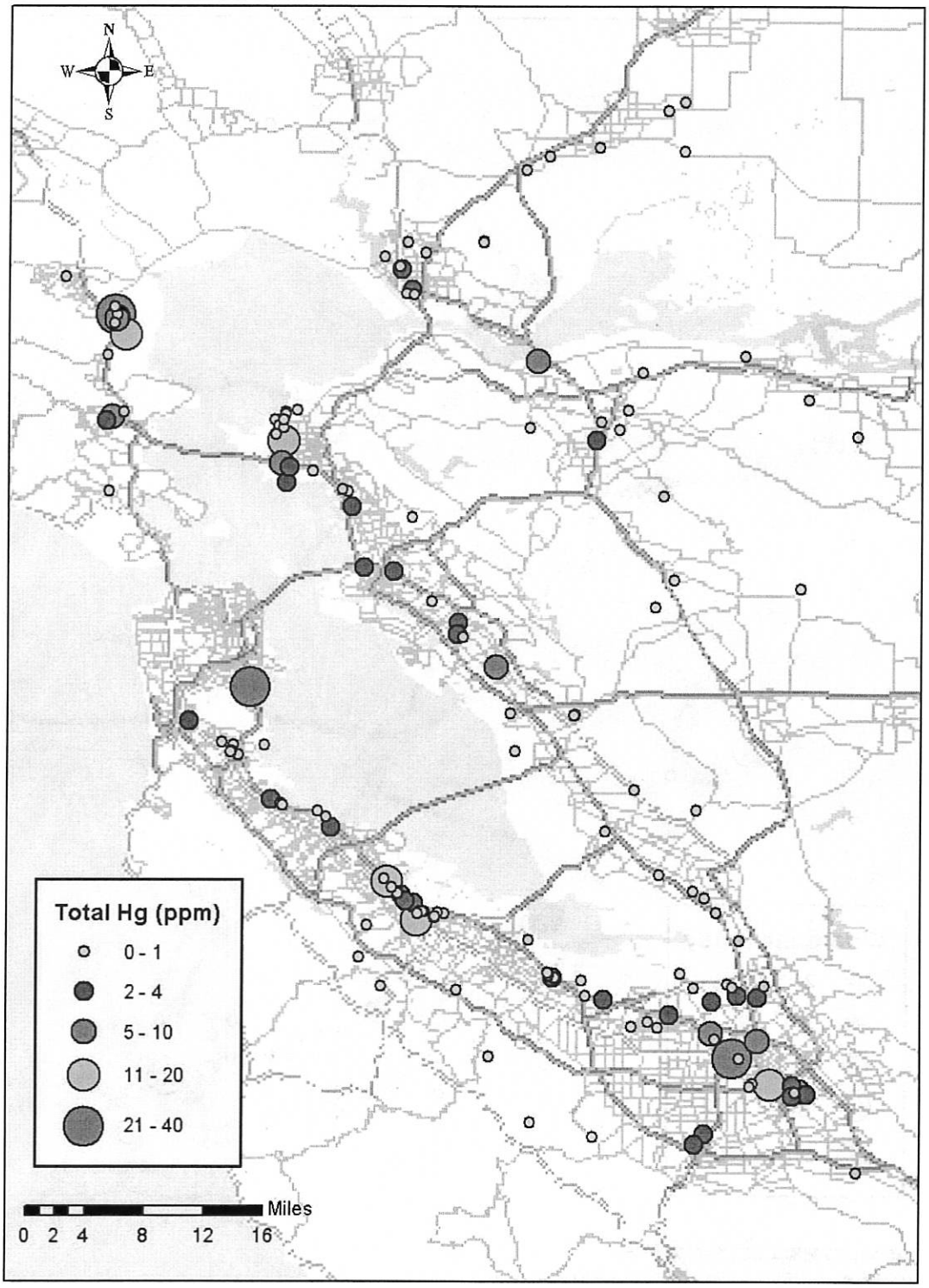

Figure 14. Concentrations of total mercury measured in storm drains throughout the study area. All data normalized to the fine fraction (<62.5 micron). Includes all data from 2000 and 2001 surveys. Alameda data limited to 2000 survey.

SARB_016462

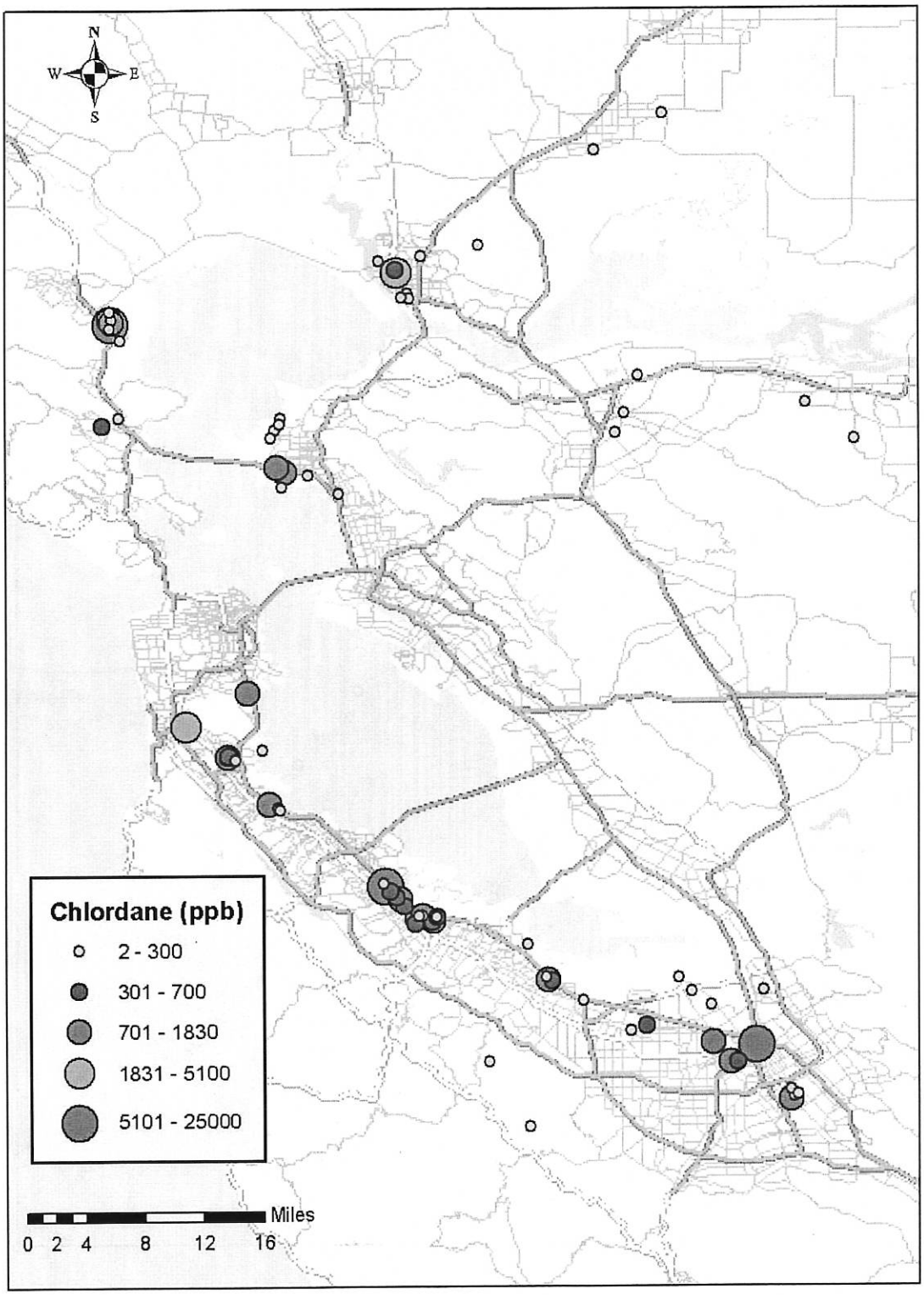

Figure 15. Concentrations of total chlordane measured in storm drains throughout the study area. All data normalized to the fine fraction (<62.5 micron).

SARB_016463

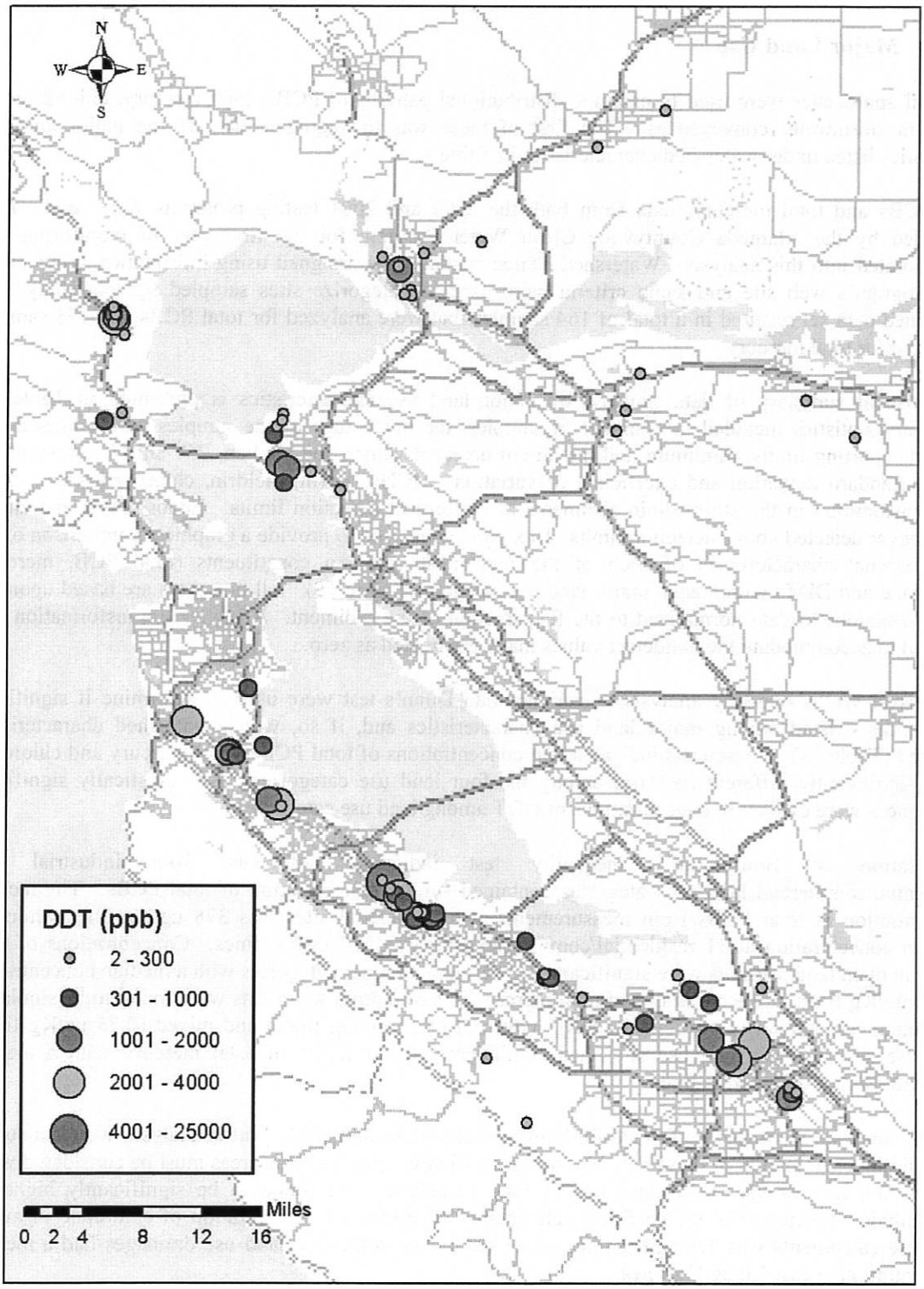

Figure 16. Concentrations of total DDT measured in storm drains throughout the study area. All data normalized to the fine fraction (<62.5 micron).

SARB_016464

3.1 Major Land Use

Several approaches were used to examine distributional patterns of PCBs, total mercury, chlordane and DDT in stormwater conveyances. The first of these was to aggregate data in the major land use categories listed under watershed characteristics in Table 1.

For PCBs and total mercury, data from both the 2000 and 2001 testing programs were used. Data provided by the Alameda Countywide Clean Water Program for the first year of monitoring was incorporated into this analysis. Watershed characteristics were assigned using information provided on the Program's web site and same criteria were used to categorize sites sampled by this study. The combined data set resulted in a total of 164 samples that were analyzed for total PCBs and 153 samples analyzed for total mercury.

A statistical summary of data grouped by major land use characteristics is presented in Table 17. Summary statistics included the number of samples, the percentage of the samples with values above project reporting limits, minimum and maximum detected values, the median, 25th and 75th percentiles, mean, standard deviation and coefficient of variation. HCHs, aldrin, dieldrin, chlorpyrifos and mirex were uncommon in the storm drain sediments at the project detection limits. Endosulphan and endrin were never detected above detection limits. Box plots were used to provide a graphical comparison of the distributional characteristics of each of the four most common constituents (total PCB, mercury, chlordane and DDT) within each major land use category (Figure 17). All box plots are based upon log transformations of data normalized to the fine fraction of the sediment. A log(x+1) transformation was utilized to accommodate the nondetect values that were treated as zero.

A Kruskal-Wallis one-way analysis of variance and Dunn's test were used to determine if significant differences existed among major land use characteristics and, if so, which watershed characteristics differed (Table 18). These tests indicated that concentrations of total PCBs, total mercury and chlordane were significantly different ($p<0.05$) among the four land use categories. No statistically significant differences were evident in concentrations of DDT among land use categories.

Application of Bonferonni's inequality test indicated sediments from industrial and residential/commercial land use categories contained similar concentration of total PCBs. The median concentration of total PCBs from measurements at 68 industrial sites was 378 ug/Kg fines while the median concentration at 31 residential/commercial sites was 327 ug/Kg fines. Concentrations of total PCBs in open land use sites were significantly lower than all other categories with a median concentration of 2.2 ug/Kg fines. Concentrations of total mercury in storm drain sediments were found to be similar in residential/commercial (1.40 mg/Kg fines), industrial (1.22 ug/Kg fines) and mixed (0.75 ug/Kg fines) land use sites. Open land use sites had significantly lower levels of total mercury with a median concentration of 0.21 ug/Kg fines.

Similar analyses were also performed for both total chlordane and DDT. These analyses were conducted as an initial examination of these data but low replication in open land use areas must be considered when interpreting the results. Concentrations of total chlordane were found to be significantly higher in residential/commercial (89 ug/Kg fines) catchments. The median concentration of chlordane in mixed land use catchments was 7.4 ug/Kg fines while sediments from open land use drainages had a median concentration of just 1.0 ug/Kg fines.

Concentrations of DDT were statistically similar in sediments from all four land use categories.

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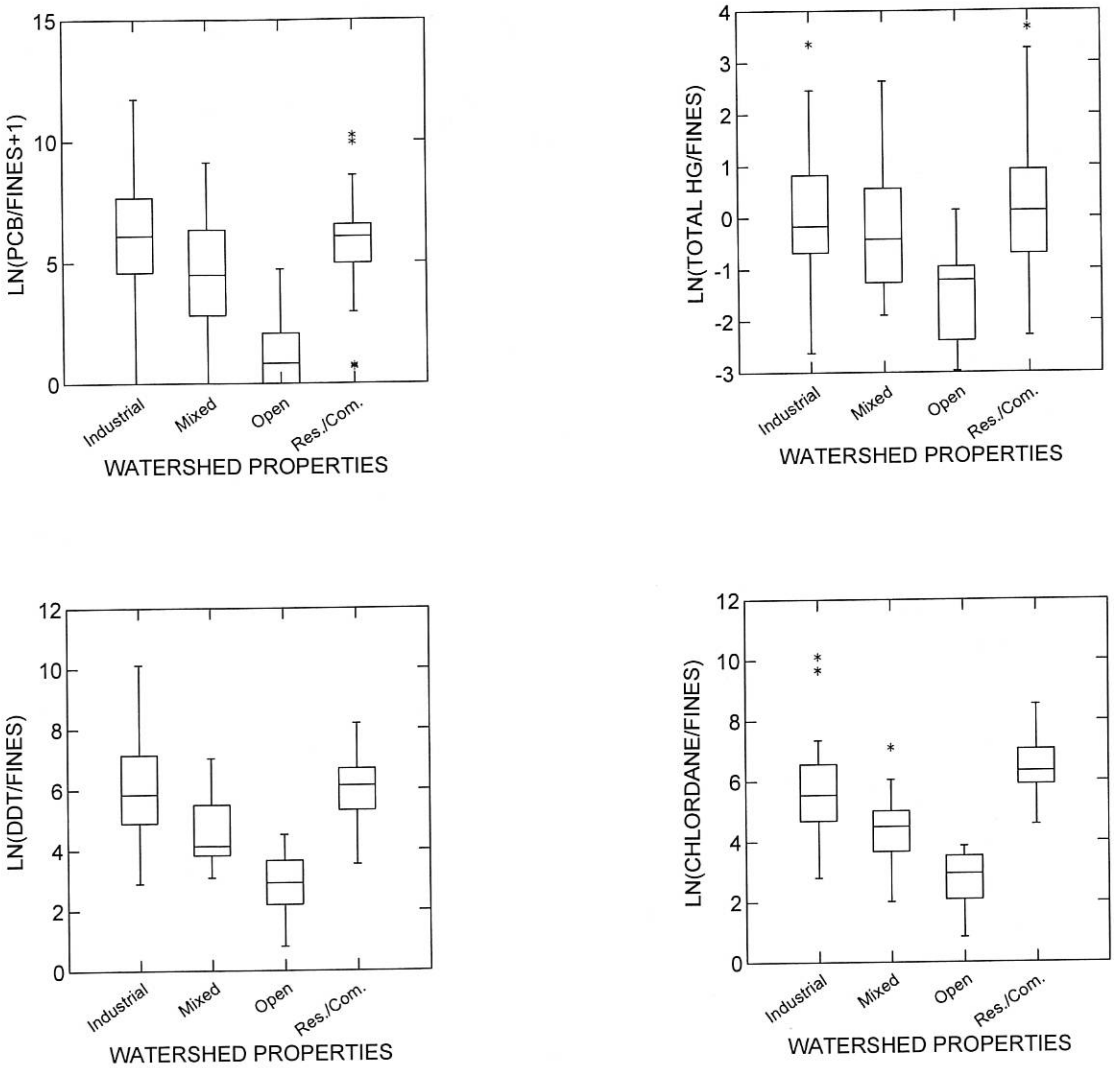
Table 17. Statistical summary of results by major land use classification. All data normalized to the fine fraction (<62.5 microns). Bolded values represent exact calculations

Parameter	Units (Dry Wt)	n	% Detected	Min Detected	Max Detected	Mean	SD	CV	Percentiles 25th	50th	75th
Industrial											
Total PCBs	ug/Kg fines	**68**	**94.1**	**4.84**	**124198**	4455	19121	4.29	**94**	**445**	**2264**
Total Mercury	mg/Kg fines	**65**	**100**	**0.07**	**28.79**	**2.44**	**4.57**	**1.87**	**0.504**	**0.84**	**2.34**
Total Chlordane	ug/Kg fines	**45**	**77.8**	**1.7**	**24296**	1315	4849	3.7	**2.8**	**69.0**	**404**
Total DDT	ug/Kg fines	**45**	**68.9**	**19.1**	**24541**	881	4915	5.6	16.4	**97.9**	**426**
Total HCH	ug/Kg fines	**45**	**4.4**	**2.4**	**590**	13.2					
Endosulphan	ug/Kg fines	**45**	**0**								
Aldrin	ug/Kg fines	**45**	**2.2**	**11**	**11**	0.2					
Dieldrin	ug/Kg fines	**45**	**13.3**	**4.4**	**2.8**	1.5					
Endrin	ug/Kg fines	**45**	**0**								
Chlorpyrifos	ug/Kg fines	**45**	**31**	**3.0**	**46**	4.2					
Mirex	ug/Kg fines	**45**	**4.4**	**0.85**	**6.6**	0.2					
Residential/Commercial											
Total PCBs	ug/Kg fines	**31**	**100**	**1.02**	**28003**	**2224**	**6629**	**2.98**	**96**	**431**	**713**
Total Mercury	mg/Kg fines	**28**	**100**	**0.10**	**39.6**	**4.64**	**9.68**	**2.09**	**0.601**	**1.13**	**2.54**
Total Chlordane	ug/Kg fines	**11**	**100**	**54.3**	**3744**	**964**	**1185**	**1.2**	**327**	**550**	**1633**
Total DDT	ug/Kg fines	**11**	**72.7**	**7.2**	**1307**	239	455	1.9	17.7	**161**	**188**
Total HCH	ug/Kg fines	**11**	0								
Endosulphan	ug/Kg fines	**11**	**0**								
Aldrin	ug/Kg fines	**11**	**0**								
Dieldrin	ug/Kg fines	**11**	**36.4**	**6.6**	**70**	11					
Endrin	ug/Kg fines	**11**	**0**								
Chlorpyrifos	ug/Kg fines	**11**	**18.2**	**45**	**1000**	95					
Mirex	ug/Kg fines	**11**									
Mixed											
Total PCBs	ug/Kg fines	**41**	**97.6**	**0.25**	**9113**	724	2010	2.78	**15.8**	**89.1**	**567**
Total Mercury	mg/Kg fines	**36**	**100**	**0.15**	**8.57**	**1.31**	**1.80**	**1.37**	**0.240**	**0.55**	**2.03**
Total Chlordane	ug/Kg fines	**13**	**84.6**	**4.5**	**268**	65	87	1.3	**5.2**	**34**	**109**
Total DDT	ug/Kg fines	**13**	**84.6**	**14.1**	**734**	123	240	1.9	**17.1**	**39.8**	**98.0**
Total HCH	ug/Kg fines	**13**	**7.7**	**0.64**	**0.64**	0.1					
Endosulphan	ug/Kg fines	**13**	**0**								
Aldrin	ug/Kg fines	**13**	**0**								
Dieldrin	ug/Kg fines	**13**	**7.7**	**3.4**	**3.4**	0.52					
Endrin	ug/Kg fines	**13**	**0**								
Chlorpyrifos	ug/Kg fines	**13**	**30.8**	**1.3**	**25**	2.0					
Mirex	ug/Kg fines	**13**	**0**								
Open											
Total PCBs	ug/Kg fines	**22**	**54.5**	**0.40**	**113**	9.4	30	3.14	0.31	**1.16**	**6.95**
Total Mercury	mg/Kg fines	**22**	**100**	**0.05**	**14.0**	**0.92**	**4.10**	**4.44**	**0.086**	**0.32**	**0.43**
Total Chlordane	ug/Kg fines	**4**	**75**	**0.72**	**4.0**	1.6	2.2	1.3			**3.3**
Total DDT	ug/Kg fines	**4**	**25**	**0.82**	**0.82**						
Total HCH	ug/Kg fines	**4**	**25**	**0.19**	**0.19**						
Endosulphan	ug/Kg fines	**4**	**0**								
Aldrin	ug/Kg fines	**4**	**0**								
Dieldrin	ug/Kg fines	**4**	**0**								
Endrin	ug/Kg fines	**4**	**0**								
Chlorpyrifos	ug/Kg fines	**4**	**0**								
Mirex	ug/Kg fines	**4**	**0**								

SARB_016466



Horizontal Bar=Median, Upper Box Hinge=Third Quartile, Lower Box Hinge=First Quartile, Upper Whisker=Upper Hinge+(1.5*(Median-Upper Hinge)), Lower Whisker=Lower Hinge-(1.5*(Median-Lower Hinge)), *=Outside Value, o=Very Outside Value

Figure 17. Comparison of concentrations and distributional properties of total PCBs, total mercury, DDT and chlordane in the fine fraction of storm drain sediments from four major land use categories.

SARB_016467

Table 18. Statistical comparison of analyte concentration in sediments from storm drainages in four major land use categories.

Analyte	Probability[2]	Ranked Land Use Classifications[3] (High to Low Concentrations)			
Total PCBs[1]	**<0.000**	**IND**	**RES/COM**	**MIXED**	**OPEN**
Total Mercury	**<0.000**	**RES/COM**	**IND**	**MIXED**	**OPEN**
Total Chlordane	**<0.000**	**RES/COM**	**IND**	**MIXED**	**OPEN**
Total DDT	0.134	**RES/COM**	**IND**	**MIXED**	**OPEN**

1. Summation of all 54 congeners.
2. Significance of Kruskal-Wallis test based upon $p<0.05$. Significant probabilities are bolded.
3. Underlined land use categories indicate categories that are not significantly different ($p<0.05$) based upon Bonferonni's inequality.

3.2 Urban and Nonurban

Land use types were further aggregated to compare concentrations of PCBs, mercury, chlordane and DDT in the urban portions of the study area with nonurban or open land use. Urban sites were considered to include industrial, residential/commercial, and mixed land use types. Nonurban were considered synonymous with open land use. Reclassification of sampling sites in this manner resulted in 143 urban and 21 nonurban sites for PCBs. A statistical summary of urban and nonurban data is presented in Table 19. As in the previous section, summary statistics are included only for contaminants that were commonly detected in the storm drain sediments. HCHs, aldrin, dieldrin, chlorpyrifos and mirex were uncommon in the storm drain sediments at the project detection limits. Endosulphan and endrin were never detected above detection limits. Box plots showing the distributional characteristics for each of the four commonly encountered sediment contaminants are presented in Figure 18. As in section 3.1, box plots are based upon natural log transformations of the concentrations of each contaminant after normalizing to the fine fraction. For plotting purposes, an $\ln(x+1)$ transformation was used to allow inclusion of nondetect values that were treated as zero.

Statistical comparisons (Table 20) using the Mann-Whitney test indicated that samples taken from urban environments had significantly higher levels of total PCBs, total mercury, chlordane and DDT. The median concentration of total PCBs and DDT in urban samples was on the order of two orders of magnitude or roughly 100 times the median value in open land use areas. Concentrations of chlordane in urban storm drains were approximately 40 times higher than observed in open land use areas. The median concentration of total mercury, however, was only 3 times greater in sediments from urban land use areas.

In the case of both chlordane and DDTs, the number of samples from open land use is limited to four sites. Although the differences between urban and nonurban sites was large and statistically significant, the numbers of samples from nonurban areas are far too low to be considered representative of open land use areas. Low numbers of open land use sites were sampled this year since the focus was on PCBs and improving coverage of areas characterized by industrial land use activities.

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3.2.1 Comparison of Storm Drain Sediments with Recent San Francisco Bay Data

Data from the1999 and 2000 Regional Monitoring Program (RMP; SFEI 2000) and the Bay Protection and Toxic Cleanup Program (BPTCP; Hunt et al. 1998) were used as reference points for comparison with concentrations measured in Bay area storm drainages. For consistency, data obtained from these two programs were all normalized to the fine fraction. In 1999 and 2000, the RMP measured PCBs, mercury, chlordane and DDT in Bay sediments at 47 sites. Between one and three samples were taken at each site during this time period.

Data from these two programs suggest that concentrations of PCBs, chlordane and DDTs in Bay sediments are far less than those measured in storm drain sediments from urban areas (Figure 18). As an example, the median of PCB measurements by the RMP was 5.7 ug/Kg fines. The median concentration of PCBs reported by the BPTCP was 22.5 ug/Kg fines, approximately 1/10 of the median concentration in the urban storm drains. The median in urban storm drainages was 311 ug/Kg fines. In contrast, PCBs in sediments collected from open land use catches had a median concentration of only 1.16 ug/Kg fines.

In the case of total mercury, concentrations measured in sediments from urban stormwater drainages were found to be relatively comparable to values from the 1999 and 2000 RMP surveys as well as the earlier BPTCP studies. The median concentration of total mercury was 0.93 mg/Kg fines in urban storm drain sediments during the current study compared to 0.39 mg/Kg fines for all San Francisco Bay stations sampled by the RMP in 1999 and 2000 and 0.46 mg/Kg fines at BPTCP sites. The median concentration of mercury from open land use sites was 0.32 mg/Kg fines.

In all cases the contaminant concentrations in sediments sampled from open land use drainages contained levels near or lower than found in San Francisco Bay sediments or in sediments from urban storm drains (Figure 18).

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Table 19. Statistical summary of results by urban and nonurban land use categories. All data normalized to the fine fraction (<62.5 microns). Bolded values represent exact calculations

Parameter	Units (Dry Wt)	n	% Detected	Min Detected	Max Detected	Mean	SD	CV	Percentiles		
									25th	50th	75th
Urban											
Total PCBs	ug/Kg fines	**140**	**96.4**	**0.25**	**124198**	2868	13576	4.73	**61.4**	**311**	**1254**
Total Mercury	mg/Kg fines	**129**	**100**	**0.07**	**39.6**	**2.60**	**5.54**	**2.13**	**0.43**	**0.93**	**2.35**
Total Chlordane	ug/Kg fines	**69**	**82.6**	**1.7**	**24296**	1023	3957	3.9	**8.5**	**69**	**433**
Total DDT	ug/Kg fines	**69**	**72.5**	**7.2**	**24541**	636	3966	6.2	13.5	**78.9**	**353**
Total HCH	ug/Kg fines	**69**	**4.3**	**0.64**	**590**						
Endosulphan	ug/Kg fines	**69**	**0**								
Aldrin	ug/Kg fines	**69**	**1.4**	**11**	**11**	0.16					
Dieldrin	ug/Kg fines	**69**	**15.9**	**3.4**	**70**	2.8					
Endrin	ug/Kg fines	**69**	**0**								
Chlorpyrifos	ug/Kg fines	**69**	**29**	**1.3**	**1000**	18.4					
Mirex	ug/Kg fines	**69**	**2.9**	**0.85**	**6.6**	0.1					
Nonurban (Open)											
Total PCBs	ug/Kg fines	**22**	**54.5**	**0.40**	**113**	9.4	30	3.14	0.31	**1.16**	**6.95**
Total Mercury	mg/Kg fines	**22**	**100**	**0.05**	**14.0**	**0.92**	**4.10**	**4.44**	**0.086**	**0.32**	**0.43**
Total Chlordane	ug/Kg fines	**4**	**75**	**0.72**	**4.0**	1.6	2.2	1.3		1.6	**3.3**
Total DDT	ug/Kg fines	**4**	**25**	**0.82**	**0.82**						
Total HCH	ug/Kg fines	**4**	**25**	**0.19**	**0.19**						
Endosulphan	ug/Kg fines	**4**	**0**								
Aldrin	ug/Kg fines	**4**	**0**								
Dieldrin	ug/Kg fines	**4**	**0**								
Endrin	ug/Kg fines	**4**	**0**								
Chlorpyrifos	ug/Kg fines	**4**	**0**								
Mirex	ug/Kg fines	**4**	**0**								

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Table 20. Statistical comparison of analyte concentration in sediments from urban and nonurban (open) storm drainages.

Analyte	Probability[1]	Urban Median	Nonurban Median
Total PCBs (ug/Kg fines)	**<0.000**	311	1.16
Total Mercury (mg/Kg fines)	**<0.000**	0.93	0.32
Total Chlordane (ug/Kg fines)	**<0.001**	69	1.6
Total DDT (ug/Kg fines)	**<0.001**	78.9	0.82

1. Mann-Whitney Test. Significance based upon $p<0.05$. Significant probabilities are bolded.

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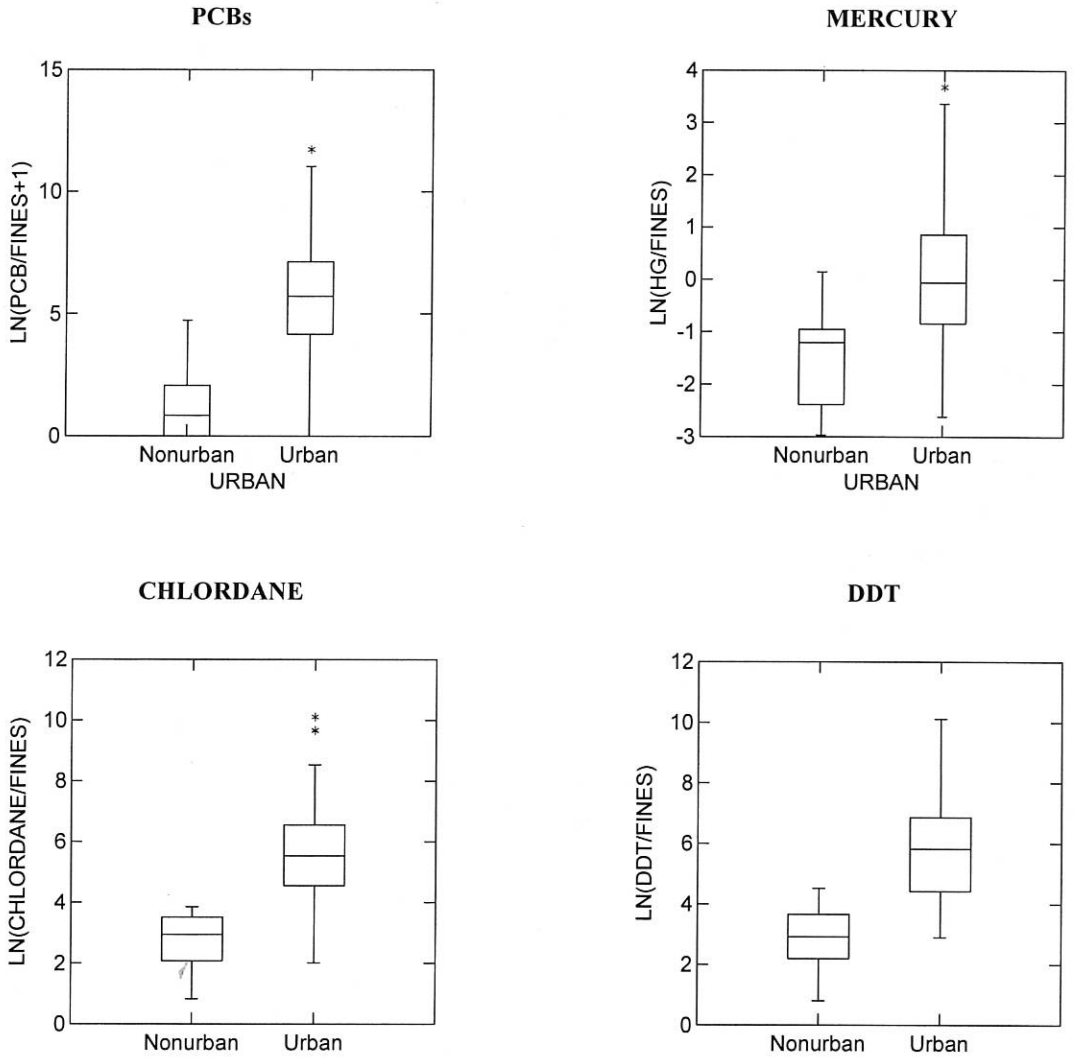

Horizontal Bar=Median, Upper Box Hinge=Third Quartile, Lower Box Hinge=First Quartile, Upper Whisker=Upper Hinge+(1.5*(Median-Upper Hinge)), Lower Whisker=Lower Hinge-(1.5*(Median-Lower Hinge)), *=Outside Value, o=Very Outside Value

Figure 18. Comparison of concentrations and distributional properties of total PCBs, total mercury, chlordane and DDT in storm drains from urban and open land use areas tributary to San Francisco Bay.

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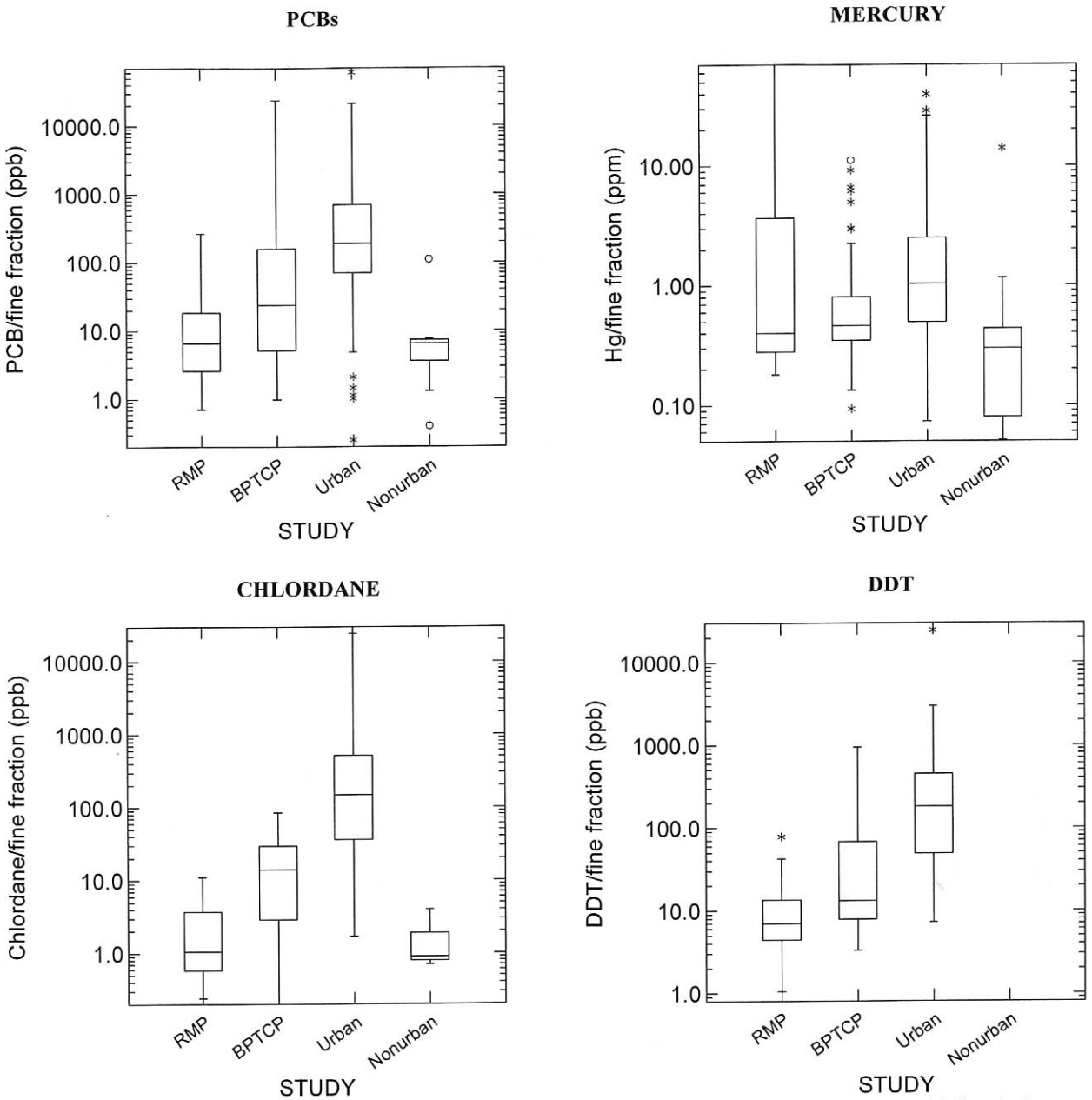

RMP=Regional Monitoring Program, BPTCP=Bay Protection and Toxics Cleanup Program, Urban and Nonurban (Open) indicate land use classifications used in this study.

Horizontal Bar=Median, Upper Box Hinge=Third Quartile, Lower Box Hinge=First Quartile, Upper Whisker=Upper Hinge+(1.5*(Median-Upper Hinge)), Lower Whisker=Lower Hinge-(1.5*(Median-Lower Hinge)), *=Outside Value, o=Very Outside Value

Figure 18. Comparison of concentrations of total PCBs, mercury, chlordane and DDT in storm drains from urban and nonurban (open) land use areas with levels measured in San Francisco Bay sediments.

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3.3 Stormwater Load Estimates

Estimates of stormwater loads to San Francisco Bay are summarized by both hydrologic area (Table 21) and by major land use activity (Table 22). In both cases the low and high estimates of loading are based upon the 25th and 75th percentile estimates for contaminant concentrations and loading is estimated in terms of pounds per year.

Several major assumptions were necessary to develop these load estimates. It was first necessary to assume that contaminants in sediments from storm drains were 100 percent associated with particles less than 62.5 microns in size. Secondly, it had to be assumed that this fine fraction of the bedded sediment was representative of the suspended material measured as Total Suspended Solids (TSS) by stormwater monitoring programs. Considerable controversy exists regarding the latter assumption. There is substantial concern that TSS measurements are inherently inaccurate when measuring suspended material in storm water. The Suspended Sediment Concentration (SSC) method (ASTM D3977-97) is currently recommended for this purpose. USGS (Gray et al. 2000) analyzed results from 3,235 paired samples using both procedures and found the TSS method to be negatively biased by a factor of 25 to 34 percent and there was no clear relationship between the two procedures. Using good subsampling procedures, automated sampling procedures and TSS methods can include suspended material as large as 1 to 2 mm. Inconsistent procedures used by different sampling groups and laboratories introduce additional variability in TSS results. Using either the SSC or TSS methods, it is likely that the particle size composition of suspended material included with these measurements includes material larger than 62.5 microns. Since the particle size distribution of suspended matter in stormwater is rarely measured, it is unknown what proportion of measured TSS is represented by particles greater than 62.5 microns. This problem (violation of assumptions) would actually be exacerbated if the SSC method were in common use.

The overall load estimate for PCBs from urban sources was estimated to range from 19 and 228 pounds per year with a median estimate of 87 pounds per year (Table 22). Urban mercury loads were estimated at 115 to 497 pounds per year with a median of 210 pounds per year. Estimates of mercury loads associated with stormwater discharges specifically do not include large point sources associated with historic mercury mines located within San Francisco Bay watersheds. These sources were not characterized in this study.

Far less information is currently available for chlordane and DDT. Preliminary estimates were made based upon data from this year. Based upon this limited set of data it is estimated that 48 to 260 pounds of chlordane and 2.3 to 50 pounds of DDT are discharged to the Bay from urban sources on an annual basis (Table 22).

3.3.1 Assessment of potential impacts of cleanup activities on PCB loading

Alternative scenarios were analyzed to assess the possible effects of cleaning storm drains and/or contaminant sources contributing to those storm drains with high concentrations of PCBs. This evaluation was based upon the assumption that cleanup activities were conducted at all top 15 percentile sites. It was further assumed that the cleanup activities would be able to effectively reduce the sources to levels equivalent to either the 75th percentile (1,254 ug/Kg fines) or the 50th percentile (311 ug/Kg fines) concentrations in urban storm drains. The results of this assessment are summarized in Table 23 and Figure20.

This assessment indicated that cleaning up the top 15th percentile PCB sources to levels consistent with the 75th percentile urban site reduces the upper range of the loading estimate by 24% but has no impact on either the median or low estimates. PCB loads under this scenario were estimated to range from 19 to 173 pounds per year. By setting the cleanup standard to the median concentration of 311 ug/Kg fines, load

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estimates were further reduced to 19 to 112 pounds per year, a reduction of just over 50% in the upper estimate from the baseline estimate. The estimate of the median load was reduced by 28%.

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Table 21. Estimates of annual loading (lbs/year) of PCBs, total mercury, chlordane and DDT to San Francisco Bay from each major watershed.

WATERSHED	Acres	Median PCBs (lbs)	High PCBs (lbs)	Low PCBs (lbs)	Median Total Hg (lbs)	High Total Hg (lbs)	Low Total Hg (lbs)	Median Chlordane (lbs)	High Chlordane (lbs)	Low Chlordane (lbs)	Median DDTs (lbs)	High DDTs (lbs)	Low DDTs (lbs)
Alameda Creek	232597	4.8	13.7	1.0	17	35	7.7	4.3	13.3	2.4	1.2	2.9	0.13
Berkeley	21653	3.1	9.2	0.7	7	18	4.1	2.7	8.6	1.5	0.8	2.0	0.09
Concord	160264	9.4	23.9	2.1	25	57	13.0	9.3	28.7	5.3	2.6	5.3	0.25
Coyote Creek	115864	4.1	12.0	0.9	12	26	5.8	3.6	11.3	2.0	1.0	2.6	0.12
East Bay Cities	132964	12.5	35.9	2.7	30	72	16.5	11.1	34.8	6.2	3.2	7.7	0.35
Fairfield	217032	4.0	11.1	0.9	23	41	9.0	3.9	11.7	2.1	1.0	2.4	0.11
Fremont Bayside	47255	2.1	6.8	0.5	6	13	2.9	1.7	5.3	0.9	0.5	1.4	0.06
Guadalupe River	53194	4.6	10.5	1.0	12	28	6.4	4.9	15.0	2.9	1.3	2.4	0.12
Napa River	231864	4.8	10.7	1.1	26	47	10.2	5.5	16.2	3.1	1.4	2.5	0.12
Novato	45482	2.5	4.7	0.5	8	17	3.9	3.0	8.8	1.7	0.8	1.2	0.06
Palo Alto	148253	11.7	29.9	2.6	29	68	15.6	11.4	35.3	6.5	3.2	6.7	0.31
Petaluma River	93361	2.4	6.1	0.5	14	24	5.3	2.4	7.3	1.3	0.6	1.3	0.06
Pinole	37306	2.8	8.9	0.6	7	16	3.6	2.2	7.1	1.2	0.7	1.9	0.08
San Francisco Bayside	7111	0.9	1.6	0.2	2	5	1.2	1.1	3.2	0.6	0.3	0.4	0.02
San Mateo Bayside	105483	10.0	28.7	2.2	24	57	13.0	8.7	27.5	4.9	2.5	6.2	0.28
San Rafael	38976	5.9	10.6	1.3	16	35	8.3	7.3	21.7	4.3	1.9	2.7	0.14
Sonoma Creek	106246	1.6	3.9	0.4	13	22	4.6	1.7	5.0	0.9	0.4	0.9	0.04
TOTALS	**1794905**	**87**	**228**	**19.2**	**271**	**578**	**131**	**85**	**261**	**48**	**23**	**51**	**2.3**

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Table 22. Estimates of annual loading of PCBs, total mercury, chlordane and DDT to San Francisco Bay from each major land use category.

Constituent	Res	Com	Ind	Ag	Open	All 17 Bay Watersheds		Urban Areas Only	
	(lbs/year)					(lbs/year)	(kg/year)	(lbs/year)	(kg/year)
PCBs									
Median	46	17	24	0.19	0.02	**87**	**39.5**	**87**	**39.5**
High	76	28	123	1.2	0.15	**228**	**103.6**	**227**	**103.2**
Low	35	13	21	0.37	0.05	**19**	**8.6**	**19**	**8.6**
Total Mercury									
Median	120	45	46	53.6	6.8	**271**	**123.2**	**210**	**95.5**
High	269	101	127	72	9.1	**578**	**262.7**	**497**	**225.9**
Low	64	24.0	27	14	1.8	**131**	**59.5**	**115**	**52.3**
Chlordane									
Median	58	22	3.7	0.67	0.09	**85**	**38.6**	**84**	**38.2**
High	173	65	22	0.67	0.09	**261**	**118.6**	**260**	**118.2**
Low	35	13	0.2	0.12	0.02	**48**	**21.8**	**48**	**21.8**
DDT									
Median	15	5.2	3.0	0.001	0.004	**23**	**10.5**	**23**	**10.5**
High	20	7.4	23	0.14	0.02	**51**	**23.2**	**50**	**22.7**
Low	1.1	0.4	0.9	0.00	0.00	**2.3**	**1.0**	**2.3**	**1.0**

Table 23. Comparison of current annual PCB load estimates with two source reduction scenarios. 1) cleanup of the top 15th percentile sites to the 75th percentile concentration (1254 ug/Kg fines) and to the 50th percentile concentration (311 ug/Kg fines).

PCBs	Annual Load (lbs/year)	Percentage Reduction
Existing Conditions		
Median	87	NA
High	228	NA
Low	19	NA
Cleanup to 75th Percentile		
Median	87	0
High	173	24
Low	19	0
Cleanup to 50th Percentile		
Median	62	28
High	112	51
Low	19	0

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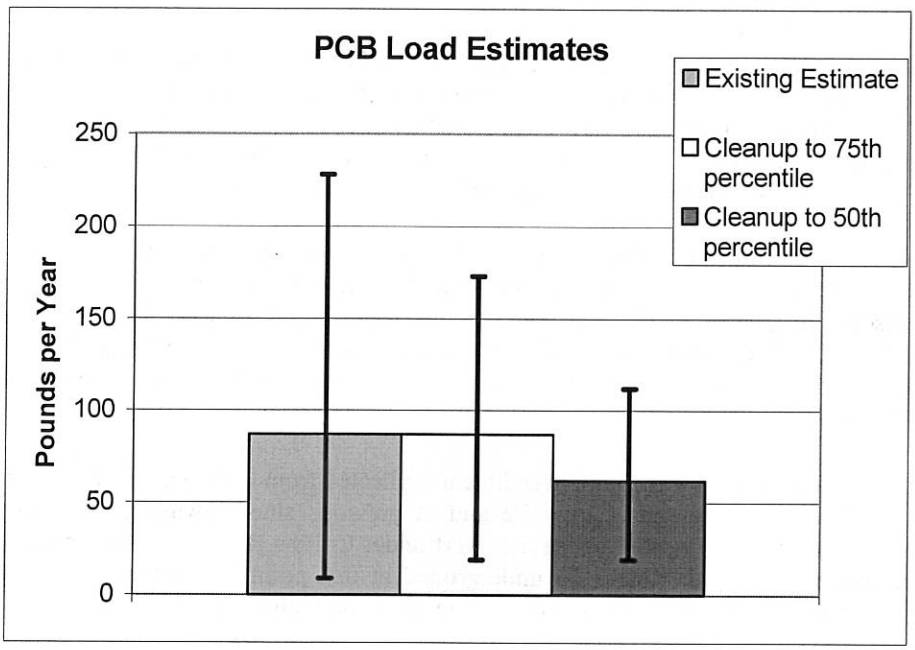

Figure 20. PCB annual loading estimates based upon existing conditions two cleanup scenarios for the top 15th percentile sites. Error bars represent the 25th and 75th percentile load estimates. Bars indicate the median load estimate.

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3.4 Top 15th Percentile Sites

Table 24 lists sites with concentrations of PCBs and mercury in the top 15th percentile of all sediments tested in the past two years. All concentrations are normalized to the fine fraction. Shaded areas indicate sites that were sampled in the previous year. Samples taken in 2000 are summarized in the table but are not discussed below. Many of the sites with higher concentrations from last year have been the subject of case studies. Figure 21 illustrates the general distribution of PCBs and total mercury measured at all sites.

Highest concentrations of PCBs were encountered in sediments collected from a manhole in an industrial catchment in San Carlos (SMC020). The sample was taken in front Spacesonic, on the west side of Industrial Road south of Quarry Road. This site receives runoff from an area that includes Delta Star (270 Industrial Road), a former generator of PCBs and manufacturer of transformers. PCBs and other pollutants have been found in soil samples from the site. The Regional Board has adopted site cleanup requirements (Order No. 99-062).

The second highest concentration was found in sediments collected from Colma Creek (SMC024). An oil and grease sheen has been observed at this site and at previous sites downstream of this sampling location. The sampling point is located inside a culvert under Collins Road. Several sources appear to converge at this point. All conveyances go underground at this point and mapping information was limited. The catchment includes a number of automobile sales and maintenance activities.

Sediments collected from the Pulgas Creek Pump Station (SMC023) in San Carlos contained the third highest concentration of PCBs. Sediments at this site were anoxic. The composition of the PCBs at this site showed signs of weathering typical of anoxic conditions. Congeners with three to four chlorine atoms were more abundant than expected in typical Arochlor formulations.

Sediments collected from a manhole near Nebraska Street in Vallejo (VFC006) contained the fourth highest concentrations of PCBs encountered this year. This is primarily a residential catchment that ultimately discharges through Austin Creek.

Samples collected at SMC040 contained the fifth highest levels of PCBs. This site was actually part of a case study investigation conducted to examine sources of PCBs to the South Maple Pump Station in Redwood City.

Sediment sampled for CCC032 was comprised of a composite of four catch basins located on the north side of West Cutting Boulevard near South 1st Street. PCBs in this composite sample were measured at 12,538 ug/Kg fines in the fine fraction of the sediment. Catch basin number one was located west of South 1st Street in front of the Richmond Distribution Center. Catch basin number two was located west of South 1st Street in front of the PG&E substation. Catch basin number three was located on the east side of South 1st Street at the intersection of West Cutting Boulevard next to Precision Machining. Catch basin number four was located on West Cutting Boulevard east of South 1st Street near the eastern edge of Precision Machining.

The highest concentrations of mercury were measured in sediments from three sites in Marin County (MCS007, MCS011, and MCS010), three in San Mateo County (SMC025, SMC030, and SMC020) and one Santa Clara Valley site (SCV028). The Marin County sites were all located in the lower portions of the Pacheco and Arroyo San Jose watersheds. Both ultimately discharge through Pacheco Pond to San Francisco Bay. The San Mateo sites include SMC020 where high PCBs were also encountered. Other San Mateo sites included (SMC025) which is an industrial area where sediments were collected from a manhole located at the eastern end of Beatty Avenue. SMC030 is located in the Jefferson Branch of Redwood Creek just northwest of Harrison Street where it runs underneath Duane Street. Drainage for

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this branch of the Creek includes Stulsaft Park on Farm Hill Boulevard. During redevelopment of the Park, it was discovered that the Park was the site of a mercury mine in the 1950's. San Mateo County Health Service Agency and Redwood City discovered residual mercury contamination in the soils and have planned remediation efforts before continuing with the redevelopment process.

Table 25 lists sites that were found to have concentrations of total chlordane and DDT in sediments that ranked within the top 15th percentile of all sites investigated in 2001. These two groups of compounds were only measured during the past year. The general distribution of total chlordane and DDT among all sites is illustrated in rank order in Figure 22.

Many of the sites noted to have sediments with higher levels of PCBs and mercury were also found to have higher concentrations of both chlordane and DDT. Sediments from both the Delta Star site (SMC020) in San Carlos and Pulgas Creek Pump Station (SMC023) had high concentrations of both chlordane and DDTs. The highest concentration of chlordane (24,541 ug/Kg fines) was found in sediments from an industrial catchment in San Jose (SCV034). Sediment was collected from a manhole located at the convergence of 5th and 7th Streets. High levels of chlordane were also encountered at VFC006 in Vallejo where elevated levels of PCBs were also found.

One Marin County site, MCS008, was found to have high levels of both chlordane (15,396 ug/Kg fines) and DDT (2,054 ug/Kg fines). Sediment was collected from a corrugated metal outfall near 31 Pamaron Way that flows into Pacheco Creek. A followup investigation was conducted by Marin County to evaluate potential sources.

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Table 24. List of sites identified with the top 15th percentile concentrations of total PCBs and total mercury from sampling conducted in both 2000 and 2001. (All data are normalized to the fine fraction.)

Site	Date Collected	Area Property	Concentration in Fine Fraction
Total PCBs			**(ug/Kg fines)**
SMC020	20-Sep-01	Industrial	124198
SCV001[1]	30-Oct-00	Industrial	61912
SMC024	06-Sep-01	Res./Com.	28003
SMC023	25-Sep-01	Industrial	25044
VFC006	16-Oct-01	Res./Com.	21231
SMC040	02-Oct-01	Industrial	13842
CCC032	01-Oct-01	Industrial	12538
ALA004	26-Sep-00	Mixed	9113
SCV022	27-Oct-00	Mixed	8200
SCV033	10-Sep-01	Industrial	7082
SCV029	05-Oct-01	Industrial	6306
SCV028	05-Oct-01	Res./Com.	5398
CCC031	01-Oct-01	Industrial	4915
SCV038	25-Sep-01	Industrial	3381
SCV003	27-Oct-00	Industrial	3179
SCV039	25-Sep-01	Industrial	3125
SMC021	20-Sep-01	Industrial	3018
SMC022	20-Sep-01	Industrial	2709
CCC006	27-Oct-00	Industrial	2705
SMC038	04-Oct-01	Res./Com.	2525
SCV044	25-Sep-01	Industrial	2443
SMC025	20-Sep-01	Industrial	2376
SMC002	24-Oct-00	Industrial	2372
SMC009	25-Oct-00	Mixed	2110
Total Mercury			**(mg/Kg fines)**
MCS007	25-Jun-01	Res./Com.	39.6
SMC025	20-Sep-01	Industrial	28.8
SCV028	05-Oct-01	Res./Com.	26.1
SCV012	30-Oct-00	Res./Com.	19.9
MCS011	25-Jun-01	Mixed	14.0
SMC030	04-Oct-01	Res./Com.	11.8
CCC006	27-Oct-00	Industrial	11.8
SMC020	20-Sep-01	Industrial	11.3
SCV006	27-Oct-00	Industrial	9.8
MCS010	25-Jun-01	Industrial	9.3
MCS002	30-Oct-00	Mixed	8.6
SCV034	05-Oct-01	Industrial	6.5
SCV031	10-Sep-01	Industrial	6.2
CCC032	01-Oct-01	Industrial	6.1
MCS008	25-Jun-01	Industrial	5.9
CCC007	27-Oct-00	Industrial	5.2
ALA010	28-Sep-00	Mixed	4.6
CCC019	25-Oct-00	Res./Com.	4.2
SCV019	26-Oct-00	Mixed	3.9
SCV024	31-Oct-00	Mixed	3.8
SMC023	25-Sep-01	Industrial	3.6

1. Shaded lines indicate samples from the 2000 survey

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Table 25. List of sites identified with the top 15th percentile concentrations of total chlordane and total DDT from sampling conducted in 2001. All data are normalized to the fine fraction.

Site	Area Property	Concentration in Fine Fraction (ug/Kg fines)
Total Chlordane		
SCV034	Industrial	24296
MCS008	Industrial	15396
SMC020	Industrial	11971
VFC006	Res/Com	3744
SCV028	Res/Com	1680
SMC024	Res/Com	1633
SMC016	Industrial	1074
SMC023	Industrial	902
MCS007	Res/Com	898
SMC031	Res/Com	857
SCV038	Industrial	627
SMC025	Industrial	616
Total DDT		
SMC020	Industrial	24541
SMC015	Industrial	2973
MCS008	Industrial	2054
SCV029	Industrial	1453
SMC023	Industrial	1410
SCV028	Res/Com	1307
CCC031	Industrial	916
SCV027	Industrial	813
SMC009	Mixed	734
SMC025	Industrial	607
MCS010	Industrial	604
SCV038	Industrial	456
SCV026	Mixed	450

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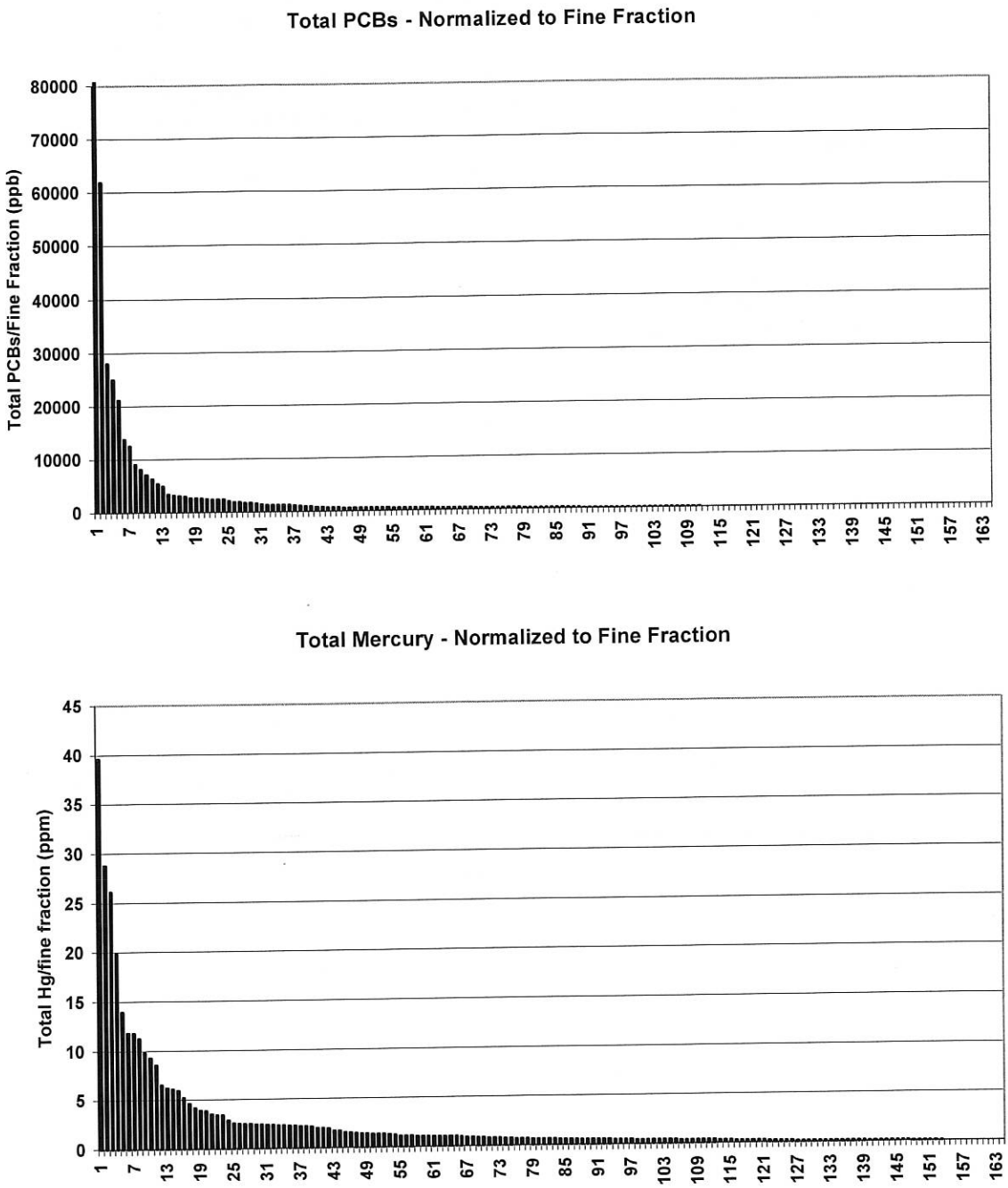

Figure 21. Ranked distribution of total PCBs and mercury. (All data normalized to the fine fraction. Concentration of 124,198 ug/Kg fines of PCBs at SMC020 is offscale)

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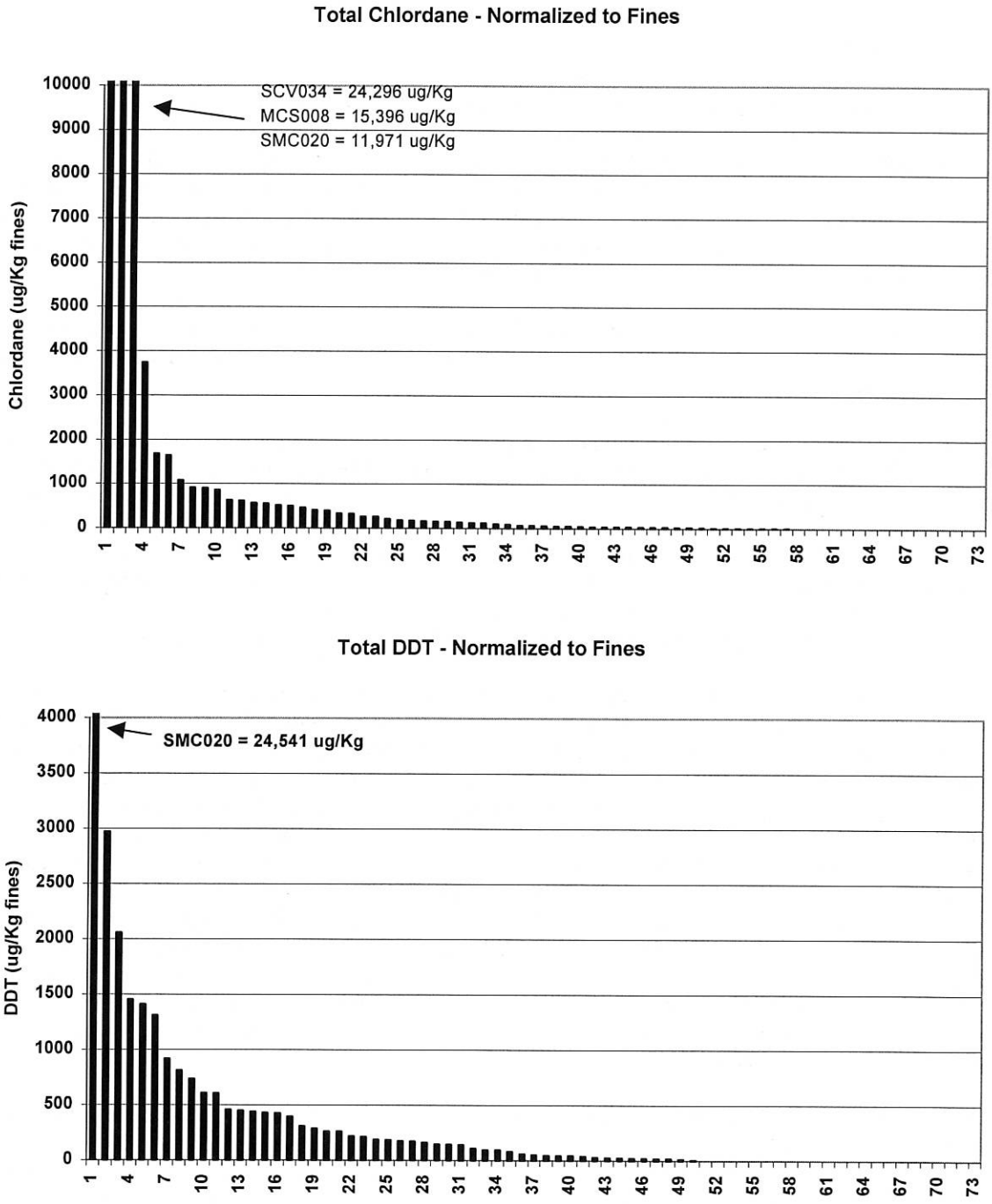

Figure 22. Ranked distribution of total chlordane and DDT. (All data normalized to the fine fraction. Concentrations of chlordane at SCV034 (24,296 ug/Kg fines), MCS008 (15,396 ug/Kg fines) and SMC020 (11,971 ug/Kg fines) and a DDT concentration of 24,541 ug/Kg fines at SMC020 are all offscale)

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3.5 PCB Homologs

PCBs in the United States were primarily manufactured by the Monsanto Corporation under the trade name of Arochlors. These commercial preparations consisted of complex mixtures of PCB congeners. A number of different grades were manufactured with names like Arochlor 1016, 1242,1248, 1254 and 1260. In the case of Arochlors designated by 12xx, the last two digits indicated the percentage of chlorine by weight in the mixture. Arochlor 1016 was a unique formulation that consisted mostly of tri- and tetrabiphenyls with pentachlorobiphenyls and above removed. Arochlor 1016 was intended to replace Arochlor 1242 and contained 41% chlorine by weight (SWRCB 1983).

The degree of chlorination was determined roughly by the amount of time that biphenyls were exposed to anhydrous chlorine. Due to the manufacturing process, the specific composition of different batches was always slightly different.

Figure 23 illustrates differences in the composition of several Arochlor formulations as analyzed by the Agency for Toxic Substances and Disease Registry (ATSDR) (1997) and Frame et al. (1996). These data have been modified to reflect percentages of each homolog that would be expected based on the 54 congeners analyzed as part of this project. These illustrations demonstrate the substantial variation that can result from different batches of Arochlors. It also illustrates the general trend of increasing abundance of the penta-, hexa-, and heptachlorobiphenyls in the mixtures as percent chlorine by weight increases from 42 to 60 percent. Hepta- and octachlorobiphenyls are only present in substantial proportions in Arochlor 1260, the most highly chlorinated PCB mixture in this comparison.

In the natural environment, PCBs often do not appear to match specific Arochlor formulations. Typical reasons for this are either the effects of weathering processes or the possibility of multiple sources of different formulations. The lighter, less chlorinated PCB homologs typically decay faster in the weathering process (SWRCB 1983) due to being more volatile and soluble. Different ambient conditions, however, can have a major influence on the weathering process. Dechlorination occurs primarily in association with anaerobic conditions. Under aerobic conditions volatilization of lower weight congeners may be more significant. The dechlorination process of weathering also results in an accumulation of ortho-chlorinated congeners and losses of meta- and para-chlorinated congeners. Although there are some exceptions, degradation rates are typically inverse to the degree of chlorination. Homologs with at least four chlorine atoms (tetrachlorobiphenyls) degrade extremely slowly. Thus weathered samples of a specific Arochlor may tend to contain higher percentages of the more chlorinated congeners or homologs than the original sample if volatilization is the primary degradation process. The anaerobic dechlorination process generally results in lowering proportions of highly chlorinated congeners while increasing relative composition of less chlorinated congeners.

The relative percentage of PCB homologs in typical commercial formulations was compared against the composition of PCB homologs measured in storm drain sediments from all sites with total PCB concentrations greater than 100 ug/Kg fines (Figure 24 and 25). Comparison of the environmental samples of PCB concentrations provides some insight as to the age of the source as well as useful information for tracking the source when unique patterns are encountered. Nevertheless, interpretation can be confounded by lack of knowledge as to the original characteristics of the PCB source or possible multiple sources with different initial formulations. Figure 24 illustrates the relative composition of PCBs in samples from 16 sites with bulk sediment concentrations greater than 300 ug/Kg fines. Samples with concentrations in this range provide information that is more useful since relative proportions of each homolog are not highly biased by relatively small differences or analytical variability. Figure 25 illustrates the relative composition of homologs for all sites with total PCB concentrations between 100 and 300 ug/Kg fines. As noted last year, PCB mixtures at most sites were typically similar to Arochlor

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1254 with enhanced abundance of homologs with 7 or more chlorine atoms. Some significant exceptions exist to this generalization.

Three sites, SMC023, CCC032 and SCV032, had unusually high proportions of tri- and tetrachlorobiphenyls. SMC023 is the Pulgas Creek Pump Station located in San Carlos in San Mateo County. CCC032 was a set of four catch basins sampled on West Cutting Boulevard near 1st Street in Richmond. SCV032 was a composite of sediment from three catchbasins located at 1850, 1854 and 1760 7th Street in San Jose. All areas were classified as industrial catchments. The high proportions of lower molecular weight, less chlorinated congeners combined with relatively high proportions of higher molecular weight, more chlorinated congeners is a relatively unique characteristic. PCBs in sediments from these sites either are from two or more Arochlor formulations or show evidence of a successive dechlorination due to weathering. Since two of these sites are from relatively small areas (an estimated 3-4 acres), it is unlikely that the PCBs in these samples are from multiple sources.

Samples collected from a residential catchment in Vallejo (VFC006) were unique in having disproportionate quantities of heavier, more chlorinated (heptachlorobiphenyl and greater) congeners. Sediments collected from this site were covered by water.

Overall, examination of the composition of various PCB homologs has not provided highly useful information. Studies that have examined weathering of PCBs in sediment have primarily been conducted in sediment profiles from receiving water environments. In storm drains, it is impossible to know how long sediments have been exposed to different environmental conditions. In the best case, it can be assumed that the conditions existing at the time of sample collection were relatively stable for the past six to seven months. Since long-term environmental conditions impact the weathering process, the lack of knowledge of this history confounds interpretation of the data. Nevertheless, in cases where high concentrations of PCBs are measured and the homolog signature is unique, these data may still provide some assistance in tracing the source. This would be most effective in small catchments where distances from sources are relatively small.

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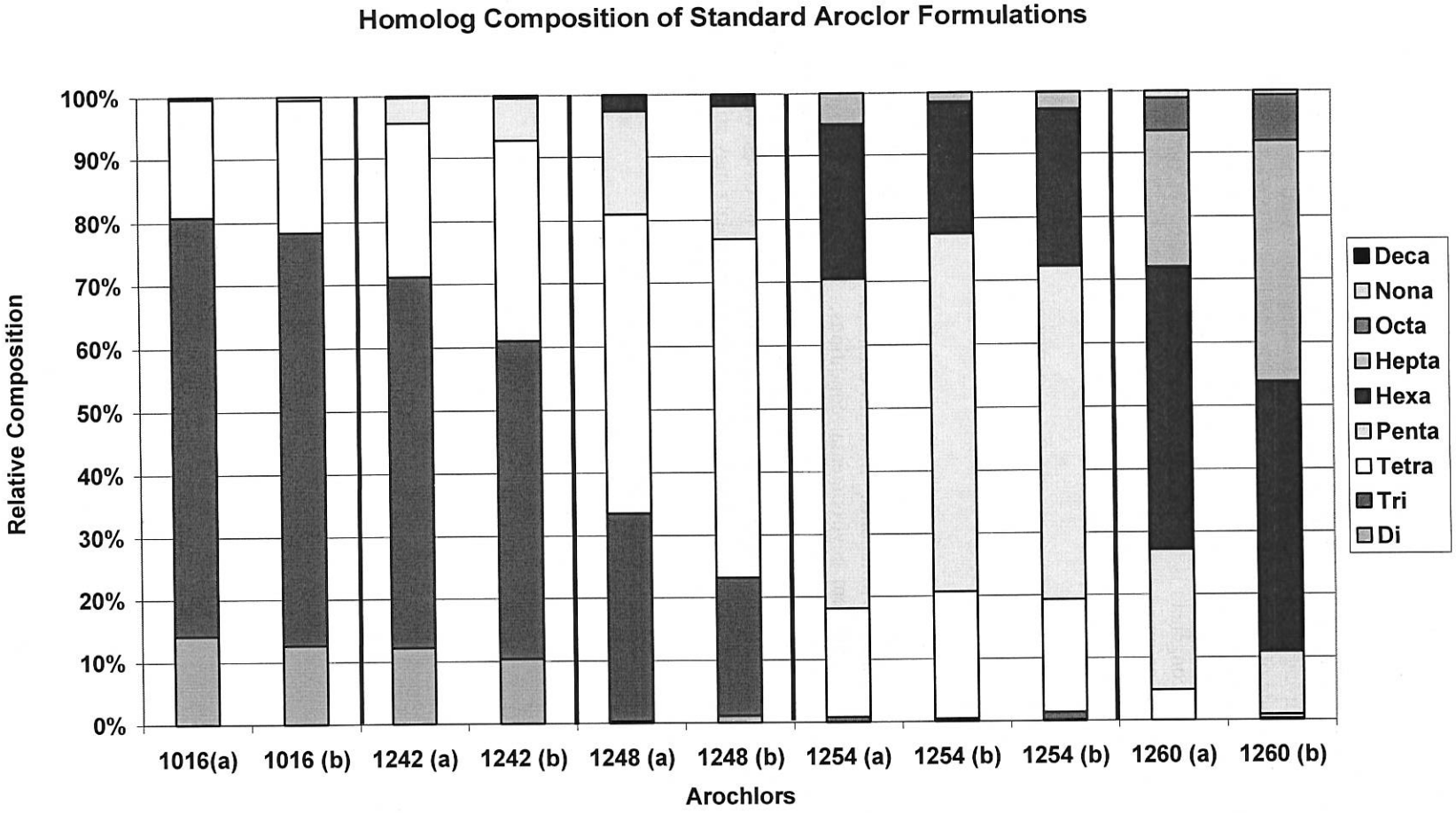

Figure 23. Distribution of PCB homologs measured in standard formulations of Arochlors.

Data Source: Modified from U.S. EPA Region 5, Toxic Reduction Team, PCB Congener Database. Relative composition of homologs within each Arochlor was based only on congeners measured in conjunction with the current study. Original data was summarized by EPA Region 5 Team from (a) Agency for Toxic Substances and Disease Registry (ATSDR) 1997 and (b) Frame, G. M., Cochran, J.W., and Bosewadt, S.S. 1996.

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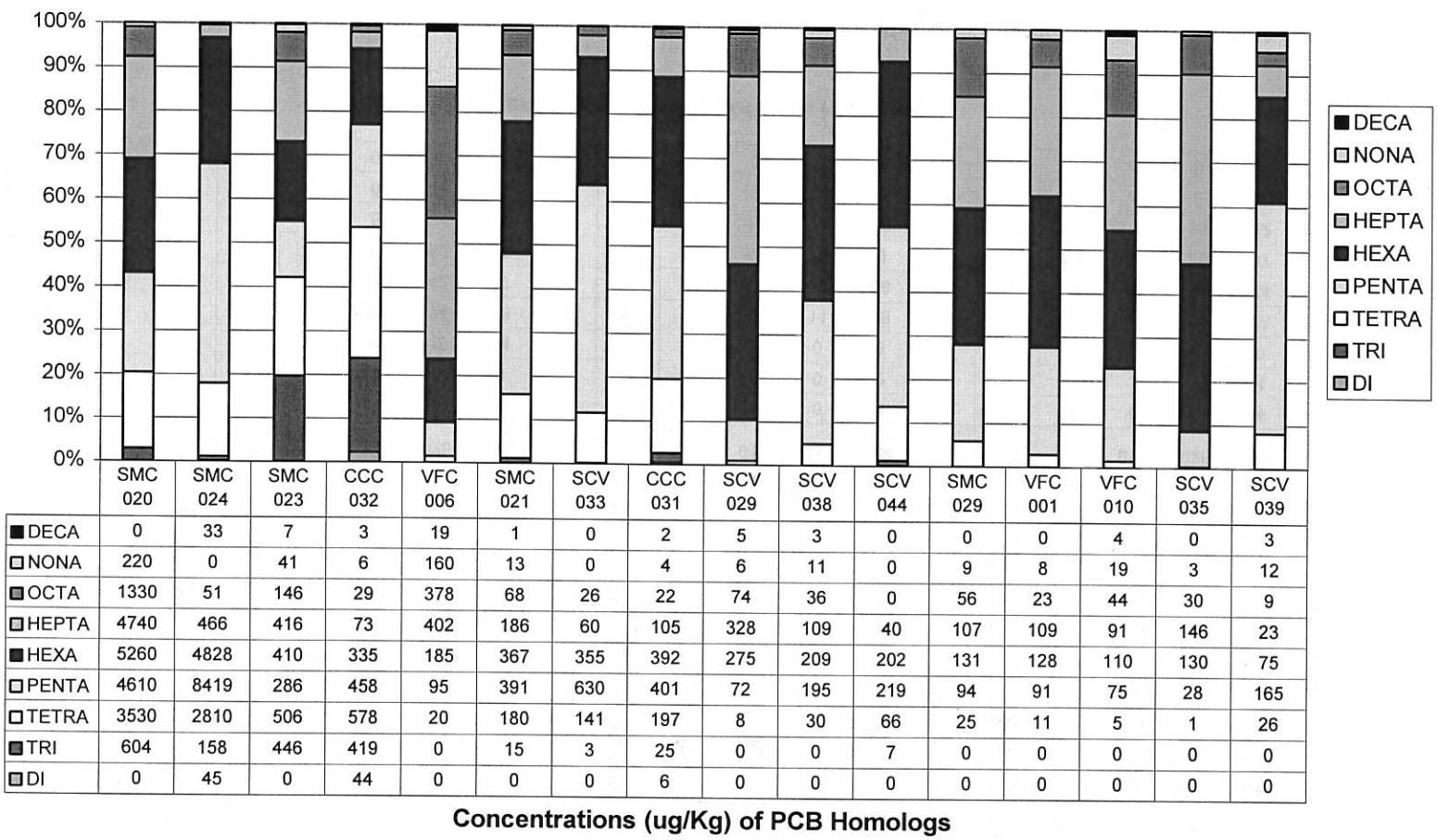

	SMC 020	SMC 024	SMC 023	CCC 032	VFC 006	SMC 021	SCV 033	CCC 031	SCV 029	SCV 038	SCV 044	SMC 029	VFC 001	VFC 010	SCV 035	SCV 039
DECA	0	33	7	3	19	1	0	2	5	3	0	0	0	4	0	3
NONA	220	0	41	6	160	13	0	4	6	11	0	9	8	19	3	12
OCTA	1330	51	146	29	378	68	26	22	74	36	0	56	23	44	30	9
HEPTA	4740	466	416	73	402	186	60	105	328	109	40	107	109	91	146	23
HEXA	5260	4828	410	335	185	367	355	392	275	209	202	131	128	110	130	75
PENTA	4610	8419	286	458	95	391	630	401	72	195	219	94	91	75	28	165
TETRA	3530	2810	506	578	20	180	141	197	8	30	66	25	11	5	1	26
TRI	604	158	446	419	0	15	3	25	0	0	7	0	0	0	0	0
DI	0	45	0	44	0	0	0	6	0	0	0	0	0	0	0	0

Figure 24. **Concentrations of PCB homologs in sediments from all 2001 sampling sites with total PCB concentrations greater than 300 ug/Kg fines.**

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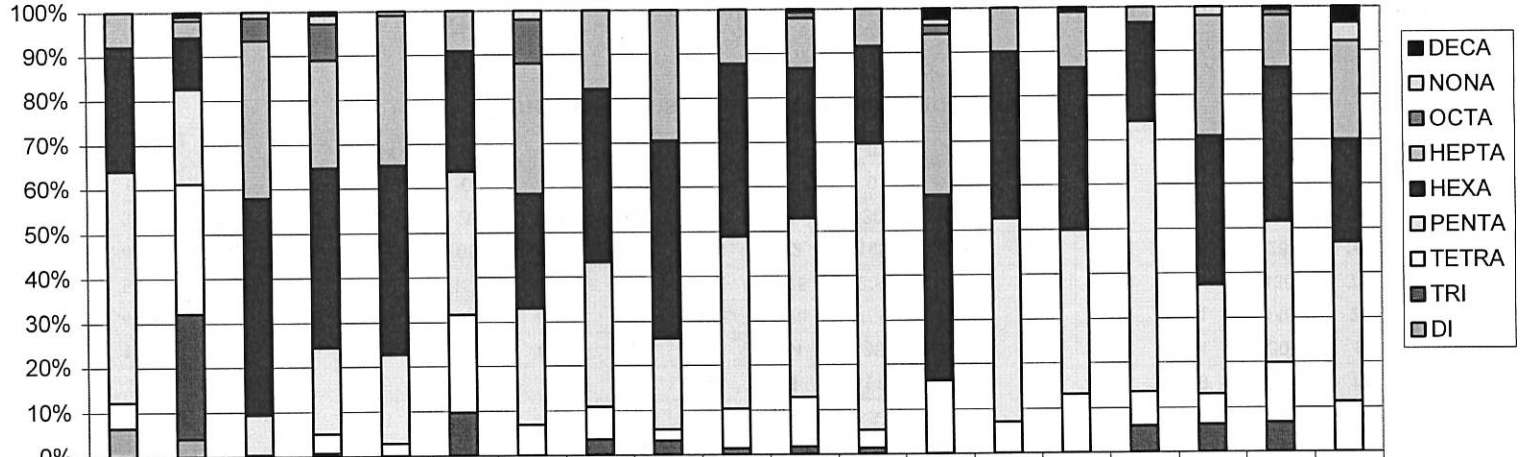
Distribution of PCB Homologs



	CCC 030	SCV 032	SMC 022	CCC 023	SCV 028	CCC 026	CCC 020	CCC 025	SMC 025	SMC 025 FD	SMC 017	SMC 031	SCV 034	CCC 039	CCC 002	CCC 042	SMC 011	SMC 026	CCC 041
DECA	0	3	0	2	0	0	0	0	0	0	1	0	3	0	2	0	0	0	4
NONA	0	3	4	5	2	0	3	0	0	0	0	0	2	0	0	0	3	1	4
OCTA	0	0	15	20	0	0	14	0	0	0	2	0	3	0	0	0	0	2	0
HEPTA	24	12	104	59	56	14	43	26	42	30	16	11	49	13	16	5	34	14	23
HEXA	83	34	141	97	70	42	37	56	63	94	47	30	56	50	48	29	41	40	24
PENTA	154	63	26	47	33	50	38	47	29	93	56	86	0	60	48	80	31	36	37
TETRA	17	86	0	11	5	34	10	11	4	22	15	6	22	9	17	10	8	15	12
TRI	0	82	1	2	0	15	0	5	5	3	2	2	0	0	0	8	8	8	0
DI	19	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Concentrations (ug/Kg) of PCB Homologs

Figure 25. **Concentrations of PCB Homologs in sediments from all 2001 sampling sites with total PCB concentrations between 100 and 300 ug/Kg fines.**

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4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions are based upon analysis of data from the full two years of sediment testing conducted in San Francisco Bay area storm drains. In all cases, data analyses were based upon sediment contaminant concentrations normalized to the fraction of the sediment less than 62.5 microns (fine fraction). This general assumption was based upon evidence that suggests that all contaminants of concern tend to be associated with the fine fraction.

- Concentrations of total PCBs and total mercury, normalized to the fine fraction, are significantly different among the four major land use categories. In each case, sediments from sites representative of open land use contained significantly lower levels of both total PCBs and total mercury. No statistically significant differences were evident among samples collected in storm drains from areas characterized as residential/commercial and industrial land use. The highest concentrations of total PCBs were associated with residential/commercial and industrial land use areas.

- Preliminary statistical comparisons were conducted on the distributions of total chlordane and DDT compounds in Bay area storm drains. These tests indicate that concentrations of total chlordane in sediments from residential/commercial land use areas are significantly higher than all other land use classifications. No statistically significant differences were evident in the distribution of DDT compounds among the four land use classifications.

- Concentrations of both total PCBs and mercury are significantly higher in urban storm drains when compared to open (nonurban) land use.

- Preliminary comparisons of concentrations of total chlordane and DDT compounds in sediments from urban and nonurban storm drains suggest that concentrations of both are significantly higher in the urban environment. Currently, however, concentrations of these compounds in the nonurban environment are not considered to be adequately characterized.

- Planning level estimates of stormwater loads were developed for 17 watersheds that drain directly to San Francisco Bay. Urban sources within these watersheds were estimated to contribute 19 to 227 pounds of PCBs per year and 115 to 497 pounds of total mercury per year. Similar estimates were developed for total chlordane and DDT, however, results are considered preliminary due to limited spatial coverage. A total of 48 to 260 pounds of chlordane and 2.3 to 50 pounds of DDT were estimated based upon current data.

- An evaluation of the possible effects of remediation at locations with PCB concentrations in the top 15 percent of all urban sites was conducted to examine sensitivity to such measures. Clean up to an objective equivalent to the 75th percentile reduced estimated high-end loads by 24%. Use of the median urban concentration as a cleanup objective reduced high-end load estimates by approximately 50%.

- Median concentrations of total PCBs, total chlordanes, and DDT compounds measured in urban storm drain sediments are roughly two orders of magnitude greater than median concentrations measured in receiving water sediments by the San Francisco Bay Regional Monitoring Program (RMP).

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- The median concentration of mercury in urban storm drains was generally comparable to levels measured in the Bay by the RMP. The median concentration of mercury in urban storm drains was 0.93 mg/Kg fines compared to 0.39 mg/Kg fines at all RMP sites during the 1999 and 2000 surveys.

4.2 Recommendations

The project work group met March 26, 2002[3] to discuss the results of the studies, including PCBs case studies performed by individual stormwater programs.[4] Based on the first two years of work, the following recommendations were developed with the assistance of the work group:

- The participating agencies should redirect resources used the past two years for PCBs watershed characterization to case study work in areas with elevated PCBs. The objectives will include continuing to develop a better understanding of PCBs sources, developing and costing controls,[5] and estimating the impact of such controls on reducing loads of urban runoff PCBs to San Francisco Bay. This information will help determine the feasibility and effectiveness of PCBs control options and inform future monitoring efforts. The overall goal is to assist Regional Board staff to prepare the urban runoff implementation portion of the PCBs TMDL for the Bay.

- Bay area stormwater agencies should continue working with Regional Board staff on the design and implementation of the PCBs case studies. The project work group should also continue to meet to coordinate PCBs case study work and share information.

- Bay area stormwater agencies should work with Regional Board staff and the BASMAA Monitoring Committee to determine future regional watershed monitoring needs, strategies and priorities for mercury, chlorinated pesticides and other pollutants of concern. The participating agencies may also wish to begin planning additional source investigations in areas with elevated levels of DDTs and chlordanes, depending on their monitoring priorities and available resources. Such future additional efforts should also be prioritized and coordinated through the BASMAA monitoring committee.

[3] The meeting was attended by Jon Konnan (SMSTOPPP/SCVURPPP), Adam Olivieri (SCVURPPP), Liz Lewis (MCSTOPPP), Jack Betourne (VFCSD), Chris Sommers (CCCWP), Larry Bahr (FSSD), Kevin Cullen (FSSD), Arleen Feng (ACCWP), Fred Hetzel (RWQCB), James Downing (City of San Jose) and Marty Stevenson (KLI).

[4] Individual stormwater programs will submit separate reports to the Regional Board documenting the results of PCBs case studies.

[5] Preliminary information on PCBs controls is included in the Santa Clara Valley Urban Runoff Program's March 1, 2002 Control Program for PCBs, Attachment 2 (*Preliminary Comparison of Potential Options to Eliminate or Reduce Discharges of PCBs from Urban Runoff Conveyance Systems*). This document was handed out at the March 6, 2002 BASMAA Monitoring Committee meeting.

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USGS
science for a changing world

Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin

Introduction

Transport of nutrients (primarily forms of nitrogen and phosphorus) to lakes and resulting accelerated eutrophication are serious concerns for planners and managers of lakes in urban and developing suburban areas of the country. Runoff from urban land surfaces such as streets, lawns, and rooftops has been noted to contain high concentrations of nutrients; lawns and streets were the largest sources of phosphorus in residential areas (Waschbusch, Selbig and Bannerman, 1999). The cumulative contribution from many lawns to the amount of nutrients in lakes is not well understood and potentially could be a large part of the total nutrient contribution.

Why study runoff from lawns?

The shorelines of many lakes are already highly developed, and the potential water-quality effects of this development are increasing. Many lawn-care professionals and homeowners hold a common belief that runoff from lawn surfaces is minimal and that phosphorus movement from lawns is not a problem (Barth, 1995). The homeowners' goal to maintain lush green lawns may conflict with the lake manager's goal to minimize nutrient inputs. In cooperation with the Lauderdale Lakes Lake Management District and the Wisconsin Department of Natural Resources, the U.S. Geological Survey (USGS) conducted a study during 1999–2000 to determine the magnitude of nutrient runoff from nearshore residential lawns surrounding a lake and to determine whether fertilizer application and the type of fertilizer (regular or nonphosphorus types) affect the amount of nutrients in runoff from lawns. Such information is important for developing stormwater best-management practices and for developing or improving shoreland zoning ordinances and other local regulations to protect or improve the water quality of lakes (Wisconsin Department of Natural Resources, Wisconsin Shoreland Management Program, http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/title.htm, accessed February 8, 2002).

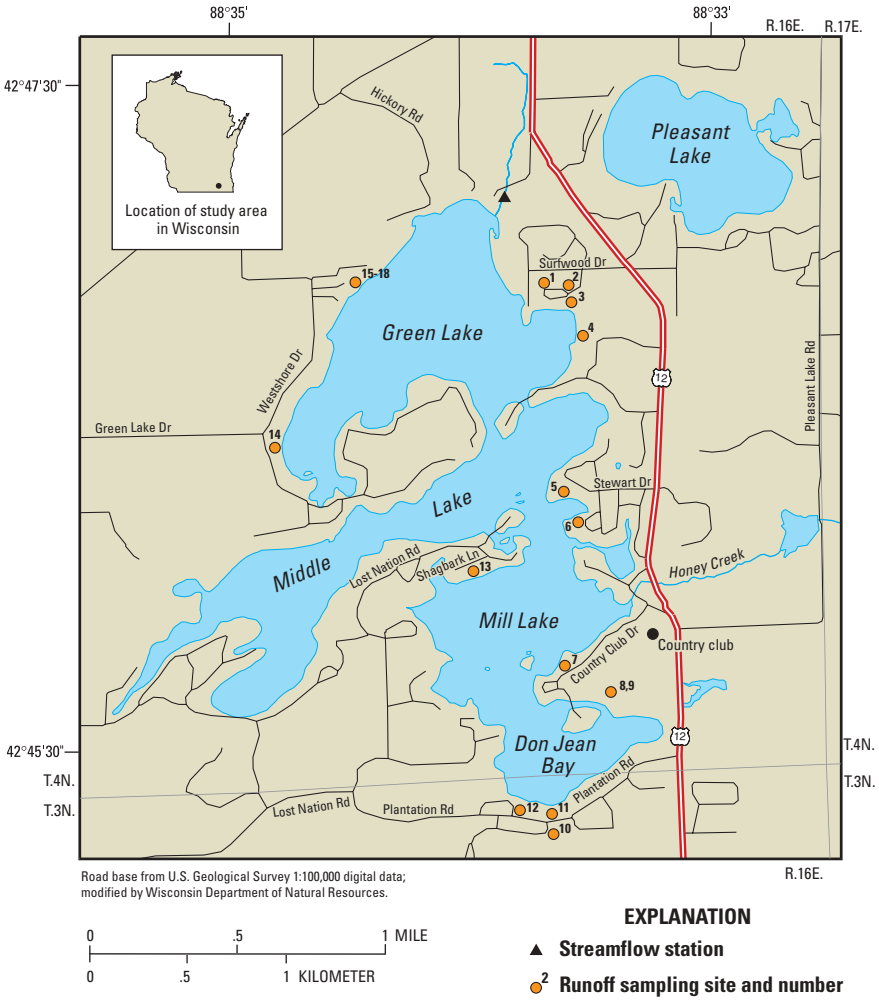

Figure 1. Site locations surrounding Lauderdale Lakes, Wis.

The study area was located at Lauderdale Lakes in Walworth County, a chain of lakes in the more populated southeastern part of Wisconsin (fig. 1). The 15-mile shoreline of the lakes is about 70 percent developed, primarily as single-family housing, and is the focus for additional residential development. Most of the lakefront homes have sloping lawns that are maintained to the water's edge (fig. 2). Information about the specific sources and amounts of phosphorus entering the lakes was needed to develop a plan for reducing the input of phosphorus. The lakes are phosphorus limited, meaning that phosphorus is the nutrient limiting plant growth and affecting lake productivity. A previous study (Garn and others, 1996) found that surface-water inflow from the small nearshore contributing drainage area accounted for only 4 percent of the water inflow to the lake but represented 51 percent of the total annual phosphorus input from all sources. The Lake Management District is in the process of installing



Figure 2. Lakeshore development and lawns at Lauderdale Lakes, Wis.



Figure 3. Tube-type lawn sampler (site 2).

and implementing various measures to reduce the phosphorus input to the lakes, among which is a "lake-friendly" fertilizer program that encourages residents to apply nonphosphorus turf fertilizer. The Lake Management District has been supplying residents with phosphorus-free fertilizer for purchase for about 3 years, and data were needed to evaluate the effectiveness of the program.

Equipment and Methods

In 1999 and spring 2000, lawn samplers designed to collect surface runoff were installed using methods described in Waschbusch, Selbig, and Bannerman (1999, p. 7). The samplers collect runoff through two 5-foot pieces of 1/2-inch-diameter PVC tubing placed flush with the surface of the ground, on a sloping lawn, with an angle of about 150 degrees between the two tubes (fig. 3). Runoff entered the tubing through a 1/8-inch slot cut at intervals along the length of the tube; each tube was then wrapped with fiberglass screen to prevent insects and large debris from entering. The tube was held in place on the lawn surface with wire staples. At the end of each tube, a connecting piece of 1/2-inch silicone tubing directed the collected runoff into a covered 1-quart glass jar placed in the ground in a 4-inch-diameter protective PVC sleeve with a cover.

During the summer of 2000, the original sampler design was modified to increase sample volumes at sites that did not generate sufficient runoff samples and to minimize contamination problems caused by insects and earthworms entering the samples despite the fiberglass screen. One variation to increase runoff-collection efficiency was to enlarge the slots cut in the pipes to 1/4-inch. Another technique used at sites with the least runoff production was to replace the tubing with two lengths of 4-foot-long plastic lawn edging that directed runoff toward the collecting jar (fig. 4); this solution was more effective at increasing captured runoff and minimizing contamination than increasing the slot size.

Clean sample bottles were placed in the lawn samplers before each expected storm or at about 2-week intervals when sites were inspected if there was no rain. Samplers were cleaned and rinsed with deionized water during each visit to remove any accumulated dirt or debris. Notes were kept on volume of runoff in the collection bottle; color and noticeable sediment, debris, or insects in the bottle; and site condition. Sample bottles were collected as soon as possible after each storm (usually within 1 to 5 days) and brought to Madison, where the contents were filtered with a 0.45-micrometer filter, preserved with sulfuric acid, and then delivered to the Wisconsin State Laboratory of Hygiene for nutrient analyses. Samples were analyzed according to standard laboratory methods (Wisconsin State Laboratory of Hygiene, written commun., 2001) for concentrations of total phosphorus (TP), total dissolved phosphorus, total Kjeldahl nitrogen (TKN), dissolved ammonia nitrogen, and dissolved nitrate plus nitrite nitrogen. When insufficient sample volume was collected from a storm to analyze for all nutrients, analyses were done first for total phosphorus.



Figure 4. Edging-type lawn sampler (site 5).

Description of Sampling Sites

The Lauderdale Lakes are a chain of three interconnected lakes with a surface area of 807 acres. The lakes are ground-water drainage lakes in which more than 90 percent of the water inflows are from ground water and direct precipitation. Some surface water enters the lakes by way of a few ephemeral drainageways or as overland flow from the nearshore area. Lake and drainage-basin characteristics are described in detail by Garn and others (1996). Lakeshore developments include about 1,010 single-family homes, of which about 30 percent are year-round residences. Other developments include a golf course, a boat marina, and two recreational camps.

In the lakeshore area within 300 feet of the shoreline, soils consist primarily of the Casco-Rodman Complex (60 percent of the area), Rodman-Casco Complex (12 percent of the area), and Casco-Fox Silt Loam (6 percent of the area). The Casco-Rodman Complex is found on 20–30 percent slopes; surface textures range from loam to silt loam, and subsoils are clay loam to sandy loam. The Rodman-Casco Complex is found on slopes of 30 to 45 percent formed in loamy deposits over sand and gravel. The Casco-Fox soils are found on slopes of 6 to 12 percent and have a silt loam texture (Haszel, 1971). Soil disturbance can be severe during building construction in suburban areas, commonly resulting in subsoil compaction by heavy equipment followed by layering with topsoil. Such disturbance has the potential for greatly increasing runoff and nutrient losses.

Samplers were installed at 18 locations along the lakeshore (fig.1), representing different types of lawn-fertilizer use, undeveloped areas, and one area of mixed land use (part agricultural, ditched paved roads, and lawns). Sites were grouped into three categories: regular-fertilizer sites, nonphosphorus-fertilizer sites, and unfertilized sites. Samplers were installed at 12 sites and operated during the growing season in 1999. In 2000, six additional sites were installed, including two samplers in a swale. Samplers were installed at seven lawn sites where traditional fertilizer was applied, three sites where nonphosphorus fertilizer was applied, and six control sites where no fertilizer was applied (three steep, wooded sites; two lawns; and an undeveloped grass field). Much of the area is wooded, and many of the lawns have an overhead canopy of hardwood trees. Two samplers were installed in a swale area on the south side of Mill Lake (Don Jean Bay) that collected mixed runoff from an agricultural field, lawns, and streets. The drainage area of the upgradient sampler was 8 acres and of the downgradient sampler was 38 acres, of which about 25 percent was cropland.

Property owners were asked to participate in the runoff study. It was assumed that most lawn fertilizer users followed usual manufacturer recommendations of four applications per season made in about April–May, June–July, August–September, and October at 3 to 3.5 pounds per 1,000 square feet. Homeowners applying regular fertilizer fertilized their lawns two or more times per year. Each participant's property was inspected to ensure that lawn slope was at least 20 feet long, grade was at

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Table 1. Physical characteristics of sampling sites at Lauderdale Lakes, Wis. [P, phosphorus; ppm, parts per million; %, percent, turf-quality values are defined in text; ft², square feet; --, no data]

Site ID	Station number	Site type	Soil type/texture[a]	Soil P concentration[b] (ppm)	Slope (%)	Vegetative cover density (%)	Turf quality	Runoff area (ft²)	Number of samples	Percentage of storm events
Regular fertilizer application sites										
2	424652088333901	Wooded lawn	Hebron loam, gravelly	68	21	65	6	150	10	67
3	424650088333501	Lawn	Hebron loam	32	9	90	8.5	180	8	80
5	424616088334201	Wooded lawn	Casco-Rodman loam-silt loam	66	20	100	9	114	8	33
8	424541088334602	Golf course lawn	Casco-Rodman loam-silt loam	35	20	100	9.5	250	15	63
9	424541088334601	Golf course lawn	Casco-Rodman loam-silt loam	78	24	100	9.5	186	9	54
10	424514088334001	Swale	Casco-Fox silt loam	--	5	--	--	8 acres	9	69
11	424518088334301	Swale	Casco-Fox silt loam	--	4	--	--	38 acres	10	77
12	424519088334101	Lawn	Casco-Fox silt loam	28	16	100	10	104	1	8
15	424654088343103	Lawn	Fox silt loam	11	11	60	6	152	5	24
Nonphosphorus-fertilizer application sites										
6	424611088334001	Wooded lawn	Casco-Rodman loam-silt loam	20	14	80	7.5	250	18	67
13	424603088340201	Wooded lawn	Casco-Rodman loam-silt loam	21	34	60	5	140	15	54
14	424623088345101	Wooded lawn	Casco-Rodman loam-silt loam	70	14	85	8	225	8	30
Unfertilized sites										
1	424652088334401	Grass field	Fox sandy loam	65	9	100	7	128	2	13
4	424643088333601	Wooded lawn	Casco-Rodman loam-silt loam	38	12	85	8	188	6	47
7	424543088334001	Wooded lawn	Casco-Rodman loam-silt loam	14	22	70	6	209	12	46
16	424654088343101	Wooded	Rodman-Casco loam/sand,gravel	28	41	95	1	200	9	33
17	424654088343102	Wooded	Rodman-Casco loam/sand,gravel	24	33	95	1	300	13	48
18	424654088343104	Wooded	Rodman-Casco sandy, gravelly	16	30	65	2	140	7	28

[a] From Haszel, 1971.

[b] 50–75 ppm P optimum recommendation for turfgrass. Analysis by Soil and Plant Laboratory, University of Wisconsin, Madison.

least 5 percent, and sample catchment area was not affected by runoff from rain gutters, driveways, or other lawns or sources. A soil sample collected at the time of sampler installation was analyzed for soil texture, pH, and phosphorus content by the University of Wisconsin Soil and Plant Analysis Laboratory. A visual vegetative soil-cover density, in percent, and a turf-quality rating were assigned to each lawn during visits. Turf quality was based on a 1 to 10 scale: for example, a score of 10 represented 100 percent best-quality green grass cover, 5 represented 50 percent grass cover with bare spots, weeds, and dead grass providing additional cover, and 1 indicated no turfgrass cover, with dead grass, weeds, and other vegetation providing primary soil cover. The more heavily fertilized sites (5, 8, 9, 12) had the best turf-quality ratings. Various physical characteristics of the sampling sites are summarized in table 1.

Nutrient Concentration in Runoff

Rainfall and Runoff

Long-term precipitation records from the National Weather Service stations at Whitewater (about 9 miles northwest of Lauderdale Lakes) and Lake Geneva (about 13 miles southeast) were used to estimate rainfall at Lauderdale Lakes (National Oceanic and Atmospheric Administration, 1999–2000). Data from a recording rain gage at a USGS streamflow-gaging station at Jackson Creek near Elkhorn (9 miles south) was used after the rain gage was installed on May 25, 1999. Rainfall was above the 1961-90 average for April, May, and June 1999 and near or below average the remainder of the season. In 2000, rainfall amounts for May, June, and September were substantially above average (fig. 5). Ten runoff events occurred from 12 storms in the 1999 sampling season and 13 runoff events occurred from 15 storms in 2000; generally, the storms in 2000 were larger than those in 1999. A storm event was defined as more than 0.3 inches of rain, and a runoff event as one that resulted in at least two runoff samples with sufficient volume for analysis (about 100 ml). A summary of the storm dates and precipitation amounts is given in table 2.

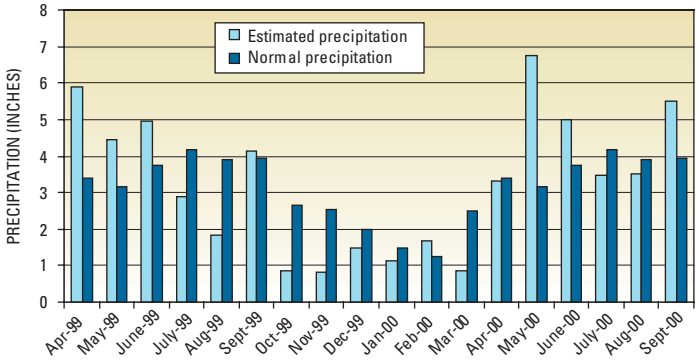

Figure 5. Estimated monthly precipitation at Lauderdale Lakes, Wis., during 1999–2000 compared to normal monthly precipitation.

Although measurement of quantity of runoff was not part of this study, a qualitative evaluation of runoff may be obtained by comparing the

Table 2. Storm information and number of sites with runoff samples at Lauderdale Lakes, Wis., 1999–2000 [est, estimated]

Storm number	Storm start date	Total precip amount (inches)	Number of sites with runoff samples
99S1	4/9/1999	0.86 [a]	4
99S2	4/22/1999	3.73 [a]	9
99S3	5/12/1999	0.63 [a]	3
99S4	5/16/1999	0.80 [a] est	4
99S5	5/17/1999	0.66 [a] est	3
99S6	6/1/1999	0.70	8
99S7	6/10/1999	3.35	6
99S8	7/17/1999	1.11	4
99S9	8/13/1999	0.37	5
99S10	9/27/1999	3.66	11
00S1	2/21/2000	2.0 [b]	11
00S2	4/19/2000	2.59	2
00S3	5/9/2000	1.36	9
00S4	5/18/2000	1.95	5
00S5	5/27/2000	3.85	14
00S6	6/11/2000	1.95	9
00S7	7/2/2000	1.40	12
00S8	7/10/2000	1.33	5
00S9	7/31/2000	1.62	3
00S10	8/5/2000	1.17	16
00S11	8/17/2000	0.70	5
00S12	9/11/2000	1.94	17
00S13	9/22/2000	1.89	9

[a] Measured at Whitewater.

[b] From 6 inches snowmelt and light rain.

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Figure 6. Site 12 at Lauderdale Lakes, Wis.—an example of high-quality turfgrass.

number of sites where runoff was sampled for each storm (table 2) and the number of storms sampled at each site (table 1). The magnitude of runoff is dependent on a combination of factors including rainfall amount and intensity, soil-surface storage and detention, and infiltration rate. Infiltration is affected by soil type, vegetative cover, slope, and other factors (Haan, Barfield, and Hayes, 1994, p. 52–54). In general, sites with dense vegetative cover and coarse soils with high infiltration rates produced less runoff. Specifically, site 12 of the fertilized sites (fig. 6), which had the best-quality turf and fertilizer applications of 4 times per year, produced the least runoff (only 8 percent of all storms). Other sites (5, 8, 9) with high turf quality and density produced more frequent runoff samples, possibly because of steeper slopes or other factors. At six of the lawn sites, more than 50 percent of the storm events produced runoff.

The phenomenon of soil-water repellency, or hydrophobicity, was observed at many of the lawn sites, especially after dry periods. Water repellency of soils reduces affinity to water so that the soil resists wetting, thus reducing infiltration capacity, decreasing plant growth, and increasing surface runoff. The phenomenon has been widely accepted as a problem for many soils in seasonally dry climates. Soils with grass cover in temperate climates have recently been found to develop resistance to wetting—a common problem known as "localized dry spot" on golf courses (Doerr, Shakesby and Walsh, 2000; Kostka, 2000). Therefore, water repellency could be an additional factor influencing runoff from residential lawn soils (L.F. DeBano, University of Arizona, oral commun., 2001). At Lauderdale Lakes, there was also some indication that lawn shading by trees and less frequent use of fertilizer (sites 6, 7, and 13) resulted in less dense and patchy turf cover, increasing runoff. In ongoing turf studies at the University of Wisconsin (W.R. Kussow, Department of Soil Science, written commun., 2000), researchers found that not fertilizing turfgrass caused thinning of the turf, increased the amount of runoff, and increased nitrogen and phosphorus loss. Generally, the percentage of storms resulting in surface runoff from many of the lawns was higher than expected. Runoff from lawns may occur more frequently than previously thought because of the complex interaction of many factors.

Nutrient Concentrations in Runoff and Effects of Fertilizer Use

Summary statistics of nutrient concentrations measured in runoff from different site categories are given in table 3 and compared in figure 7. Detailed data for each of the sites were published annually in the U.S. Geological Survey Water-Data Reports (Holmstrom and others, 2000; Garn and others, 2001). There was a wide range in concentration of most nutrients among storms during the study period. Given this variability, geometric means or medians are more meaningful for comparison because they are better estimates of central tendency than arithmetic means. The nonparametric Kruskal-Wallis test was used to test for overall differences in concentration distributions, and the Wilcoxon rank sum test was used to test

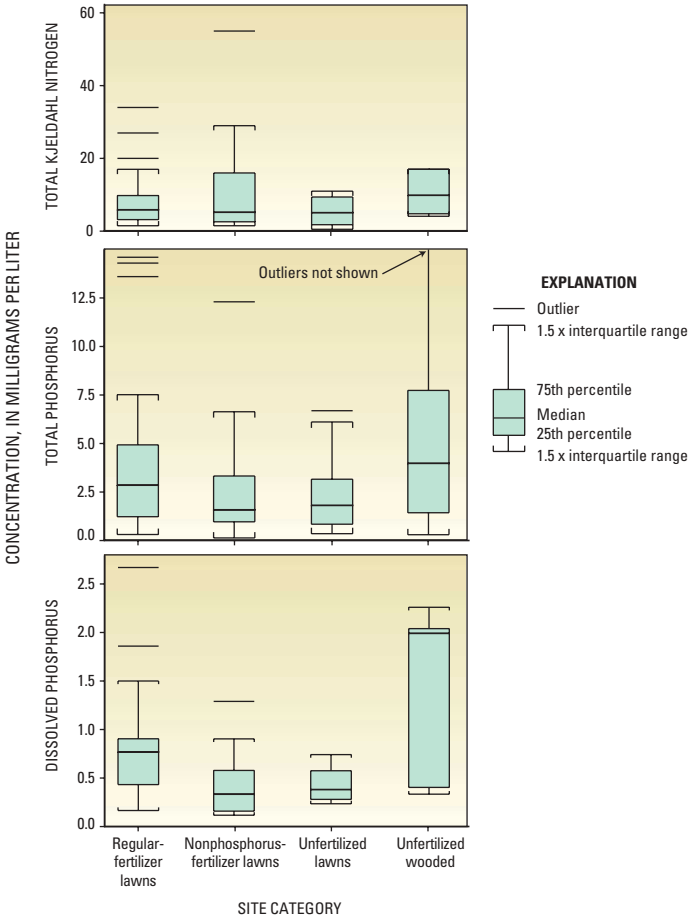

Figure 7. Nutrient concentrations in runoff from different categories of sampling sites at Lauderdale Lakes, Wis.

for differences in medians between pairs of lawn categories (P.W. Rasmussen, Wisconsin Department of Natural Resources, written commun., 2001). A confidence level of 10 percent ($p = 0.10$) was chosen to evaluate the results of the statistical tests. The difference in medians for samples from two different lawn categories was considered statistically significant if p values were less than 0.10.

A quality-control study was done to determine nutrient-concentration effects of grass clippings, earthworms, and insects that managed to get into water samples. All of these contamination sources had a large effect by increasing nitrogen and phosphorus concentrations. Samples that were affected by these contamination sources, identified from field notes, were excluded from data analysis, but the exclusions did not significantly change the overall results.

No significant differences in concentration among lawn categories were found for any of the nitrogen species. Fertilizer use did not affect total nitrogen concentrations in runoff. In addition, nitrite plus nitrate concentrations in runoff were generally low.

Dissolved phosphorus concentrations were significantly different ($p = 0.02$) among the lawn categories. Moreover, the median concentration of dissolved phosphorus from regular-fertilizer sites (0.77 milligram per liter (mg/L)) was significantly greater than that from nonphosphorus-fertilizer sites (0.33 mg/L) and unfertilized lawn sites (0.38 mg/L). Total phosphorus in runoff from regular-fertilizer sites compared to nonphosphorus-fertilizer and to unfertilized-lawn sites had p-values of 0.11 and 0.14, respectively. Thus, median total phosphorus concentrations were not significantly different at $p < 0.1$. Dissolved phosphorus was a fraction of total phosphorus, and its concentrations ranged from 22 to 45 percent of total phosphorus for all lawn categories.

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Figure 8. Dense understory vegetation on wooded slope of sites 16 and 17 at Lauderdale Lakes, Wis.

The median dissolved phosphorus concentration in lawn runoff from regular-fertilizer sites was twice that for unfertilized and nonphosphorus-fertilizer sites. Runoff from lawn sites with nonphosphorus-fertilizer applications had a median dissolved phosphorus and total phosphorus concentration that was similar to unfertilized sites. Dissolved phosphorus in runoff is important because it is readily available for plant growth. Although not significant at $p < 0.1$, lawn sites with regular fertilizer applications had a median total phosphorus concentration in runoff that was 1.6 times that for unfertilized sites and 1.8 times that for nonphosphorus-fertilizer sites.

In comparison with other studies, phosphorus concentrations in lawn runoff at Lauderdale Lakes were slightly higher than concentrations found in runoff from urban lawns in Madison, Wis. (Waschbusch, Selbig and Bannerman, 1999), but were similar to those in lawn runoff from suburban lawns in Minneapolis/St. Paul, Minn. (Barten and Jahnke, 1997). Surprisingly, nutrient concentrations in runoff from the unfertilized, steep, wooded hillsides (sites 16, 17, and 18) were higher than those from the lawn sites and thus were separated from the unfertilized lawn sites in the data comparisons. These wooded sites (fig. 8) may be different from other wooded sites because of their steep slopes, thick surface organic and litter layer, and dense understory vegetation (crown vetch) planted for erosion control. Waschbusch, Selbig, and Bannerman (1999) found a direct relation between phosphorus concentration and percentage of overhead tree canopy that could affect source-area concentrations. In the Lauderdale Lakes study, however, all lawn categories contained sites with overhead tree canopy, and the lawn sites treated with regular fertilizer had the fewest trees; therefore, differences between regular-fertilizer sites and the other lawn sites could be even greater if there was an effect from tree cover.

Total phosphorus concentration in lawn runoff had a significant ($p = 0.08$) relation to soil-phosphorus concentration (table 1); total dissolved phosphorus had no significant relation. The low category of soil-phosphorus concentration (0 to 24 parts per million (ppm)) had a significantly lower median concentration of total phosphorus in lawn runoff (about half) than the medians from medium (25-65 ppm) or high (66 ppm or more) soil-phosphorus concentration lawns. There was no significant difference between runoff concentrations from medium and high soil-phosphorus concentration lawns. Barten and Jahnke (1997) also found a significant difference in concentration of phosphorus in runoff from different categories of lawn soil fertility. In their study, total and soluble reactive phosphorus concentrations in runoff from high soil-phosphorus concentration lawns were twice as large as the concentrations in runoff from low soil-phosphorus concentration lawns.

Median nutrient concentrations from the Don Jean Bay swale area with mixed land use were more similar to those from the unfertilized wooded sites and fertilized lawn sites than to those from other lawn sites (table 3). The range in concentrations for ammonia nitrogen and total Kjeldahl nitrogen in runoff from the swale, however, was greater than those for the other sites.

Although it was not within the scope of this study to measure runoff volumes from each of the sites and quantify the mass of nutrients transported offsite, the concentration data will be useful for future computations of unit-area loads (that is, mass of a particular nutrient species per unit contributing area). Concentrations of nutrients from lawns observed in this

Table 3. Statistical summary of nutrient concentrations in runoff from different site categories, Lauderdale Lakes, Wis. [n, number of samples; TKN, total Kjeldahl nitrogen; NO_2, nitrite nitrogen; NO_3, nitrate nitrogen; TP, total phosphorus; Diss P, dissolved phosphorus; all concentrations in milligrams per liter]

	Ammonia N	TKN	$NO_2 + NO_3$	TP	Diss P
Regular-fertilizer lawn sites					
Geometric mean	1.11	5.9	0.09	2.57	0.7
Median	1.07	5.9	0.12	2.85	0.77
Mean	2.18	8.6	0.17	4.02	0.93
Max	14.5	34	0.56	23.2	3.32
Min	0.05	1.5	0.01	0.31	0.17
n	23	23	23	58	23
Nonphosphorus-fertilizer lawn sites					
Geometric mean	1	6.5	0.14	1.89	0.34
Median	0.93	5.2	0.14	1.58	0.33
Mean	3.95	12.2	0.57	3.3	0.45
Max	36.2	55	5.22	23.5	1.29
Min	0.04	1.5	0.14	0.14	0.12
n	14	14	14	38	15
Unfertilized lawn sites					
Geometric mean	0.76	4.08	0.12	1.73	0.4
Median	0.63	5.1	0.14	1.81	0.38
Mean	1.12	5.85	0.17	2.33	0.43
Max	2.98	11	0.4	6.69	0.74
Min	0.22	0.53	0.01	0.36	0.23
n	9	9	9	19	8
Unfertilized wooded sites					
Geometric mean	2.95	12.7	0.16	3.52	1.04
Median	4.38	9.8	0.24	3.98	1.99
Mean	5.33	29.3	0.9	6.78	1.4
Max	11.6	130	2.24	30.6	2.26
Min	0.41	4.1	0.01	0.3	0.33
n	5	6	5	28	5
Don Jean Bay swale sites					
Geometric mean	3.48	14.5	0.06	2.46	0.49
Median	3.96	19	0.04	2.66	0.41
Mean	11.91	31.3	0.15	3.55	0.91
Max	88.1	160	0.6	9.07	3.33
Min	0.56	2	0.01	0.37	0.18
n	11	11	10	19	9

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study are much greater (by 3 to 5 times) than the estimated concentrations used to calculate total phosphorus load from surface runoff to Lauderdale Lakes in a previous study by Garn and others (1996, p. 16). All of the nutrient load from lawn runoff may not actually reach or be deposited in the lake because of varying flowpaths, soil permeability, breaks in slope, vegetative buffers, and other obstructions; however, in many cases, lawns extend and slope continuously to the water's edge to provide a direct source of loading.

The annual phosphorus load from the nearshore area of Lauderdale Lakes may be greater than the 430 pounds previously estimated. Using a revised median concentration of 2.3 mg/L for surface runoff from an estimated 220 acres of developed shoreline (67 percent of shoreline) within 200 feet from the edge of water, annual total phosphorus load from residential lawns could be as much as 370 pounds (assuming all of the phosphorus reaches the lake). If a delivery of 50 percent of the load is assumed, and the total surface-water load is recomputed using the surface runoff values from the previous study, the total annual surface-water load from the nearshore drainage area would be 620 pounds, which represents 60 precent of the total annual phosphorus input from all sources. Studies at Lauderdale Lakes and several other ongoing studies by the USGS in Wisconsin will provide additional information on the effects of lawns and shoreline development on nutrient loads to lakes.

Limitations of Results

- Many runoff samples (about 30 percent) overflowed the collecting bottle and may not be truly representative of the mean concentration from each storm. According to T.D. Stuntebeck (U.S. Geological Survey, unpub. data, 2002), overflow samples for suspended solids and total phosphorus had higher concentrations than those from samples that did not overflow the container, but the opposite was true for dissolved phosphorus. Barten and Jahnke (1997) also found that overflow samples had lower concentrations for some constituents. Overflow occurred, however, for all categories of sites, and differences noted could potentially be even greater.
- The number of samples for some categories was relatively small for rigorous statistical analysis, and the small numbers could lead to inconsistencies among comparisons for different pairs of categories.
- Nutrient-concentration data are for onsite runoff and should be used with caution when making offsite interpretations. Not all of the nutrient load from lawn runoff may actually enter the lake.
- Some changes in nutrient species composition affecting dissolved constituents may have occurred in those samples that were not collected within 2 days after a storm.

Conclusions

- A high percentage of storms resulted in surface runoff from many of the lawns. Runoff from lawns may occur relatively frequently, more than 50 percent of the storms for many lawns.
- Fertilizer use did not affect nitrogen concentrations in runoff. Nitrite plus nitrate concentrations in runoff were generally low.
- Total phosphorus concentration in lawn runoff was directly related to the phosphorus concentration of lawn soils.
- Dissolved phosphorus concentrations were significantly different among the lawn categories; the median from regular-fertilizer sites was twice that from unfertilized or nonphosphorus-fertilizer sites.
- Runoff from lawn sites with nonphosphorus fertilizer applications had a median total phosphorus concentration that was similar to that of unfertilized sites, an indication that nonphosphorus fertilizer use may be an effective, low-cost practice for reducing phosphorus in runoff.

Acknowledgments

Thanks are extended to Scott Mason of the Lauderdale Lakes Lake Management District for his assistance in this study; to the lakeshore homeowners that allowed us to install sampling equipment in their lawns; and to the Wisconsin Department of Natural Resources, Lake Protection Grant Program.

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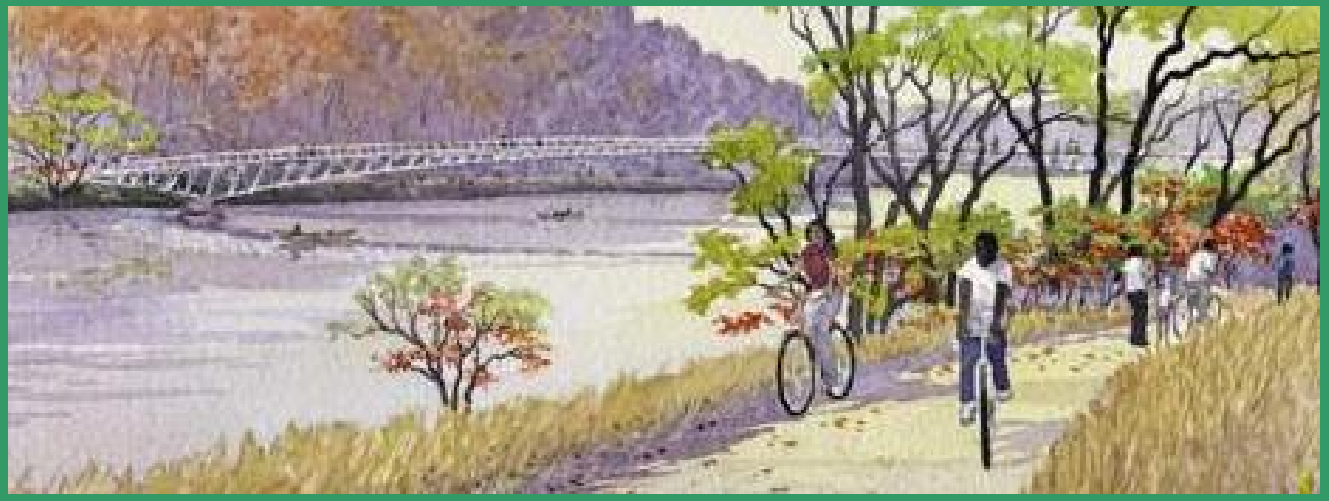
SARB_016501

Anacostia Waterfront Corporation
Final Environmental Standards – June 1, 2007

RESTORE and REVITALIZE

Water Air Habitat Community



Imagine a beautiful day on the restored Anacostia River. Imagine your neighbors from Historic Anacostia, Capitol Hill and across the District and region converging to swim and play in its waters, fish for bass or catfish, jog or bike unimpeded along miles of riverbank trails, and stroll through an unmatched urban forest intent on seeing a bald eagle.

This is the vision of the Anacostia Waterfront Initiative, and the Anacostia Waterfront Corporation can set a new standard for development and stewardship that will make the vision a reality.

– ***Roger Sant**, AWC Board member and Chairman of the Summit Fund of Washington, and **Nancy Stoner**, Natural Resources Defense Council Clean Water Project, Co-Chairs of the AWC Environmental Standards Development Committee*













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Green Roofs
(photo courtesy of Roofscapes, Inc.)



Vegetated Streetscapes
(photo courtesy of Portland Bureau of Environmental Services)

ANACOSTIA RESTORATION – MAKING THE VISION A REALITY

Restoring the Anacostia River is central to the Anacostia Waterfront Corporation's (AWC) mission. A clean, healthy, and vibrant River will be an economic and community asset—and source of pride—for residents of the District of Columbia. To make restoration a reality, we must act now to adopt new, sustainable methods of development and to aggressively pursue opportunities to restore water and air quality, wetlands and other critical habitat, and recreational amenities that will reconnect surrounding neighborhoods to the Anacostia River.

As the lead agent for the District of Columbia overseeing redevelopment around the Anacostia River, AWC is charged not only with the economic revitalization of neighborhoods, but also with the cleanup, restoration, and stewardship of the River itself. To restore the Anacostia, the District must become a leader in environmentally sensitive development—also known as *sustainable development*. Technologies are now available to ensure that development will help restore the Anacostia River and create healthy, livable neighborhoods. AWC's development partners—and other developers, agencies, community groups, and individuals throughout the watershed—are encouraged to make sustainability not only a goal, but a new way of doing business.

With the adoption of these environmental standards, AWC and the District join a growing number of cities implementing cutting-edge environmental policies that acknowledge the environmental *and* economic benefits of making our urban areas "green" and sustainable.

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These environmental standards define a new standard—the **"AWC Gold Standard"**—that will deliver:

Cleaner Water – Green roofs, rain gardens, restored wetlands and innovative green infrastructure capture and clean rainwater runoff, reducing the amount of trash, chemical pollution, sediment, and sewage flowing into the Anacostia.

Cleaner Air – Trees and other vegetation improve air quality by filtering many airborne pollutants and green building techniques improve indoor air quality in homes and offices – all of which help reduce the amount of respiratory illness.

Cooler Summertime Temperatures – Trees, green roofs, and green building techniques create shade, reduce heat absorption, and release water vapor – all of which cool the air and make us more comfortable during the summer and provide a healthier environment.

Increased Energy Efficiency – Green building techniques greatly reduce energy consumption, saving owners and renters money and improving air quality by reducing pollution caused by power generation.

Livable Neighborhoods – Sustainable development techniques make our communities more beautiful, livable, and healthy by reducing pollution and providing green public spaces, new recreational opportunities, and critical wildlife habitat along our waterfront.

Economic Revitalization – Cleaner, healthier communities and a more beautiful Anacostia River bring new residents, businesses, and tourists and enhance quality of life for all.

Mitigating Climate Change – Green buildings that incorporate energy efficient systems and green roofs reduce demands for energy which, in turn, reduces emissions of greenhouses gases produced by the burning of coal and other fossil fuels. Walkable neighborhoods accessible by mass transportation further reduce carbon dioxide emissions. While climate change impacts are global, buildings and infrastructure along the Anacostia waterfront face unique threats from sea level rise due to their low elevation.

Useful Links and Resources

- U.S. Green Building Council and Leadership in Energy and Environmental Design (LEED) – *www.usgbc.org*
- Green Communities – *www.enterprisefoundation.org*
- U.S. EPA Energy Star Programs – *www.energystar.gov*
- 2030 Challenge Climate Initiative – *www.architecture2030.org*
- DDOT Anacostia Waterfront Transportation Architecture Design Standards – *www.ddot.dc.gov*
- DC Green Building Act of 2006 – *www.dccouncil.washington.dc.us*

Links to additional resources are available on the AWC website: *www.anacostiawaterfront.net*

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INTRODUCTION

In May 2006, the Anacostia Waterfront Corporation (AWC) Board of Directors resolved that AWC would "be a regional leader to clean up and restore the Anacostia River" and would adopt written environmental standards "to minimize or eliminate the harmful ecological effects of existing pollutants and ongoing pollution sources entering the Anacostia River."

To that end, the AWC Board formed an Environmental Standards Development Committee (Committee) under the leadership of AWC Board member Roger Sant and Nancy Stoner of the Natural Resources Defense Council to develop recommended environmental standards for AWC Board consideration. The Committee developed these environmental standards to further the restoration of the Anacostia River and the development of vibrant, sustainable communities along its shores.

The AWC Board adopted these standards on **June 1, 2007**. The standards will apply to all AWC development projects and will be implemented through agreements with development partners.

For more information on the AWC Standards and programs to restore the Anacostia watershed, contact:

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Acknowledgments

The following members of the Committee gave generously of their time and provided thoughtful input on these draft standards:

- Roger Sant (Committee Co-Chair), AWC Board Member and Chairman, The Summit Fund of Washington
- Nancy Stoner (Committee Co-Chair), Natural Resources Defense Council Clean Water Project
- Carl Cole, AWC Board Member and Chairman, AWC Audit and Finance Committee
- Chip Akridge and David Tuchmann, Akridge
- Uwe Brandes and Brendan Shane, AWC
- Mary Jane Goodrick, DC Appleseed Center for Law & Justice
- Linda Howard, The Summit Fund of Washington
- Roger K. Lewis, FAIA, Architect, Professor Emeritus University of Maryland and Washington Post columnist
- Russell Randle and Michele Walter, Patton Boggs (counsel to DC Appleseed)
- Doug Siglin, Chesapeake Bay Foundation
- Neil Weinstein and Christopher Kloss, Low Impact Development Center

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AWC HISTORY AND MANDATE

In 2000, the District joined 16 federal and regional agencies to form an unprecedented partnership, the Anacostia Waterfront Initiative (AWI). Over the next three years, the partnership conducted over 20 community workshops, briefing over 5,000 people and over 3,000 workshop participants.

In 2004, the partnership finalized the AWI Framework Plan that defined a shared vision for a world-class waterfront along the banks of the Anacostia River. The plan outlined five themes for Anacostia restoration that recognize the critical relationship between economic and community revitalization and environmental restoration:

1 – A Clean and Active River
2 – Gaining Access to, Along, and Across the River
3 – A Great Riverfront Park System
4 – A Riverfront of Distinct Places and Cultural Destinations
5 – Building and Sustaining Strong Waterfront Neighborhoods

The AWI Framework Plan also defined an environmental agenda to eliminate pollution from stormwater run-off and sewage overflow, restore streams and wetlands, expand natural habitat areas, and promote water activities. Environmental goals were defined in six areas: water quality; air quality; toxins remediation; habitat enhancement; sustainable design practices; and outreach and education. Closely related to the environmental agenda is the plan to create a great riverfront park system that connects and revitalizes existing parks, creates over 100 acres of new parks, and provides high quality recreational opportunities and vibrant gathering places for the citizens of surrounding neighborhoods, the District, and the region.

AWC was formed by Mayor Anthony Williams and the DC Council in 2004 to implement the AWI Framework Plan and its environmental agenda. They acknowledged the unique vision of simultaneous economic and environmental revitalization of the Anacostia River watershed. As directed by the legislation creating AWC, AWC is:

"…responsible for the development, redevelopment, and revitalization of the lands adjacent to the Anacostia River and associated waterways and for the environmental restoration of the Anacostia River and associated waterways…"

AWC's Local Jobs and Affordable Housing Mandates

AWC is required by DC law to implement the vision defined in the Anacostia Waterfront Initiative Framework Plan. This comprehensive plan addresses five themes for creation of a world-class waterfront. In addition to its environmental restoration mandate, AWC must comply with affordable housing, DC resident employment, and local and disadvantaged business hiring requirements that will directly benefit residents in existing communities along the Anacostia. The Framework Plan and AWC's jobs and affordable housing requirements can be viewed at AWC's website: *www.anacostiawaterfront.net*

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EXECUTIVE SUMMARY

AWC's mission is to transform the underutilized Anacostia and realize its potential as one of the Nation's great urban rivers. The AWI Framework Plan, adopted by the DC Council to guide AWC's development activity, highlights the importance of "A Clean and Active River."

The environmental standards adopted by AWC will help achieve the environmental goals in the AWI Framework Plan by "greening" development. We adopt a four-pronged approach that supplements accepted green building practices with creative design, enhanced stormwater control, and site preservation requirements. This approach—the ***"AWC Gold Standard"***—will produce environmentally responsible buildings and greatly reduce the flow of pollutants into the Anacostia River and associated waterways.

For each element below, there is a minimum standard with which all AWC projects must comply. We also identify a goal that all AWC projects should aspire to. In addition to meeting minimum standards, we encourage all developers to adopt these goals as their own, reexamine old ways of doing business, and explore new technology and design that will help restore the Anacostia River and create healthier neighborhoods. These standards can be a model across the Anacostia watershed and the region of flexible, creative performance requirements to improve the environmental quality of our community.

These environmental standards do not replace applicable District of Columbia or federal laws or regulations. All projects must comply with applicable District and federal laws and regulations, including permitting requirements of DC Water and Sewer Authority (WASA), District Department of the Environment (DDOE), Department of Consumer and Regulatory Affairs (DCRA), the Army Corps of Engineers, U.S. Environmental Protection Agency (USEPA) and other agencies as applicable. The AWC Environmental Standards supplement existing environmental and development standards.

I. Integrated Environmental Design

Goal: To require early identification and adoption of environmental design elements during project development.

Minimum Standard:

The developer and AWC shall meet as early as possible in the development and design process to discuss the AWC environmental standards. Throughout the development process, meetings to review environmental planning and design shall be held no less than quarterly. The developer shall retain a consultant accredited by the U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) program or maintain an experienced LEED-accredited member on staff. The developer shall also select an architect of record and general contracting firms that have achieved LEED-certification on at least two major projects.

The developer shall prepare an overall sustainability plan as a component of the concept design package, which shall identify the project elements used to satisfy the Green Building, Stormwater Control, and Site Planning and Preservation elements of the AWC environmental standards. The developer shall submit to AWC any draft or final checklists and other materials submitted to demonstrate LEED, Green Communities, and/or Energy Star compliance.

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II. Green Building

Goal: To develop sustainable buildings through maximum integration of environmentally sensitive technology and design.

Minimum Standard: All non-residential buildings constructed on AWC land or financed by AWC must be verified by a third-party as having fulfilled or exceeded the requirements of the LEED program at the Gold level. All residential buildings must be verified by a third-party as having fulfilled or exceeded the requirements of the LEED program at the Silver level. The LEED program sets out a standard of measurement for what constitutes a green building. On a case-by-case basis, affordable and small residential buildings may be permitted to comply with the Green Communities program created by the Enterprise Foundation and Natural Resources Defense Council. The LEED and Green Communities rating systems require an integrated design approach to promote early identification of options to improve energy and water efficiency, minimize waste streams, and enhance indoor environmental quality. In addition, all projects must satisfy requirements of the USEPA Energy Star program and be designed to be 30 percent more energy efficient than the ASHRAE 90.1 2004 standard.

III. Stormwater Control

Goal: To eliminate the flow of pollution into the Anacostia River and associated waterways.

Minimum Standard: While green buildings deliver many environmental benefits, green building standards do not include mandatory requirements to reduce pollution carried by stormwater runoff into our rivers and streams. To ensure significant reductions in pollution, all projects developed on AWC land or financed by AWC must implement enhanced stormwater management to retain and reuse on-site the precipitation from a "one-inch in twenty-four hour" storm event following 48 hours of dry conditions. Any discharge of stormwater from the project, up to the volume of a 2-year storm, shall be treated to substantially remove pollutants of concern. When designing stormwater control systems, developers must first use green roofs and other vegetated systems that provide air quality, habitat, and heat island benefits in addition to stormwater treatment and control.

What is Stormwater?

Stormwater is rainwater or snowmelt that drains from roofs, sidewalks, streets, and other hard surfaces (also known as impervious surfaces). Urban areas create significantly more stormwater than undeveloped land, because buildings and pavement prevent rain from soaking into the ground. Stormwater is most often directed along streets and through pipes, carrying a variety of pollutants and trash into streams and rivers and degrading water quality. The large volume of runoff also erodes streambanks and carries large amounts of sediment that further pollute waterways. In the highly urbanized Anacostia River watershed, stormwater flows carry thousands of tons of pollutants, sediment, and trash into the waterways each year.

IV. Site Planning and Preservation

Goal: To create healthy, livable neighborhoods by preserving public access to the Anacostia River and associated waterways, revitalizing parks and recreational opportunities, and restoring and expanding natural areas.

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Minimum Standards: Development of AWC projects shall:

1. Ensure public access to the Anacostia River and associated waterways and the Riverwalk system of parks and trails.
2. Preserve existing public parks, with at least 1-to-1 replacement for any loss of park area caused by project development.
3. Protect delineated wetlands and buffer land within 100 feet of wetlands, with 3-to-1 mitigation for any impacts.
4. Daylight and/or restore streams wherever practical including Watts Branch, Piney Run, Fort Dupont, Pope Branch, Fort Davis, Fort Stanton, and Stickfoot Creek.
5. Preserve or create woodland or meadow buffers along the Anacostia River, as provided in the AWI Framework Plan, and for tributary streams, incorporating bioengineered edge designs from the AWI Framework Plan.
6. Preserve or create vegetated buffers within the right-of-way of all roadways.
7. Design all roadways to comply with the transportation construction and design guidelines in the District Department of Transportation (DDOT) Anacostia Waterfront Transportation Architecture Design Standards.
8. Provide tree canopy coverage within 20 years of project occupancy for a minimum of: (a) 30 percent of non-roof impervious surfaces; and (b) 40 percent of the overall non-roof project area.
9. Design all Riverwalk trails to comply with the construction and design guidelines in the AWI Anacostia Riverparks Plan and Riverwalk Design Guidelines.
10. Bring any existing or new marinas into compliance with the Clean Marina Guidebook issued by the National Park Service.
11. Coordinate habitat restoration activities with DDOE.

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I. Integrated Environmental Design

Goal:

To require early identification and adoption of environmental design elements during project development.

Minimum Standards:

1. The developer and AWC shall meet as early as possible in the development and design planning process to review the AWC environmental standards and to plan for a design workshop to identify methods for complying with and preferably exceeding the AWC environmental standards. Developer shall organize and fund the environmental design workshop. Regular meetings to review environmental planning and design shall be held no less than quarterly thereafter.

2. The developer shall retain a LEED-accredited consultant to guide the overall development process, or maintain an experienced LEED-accredited member on staff.

3. The developer shall prepare an overall sustainability plan as a component of the concept design package, which shall identify the project approach and elements used to satisfy the Green Building, Stormwater Control, and Site Planning and Preservation elements of the AWC environmental standards. The plan shall include project analysis using the DOE-2 energy model and stormwater management modeling. The sustainability plan shall be submitted to AWC and made available to the public.

4. The developer shall select a design team, including architects, engineers, and general contractors, that have designed and built projects that have been LEED-certified, or otherwise demonstrate capability to implement these environmental standards.

5. The developer shall submit to AWC any draft or final checklists and other materials submitted to demonstrate LEED, Green Communities, and Energy Star compliance.

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II. Green Building

Goal:

To develop sustainable buildings through maximum integration of environmentally sensitive technology and design.

Minimum Standards:

The DC Green Building Act of 2006 establishes minimum green building standards for projects owned or financed by AWC—an instrumentality of the District government. AWC's environmental standards complement the District-wide requirements and, rather than being phased-in over the next two to three years, will take effect immediately and apply to all AWC projects.

These standards apply to all buildings financed by AWC or constructed on property under AWC control (AWC Buildings).

1. DC Green Building Act Compliance

These Green Building standards are intended to achieve a higher level of environmental and energy performance than is required under the DC Green Building Act of 2006 (Green Building Act). Where these standards are not more stringent than the Green Building Act, all new AWC Buildings shall immediately comply with the requirements of Section 3 of the Green Building Act, which applies to publicly owned or financed buildings.

2. LEED Compliance

(a) All new non-residential AWC Buildings shall be verified by a third-party approved by AWC as having fulfilled or exceeded the U.S. Green Building Council LEED standard for new construction (LEED-NC) and/or core and shell (LEED-CS) at the Gold level. Major renovations of existing non-residential buildings shall be verified by a third-party approved by AWC as having fulfilled or exceeded the LEED-NC standard at the Gold level. Improvements to interiors of new or existing non-residential buildings shall be verified by a third-party approved by AWC as having fulfilled or exceeded the LEED for Commercial Interiors (LEED-CI) standard at the Gold level.

(b) All new residential AWC Buildings shall be verified by a third-party approved by AWC as having fulfilled or exceeded the U.S. Green Building Council LEED standard for new construction (LEED-NC) and/or core and shell (LEED-CS) at the Silver level. Major renovations of existing residential buildings shall be verified by a third-party approved by AWC as having fulfilled or exceeded the LEED-NC standard at the Silver level.

3. Energy Star Compliance

(a) All new non-residential AWC Buildings shall be designed to:

(i) achieve 85 points on the EPA national energy performance rating system as determined by the Energy Star Target Finder Tool, provided the AWC Building is of a type for which the Energy Star tools are available; and
(ii) be 30 percent more energy efficient than required by ASHRAE 90.1 2004.

Performance for non-residential AWC Buildings shall be benchmarked annually using the Energy Star Portfolio Manager benchmarking tool. Benchmark and Target Finder scores and Energy Star statements of energy performance for

each AWC Building shall be provided to AWC and made available to the general public within 60 days after they are generated.

(b) All new residential AWC Buildings shall be designed to achieve the Energy Star label and to be 30 percent more energy efficient than required by ASHRAE 90.1 2004.

4. Affordable and Small Residential Projects

In order to help AWC meet its affordable housing mandate, AWC may, on a case-by-case basis, approve construction of affordable and/or small residential projects (or components of larger projects) that comply with the Green Communities standards created by the Enterprise Foundation and NRDC, rather than the LEED Silver standard, but must still achieve Energy Star.

Affordable projects or affordable elements of larger projects are those constructed for persons earning less than 60 percent of the Area Median Income. Small residential projects are those less than 10,000 square feet of gross building floor area. When approving use of an alternative green building standard for affordable or small residential projects, AWC will work with the developer to achieve the greatest number of Green Communities points as possible.

Green Communities closely tracks the LEED green building standards and was specifically designed by Enterprise and NRDC to bring the benefits of green building to affordable housing construction.

See www.enterprisefoundation.org

5. 2030 Challenge

To address the impacts of climate change, developers should seek to align project design with the greenhouse gas reduction goals outlined in the 2030 Challenge.

The 2030 Challenge – Addressing Climate Change

The 2030 Challenge calls on the architecture and building community to take immediate action to stabilize and reduce global warming and climate change impacts. The Challenge sets realistic targets, achievable over time, to eliminate the use of carbon-based energy to power buildings. Making a commitment to the goals of the 2030 Challenge is a strong signal that a developer is committed to reducing energy use and protecting our environment. The Challenge calls for new buildings, developments, and major renovations to be designed to meet the following fossil fuel reduction goals:

- 50% immediately
- 60% in 2010
- 70% in 2015
- 80% in 2020
- 90% in 2025
- Carbon-neutral by 2030 (using no fossil fuel, greenhouse gas emitting energy to operate)

The 2030 Challenge has been adopted by the U.S. Conference of Mayors, the American Institute of Architects, and other major non-profit and professional associations.

See www.architecture2030.org

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III. Stormwater Control

Goal:

To eliminate the flow of pollution into the Anacostia River and associated waterways.

Minimum Standards:

While green buildings deliver many environmental benefits, current green building standards do not include mandatory requirements to reduce pollution carried by stormwater runoff into our rivers and streams. To address the urgent need to clean and restore the ecological integrity of the Anacostia River and associated waterways, additional measures to control the flow of pollution and sediment into our waters are required.

This standard will significantly improve stormwater control by requiring retention and on-site reuse of the stormwater from the "one-inch in twenty-four hour" storm following 48 hours of dry conditions. Data for the Washington area indicates that capturing and reusing the first inch of precipitation will reduce annual stormwater volume flowing into the combined and separated sewer systems by 85 percent. The standard will significantly improve the quality of stormwater flowing from AWC projects.

The standard prioritizes use of vegetative methods for capturing and filtering stormwater because of their practicality, potential cost advantages over "end-of-pipe" treatment systems, and other benefits for the developer and community, including reduced energy consumption, improved air quality and wildlife habitat, and reductions in the urban "heat island" effect (lower summertime air temperatures).

Where it is infeasible or inappropriate for reasons of public safety or environmental protection to manage stormwater on-site, "offsets" may be approved. Offsets are off-site reductions of stormwater volumes to address the difference between the stormwater volume that can be prudently managed on-site and the volume that must be managed to comply with this standard.

1. Retention and Reuse Requirement

The developer shall design and construct the project to retain and beneficially reuse the stormwater generated on-site by a "one-inch in twenty-four hour" storm following 48 hours of dry conditions. This standard applies to all private and public spaces in the project (*i.e.*, buildings, sidewalks, streets, lawns, and other areas). Once completed, the owner of the property, or tenant if AWC is the owner, shall operate and maintain the control measures and any offset measures to ensure ongoing compliance with this standard.

2. Permissible Control Methods

The developer, in consultation with AWC, shall satisfy the stormwater standard using the methods identified below, which are listed in order of preference:

(a) Vegetated controls including: "green" roofs designed to retain and beneficially use stormwater to support vegetation; rain gardens or bioretention cells; infiltration planters and vegetated swales, large filtered cells for growing trees, pocket wetlands;

(b) Where compatible with groundwater protection, permeable asphalt, concrete, or pavers; infiltration trenches; dry wells; and downspout disconnections to areas designed to infiltrate runoff;

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(c) Collection and reuse of stormwater for on-site irrigation using cisterns and rain barrels;

(d) Other appropriate on-site design techniques as agreed upon by AWC and the developer; and

(e) Offsets where on-site techniques are insufficient to meet the standard.

Stormwater control systems for public space regulated by the DDOT shall utilize the Low Impact Development (LID) technologies in the Anacostia Waterfront Transportation Architecture Design Standards, or other measures approved by AWC and DDOT.

3. Comprehensive Stormwater Planning

Developers are strongly encouraged to coordinate stormwater planning for phased projects and with adjacent parcels to increase overall retention, reuse, and treatment volumes. Coordinated planning can also facilitate: (a) sharing of monitoring, reporting and administrative costs; and (b) opportunities for local offsets by managing stormwater from related development that otherwise would not be retained, reused, or treated.

4. Construction Phase Requirements

Developers shall fully comply with all requirements for sediment and pollution control during the construction phase of the project. Developers shall work in consultation with AWC to identify measures to enhance controls for water and wind erosion that carry sediment and pollutants from the site. Developers will report to AWC every other month on these pollution control methods and conduct periodic site tours at AWC request.

5. Stormwater Quality Treatment

(a) Stormwater management systems shall be designed so that all stormwater passes through a filtering medium designed to remove sediment and pollutants. As noted above, the first preference for filter design is implementation of vegetated systems.

(b) It is understood that rainfall may exceed the design capacity of the stormwater management system under extreme conditions. Any discharge of stormwater from the project up to the volume of a 2-year storm shall meet the following requirements:

(i) discharge to the combined sewer system shall pass through vegetated filtration systems or other on-site controls that are designed, constructed, operated and maintained to substantially remove pollutants of concern as identified in permits by DDOE or WASA; and

(ii) discharge to a separate sewer system shall pass through vegetated filtration systems and other onsite controls that are designed, constructed, operated, and maintained to substantially remove pollutants impairing the Anacostia River, including but not limited to:

- Total Suspended Solids
- Bacteria
- Metals (arsenic, copper, lead, and zinc)
- Total Phosphorus
- Total Nitrogen
- Organics (such as PAHs and PCBs)
- Petroleum

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(c) All stormwater discharge from the project shall comply fully with any applicable governmental discharge limitations, whether imposed by permit, contract, regulation, or otherwise.

(d) Developers must establish contractually enforceable limitations to:

(i) prevent overuse of fertilizers, herbicides, and pesticides that could be carried from the project by stormwater, including through use of integrated pest management; and

(ii) prevent use of coal tar sealants for paved surfaces including roads, driveways, alleys, and parking lots.

6. Protection of Ongoing Remediation

(a) Where existing soil contamination documented as part of a government-approved remediation effort will not be removed, or where previously approved remedial plans provide for capping or other limitations on groundwater infiltration, and such systems are not being replaced as part of redevelopment, the developer shall design vegetative and other control systems with an impermeable liner or other measures to prevent stormwater migration into underlying soil and groundwater.

(b) If a project property is the subject of ongoing soil or groundwater remediation of hazardous substances or petroleum contamination, the developer shall assure that such remediation is completed as part of the development process, or that properly functioning long-term remedial measures are in place at the conclusion of construction. The developer of the property shall, as part of the initial compliance certification, obtain certification from a registered professional engineer satisfactory to AWC that remediation has been properly completed or that properly functioning long-term remedial measures, as approved by the relevant regulatory agency, are in place.

7. Groundwater Treatment

Where groundwater is produced at a project after completion of construction due to dewatering wells or other systems, the developer, owner, or tenant must comply with the following requirements:

(a) Any groundwater discharged to a combined sewer shall conform to WASA requirements. If any pollutant-specific stormwater treatment requirement defined pursuant to paragraph 5 above is more stringent than the WASA groundwater discharge requirements, the groundwater discharge must comply with the more stringent treatment requirement.

(b) Any groundwater discharged to a separated sewer shall be submitted to the DDOE for review and approval before the discharge begins and must comply with the terms of any discharge permit for the project issued by USEPA or DDOE. If any pollutant-specific stormwater treatment requirement defined pursuant to paragraph 5 above is more stringent than the corresponding discharge limitations, any discharge must comply with the more stringent treatment requirement. In no case shall any such discharge have a visible oily sheen.

(c) Any discharge of groundwater to the combined *or* separated sewer systems produced from a site that is the subject of ongoing soil or groundwater remediation of hazardous substances or petroleum contamination shall comply with applicable discharge limitations, whether imposed

by permit, contract, regulation, or otherwise. In no case shall any such discharge to the separated sewer system have a visible oily sheen.

8. Monitoring, Maintenance, and Inspection

Sale agreements and leases for property subject to these environmental standards shall:

(a) Impose contractually enforceable obligations on the transferee or lessee for as long as it owns or leases the property to arrange at transferee's sole cost for maintenance, annual third-party inspection, monitoring and reporting requirements (to AWC, owner, and the tenants) in order to assure that the stormwater control system is functioning properly;

(b) Require an annual certification of compliance by a registered professional engineer that the system and any offsets (other than a one-time monetary payment) have been and are being properly operated and maintained and are functioning properly, based on those certified inspections, appropriate monitoring, and maintenance records; and

(c) Impose contractually enforceable requirements for the payment by the transferee or lessee of an annual fee to finance AWC stormwater monitoring activities. This annual fee shall be calculated based on the gross land area of the project and shall be equal to $0.25 per square foot in 2007, and shall be adjusted annually, as of January 1 each year, by the consumer price index as published in the Wall Street Journal.

Offset Provisions

9. Necessity and Volume Determination

(a) Underlying soil or groundwater conditions at a specific project may limit the feasibility or appropriateness of on-site stormwater management. Examples of such conditions may include:

(i) very shallow water table conditions or highly impermeable soils;
(ii) the presence of combined sewer pipes undergoing significant groundwater infiltration, as documented by WASA;
(iii) potentially serious water problems with neighbors' basements, buried utilities at nearby properties, or with highway or Metro tunnels;
(iv) contaminated soil or groundwater at or nearby the site, where the contamination is not to be removed or the remedial system reconstructed as part of the project.

(b) If the developer and AWC jointly determine that underlying soil or groundwater conditions limit the feasibility or appropriateness of on-site stormwater management, they shall, using generally accepted engineering methods, jointly estimate the volume of stormwater generated by the project to comply with this standard that cannot be beneficially reused or safely infiltrated on-site. The developer shall procure offsets for this volume pursuant to the rules set forth below. AWC and the developer shall make public the specific methods used to make such estimates and show specifically how the volumes were calculated using these methods.

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10. Acceptable Offsets

The following types of offsets in the Anacostia watershed or associated waterways within the District will be acceptable to AWC. The preference and appropriate mix of financial and physical offsets for a particular project will be determined by AWC in consultation with the developer on a case-by-case basis:

(a) Physical offsets shall consist of contractually enforceable measures at off-site locations to procure 1½ times the reduction in stormwater flow through the use of green roofs, potable water conservation measures, and LID measures shown to be effective for such purposes. Where off-site potable water conservation measures are employed, such as installation of low-flow fixtures where not already required by building codes, the volume of stormwater reduction for purposes of the offset shall be 25 percent of the annual volume saved, because most of the potable water savings occur outside wet weather, combined sewer overflow periods. Thus, if fixture retrofits would save 100 gallons per year in potable water, a 25 gallon stormwater reduction would be credited to the developer.

(b) Financial offsets shall consist of payments to the Anacostia River Trust Corporation, a non-profit 501(c)(3) subsidiary of AWC, for twice the cost of obtaining an equivalent reduction of the stormwater flow being offset.

(i) AWC shall calculate the offset payment in the following manner. AWC will obtain an engineering cost estimate for the fully-loaded 2007 construction costs to retrofit streetscape covering one acre for optimal stormwater infiltration and retention, together with the discounted long-term operation and maintenance (O&M) costs for the design life of this improved streetscape. From this total cost figure and estimated reduction in stormwater volume, AWC will calculate a cost per stormwater gallon. The resulting per gallon figure shall be multiplied by the volume of offsets a developer seeks to offset. This number shall be multiplied by two; the final dollar figure shall be paid AWC or its designee. This price includes a premium to compensate AWC for the performance risk it is undertaking.

(ii) AWC will adjust the per gallon cost figure annually, based on appropriate published indexes of construction cost inflation, including the appropriate Dodge Reports and R.S. Means indexes of construction costs.

General Compliance and Financial Assurance Provisions

11. Initial Compliance and Performance Bond

(a) The final design and the as-built drawings of the project shall be reviewed by a registered professional engineer for the developer, owner, or tenant as appropriate, and certified as compliant with this stormwater standard, or corrections shall be made until such certification can be provided. The certification shall be delivered to AWC within 30 days.

(b) A performance bond, letter of credit, or other form of financial security satisfactory to AWC shall be posted at the beginning of construction to assure that the measures are constructed in compliance with plans and perform as designed, and for offsets, that appropriate commitments are in place for their long-term maintenance. The bond, letter of credit or other financial security may be released after the certificate of occupancy for the building issues and a

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satisfactory compliance inspection has been obtained from an independent professional engineer of the systems and offsets. If compliance is deficient, the developer, owner, or tenant, depending on which is contractually responsible, shall take steps to correct the deficiencies and bring the project into compliance. In the event such measures are unsuccessful after a reasonable time, AWC may draw upon the performance bond or letter of credit in order to finance such corrective measures.

12. Offset Measure Compliance and Financial Assurance

Except for offsets consisting of one-time monetary payments, contractually enforceable provisions must be in place to provide for operation and maintenance (O&M) of any off-site stormwater reduction measure claimed as an offset. Such provisions shall entitle AWC to bring an enforcement action if the commitments are not properly performed. Appropriate financial assurance of such O&M for the life of the offset measure must also be provided, and must be in a form satisfactory to AWC.

13. Subsequent Compliance Corrections and Performance Bond for Corrective Measures

If ongoing compliance with this stormwater standard for a project or offset measure location(s) cannot be certified by a registered professional engineer without corrective measures, the owner or tenant, as is appropriate, shall enter into binding contractual commitments, also explicitly enforceable by AWC, to correct the deficiencies. If the estimated cost of performing the corrective measures exceeds $50,000, or if the performance of corrective measures takes more than 120 days (regardless of cost), the owner shall post a performance bond, letter of credit, or other appropriate financial security in a form satisfactory to AWC in the sum reasonably estimated to be necessary to perform the work correctly.

14. Performance Bond Requirements

The form of any performance bond, letter of credit, or other financial security posted to satisfy these rules must be provided to AWC at least 30 days in advance of its proposed posting and must be satisfactory to AWC. The sum of any such performance bond, letter of credit, or other financial security posted to assure performance shall include a contingency figure, in a percentage customary for such engineering and construction work.

15. Release of Performance Bond

The performance bond, letter of credit, or other financial security posted in order to comply with these rules shall be released upon a satisfactory demonstration to AWC of compliance with these standards. In the event such measures are unsuccessful after a reasonable time, appropriate to test performance and any cure period, the AWC may draw upon the performance bond or letter of credit in order to finance such corrective measures. In the event that correction costs more than the bond or letter of credit has provided, AWC may perform such work at owner's or tenant's expense, which cost shall be a lien on the property and/or a charge under any applicable lease until paid.

16. Engineer Certifications

The engineer certifications required pursuant to these standards shall not be provided by any engineer having any financial interest in the underlying development project, and shall not be provided by an officer or employee of any company (including direct and indirect subsidiaries) with a

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financial interest in the development project reviewed by that engineer.

17. Recording of Commitments

The developer shall record a deed notice with the District Recorder of Deeds that summarizes all obligations associated with ownership or operations and maintenance of AWC projects that are required to ensure ongoing compliance with the AWC Environmental Standards.

IV. Site Planning and Preservation

Goal:

To create healthy, livable neighborhoods by preserving public access to the Anacostia River and associated waterways, revitalizing parks and recreational opportunities, and restoring and expanding natural areas.

Minimum Standards:

1. Access to the River

The AWI Framework Plan envisions a continuous Anacostia Riverwalk and Trail along both banks of the Anacostia, as well as neighborhood parks within developments away from the water. The RiverParks initiative will connect and enhance existing parks and create additional parks to increase recreational uses of the Anacostia River. Development shall ensure a continuous RiverParks system and permit public access to the RiverParks, the Anacostia River, and associated waterways.

2. Parkland

Existing public parks shall be preserved and, where possible, expanded. Where development in public parks cannot be practicably avoided, any encroachment shall be mitigated in-kind at a minimum acreage ratio of at least one-to-one. Both on-site remaining parks and off-site mitigation areas shall be permanently protected.

3. Wetlands

No construction shall disturb delineated wetlands or land within 100 feet of delineated wetlands. The land within 100 feet of delineated wetlands shall be treated as if it were a riparian buffer. Where DDOE and the U.S. Army Corps of Engineers determine that construction in these areas cannot be avoided, any impacts on wetland areas shall be mitigated in-kind and on-site at a minimum acreage ratio of three-to-one. Only if on-site locations are unavailable may off-site locations be considered. Preference for mitigation should be given to restoring degraded wetlands or recreating former wetlands, not creating new wetlands. On-site remaining wetlands and buffers and off-site mitigation areas shall be permanently protected.

4. Daylighting and/or Restoration of Streams

Streams that have previously been piped or covered shall be daylit and/or restored to enhance the ecological integrity of the Anacostia River system, unless determined by AWC to be infeasible. Similarly, open air streams that have been degraded by stormwater runoff and other causes should be restored, unless determined by AWC to be infeasible. Among others, the AWI Framework Plan identifies seven streams east of the Anacostia River for daylighting and/or restoration: Watts Branch; Piney Run; Fort Dupont; Pope Branch; Fort Davis; Fort Stanton; and Stickfoot Creek.

5. River (Riparian) Buffers

The AWI Framework Plan established specific goals for creation of woodland and meadow buffers along the main channel of the Anacostia River (Location and Type of Riparian Buffers, p. 33). Development shall maintain these minimum riparian buffer goals, which range from 50 to 300 feet depending on location, except where necessary to ensure public access and use of the riverfront. Development along open air or daylit tributary streams shall maintain a minimum riparian buffer of 25 feet. Where development within buffer

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areas cannot be practicably avoided, any reductions in buffer area shall be mitigated in-kind and on-site at a minimum acreage ratio of three-to-one. Only if on-site locations are unavailable may off-site locations be considered. On-site buffers and off-site mitigation areas shall be permanently protected. Where appropriate, buffer design should incorporate bioengineered edges referenced in the AWI Framework Plan (p. 31).

6. Roadway Buffers

Development shall incorporate planted vegetated buffers within the right-of-way of all roadways to increase treecover and shade, help mitigate traffic noise, absorb toxic emissions, and minimize stormwater runoff.

7. Roadway Design

Roadways shall comply with the Anacostia Waterfront Transportation Architecture Design Standards developed by DDOT.

8. Tree Canopy

Development shall provide canopy coverage within 20 years of project occupancy for a minimum of: (a) 30 percent of non-roof impervious surfaces; and (b) 40 percent of the overall non-roof project area.

9. RiverWalk Trails

Development along both sides of the Anacostia River and along associated waterways shall include continuous, publicly accessible trails that comply with the Anacostia Riverparks Plan and Riverwalk Design Guidelines.

10. Clean Marinas

New or existing marinas shall comply with the program elements outlined in the Clean Marina Guidebook issued by the National Park Service and any site specific compliance requirements established by DDOE or EPA. The owner or developer of the marina shall submit a copy of its Clean Marina Checklist and any supporting documentation to AWC.

11. Habitat Restoration

Habitat restoration components of any development shall be coordinated with DDOE and the Wildlife Division's Wildlife Action Plan.

Facilitating Off-Site Restoration and Preservation

AWC recognizes that, to achieve the desired outcome of a restored Anacostia River, we must extend application of these environmental standards beyond the footprint of AWC projects. The AWC is charged with promoting restoration throughout the Anacostia River watershed. To achieve this goal, each community within the Anacostia watershed must adopt a watershed focus that leverages available resources and facilitates additional restoration activity throughout the watershed in the District and Maryland.

AWC will coordinate and work cooperatively with government, private, and non-profit partners throughout the watershed to promote and facilitate, to the greatest extent possible, the following kinds of projects:

(a) Restoration of specific wetlands within the tidal portion of the Anacostia watershed;

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(b) Purchase and dedication of specific tracts of land for vegetated river (riparian) buffer along the tidal portion of the Anacostia or associated waterways;

(c) Planting of trees of native species at specified locations in the Anacostia watershed, including costs for appropriate tree boxes and captured recycled water irrigation;

(d) Funding to replace streetscapes, medians strips, traffic islands, surface parking, and sidewalks to maximize stormwater infiltration within the Anacostia watershed;

(e) Funding to purchase specific property for dedication to additional public open space in the Anacostia watershed; or

(f) Other projects with specific water quality benefits.

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Technical Guidance on Implementing
Section 438 of the Energy Independence and Security Act

INTRODUCTION

In December 2007, Congress enacted Energy Independence and Security Act. Section 438 of that legislation establishes strict stormwater runoff requirements for Federal development and redevelopment projects. The provision reads as follows:

> **"Storm water runoff requirements for federal development projects.** The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

The intent of Section 438 of the Energy Independence and Security Act (EISA) is to require federal agencies to develop and redevelop applicable facilities in a manner that reduces stormwater runoff and associated pollutant loadings in order to protect or restore the waters of the U.S. Until recently, stormwater programs established under the Clean Water Act Amendments of 1987 have been administered to control traditional pollutants that are commonly associated with municipal and industrial discharges, e.g., nutrients, sediment, and metals. Increases in runoff volume and peak discharge rates have been regulated through State and local flood control programs. Although these programs have merit, knowledge accumulated during the past 20 years has led stormwater experts to the conclusion that conventional approaches to control runoff have not resulted in adequate protection of the nations water resources (National Research Council, 2008).

Stormwater management practices, e.g., extended detention ponds, that have been designed to reduce peak flows and trap pollutants entrained in the runoff have been proven to inadequately protect receiving waters both in terms of maintaining stream channel stability and the biotic integrity of the waterbody. What research has shown is that the use of conventional stormwater management practices fails to achieve the desired management goals and as a result there is an increased incidence of runoff events that have flow volumes and runoff rates that are erosive and detrimental to the stability of the stream. In addition, the higher volumes and velocities also cause and carry increased pollutant loadings (Shaver, et al., 2007; Holz testimony, 2008; Horner testimony, 2008). A 2008 National Research Council report on urban stormwater confirmed the shortcomings of current stormwater control efforts. Three of the report's findings on stormwater management approaches are particularly relevant (National Research Council, 2008).

1. Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds;
2. Stormwater control measures such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use

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planning can dramatically reduce the volume of runoff and pollutant load from new development; and

3. Stormwater control measures that harvest, infiltrate, and evapotranspire stormwater are critical to reducing the volume and pollutant loading of small storms.

Purpose and Organization of this Guidance

The purpose of this document is to provide guidance and background information on Section 438. The document contains guidance on how compliance with Section 438 can be achieved, measured, evaluated, and reported. In addition, information detailing the rationale for the stormwater management approach contained herein has been included.

The following information is presented within this document:

Part I: Implementation Framework

A. Background
B. Benefits and outcomes of the new stormwater performance requirements
C. How to meet the requirements of Section 438
D. Applicability and definitions
E. Complying with the performance requirement
F. Calculating the 95th percentile rainfall event

Part II: Case Studies on Capturing the 95th Percentile Storm Using Onsite Management Practices

Case studies representing typical Federal installations have been included. The case studies were selected to demonstrate the feasibility of providing adequate stormwater control for a range of site conditions and building designs. Each case study includes a description of a method that can be used to determine the design objectives of the project based on controlling the 95th percentile storm. Examples of on-site technologies and practices have also been provided. The case studies are intended to provide examples of modeling procedures that can be used to quantify treatment system performance and processes for assessing sites and determining appropriate control techniques.

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Part I: Implementation Framework

A. BACKGROUND

This section contains background on the causes and consequences of stormwater discharges, solutions that can be used to address the causes and consequences of stormwater discharges and how to implement those solutions to comply with Section 438 of EISA.

Alterations to Natural Hydrology and the Impact on Stormwater Runoff

In the natural, undisturbed environment rain that falls is quickly absorbed by trees, other vegetation, and the ground. Rainfall that is not intercepted by leaves infiltrates into the ground or is returned to the atmosphere by the process of evapotranspiration. Very little rainfall becomes stormwater runoff, and runoff generally only occurs with larger precipitation events. Traditional development practices cover large areas of the ground with impervious surfaces such as roads, driveways, sidewalks, and buildings. Once such development occurs, rainwater cannot infiltrate into the ground and as a result, runs off the site at rates and volumes that are much higher than would naturally occur. Under developed conditions runoff occurs even during small precipitation events that would normally be absorbed by the soil and vegetation. The collective force of the increased runoff scours streambeds, erodes stream banks, and causes large quantities of sediment and other entrained pollutants to enter the water body each time it rains (Shaver, et al., 2007; Booth testimony, 2008).

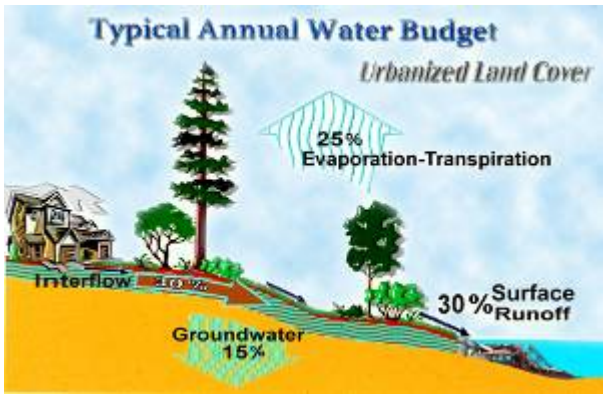
As watersheds are developed and impervious surfaces increase in area, the hydrology of the watersheds fundamentally changes over time which results in degraded aquatic ecosystems. In recognition of these problems, stormwater managers employed extended detention approaches to mitigate the impacts of increased runoff peak runoff rates. However, wet ponds and similar practices inadequately protect downstream hydrology because of the following inherent limitations of these conventional practices (National Research Council, 2008; Shaver, et al., 2007):

- Poor peak control for small, frequently-occurring storms;
- Negligible volume reduction; and
- Increased duration of peak flow.

Detention storage targets relatively large, infrequent storms, such as the two and 10-year/24-hour storms for peak flow rate control. As a result of this design limitation, flow rates from smaller, frequently-occurring storms typically exceed pre-development levels and result in flows erosive to stream channel stability (Shaver, et al., 2007). Section 438 is intended to address the inadequacies of the historical detention approach to managing stormwater and promote more sustainable practices that have been selected to maintain or restore predevelopment site hydrology.



Pre-development Hydrology. *Courtesy of C. May, University of Washington.*



Post-Development Hydrology. *Courtesy of C. May, University of Washington.*

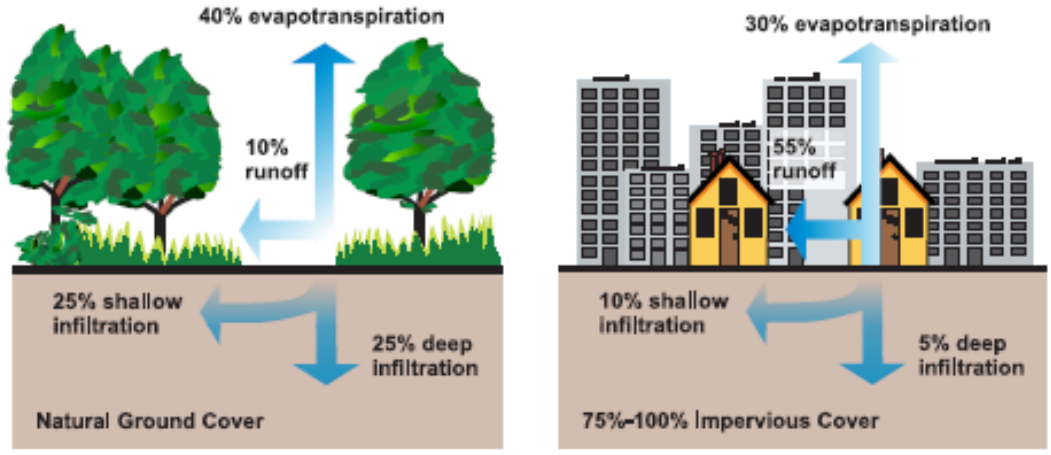


Figure 1. Pre-Development and Post-Development Hydrology. (USDA).

Land cover changes including increased imperviousness, soil compaction, loss of vegetation, and loss of natural drainage patterns result in increased runoff volumes and peak runoff rates. The cumulative impacts of the land cover changes result in alterations of the natural hydrology of a site, which disrupts the natural water balance and changes water flow paths. The consequences of these impacts include:

1. *Increased volume of runoff*. With decreased area for infiltration and evapotranspiration due to development, a greater amount of rainfall is converted to overland runoff which results in larger stormwater discharges.
2. *Increased peak flow of runoff*. Increased impervious surface area and higher connectivity of impervious surfaces and stormwater conveyance systems increase the flow rate of stormwater discharges and increase the energy and velocity of discharges into the stream channel.
3. *Increased duration of discharge*. Detention systems generate greater flow volumes for extended periods. These prolonged higher discharge rates can undermine the stability of the stream channel and induce erosion, channel incision and bank cutting.

4. *Increased pollutant loadings*. Impervious areas are a collection site for pollutants. When rainfall occurs these pollutants are mobilized and transported directly to stormwater conveyances and receiving streams via these impervious surfaces.
5. *Increased temperature of runoff*. Impervious surfaces absorb and store heat and transfer it to stormwater runoff. Higher runoff temperatures may have deleterious effects on receiving streams. Detention basins magnify this problem by trapping and discharging runoff that is heated by solar radiation (Galli, 1991; Schueler and Helfrich, 1988).

The resulting increases in volume, peak flow, and duration are illustrated on a hydrograph, which is a representation of a site's stormwater discharge with respect to time. The hydrograph below reflects the impacts of development on runoff volume and timing of the runoff. Individual points on the curve represent the rate of stormwater discharge at a given time. The graph shows that development and corresponding changes in land cover result in greater discharge rates, greater volumes, and shorter discharge periods. In a natural or pre-development condition, runoff rates are slower and occur over a longer time period. The predevelopment peak discharge rate is also much lower than the post-development peak discharge rate due to attenuation and absorption by soils and vegetation. In the post-development condition there is generally a much shorter time before runoff begins because of increased impervious surface area, a higher degree of connectivity of these areas and the lost of soils and vegetative cover that slow or reduce runoff.

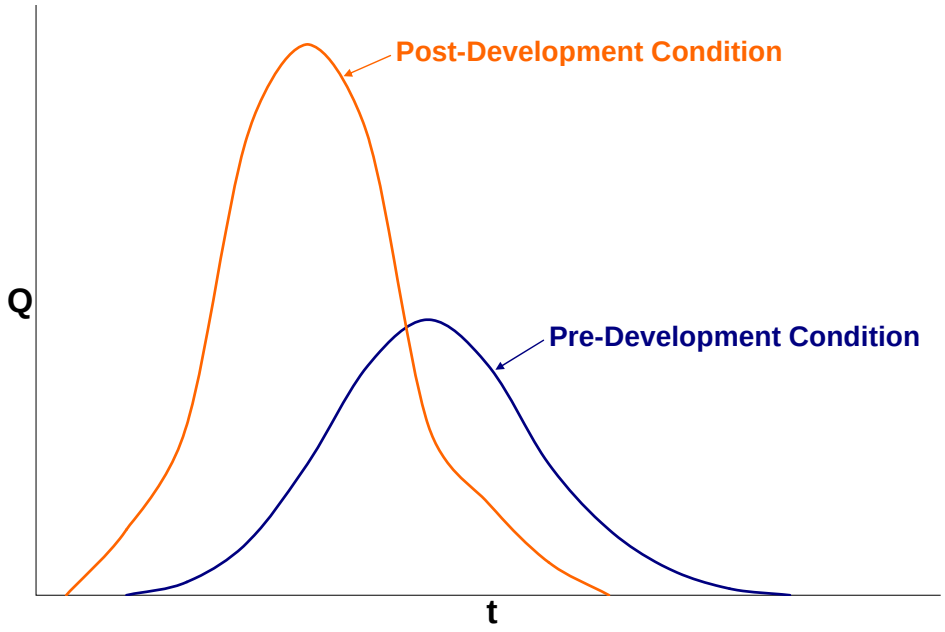


Figure 2. Post-Development Hydrograph.
(Q = volumetric flow rate; t = time)

In addition to the problems caused by stormwater and nonpoint source runoff, many older cities (including many of the largest cities in the United States), have combined sewage and stormwater pipes that frequently overflow due to precipitation events. By the late 20th century, most cities that attempted to reduce sewer overflows did so by separating combined sewers, expanding treatment capacity or storage within the sewer system, or by replacing broken or decaying pipes. However, these practices can be enormously expensive and take decades to

implement. Moreover, piped stormwater and combined sewer overflows (CSOs) may also, in some cases, have the adverse effect of upsetting the hydrological balance by moving water out of the watershed, thus bypassing local streams and ground water.



Figure 3. Stream Displaying the Effects of Stormwater Runoff and Channel Downcutting.

The Solution: Preserving and Restoring Hydrology

A new approach has evolved in recent years to eliminate or reduce the amount of water and pollutants that run off a site and ultimate are discharged into adjacent waterbodies.

The fundamental principle is to employ systems and practices that use or mimic natural processes to 1) infiltrate and recharge, 2) evapotranspire, and/or 3) harvest and reuse precipitation near to where it falls to earth.

Green infrastructure practices include a wide variety of practices that utilize these mechanisms. They can be used at the site, neighborhood and watershed/regional scales. In this document the focus is on site-level practices, which is most consistent with the terms used in Section 438: "project", "facility", and "property."

The purpose of the new approach is to replicate pre-development hydrology to protect and preserve both the water resources onsite and those downstream. For example, if prior to development, five (5) percent of the annual rainfall runs directly into the stream and the remainder infiltrates into the ground or is evapotranspired into the air, then the post-development goal should be to limit runoff to five (5) percent while maintaining the correct aquifer recharge rate. This has the benefit, in most cases, of delivering water to the stream at approximately the same rate, volume, duration and temperature as the stream had evolved to handle most effectively and safely. The result will be to eliminate or minimize the erosion of streambeds and streambanks, significantly reduce the delivery of many pollutants to water bodies, and retain historical instream temperatures.

Restoring or maintaining pre-development hydrology has emerged as a control approach for several reasons. Most importantly, this approach is intended to directly address the root cause of impairment. Current control approaches have been selected in an attempt to control the symptoms (peak flow, and excess pollutants), but this strategy is largely ineffectual because of the scale of the problem, the cumulative impacts of multiple developments and the need to manage both site and watershed level impacts. With current approaches, it is also difficult to adequately protect and improve water quality because the measures employed are not addressing the main problem which is a hydrologic imbalance.

Designing facilities based on the goal of maintaining or restoring predevelopment hydrology provides a site specific basis and objective method with which to determine appropriate practices to protect the receiving environment.

Using pre-development hydrology as the guiding control principal also allows the designer to consider climatic and geologic variability and tailor the solutions to the site and geographic location. Thus the need for a one size fits all approach is rendered unnecessary since the design objective is dictated by the pre-development site conditions and not a solution based on ease of administration. Instead of prescribed approaches dictating discharge volumes or flow rates, site assessments of historical infiltration and runoff rates will inform the designer and provide the basis for a suitable design. The use of this approach will minimize compliance complications that may arise from prescriptive designs approaches which do not account for the variability of precipitation frequencies, rainfall intensities and land cover and soil conditions that influence infiltration and runoff.

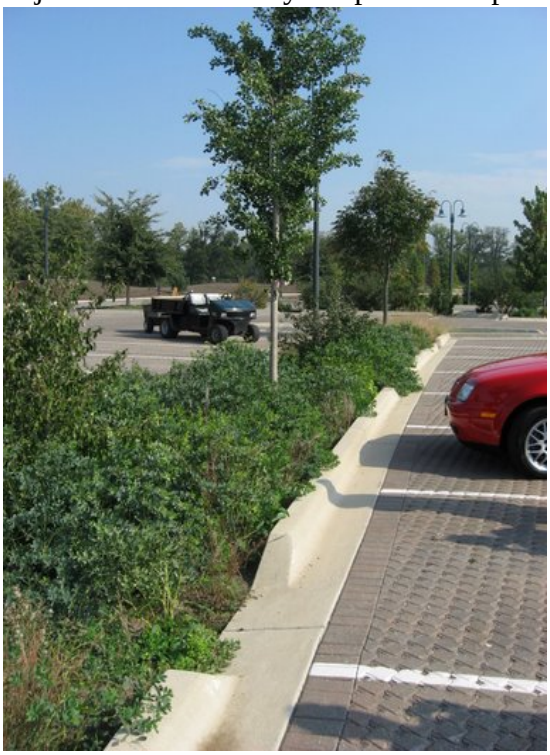


Figure 4. Parking lot bioswale and permeable pavers in Chicago.

This approach also helps to prevent and reduce pollutant loadings to both groundwater and surface waters. Traditional stormwater controls typically are designed to reduce the concentration of pollutants in runoff without addressing the increased volume of stormwater discharged from developed areas. Although removal of pollutants is an important aspect of stormwater management, the larger problem resulting from increased flow volumes and rates often overshadows the gains achieved by a pollutant focused approach. Even with stormwater controls and high rates of pollutant removal, absent volume reductions, urban areas will contribute more pollution than pre-development conditions making it difficult to achieve water quality standards. Table 1 below highlights this condition with the familiar example of the runoff from a one-acre meadow and one-acre parking lot after one-inch of rain.

Table 1. Runoff Volume and Pollutant Load from One-Acre Parking Lot with Treatment and Meadow for a One-Inch Rain Event (Schueler and Holland, 2000)(Wisconsin DNR, 2008).

Land Use	Pollutant	Concentration (mg/L)	% Removal	Effluent Concentration (mg/L)	Runoff Volume (gal)	Pollutant Load (lbs)
Paved Parking Lot with Treatment	TSS	130	80	26	25,800	5.6
Meadow		25	0	25	1,600	0.34

The data in the table show that even when treatment measures were used to reduce discharge (effluent) pollutant concentrations to levels similar to pre-development conditions, the large increase in runoff volume due to the parking lot caused a pronounced increase in total pollutant loadings. To maintain predevelopment pollutant loadings, the designer has two main choices, i.e., reduce pollutant loadings by designing the site and treatment systems to mimic the pre-development hydrology of the site or significantly raise the pollutant removal rates (% removal) to almost irreducible levels using very effective and probably expensive practices.

B. Benefits and Outcomes of the New Stormwater Performance Requirements

Implementation of these new stormwater performance requirements provides numerous environmental and economic benefits in addition to reducing the volume of sewer overflows and runoff:

Benefits to Water Resources:

- *Cleaner Water.* The use of plants, soils and water reuse practices can reduce stormwater runoff volumes and pollutant loadings and the frequency and magnitude of combined sewer overflows (volume and pollutant loading reductions). These practices are part of a larger set of practices called Green Infrastructure.
- *Clean and Adequate Water Supplies.* Green infrastructure approaches using soil based vegetated infiltration systems can be used to recharge groundwaters and maintain stream base flow. By recharging groundwater aquifers, aquatic ecosystem health is maintained and base flows are increased which helps ensure more constant flows for drinking water withdrawals. Harvesting and reusing rainwater also reduces the need to use potable water for all uses and can reduce both the infrastructure and energy needed to treat and transport both drinking water and stormwater.
- *Source Water Protection.* Green infrastructure practices provide pollutant removal benefits, thereby providing some protection for both ground water and surface water sources of drinking water. In addition, green infrastructure provides groundwater recharge benefits.

Green infrastructure for managing wet weather is a set of management approaches and technologies that utilize and/or mimic the natural hydrologic cycle processes of infiltration, evapotranspiration and reuse. Green infrastructure practices include green roofs, trees and tree boxes, rain gardens, vegetated swales, pocket wetlands, infiltration planters, porous and permeable pavements, vegetated median strips, reforestation and revegetation and protection of riparian buffers and floodplains. Green infrastructure can be used almost anywhere soil and vegetation can be worked into the urban or suburban landscape. Green infrastructure includes decentralized harvesting approaches such as rain barrels and cisterns that can be used to capture and re-use rainfall for watering plants or flushing toilets.

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Other Social and Environmental Benefits:

- *Cleaner Air.* Trees and vegetation improve air quality by filtering many airborne pollutants and can help reduce the amount of respiratory illness (Vingarzan and Taylor, 2003).
- *Reduced Urban Temperatures.* Summer city temperatures can average 10ºF higher than nearby suburban temperatures (Casey Trees, 2007). High temperatures are also linked to higher ground level ozone concentrations. Vegetation creates shade, reduces the amount of heat absorbing materials and emits water vapor – all of which cool hot air (Grant, et al., 2003). Reductions in impervious surface and the use of light colored pervious surfaces (e.g., permeable concrete) also can mitigate urban temperatures.
- *Moderate the Impacts of Climate Change.* Climate change impacts and effects vary regionally, but green infrastructure techniques can provide adaptation benefits for a wide array of circumstances. They can be used to conserve, harvest and reuse water, to recharge groundwaters and to reduce surface water discharges that could contribute to flooding. In addition, there are mitigation benefits such as reduced energy demand and carbon sequestration by vegetation.
- *Increased Energy Efficiency.* Green space helps lower ambient temperatures and, when incorporated on and around buildings, helps shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. Diverting stormwater from wastewater collection, conveyance and treatment systems can reduce the amount of energy needed to pump and treat the water. Energy efficiency not only reduces costs, but also reduces generation of greenhouse gases.
- *Community Benefits.* Trees and plants improve urban aesthetics and community livability by providing recreational and wildlife areas. Studies show that property values are higher when trees and other vegetation are present. Increased green space also has public health benefits and has been shown to reduce crime and associated the associated stresses of urban living.



Figure 5. Rainwater cistern.

C. HOW TO MEET THE REQUIREMENTS OF SECTION 438

"Section 438. Storm water runoff requirements for federal development projects. The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

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Compliance with Section 438 of the EISA can be achieved through either of the two performance requirements described below. The intention of the statute is to preserve or restore site hydrology during the development or redevelopment process. To be more specific, this requirement is intended to maintain stream flows that are protective of aquatic biota, stream channel stability, and historical aquifer recharge rates such that receiving waters are not negatively impacted by changes in runoff temperature, volumes, durations and rates. It should also be noted that a performance based approach was selected in lieu of a prescriptive requirement in order to provide site designers maximum flexibility in selecting control practices appropriate for the site. Described below are the two options site designs can use to comply with Section 438.

Option 1: Control of the 95th Percentile Rainfall Event

Design, construct, and maintain stormwater management practices that manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 95th percentile rainfall event. This objective shall be accomplished by the use of practices that infiltrate, evapotranspire and/or harvest and reuse rainwater. The 95th percentile rainfall event is the event whose precipitation total is greater than or equal to 95 percent of all storm events over a given period of record. For example, to determine what the 95th percentile storm event is in a specific location, all 24 hour storms that have recorded values over a 20 or 30 year period would be tabulated and a 95th percentile storm would be determined from this record, i.e., 5% of the storms would be greater than the number determined to be the 95th percentile storm. Thus the 95th percentile storm would be represented by a number such as 1.5", and this would be the design storm. The designer would then select a system of practices that infiltrate, evapotranspire or harvest and reuse this volume. Methods and data used to estimate the 95th percentile event are discussed in Part II of this document.

This approach has been selected because it directly addresses the statutory requirements to restore and maintain predevelopment hydrology for duration, rate and volume of stormwater flows. The 95th percentile storm event was selected because this storm size approximates the predevelopment hydrologic conditions, i.e., only large storms typically generate runoff. In addition, this approach was selected because it employs natural treatment and flow attenuation methods that are presumed to have existed on the site prior to human disturbance. Because this approach necessitates the use of practices that generally preclude extended detention, it will also typically address the issue of maintaining predevelopment temperatures. However, in cases where there are discharges to cool water streams or other sensitive receiving waters, additional care should be taken to ensure that stormwater discharges do not result in thermal impacts (Schueler and Helfrich, 1988).

One hundred percent (100%) of the volume of water from storms less than or equal to the 95th percentile event shall not be discharged to surface waters except in cases where the discharge of harvested and reused runoff is authorized or allowed to be discharged into sanitary treatment systems such as those owned and operated by a publicly owned treatment works (POTW). For example if runoff is captured for nonpotable uses such as toilet flushing or other uses that are not irrigation related, these waters potentially could be discharged into the sanitary sewer system. Preferred mechanisms for controlling discharges from storms greater than the 95th percentile event shall be through overflow or diversion for the volume that exceeds the 95th percentile

amount. Because standard underdrains typically discharge from smaller storms as well, underdrain designs, if employed, should ensure adequate retention capacity for the 95th percentile event volume. For structures such as roofs and paved surfaces that can increase the temperature of stormwater runoff, materials that minimize temperature increases (e.g., concrete vs. asphalt; vegetated roofs) should be considered and used as appropriate.

Table 2. Example 95th Percentile Storm Events for Select U.S. Cities (adapted from Hirschman and Kosco, 2008).

City	95th Percentile Event Rainfall Total (in)	City	95th Percentile Event Rainfall Total (in)
Atlanta, GA	1.8	Kansas City, MO	1.7
Baltimore, MD	1.6	Knoxville, TN	1.5
Boston, MA	1.5	Louisville, KY	1.5
Buffalo, NY	1.1	Minneapolis, MN	1.4
Burlington, VT	1.1	New York, NY	1.7
Charleston, WV	1.2	Salt Lake City, UT	0.8
Coeur D'Alene, ID	0.7	Phoenix, AZ	1.0
Cincinnati, OH	1.5	Portland, OR	1.0
Columbus, OH	1.3	Seattle, WA	1.6
Concord, NH	1.3	Washington, DC	1.7
Denver, CO	1.1		

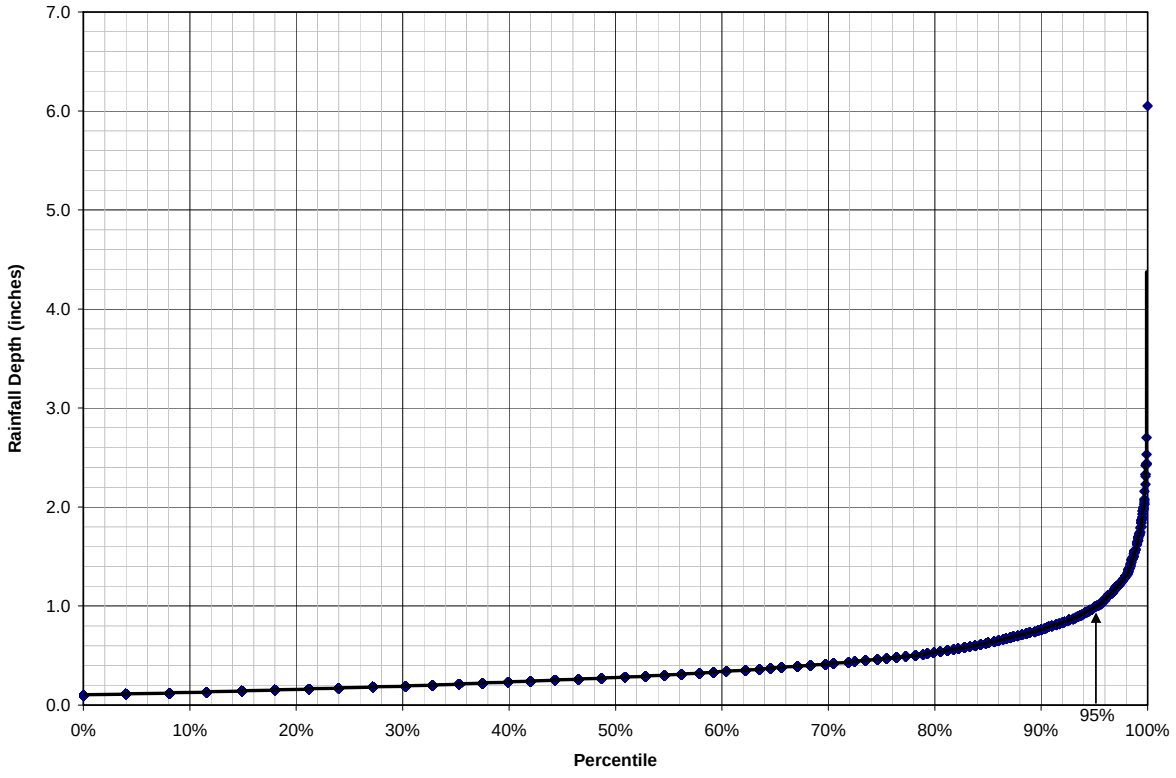

Figure 6. Rainfall Frequency Spectrum showing the 95th percentile rainfall event for Portland, OR (~1.0 inches)

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Calculating the 95th Percentile Rainfall Event
Section F of this guidance contains information on how to calculate the 95th percentile rainfall event for a specific area. A long-term record of daily rainfall amounts (ideally, at least 30 years) is needed to calculate the 95th percentile rainfall.

Option 2: Hydrologic Analysis
Design, construct/implement, and maintain stormwater management practices that preserve the pre-development runoff conditions following construction. The post-construction rate, volume, duration and temperature of runoff shall not exceed the pre-development rates and the predevelopment hydrograph for 1, 2, 10, 25, 50 and 100 year storms should be replicated through site design and other appropriate practices. These goals shall be accomplished through the use of the infiltration, evapotranspiration, and/or rainwater harvesting and reuse. Defensible and consistent hydrological assessments and modeling methods should be used and documented. Additional discussions of appropriate methodologies to use in assessing and modeling site hydrology have been included in the technical sections of this document.

Exceptions
If options 1 or 2 cannot be met using combinations of approaches that are technically feasible, alternative procedures should be developed and followed to meet the intent of Section 438. For an exception to apply the facility owner/operator must demonstrate why it is not possible to comply with either option 1 or 2. In doing so, the owner/operator should identify the factors that preclude the use of options 1 and 2 and document any of the factors listed below (or others) that are relevant to and prevent the achievement of these two options.

- The conditions on the site preclude the use of infiltration practices due to the presence of shallow bedrock, contaminated soils, near surface groundwater or other factors such as underground facilities or utilities.
- The design of the site precludes the use of soil amendments, plantings of vegetation or other designs that can be used to infiltrate and evapotranspirate runoff.
- Water harvesting and reuse are not practical or possible because the volume of water used for irrigation, toilet flushing, industrial make-up water, wash-waters, etc. is not significant enough to warrant the design and use of water harvesting and reuse systems.
- Modifications to an existing building to manage stormwater to meet options 1 or 2 are not feasible due to structural or plumbing constraints or other factors as identified by the facility owner/operator.

An exception may also be granted if it is determined that compliance with the Section 438 requirements would result in the retention and or use of stormwater on the site such that an adverse water balance impact may occur to either or both the receiving surface waterbody or groundwater.

In cases where the facility has a defensible exception and can provide adequate documentation of site conditions or other factors that preclude compliance with options 1 or 2, stormwater practices must be designed, built and maintained to infiltrate, evapotranspire and/or harvest and use the maximum amount of stormwater technically feasible. The difference between this

volume and the 95th percentile rainfall event volume must be treated, as necessary, to ensure no increase in receiving stream temperature and no increase in the peak runoff rates of stormwater leaving the site such that no adverse effects to channel stability occur.

Each Agency or Department is responsible for ensuring compliance with Section 438. The final design and as-built drawings of each facility shall be reviewed by a registered professional engineer. The Agency or Department shall develop and maintain documentation of the following design criteria:

- Site evaluation and soils analysis
- Calculations for the 95th percentile rainfall event or the pre-development runoff volumes and rates to identify the volume of stormwater requiring management
- The site design and stormwater management practices employed on the site
- Design calculations for each stormwater management practice employed
- The respective volume of stormwater managed by each practice
- Operations and maintenance protocols for the stormwater management system

The submitted documentation shall provide the necessary detail to demonstrate compliance and operation of stormwater management practices for the entire site.

Determination of Maximum Extent Technically Feasible

Compliance with Section 438 requires that stormwater management measures are implemented to the maximum extent technically feasible (METF) to maintain or restore the pre-development hydrology conditions specifically with respect to temperature, rate, volume, and duration of flow. To meet these performance requirements stormwater control practices that are effective in reducing the volume of stormwater discharge must be used. To meet the intent of the statute, the Federal facility must use all known, available and reasonable methods of stormwater retention and/or reuse to prevent the off site discharge of stormwater runoff consistent with the performance standard. In cases when a facility seeks or claims an exception, it is expected that there will be a serious and documented attempt to comply.

For projects where an exemption from the Section 438 requirements is necessary due to technical infeasibility, the designer must document and quantify, to the satisfaction of the agency or department, that the processes of infiltration, evapotranspiration, and harvesting and reuse have been used to the METF, and that full employment of these types of controls are infeasible due to site constraints. Documentation should include, but may not be limited to, engineering calculations, geologic reports, hydrologic analyses, and site maps. A determination that the performance requirements specified in options 1 and 2 cannot be met on site must include analyses that rule out the use of an adequate combination of infiltration, evapotranspiration, and reuse measures. Examples of where site conditions may prevent the full employment of appropriate management techniques include a combination of: small project sites where the lot is too small to accommodate infiltration practices adequately sized to infiltrate the volume of runoff from impervious surfaces, soils that cannot be sufficiently amended to provide for the requisite infiltration rates, situations where site use is inconsistent with the capture and reuse of stormwater or other physical conditions on site that preclude the use of plants for

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evapotranspiration or bioinfiltration. Note that a single one of these characteristics is very unlikely to preclude meeting the performance standard, but a combination of factors may.

D. APPLICABILITY AND DEFINITIONS

Applicability

1. Who is a **"Sponsor"** of a project?

Section 438 applies to the "**sponsor** of any development or redevelopment project involving a Federal facility . . . ." Section 438 requires that the "sponsor . . . shall use . . . strategies for the property to maintain or restore . . . the predevelopment hydrology. . . ." The "sponsor" should generally be regarded as the Federal department or agency that owns, operates, occupies or is the primary user of the facility and has initiated the development or redevelopment project. If the Federal agency hires another entity to perform activities such as site construction or maintenance, the agency should nonetheless be regarded as the sponsor and be responsible to assure compliance with the requirements of Section 438. Within this legal context, the agency is free to contract out various duties and responsibilities that are associated with achieving compliance.

2. What is a "**Federal facility**?

Section 438 provides that its requirements apply to the "sponsor of any development or redevelopment project involving a **Federal facility** . . . **."** Section 401(8) of EISA states: "The term `Federal facility' means any building and lands associated with a development or redevelopment project that are constructed, renovated, leased, or purchased in part or in whole for use by the Federal Government."

3. What is a **"footprint**"?

Section 438 provides that its requirements apply to a "federal facility with a **footprint** that exceeds 5000 square feet". Consistent with the purpose of Section 438 to preserve or restore predevelopment hydrology, the term "footprint" includes all hard surfaces that are constructed as part of the facility, including the building, foundations, access roads, fire lanes, driveways, alleys, walkways, sidewalks, patios, decks, and porches. In addition, consistent with the purpose of Section 438, "footprint" also includes other areas that have been disturbed and modified in a manner that changes the infiltrative and evapotranspirative characteristics of the landscape so that the hydrologic regime of the site is altered, e.g., soil compaction, tree cutting and paving with impervious materials.

4. What is "**the property**"?

Section 438 provides that the project sponsor "shall use site planning, design, construction, and maintenance strategies for the **property** to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the **property".** This clause has been interpreted to mean that the entire site is available to implement the appropriate green

infrastructure practices necessary to ensure that the site as a whole functions hydrologically in a manner equivalent to the pre-development (i.e., natural condition) hydrology of the site.

Definitions

95th percentile rainfall event. A rainfall event that is greater than 95% of all rainfall events over a period of record (this period of record should typically be > 30 years unless such data do not exist), **excluding small rainfall events that are 0.1 of an inch or less**. Note: Small rainfall events less than 0.1 of an inch or less have been excluded from this analysis because in general this volume does not result in any measureable runoff due to absorption, interception and evaporation by permeable, impermeable and vegetated surfaces.

Federal facility. The term federal facility means any building and associated land areas that are constructed, renovated, leased, or purchased in part or in whole for use by the Federal Government as defined in §410(8) of the Energy Independence and Security Act.

Development or re-development. For the purposes of this provision this term applies to any action that results in the alteration of the landscape, e.g., grading, construction of buildings and hardscapes, removal of vegetation, soil compaction, etc. such that the changes affect runoff volumes, rates and velocities and infiltration and evapotranspiration patterns. To further clarify the applicability of this requirement, the development or re-development footprint of the project includes all areas physically disturbed by the project activities and does not just include the typical "footprint" or foundation area of the structures and buildings. Examples of projects that would fall under this definition include parking lots or structures that are being reconstructed or replaced. Typical patching or superficial resurfacing of parking lots or other travel areas would not fall under this requirement.

Pre-development hydrology. The predevelopment hydrologic condition of the site is the combination of runoff, infiltration and evapotranspiration rates and volumes that typically existed on the site before human induced land disturbance occurred. In practice, determining the predevelopment hydrology of a given site can be difficult if development has already occurred or there is no suitable reference site. As a result, reference conditions for typical land cover types in the locality often are used to approximate what fraction of the precipitation ran off, soaked into the ground or was evaporated from the landscape. The use of reference conditions can be problematic if suitable data are not available or unique site conditions exist that do not fit within a typical land use cover type for the area, e.g., meadow or forest. The intent of Section 438 is not to restore the site to pre-Columbian conditions, but to develop or redevelop the site to ensure that there is a stable hydrologic regime that protects groundwater and surface waters. It should also be emphasized that the performance based approach in Option 1 is intended to be a surrogate for determining the predevelopment reference condition and this standard can be used in cases where it is difficult or infeasible to identify the relevant reference conditions for the site.

E. COMPLYING WITH THE PERFORMANCE REQUIREMENT

Controlling 100 percent of all rainfall events equal to or less than the 95th percentile rainfall event was selected as the first compliance option because small, frequently-occurring storms account for a large proportion of the annual precipitation volume, and the runoff from those storm events also significantly alters discharge frequency, rate and temperature.



Figure 7. Bioretention facility in Oregon.

The runoff produced by these small storms and the initial portion of larger storms, has a strong negative cumulative impact on receiving water hydrology and water quality. In areas that have been developed, runoff is generated from almost all storms, both small and large, due to the impervious surfaces associated with development and the loss of soils and vegetation. In contrast, natural or undeveloped areas discharge little or no runoff from small storms because the rain is absorbed by the landscape and vegetation. Studies have shown that increases in runoff event frequency, volume and rate can be diminished or eliminated through the use of green infrastructure designs and practices, which infiltrate, evapotranspire and capture and use stormwater.

This option was selected because it is a straightforward approach to meet the intent of Section 438 in contrast to Option 2 which requires the designer to conduct a detailed hydrologic analysis of the site and model potential outcomes based on site specific conditions.

Designers opting to use Option 1 would need to do the following:

1) calculate or verify the precipitation amount from the 95th percentile storm event (this number would be typically expressed in inches, e.g., 1.5", and

2) Employ on-site stormwater management controls that infiltrate, evapotranspire or harvest and use the appropriate design volume.

The 95th percentile event can be calculated by using the following procedures below (summarized from Hirschman and Kosco, 2008, *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program*, Center for Watershed Protection):

- Obtain a long-term rainfall record from a nearby weather station (daily precipitation is fine, but try to obtain at least 30 years of daily record). Long-term rainfall records can be obtained from many sources, including NOAA at www.nesdis.noaa.gov

- Remove data for small rainfall events that are 0.1 inch or less and snowfall events that do not immediately melt from the data set. These events should be deleted since they do not typically cause runoff and could potentially cause the analyses of the 95th percentile storm runoff volume to be inaccurate.
- Using a spreadsheet or simple statistical package, sort the rainfall events from highest to lowest. In the next column, calculate the percentage of rainfall events that are less than each ranked event (event number/total number of events). For example, if there were 1,000 rainfall events and the highest rainfall event was a 4" event, then 999 events (or a percentile of 999/1000, or 99.9%) are less the 4" rainfall event.
- Use the rainfall event at 95% as the 95th percentile storm event.

Option 2 allows the designer to conduct a full hydrologic analysis to determine the pre-development runoff conditions instead of using the estimated volume approach of Option 1. If the designer elects to use Option 2, the designer would then identify and model appropriate land uses for the pre-development condition of the site and quantify that the post-development runoff volume and peak flow discharges are equivalent to pre-development conditions.

Common Practices to Comply with Section 438

Although Congress did not prescribe specific practices to be used to comply with Section 438 it can be inferred that one of the goals of the Act was to promote the use of innovative stormwater management approaches, designs and practices that better protect receiving water quality, flow regimes and provide other important environmental benefits. Green infrastructure practices are preferred practices, to be supplemented with or replaced with conventional controls when site specific conditions dictate.

The green infrastructure management approaches and technologies that Federal agencies would typically use enhance and/or mimic the natural hydrologic cycle processes of infiltration, evapotranspiration, and reuse. Green infrastructure approaches include biological systems and engineered systems. These include but are not necessarily limited to:

- Green roofs
- Trees and tree boxes
- Rain gardens, bioretention, and infiltration planters
- Vegetated swales and bioswales
- Pocket wetlands
- Permeable pavements
- Reforestation/revegetation
- Protection and enhancement of riparian buffers and floodplains
- Rainwater harvesting for reuse (e.g., irrigation, HVAC make-up, non-potable indoor uses).

Green infrastructure practices were selected to achieve the intent of the Act for the following reasons:

- cost effectiveness
- overall environmental performance

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- pollutant loading reduction capability
- pollution prevention focused
- effectiveness in managing runoff volumes and rates
- energy efficient and energy conservative
- appropriate in a wide range of site condition and locations
- appropriate for new development and redevelopment projects
- appropriate at multiple scales of development, e.g., site, neighborhood, region

For more information on specific green infrastructure practices and how they function, visit: http://www.epa.gov/greeninfrastructure and www.epa.gov/nps/lid.



Figure 8. Disconnect downspout discharging to planter box.

Cost of Compliance

The cost of complying with Section 438 may require the use of approaches and techniques that initially may be more costly to design and implement. It is anticipated that as the expertise of the implementing agency or department increases and the demand for green infrastructure materials and equipment increases that the overall costs of the projects will be lower or equivalent to the costs of constructing conventional stormwater practices. Initial studies conducted by EPA and others suggest that the use of green infrastructure practices can be cost competitive. Recent evaluations of green infrastructure projects have identified opportunities for cost savings because of reduced infrastructure and site preparation demands. In addition, longer term studies have indicated that green infrastructure practices are continuing to gain cost efficiency as they are adopted more widely and with greater frequency thus reducing overall implementation costs.

In *Reducing Stormwater Costs through LID Strategies and Practices* (EPA 841-F-07-006, December 2007 - available for download at www.epa.gov/nps/lid), EPA examined 17 case studies in which conventional development costs were compared to green infrastructure costs. In the great majority of cases, the green infrastructure approach was between 15 and 80 percent cheaper and in some cases significantly they were less expensive because the incremental costs of implementing green infrastructure practices were more than offset by the cost reductions achieved by their use and management. Significant cost savings that were identified in the report include:

- Elimination or reduction of detention ponds
- Elimination or reductions of stormwater and CSO treatment and conveyance systems such as pipes, storage structures, stormwater treatment devices, and other related stormwater infrastructure

- Narrower streets with reduced material demands
- Fewer square yards of sidewalks
- Reduced land purchases for stormwater control structures

In addition, other benefits were achieved through the use of green infrastructure such as more beneficial uses of land previously dedicated to stormwater devices, increased livability and higher property values.

F. CALCULATING THE 95TH PERCENTILE RAINFALL EVENT

A long period of precipitation records, i.e., a minimum of 10 years of data, is needed to determine the 95th percentile rainfall event for a location. Thirty years or more of monitoring data are desirable to process an unbiased statistical analysis. The National Climatic Data Center (NCDC) provides long-term precipitation data for many locations of the United States. You can download climate data from their website (http://www.ncdc.noaa.gov) or by ordering compact discs (NOTE: The NCDC charges a fee for access to their precipitation data). Local airports, universities, water treatment plants, or other facilities might also maintain long-term precipitation records. Data reporting formats can vary based on the data sources. In general, each record should include the following basic information:

- Location (monitoring station)
- Recording time (usually the starting time of a time-step)
- Total precipitation depth during the time-step

In addition to the above information, a status flag is sometimes included to indicate data monitoring errors or anomalies. Typical NCDC flags include A (end accumulation), M (missing data), D (deleted data), or I (incomplete data). If there are no flags, the record has passed the quality control as prescribed by the NCDC and has been determined to be a valid data point.

There are several steps of data processing to determine the 95th percentile rainfall event using a spreadsheet. These steps are summarized below:

1. Obtain a long-term 24-hr precipitation data set for a location of interest (i.e., from the NCDC website).

2. Import the data into a spreadsheet. [Data / Import External Data / Import Data]

3. Rearrange all of the precipitation records into one column if the original data set has multiple columns of precipitation records.

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	A	B	C	D
1	Date	Prcp		
2	1/2/1921	0.05		
3	1/3/1921	0		
4	1/4/1921	0		
5	1/5/1921	0.33		
6	1/6/1921	0.08		
7	1/7/1921	0.08		
8	1/8/1921	0.19		
9	1/9/1921	0		

4. Review the records to identify if there are early periods with a large number of flagged data points (e.g., erroneous data points). Select a long period of good recording data that represents, ideally, 30 years or more of data. Remove all of the extra data (if not using the entire dataset).

5. Remove all flagged data points (i.e., erroneous data points) from the selected data set for further analysis.

6. Remove small rainfall events (typically less than 0.1 inches), which may not contribute to rainfall runoff. These small events are categorized as depressional storage, which, in general, does not produce runoff from most sites.

	A	B	C	D
1	Date	Prcp		
2	1/5/1921	0.33		
3	1/8/1921	0.19		
4	1/14/1921	1.04		
5	2/6/1921	0.12		
6	2/11/1921	0.63		
7	2/20/1921	1.33		
8	2/28/1921	0.43		
9	3/3/1921	0.13		

Note: Steps 4 through 6 can be processed by applying data sort, delete and re-sort spreadsheet functions. [Data / Sort]

7. Calculate the 95th percentile rainfall amount by applying the PERCENTILE spreadsheet function at a cell: [=PERCENTILE(precipitation data range,95%)]

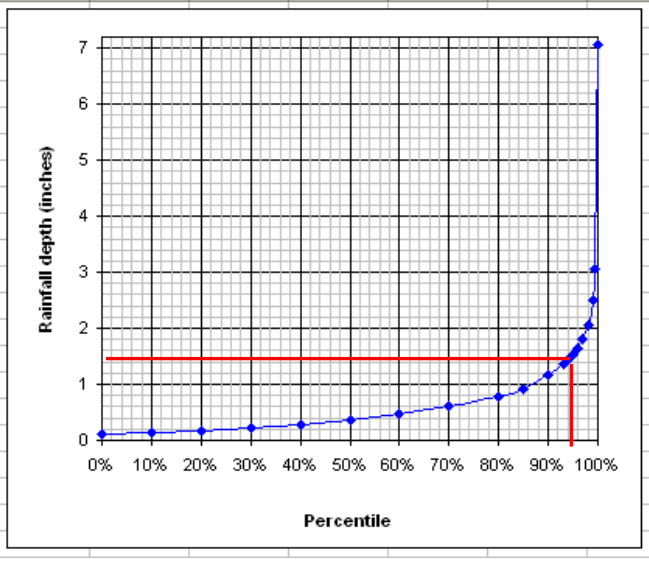
	A	B	C	D	E	F
1	Date	Prcp				
2	1/5/1921	0.33		=PERCENTILE(B:B,95%)		
3	1/8/1921	0.19		1.52		
4	1/14/1921	1.04				
5	2/6/1921	0.12				
6	2/11/1921	0.63				
7	2/20/1921	1.33				
8	2/28/1921	0.43				

Note: The PERCENTILE function returns the nth percentile of value in the entire precipitation data range. We can use this function to decide the 95th percentile storm event that captures all but the largest 5% of storms.

8. The 95th percentile rainfall event can also be determined graphically. Derive a table showing percentile versus rainfall depth to draw a curve shown as shown below. The PERCENTILE spreadsheet function can be used for each selected percent. It is recommended to include at least 6 points between 0% and 100% (several points should be between 80% and 100% to draw an accurate curve).

	A	B	C	D	E	F	G
1	Date	Prcp		Percentile	Rainfall		
2	1/5/1921	0.33		0%	=PERCENTILE(B:B,D2)		
3	1/8/1921	0.19		10%	=PERCENTILE(B:B,D3)		
4	1/14/1921	1.04		20%	=PERCENTILE(B:B,D4)		
5	2/6/1921	0.12		30%	=PERCENTILE(B:B,D5)		
6	2/11/1921	0.63		40%	=PERCENTILE(B:B,D6)		

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date	Prcp		Percentile	Rainfall							
2	1/5/1921	0.33		0%	0.1							
3	1/8/1921	0.19		10%	0.13							
4	1/14/1921	1.04		20%	0.17							
5	2/6/1921	0.12		30%	0.22							
6	2/11/1921	0.63		40%	0.28							
7	2/20/1921	1.33		50%	0.36							
8	2/28/1921	0.43		60%	0.46							
9	3/3/1921	0.13		70%	0.6							
10	3/9/1921	0.31		80%	0.79							
11	3/13/1921	0.46		85%	0.93							
12	3/25/1921	0.47		90%	1.16							
13	3/28/1921	0.12		93%	1.35							
14	4/1/1921	0.36		94%	1.44							
15	4/9/1921	0.69		95%	1.52							
16	4/15/1921	0.24		96%	1.65							
17	4/17/1921	0.32		97%	1.82							
18	4/18/1921	0.55		98%	2.068							
19	4/23/1921	0.69		99%	2.508							
20	4/24/1921	0.19		99.5%	3.049							
21	4/30/1921	1.44		100%	7.06							



Use the spreadsheet software to create of plot of rainfall depth versus percentile, as shown above. The 95th percentile storm event should correlate to the rainfall depth calculated in step 7, however the graph can be used to calculate rainfall depths at other percentiles (e.g., 50%, 90%).

Part II: Case Studies on Capturing the 95th Percentile Storm Using Onsite Management Practices

INTRODUCTION

This section contains eight case studies that are intended to be representative of the range of projects that are subject to the requirements legislated in Section 438 of the Energy Independence and Security Act. The facility examples in the case studies were selected to illustrate project scenarios for differing geographic locations, site conditions, and project sizes and types. As noted in Part I, all projects with a footprint greater than 5,000 square feet must comply with the provisions of Section 438. This means that both new development and redevelopment projects must be designed to infiltrate, evapotranspirate, and/or harvest and reuse runoff to the maximum extent technically feasible (METF) to maintain or restore the pre-development hydrology of the site. In this guidance, METF has been interpreted to mean the onsite control and management of all storms up to and including the 95th percentile storm event.

Given the site-specific nature of individual projects, the case study scenarios described herein do not include site specific design features such as runoff routing, specific site infiltration rates, the structural loading capacity of buildings, etc. in terms of stormwater practice selection.

It should be noted that an example of Option 2, which requires a detailed hydrologic analysis, has not been provided in this document because of the complexity of factors and the lack of general applicability such an analysis would have.

Background

Numerous approaches exist for determining the volume of runoff to be treated through stormwater management. Controlling stormwater runoff from all events up to and including the 95th percentile rainfall event was selected as Option 1 because small, frequently-occurring storms account for a large proportion of the annual precipitation volume. Using green infrastructure practices to control both the runoff produced by small storms and the first part of larger storms can reduce the cumulative impacts of altered flow regimes on receiving water hydrology, e.g., channel degradation and diminished baseflow. For the purposes of this guidance, control of all storms up to and including the 95th percentile storm event is analogous to maintaining or restoring the predevelopment hydrology with respect to the volume, flow rate, duration and temperature of the runoff for most sites.

Determination of the 95th Percentile Rainfall Event

The 95th percentile rainfall rainfall event was determined using the long-term daily precipitation records from the National Climate Data Center (NCDC, 2007). By analyzing the frequency and rainfall depths from daily rainfall records over 24-hour periods, the 95th percentile storm event can be determined. From a frequency analysis viewpoint, the 95th percentile event is the storm event that is greater than or equal to 95% of all storms that occur within a given period of time. Regional climate conditions and precipitation vary across the U.S. Because of local values, it is essential that the implementing agency or department establish the 95th percentile storm event for

the project site since the control volume may vary depending on local weather patterns and conditions.

Onsite Stormwater Management Practice Determinations

For the purposes of the case study scenarios, the following four categories of practices were selected as the most appropriate practices for implementing Section 438 requirements: bioretention, permeable pavements and pavers, cisterns, and green roofs. These practices were selected based on known performance data and cost. For each case study, the same hierarchy of selection criteria was used, i.e., the most cost effective practices were considered before other practices were considered. Bioretention practices were considered first because these systems generally have the lowest cost per unit of stormwater treated (Hathaway and Hunt, 2007). Thus, if the bioretention system could not be designed to adequately capture the desired runoff volume, permeable pavement and pavers, cisterns, and green roofs were considered in that order based on relative cost. In most cases a combination of practices was selected as part of an integrated treatment system. It should be noted that all treatment systems were designed to accomplish the goal of capturing the 95th percentile rainfall event onsite. Examples of onsite stormwater management practices selected for each site are presented in the results section. For the Boston, MA site, it was assumed that bioretention was not feasible in order to simulate a situation where space was severely limited; as a result, interlocking modular pavers were selected as the most cost effective stormwater management to capture the requisite design volume. To further illustrate the range of site conditions designers may encounter, and how site conditions impact the selection of appropriate control options, Scenario #3 (Cincinnati, OH) was re-analyzed as Scenario #8. In Scenario #8, it was assumed that the site had clay soils and low infiltrative capacity. Given these site conditions, the range of potential control options was more limited and a combination of modular paving blocks, a green roof, and cisterns was ultimately selected based on cost and site suitability factors.

For purposes of these modeling exercises, a number of assumptions were associated with each category of practice. These assumptions are not necessarily an endorsement of a particular design paradigm, but rather to keep a somewhat conservative cap on the scenarios in order to demonstrate feasibility of the approach. For example, bioretention retrofits can and should often be located in prior impervious locations; however, in all modeled scenarios bioretention was restricted to currently landscaped areas. The assumptions were:

- **Bioretention areas**: It is assumed bioretention practices would be installed within currently landscaped pervious areas or that pervious areas would be created for bioretention cells. While termed bioretention, these systems are designed to provide infiltration as well as temporary storage. Bioretention areas would be designed to store up to 10 inches of runoff depth from contributing areas (see Appendix A). The conceptual design of this storage depth would occur within the media and/or could be included as ponded storage. Further design storage beyond the 10 inches would be acceptable (and encouraged) above the media on a site by site basis with ponded depth generally not to exceed 12 inches.

  Uniform infiltration was assumed across the entire base of the bioretention cell. No additional media underneath the amended soils were included in the designs with

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infiltration rates in this layer governed by the *in situ* soils. Underdrains were not modeled directly but could be applied at the point of storage overflow (at a design depth of 10 inches). This approach was selected to maximize infiltration benefits of these systems. The intent was to provide maximum storage and opportunities for infiltration processes over a pass-through or filtration system which can occur when using an underdrain at the base of the bioretention cell. Because standard underdrains typically discharge from smaller storms as well, underdrain designs, if employed, should ensure adequate retention capacity for the 95th percentile event volume.

The bioretention footprint for modeling purposes was calculated as one uniform area that did not include side slopes. There is an expectation that actual bioretention cell construction would be distributed throughout the site with targeted locations based on hydrology (natural flow paths) and soils with greater infiltrative capacity. Side slopes may increase the surface excavation area required to accommodate the footprint and freeboard of these systems depending on the design or the bioretention system.

- **Porous pavement**: Infiltration was modeled for the entire porous pavement area with drainage pipes used only as overflow outlets. This design was chosen to maximize infiltration capabilities of the system. While many types of porous pavement systems are can be used, modular block type pavers were generally applied in this design category under the assumption that they typically include sufficient volumetric storage in the media layer. Depending on design, other types of porous pavement applications can include similar volumetric storage with equal or improved load bearing benefits.

  For these systems, an equivalent of 2 inches of design storage depth was assumed. This design depth could be achieved by specifying 10 inches of media depth that had 20% void space. Similarly, this could be achieved by designing six inches of media depth above the bottom surface, with specified media containing 33% void space. This alternative would have the overflow outlet at the six inch depth providing an equivalent water storage depth of 2 inches.

  The soils under the paver blocks may require or be subjected to some compaction for engineering stability. As a result, infiltration into underlying soils was modeled conservatively by applying the minimum infiltration rate for each soil type (see Appendix A).

  Generally, porous pavement is not recommended for high traffic areas or loading bays. Because of this the scenarios assumed that only a percentage of total parking and road areas on a site can be converted to porous pavement. The assumed maximum percentage applied in the scenarios was set at 60% of the total paved area.

- **Cistern**: Cisterns were modeled in cases where green roofs were not feasible or where it was necessary to include additional storage volume to meet the goal of on site rainfall runoff capture. The sizes of cisterns would be calculated by site-specific rainfall, site specific spatial and structural conditions, use opportunities and rates, and consideration of cost per volume of storage. For simplicity, cistern volume was reported as a total

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volume. This total volume could be subdivided into any number of cisterns to provide the total necessary storage but should be relative to the impervious area and runoff quantities which will flow to the cistern. Consideration of the most efficient cost per volume storage would need to be considered on a site by site basis (see Appendix A).

- **Green roof**: Frequently, green rooftop area is limited by structural capacity. In addition, other rooftop equipment may need to be accommodated in this space including HVAC systems and air handlers. For this reason, and to provide a somewhat conservative rate of application, it was assumed for these modeling analyses that up to 30% of a roof's impervious area could be converted into a green roof. Green roof area was assumed to have 1 inch of total effective stormwater storage, i.e., a 2.5 inch media depth with 40% void space (see Appendix A).

General Approach

Using site aerial photos, spatial analysis should be conducted to estimate the land cover types and areas for each site. The surface conditions of each site can be digitized using GIS techniques. Alternatively, CAD drawings can be used to estimate the surface area of each land cover type. The schematic in Figure 9 illustrates the processes used for selecting and determining the overall size of stormwater management practices for each site.

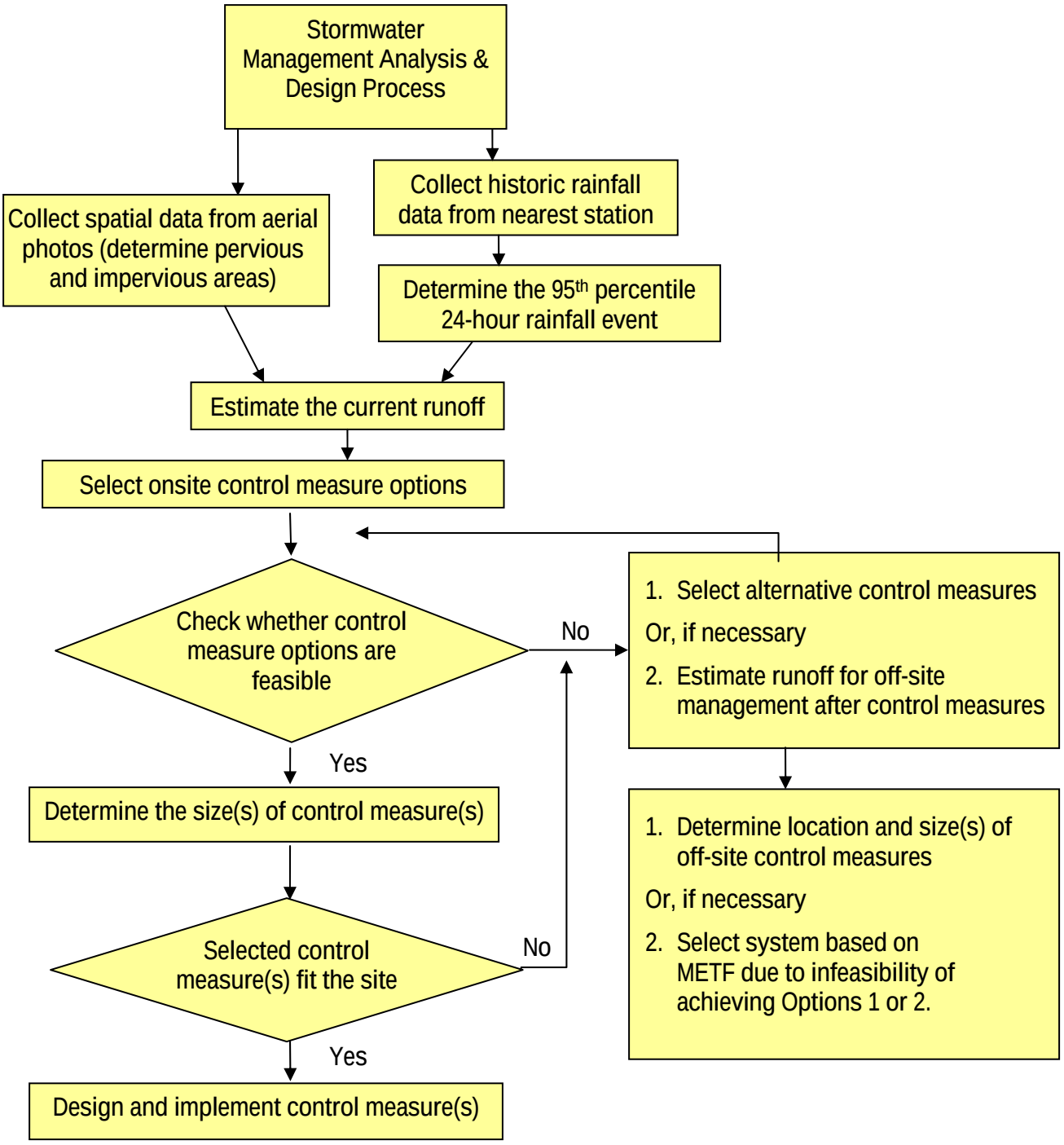

Figure 9. Flow chart depicting the process for determining control measures using the 95th percentile, 24-hour, annual rainfall event.

The following steps provide more detailed information on acquiring and calculating the necessary data to complete the processes indicated in Figure 9. This methodology was used in the scenario analyses that follow.

Collecting spatial data for a site

1. Collect an aerial orthophotograph for the desired site.
2. Digitize land use/land cover conditions using GIS techniques. If CAD drawings of the site exist, they can be used to estimate land cover area (pervious, impervious).
3. Categorize the digitized or planned land use/land cover based on surface hydrologic conditions, e.g., rooftop, pavement, and pervious/landscaped area.
4. Estimate the size of each land use/land cover category (polygon).

Determining the 95th percentile, 24-hr rainfall event

1. Obtain a long-term 24-hr precipitation data set for the location of interest (i.e., from the NCDC website or other source)
2. Import the data into a spreadsheet. *In MS Excel* [Data / Import External Data / Import Data]
3. Rearrange all of the precipitation records into one column if the original data set has multiple columns of precipitation records
4. Remove all flagged data points (i.e., erroneous data points) from the selected data set for further analysis
5. Remove small rainfall events (typically less than 0.1 inches) that may not contribute to rainfall runoff. These small storms often produce little if any appreciable runoff from most sites and for modeling purposes are typically considered as volume captured in surface depression storage.
6. Calculate the 95th percentile rainfall volume by applying the PERCENTILE spreadsheet function at a cell. The PERCENTILE function returns the nth percentile value in the entire precipitation data range. This function can be used to determine the 95th percentile storm event that captures all but the largest 5% of storms. *In MS Excel* [PERCENTILE(precipitation data range,95%)]

Placing onsite control measures to capture the 95th percentile rainfall event

1. Collect spatial data for a site, e.g., rooftop, pavement, and pervious areas as above.
2. Check soil type (USDA mapping, borings, or on-site testing) for the site to determine infiltration parameters. For this modeling, many of the assumptions that pertain to generalized soils groups and their infiltration properties come from the EPA Stormwater Management Model (SWMM 4.x) manual (see Appendix A).
3. Determine the current runoff volume that would occur during a 24 hour period by applying the 95th percentile rainfall to the existing site conditions (land use and soil properties) as above using a hydrologic model (such as TR-55 or SWMM). For this analysis, it is assumed that the rainfall amount is distributed over a 24 hour period. Actual rainfall event duration (and intensity) was not considered for rainfall runoff (however, timing was considered when modeling infiltration).
4. Determine flow paths so that management practices placements are in locations where flows can be intercepted and routed to practices (Note: This step was not included in the scenario exercises). Because this is a site specific effort and may require detailed topographic information or further surveys this would be a task to be completed onsite and therefore is not included as a part of the modeling scenario effort.

5. Select onsite control practices to capture the current 95th percentile runoff event; base the selection of appropriate options on site conditions, areas available for treatment options, and other factors such as use and other constraints.

Note: The steps above have been generalized for the purposes of this guidance. It is recommended that a qualified professional engineer determine or verify that stormwater management practices are sized, placed, and designed correctly. It should also be noted that the methodology to determine rainfall amount was subject to a 24 hour time period based on daily records. Actual rainfall events may have been shorter or longer time periods. Similarly, for modeling purposes, the 24 hour rainfall amount was distributed to pervious and impervious areas (and management practices) as a uniform event occurring during a 24-hour period. A large dataset (greater than 50 years) was used to reasonably represent rainfall depth not necessarily rain event depth. It stands to reason that more frequent, shorter duration precipitation events are better represented than less frequent, longer duration precipitation events.

Modeling Scenarios

Seven locations were selected for the 8 case studies as shown in Figure 10 and Table 3. Case study numbers 3 and 8 were both developed based on the Cincinnati, Ohio facility, although the site parameters were altered to represent differing site conditions and design constraints. Annual average rainfall depths for these locations range from 7.5 inches to 48.9 inches. Analyses of the 95th percentile rainfall events for these locations produced rainfall depths that range from 1.00 inch to 1.77 inches (Table 3).

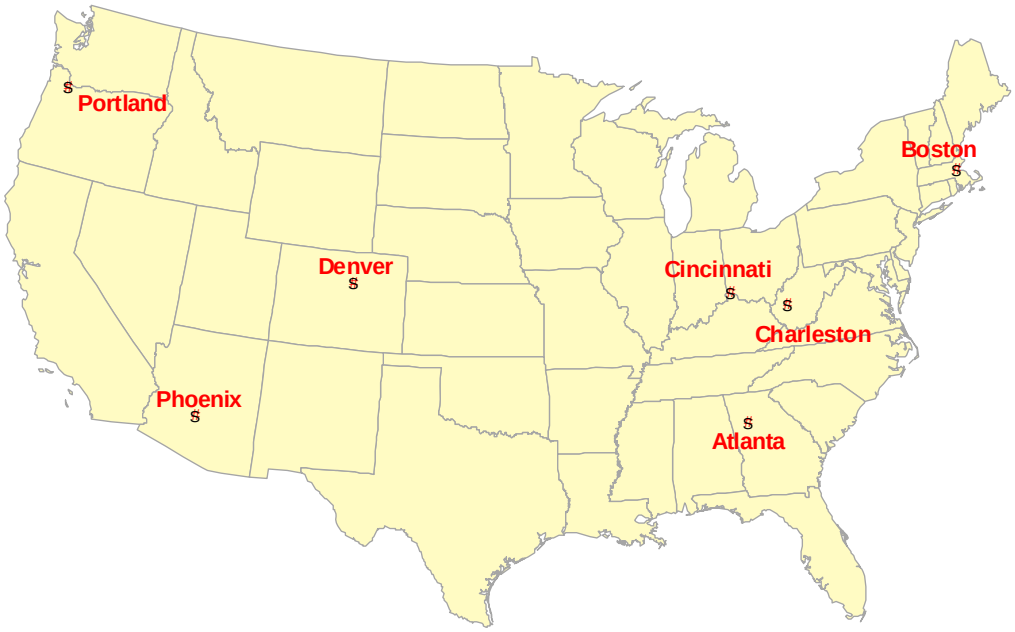

Figure 10. Locations for Analyzing Onsite Control Measures.

The government facilities in the 8 case studies were selected because they represent generic sites from the major climatic regions of the U.S. These facilities also were selected because the sites

have a range of site characteristics that can be used to illustrate different site designs and stormwater management options, e.g., pervious, roof, and pavement areas (Table 4). Site sizes ranged from 0.7 to 27 acres with percent site imperviousness area ranging from 47% to 95% of the site. Aerial photos of the sites are included along with site specific rainfall runoff and soil results.

Table 3. Summary of Rainfall Data for the Seven Locations.

No	Location	NCDC Daily Precipitation Data		Rainfall Depth (inches)	
		Period of record	Coverage	Annual average	95th percentile rainfall event
1	Charleston, WV	1/1/1948 - 12/31/2006 (59 yrs)	99%	43.0	1.23
2	Denver, CO	1/1/1948 - 12/31/2006 (59 yrs)	96%	15.2	1.07
3	Cincinnati, OH	1/1/1948 - 12/31/2006 (59 yrs)	96%	36.5	1.45
4	Portland, OR	1/1/1941 - 12/31/2006 (66 yrs)	98%	35.8	1.00
5	Phoenix, AZ	1/1/1948 - 12/31/2006 (59 yrs)	99%	7.5	1.00
6	Boston, MA	1/1/1920 - 12/31/2006 (87 yrs)	99%	41.9	1.52
7	Atlanta, GA	1/1/1930 - 12/31/2006 (77 yrs)	100%	48.9	1.77

The results of the spatial analyses were summarized and divided into three land cover categories; rooftop, pavement, and pervious area, as shown in Table 4.

Table 4. Summary of Land-use Determinations of the Study Sites.

No	Location	Facility Spatial Info (acres)				Site Imperviousness
		Rooftop	Pavement	Pervious	Total	
1	Charleston, WV	0.1	0.4	0.2	0.7	73%
2	Denver, CO	0.5	1.9	2.0	4.5	55%
3	Cincinnati, OH	1.6	8.0	9.4	19	51%
4	Portland, OR	8.8	16.9	1.3	27	95%
5	Phoenix, AZ	0.2	0.7	1.1	2	47%
6	Boston, MA	0.9	1.5	1.1	3.5	69%
7	Atlanta, GA	3.9	10.8	6.2	21	70%

Methods for Determining Runoff Volume

Direct Determination of Runoff Volume

Runoff from each land cover was estimated using a simplified volumetric approach based on the following equation:

$$Runoff = Rainfall - Depression\ Storage - Infiltration\ Loss$$

Again, this methodology does not consider routing of runoff; therefore slope is not considered when calculating on a volumetric basis.

Infiltration loss is calculated only in pervious areas (e.g., there is no infiltration in impervious areas). In this analysis, infiltration was estimated using Horton's equation:

$$f = f_{min} + (f_{max} - f_{min})\, e^{-k\,t}$$

where, f = infiltration rate at time t (in/hr)
f_{min} = minimum or saturated infiltration rate (in/hr)
f_{max} = maximum or initial infiltration rate (in/hr)
k = infiltration rate decay factor (/hr) and
t = time (hr)

Infiltration loss for the 24-hr rainfall duration was estimated by the following equation with assumptions of a half hour Δt and uniform rainfall distribution in time:

$$Infiltration\ Loss = \sum (f \cdot \Delta t)$$

To more accurately describe the dynamic process of infiltration associated with Horton's equation, infiltration loss was integrated over a 24-hour period using a half hour time step while applying the maximum and minimum infiltration rates (in/hr) with time using the appropriate soil decay factor. The results of this process are further illustrated in Appendix A.

In cases where sites had limited physical space available for stormwater management, a series of practices was used (e.g., treatment train) to simulate the runoff and infiltrative behavior of the system. For example, if there was inadequate area and infiltrative capacity to infiltrate 100 percent of the 95th percentile storm event within a bioretention system another onsite management practice was selected to manage the runoff that could provide the necessary capacity not available by another treatment system. In this manner, excess runoff was routed to another management practice in the series of treatment cells where possible.

Two types of soils were considered for every site: hydrologic soil group B and C (except for scenario 8 in which hydrologic soil group D was used). Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and either loamy sand or sandy loam textures with some loam, silt loam, silt, or sandy clay loam soil textures placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam soil textures with some clay, silty clay, or sandy clay textures placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (USDA-NRCS, 2007). The application of these hydrologic soil groups was intended to give reasonable and somewhat conservative estimates of infiltration capacity.

General hydrologic parameters in this analysis were assumed as follows (see Appendix A for citations of assumptions):

- Depression storage (or initial abstraction)
    - Rooftop: 0.1 inches
    - Pavement: 0.1 inches
    - Pervious area: 0.2 inches

- Horton Infiltration parameters
    - Hydrologic Soil Group B
        - Maximum infiltration rate: 5 in/hr
        - Minimum infiltration rate: 0.3 in/hr
        - Decay factor: 2 /hr
    - Hydrologic Soil Group C
        - Maximum infiltration rate: 3 in/hr
        - Minimum infiltration rate: 0.1 in/hr
        - Decay factor: 3.5 /hr
- Design storage assumptions of control measures
    - Bioretention: up to 10 inches
    - Green roof: 1 inch (2.5 inches deep media with 40% void space)
    - Porous pavement: 4 inches (10 inches deep media with 40% void space)

Other Modeling Methods for Estimating Runoff Volume

Runoff from a site after applying the 95th percentile storm can be estimated by using a number of empirical, statistical, or mathematical methods. Several methods were considered in this analysis. The Rational Method can be used to estimate peak discharge rates and the Modified Rational Method can be used to develop a runoff hydrograph. The NRCS TR-55 model can be used to predict runoff volume and peak discharge. TR-55 can also be used to develop a runoff hydrograph. The EPA Stormwater Management Model (SWMM) can be used to simulate rainfall-runoff, pollutant build-up and wash-off, transport-storage-treatment of stormwater flow and pollutants, backwater effects, etc. for a wide range of temporal and spatial scales. The SWMM model can be fit to model a small site with a distributed system. Hydrologic Simulation Program – Fortran (HSPF, USDA) is a watershed and land use based lumped model that can be used to compute the movement of water and pollutants when evaluating the effects of land use change, reservoir operations, water quality control options, flow diversions, etc. In general, regionally calibrated modeling parameters are applied into HSPF. QUALHYMO is a complete hydrologic and water quality model, which can be used to factor in snowmelt, soil moisture conditions or to simulate system behavior based on infiltration and ET, groundwater storage tracking, baseflow and deep volumetric losses, and other variables.

Many of the existing tools for analyzing distributed systems use some part or all of the principles or formulae of the modeling approaches highlighted above. For example, the Emoryville spreadsheet control measure model (Emoryville, CA) uses a runoff coefficient (i.e., Rational Method) for analyzing lot-level to neighborhood-scale control measure sizing. The Green Calculator (Center for Neighborhood Technologies) estimates the benefit of onsite green infrastructure options on a neighborhood-scale by applying the curve numbers (i.e., TR-55) and the Modified Rational Method. The Northern Kentucky Spreadsheet Tool uses a TR-55 based approach for control measure sizing on neighborhood or site level spatial scales. The WWHM (Western Washington Hydrology Model) is a regionally calibrated HSPF model intended for use in sizing stormwater detention and water quality facilities to meet the Washington State Department of Ecology standards. WBM-QUALHYMO is a Canadian model used in

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conjunction with the Water Balance Model (WBM). This model can be used to continuously simulate stormwater storage routing, stream erosion, drainage area flow routing, and snowmelt runoff (and ultimately freeze-thaw). Table 5 contains a summary of these different methods based on generic modeling features.

Table 5. Potential Methods for Analyzing Control Measures.

Model Considerations		Rational Method	TR-55	SWMM	Direct Determination	HSPF	QUALHYMO
Temporal scale	Single Event	Yes	Yes	Yes	Yes	Yes	Yes
	Continuous Simulation	No	No	Yes	Possible	Yes	Yes
Spatial scale	Lot-level	Yes	Yes[b]	Yes	Yes	No	No
	Neighborhood	Yes	Yes	Yes	Yes	Possible	Possible
	Regional	Yes	Yes[c]	Yes	No	Yes	Yes
Outputs	Peak Discharge	Yes	Yes	Yes	No	Yes	Yes
	Runoff Volume	Yes	Yes	Yes	Yes	Yes	Yes
	Hydrograph	Yes[a]	Yes	Yes	No	Yes	Yes
	Water Quality	No	No	Yes	Possible	Yes	Yes

[a] Modified Rational Method

[b] No less than 1 acre.

[c] No more than 25 square miles (up to 10 subareas).

From the viewpoint of modeling both lot-level and neighborhood scale projects, the Rational Method, NRCS TR-55, SWMM, and Direct Determination approaches were selected for use in scenario analyses. Strength and weakness of these methods are presented below:

Table 6. Comparison of modeling approaches for determining runoff volume.

Method	Strengths	Weaknesses
Direct Determination	• **Methodology for runoff determination is same as SWMM** • **Models basic hydrologic processes directly (explicit)** • **Simple spreadsheet can be used**	• **Direct application of Horton's method may estimate higher infiltration loss, especially at the beginning of a storm** • **Does not consider flow routing**
Rational Method	• **Method is widely used** • **Simple to use and understand**	• **Cannot directly model storage-oriented onsite control measures**
TR-55	• **Method is widely used** • **Simple to use and understand**	• **May not be appropriate for estimating runoff from small storm events because depression storage is not well accounted for**
SWMM	• **Method is widely used** • **Can provide complete hydrologic and water quality process dynamics in stormwater analysis**	• **Needs a number of site-specific modeling parameters** • **Generally requires more extensive experience and modeling skills**

Each method requires specific modeling parameters for estimating runoff from a site. Runoff coefficients for the Rational Method are assumed to be 0.9 for rooftop and pavement areas, and

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0.1 and 0.135 for Group B and C soil pervious areas, respectively (Caltrans, 2003). The slope of the pervious area was assumed to be an average of 2%. Applying these runoff coefficients for each surface, the overall area-weighted runoff coefficient can be determined.

When applying the NRCS TR-55 method, Curve Numbers (CNs) must be determined for each drainage area. For rooftop and pavement areas the CN was assumed to be 98, and pervious area CN was determined on the basis of the hydrologic soil group and the status of grass cover condition. Curve numbers for pervious areas were assumed to be 61 and 74 for Group B and C soils, respectively, with an assumption of over 75% grass cover. The overall CN can be estimated by using an area-weighted calculation (USDA-SCS, 1986).

In SWMM modeling, infiltration was modeled using Horton's equation. The same infiltration parameters and depression storage values used in the direct determination method of runoff treatment volume described earlier were applied to the SWMM analyses. The average slope of the pervious area was again assumed to be 2%. The same uniform rainfall distribution and time step was applied for the SWMM model runs. To verify the assumption that uniform distribution occurred, NRCS 24-hour rainfall distribution was modeled using SWMM.

Modeling Results

Stormwater management practice sizes were determined using the direct determination approach to capture the volume of runoff generated in a 95th percentile rainfall event at each location. Total acreage, impervious area, the 95th percentile rainfall event, the current expected runoff for the 95th percentile rainfall event, and the future runoff with stormwater management controls were reported for each site. Results were summarized for the two soil types (three soil types for scenarios #3 and #8 in Cincinnati). The spatial location of onsite control measures was also illustrated in the site aerial photo figures. Note that site practices were placed only on undeveloped or landscaped areas without regard for true flow paths or technical feasibility. It may be preferred to place practices in existing impervious areas, if possible.

To compare other approaches of runoff estimation, alternate methodologies were also employed for three scenarios. TR-55 was used for Scenario #1 (Atlanta), the Rational Method was applied to Scenario #2 (Denver), and the SWMM was run for Scenario #7 (Charleston).

For flood control purposes, TR-55 was used to model the 10 year frequency design storm for each site under the assumption that all stormwater management practices were in place. The 10-year design storms were selected from the NRCS TR-55 Manual (USDA, 1986) for both the Eastern U.S. and the Western U.S. Precipitation Frequency Maps (http://www.wrcc.dri.edu/pcpnfreq.html). The 10-year frequency design storm was selected because it represents a common design standard used by state and local governments in order to manage peak rates of runoff and prevent flooding.

Scenario #1 - Charleston, WV

A 0.7-acre site with 73% impervious area was selected from Charleston, West Virginia (Figure 11). If the 95th percentile rainfall event (1.23 inches) occurred on the existing site (i.e., with no control measures), 0.82 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.03 acres if hydrologic soil group B is present, or 0.06 acres if hydrologic soil group C (Table 7) is the predominant soil type on the site. Assuming that bioretention practices are placed in areas that are currently pervious or landscaped, a total of 0.2 acres of pervious area would be available for the placement of bioretention systems. The effective design storage depth within the designated bioretention area was assumed to be 8 inches.



Figure 11. Actual Site and Onsite Control Measures (Charleston, WV)

Table 7. Estimated Sizes of Onsite Control Measures (Charleston, WV)

Total Area (acres)	0.7	
Estimated Imperviousness (%)	73%	
95th Percentile Rainfall Event (inches)	1.23	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.82	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by Direct Determination method (acres)	0.03	0.06
Bioretention estimated by SWMM (acres)	0.03	0.05
Off-site storage necessary to control the 10-yr event of 3.9 inches (acre-ft)	0.10	0.12

Note: The two hydrologic methods used (direct determination and SWMM) estimated similar bioretention sizes.

Scenario #2 - Denver, CO

A 4.5-acre site with 55% impervious area was selected from Denver, Colorado (Figure 12). If the 95th percentile rainfall event (1.07 inches) occurred on the existing site (i.e., with no control measures), 0.53 inches of runoff from the site would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.16 acres if the hydrologic soil group B is present or 0.3 acres if hydrologic soil group C (Table 8) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 2 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 6 inches.



Figure 12. Actual Site and Onsite Control Measures (Denver, CO)

Table 8. Estimated Sizes of Onsite Control Measures (Denver, CO)

Total Area (acres)	4.5	
Estimated Imperviousness (%)	55%	
95th Percentile Rainfall Event (inches)	1.07	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.53	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination method (acres)	0.16	0.3
Bioretention estimated by Rational Method (acres)	0.16	0.28
Off-site storage necessary to control the 10-yr event of 3.2 inches (acre-ft)	0.35	0.52

Scenario #3 - Cincinnati, OH

A 19-acre site with 51% impervious area was selected in Cincinnati, Ohio (Figure 13). If the 95th percentile rainfall event (1.45 inches) occurred on the existing site (i.e., no control measures were in place), 0.68 inches of runoff from the site would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.8 acres if the hydrologic soil group B is present or 1.3 acres if hydrologic soil group C (Table 9) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 9.4 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 8 inches.

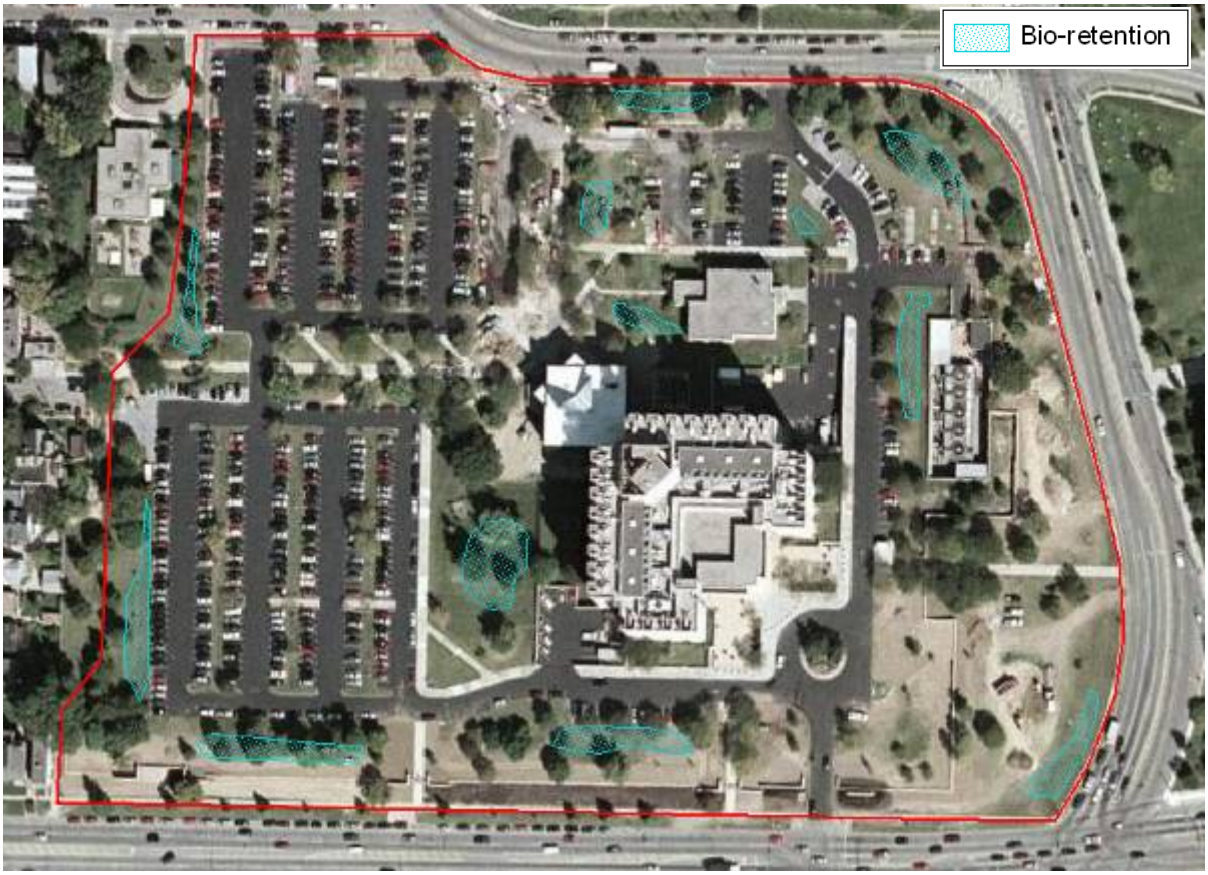

Figure 13. Actual Site and Onsite Control Measures (Cincinnati, OH)

Table 9. Estimated Sizes of Onsite Control Measures (Cincinnati, OH)

Total Area (acres)	19	
Estimated Imperviousness (%)	51%	
95th Percentile Rainfall Event (inches)	1.45	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.68	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.8	1.3
Off-site storage necessary to control the 10-yr event of 4.2 inches (acre-ft)	2.42	3.24

Scenario #4 - Portland, OR

A 27-acre site with 95% impervious area was selected in Portland, Oregon (Figure 14). If the 95th percentile rainfall event (1.0 inches) occurred on the existing site (i.e., no control measures), 0.86 inches of runoff would be generated and require management. This site has the greatest imperviousness among the 7 sites.

Given these site conditions, there is not enough pervious area to manage the entire runoff volume discharged by the 95th percentile rainfall event. As a result, other practices were evaluated and selected. The practices integrated into the design included a green roof, cisterns, and porous pavement. Based on the technical considerations of constructing and maintaining control measures at the site, it was assumed that approximately 30% of the available pervious area could be converted into bioretention cells; 20% of total rooftop area could be converted into green roofs; 40% of paved area could be converted into paver blocks; and 50,000 gallons of total volume could be captured in cisterns for use on this urbanized site. Using this system of four different practices, all runoff for the 95th percentile rainfall event would be controlled (Table 10).



Figure 14. Actual Site and Onsite Control Measures (Portland, OR)

Table 10. Estimated Sizes of Onsite Control Measures (Portland, OR)

Total Area (acres)	27	
Estimated Imperviousness (%)	95%	
95th percentile Rainfall Event (inches)	1.00	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.86	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Paver block area estimated by Direct Determination (acres)	1.4	3.5*
Bioretention estimated by Direct Determination (acres)	0.4	
Green Roof estimated by Direct Determination (acres)	1.7	
Cistern volume estimated by Direct Determination (gallons)	50,000	
Off-site storage necessary to control the 10-yr event of 3.7 inches (acre-ft)	5.37	5.62

*The size of porous pavement area was increased because the other control options were maximized based on the site-specific design assumptions.

A total of 1.3 acres of the site is pervious area or landscaped of which, 0.4 acres (30% of the pervious area) could be converted to bioretention cells that have a storage depth of 10 inches. Of the 8.8 acres of current rooftop area, 1.7 acres (20% of the rooftop area) could be retrofitted into green roof areas. Of the 16.9 acres of paved area, 1.4 acres (8% of the paved area) for hydrologic soil group B, or 3.5 acres (20% of the paved area) for hydrologic soil group C, of paver block systems could be implemented. One or more cisterns (as indicated in Figure 14) could be used to capture up to 50,000 gallons of runoff from rooftop areas. Note: The high percentage of imperviousness of the site (95%) requires that all infiltration designs be based on resident soil type and design volumes, or with adequate sub-bases or amended soils.

Scenario #5 – Near Phoenix, AZ

A 2-acre site with 47% impervious area was selected near Phoenix, Arizona (Figure 15). If the 95th percentile rainfall event (1.0 inches) occurred on the existing site (i.e., with no control measures), 0.42 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by installing bioretention systems totaling 0.06 acres if the hydrologic soil group B is present or 0.1 acres if hydrologic soil group C (Table 11) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 1.1 acres of pervious area is available for the placement of these practices. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 6 inches. Note: If the design storage depth were increased to 10 inches, the off-site storage necessary for the 10-year event could be reduced to 0.03 acre-ft for type B soils and 0.08 acre-ft for type C soils.



Figure 15. Actual Site and Onsite Control Measures (Phoenix, AZ)

Table 11. Estimated Sizes of Onsite Control Measures (Phoenix, AZ)

Total Area (acres)	2	
Estimated Imperviousness (%)	47%	
95th Percentile Rainfall Event (inches)	1.00	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.42	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.06	0.1
Off-site storage necessary to control the 10-yr event of 2.4 inches (acre-ft)	0.05	0.12

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Scenario #6 - Boston, MA

A 3.5-acre site with 69% impervious area was selected in Boston, Massachusetts (Figure 16). If the 95th percentile rainfall event (1.52 inches) occurred on the existing site (i.e., with no control measures), 0.98 inches of runoff would be generated and require management. Given these site characteristics, there is adequate area to place appropriately sized bioretention cells to capture the 95th percentile storm event. However, for the purposes of this analysis, unspecified conditions preclude the use of bioretention. As a result, a paver block system was selected as the best onsite control measure and the system was designed such that the necessary design parameters could be achieved by storing some of the volume in the paver media and by infiltrating the remainder of the volume. The runoff from the 95th percentile rainfall event could be controlled by installing a paver block area totaling 0.4 and 0.8 acres assuming soil types B and C, respectively (Table 12). For the purposes of this case study, a total of 1.5 acres of parking lot was made available to accommodate the paver block system. The area retrofitted with paver blocks would primarily be dedicated for use as parking stalls.



Figure 16. Actual Site and Onsite Control Measures (Boston, MA)

Table 12. Estimated Sizes of Onsite Control Measures (Boston, MA)

Total Area (acres)	3.5	
Estimated Imperviousness (%)	69%	
95th Percentile Rainfall Event (inches)	1.52	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.98	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Paver block area estimated by Direct Determination (acres)	0.4	0.8
Off-site storage necessary to control 10-yr event of 4.5 inches (acre-ft)	0.59	0.71

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Scenario #7 - Atlanta, GA

A 21-acre site with 70% impervious area was selected in Atlanta, Georgia (Figure 17). If the 95th percentile rainfall event (1.77 inches) occurred on the existing site (i.e., with no control measures), 1.17 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could not be adequately controlled solely with bioretention systems. Based on the technical considerations of constructing and maintaining control measures at the site, it was assumed that up to 15% of the pervious area could be converted into bioretention cells and up to 40% of paved area could be converted into a paver block system. If the stormwater management techniques used on the site include both bioretention and paver blocks as presented in Table 13, then all runoff for the 95th percentile rainfall event would be controlled.



Figure 17. Actual Site and Onsite Control Measures (Atlanta, GA)

Table 13. Estimated Sizes of Onsite Control Measures (Atlanta, GA)

Total Area (acres)	21	
Estimated Imperviousness (%)	70%	
95th Percentile Rainfall Event (inches)	1.77	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	1.17	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.9	
Paver block area estimated by the Direct Determination (acres)	0.9	3.2*
Bioretention estimated by TR-55	0.8**	0.9
Paver block area estimated by TR-55	0**	1.84
Off-site storage necessary to control 10-yr event of 6.0 inches (acre-ft)	5.85	6.62

*The size of porous pavement was increased because the bioretention was already reached its maximum size based on the site-specific design assumptions.

**Because TR-55 estimated smaller runoff in this scenario, bioretention can control all of the 95th percentile runoff if the site has soil group B.

For the example site in Atlanta, GA, areas of 1.8 acres for hydrologic soil group B, and 4.1 acres for hydrologic soil group C, would be required to manage the runoff discharged from a 95th percentile rainfall event. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 6.2 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 10 inches. Permeable pavement systems could be used to treat the remaining volume on the 10.8 acres of existing paved area.

In applying the TR-55 model, the overall curve numbers for the site were 87 and 91 for Group B and C soils, respectively. TR-55 was used to estimate 0.73 inches of runoff for soil group B and 0.97 inches for soil group C, which are smaller numbers than the 1.17 inches of runoff estimated by the Direct Determination method. As a result, the sizes of the onsite control measures designed using the TR-55 model were smaller than those designed using the Direct Determination method. Note: It is recommended that caution be exercised when using TR-55 to model storms less than 0.5 inches per event. See application of TR-55 in Table 6.

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Scenario #8 - Cincinnati, OH

A 19-acre site with 51% impervious area was selected in Cincinnati, Ohio (Figure 18). If the 95th percentile rainfall event (1.45 inches) occurred on the existing site (i.e., with no control measures), 0.68 inches of runoff would be generated and require management. The runoff from the 95th percentile rainfall event could be controlled by the installation of bioretention systems totaling 0.8 acres if the hydrologic soil group B is present or 1.3 acres if hydrologic soil group C (Table 9) is the predominant soil type on the site. Assuming that bioretention practices are only placed in areas that are currently pervious or landscaped, a total of 9.4 acres of pervious area is available for the placement of bioretention systems. Given this total available area, the design storage depth of media within the designated bioretention area must be at least 8 inches.

Scenario #8 represents an alternative to the Cincinnati, scenario in #3 (Figure 13). In this case, hydrologic soil group D was selected to represent the soil characteristics present for the entire site. Alternatively, simulations could have been run under the assumption that the use of infiltration practices were precluded by contaminated soils or high groundwater tables. Under these site conditions, bioretention options are severely limited and cannot be used to adequately capture the entire 95th percentile storm event. As a result, options such as cisterns and green roofs were considered. In the absence of management practices, the 95th percentile rainfall event discharges 1.45 inches of stormwater and 0.53 inches of this runoff is captured by onsite depression storage. The difference, 0.92 inches of runoff, would then require capture and management. Based on the technical considerations of constructing and maintaining controls at the site, it was assumed that up to 20% of pervious area can be converted into bioretention areas; up to 30% of paved area can be converted into porous pavement; and up to 30% of the rooftop area can be converted into green roofs. Cisterns can be added to the system if additional storage volume is required. It should be noted that green roofs were selected lowest in the hierarchy of practices evaluated because of cost and potential structural issues associated with design and placement on existing buildings. By using the four onsite control options as presented in Table 14, all runoff for the 95th percentile rainfall event would be controlled. From a management perspective, it was assumed that the design storage depth within the designated bioretention area was 6 inches because of the low infiltration rates adopted for this scenario.

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Figure 18. Actual Site and Onsite Control Measures (Cincinnati, OH)

Table 14. Estimated Sizes of Onsite Control Measures (Cincinnati, OH)

Total Area (acres)	19
Estimated Imperviousness (%)	51%
95th Percentile Rainfall Event (inches)	1.45
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.92
Stormwater Management Applied	Hydrologic Soil Group D
Bioretention estimated by Direct Determination (acres)	1.9
Paver block area estimated by Direct Determination (acres)	2.4
Green Roof estimated by Direct Determination (acres)	0.5
Cisterns estimated by Direct Determination (gallons)	13,000

This site contains a total of 9.4 acres of pervious area, 8.0 acres of paved area, and 1.6 acres of rooftop area. If 1.9 acres (20%) of the pervious area were converted to bioretention cells; 2.4 acres (30%) of parking lot converted to paver blocks; and 0.5 acres (30%) of rooftop area were retrofitted to green roof areas for this site, then 97% of stormwater runoff from the 95th percentile storm would be captured on site. By also adding one or more cisterns (as indicated in Figure 18), an additional 3,000 gallons could be captured, thus illustrating that 100% of the rainfall from the 95th percentile event can be managed onsite with green infrastructure practices.

Comparison of the Runoff Estimation Methods

As illustrated above, runoff of the 95th percentile storm was estimated in order to size onsite control measures. These estimates were produced by applying four different methods: the Direct Determination method, the Rational Method, the NRCS TR-55, and the EPA SWMM. The results comparing each of these methods are presented in Table 15.

Table 15. Comparison of the estimated runoff (unit: inches)

Method		Direct Determination		Rational Method		TR-55		SWMM	
Soil Groups		B	C	B	C	B	C	B	C
1	Charleston, WV	0.82	0.82	0.83	0.84	0.36	0.53	0.82	0.83
2	Denver, CO	0.53	0.53	0.57	0.59	0.12	0.26	0.53	0.53
3	Cincinnati, OH	0.68	0.68	0.73	0.76	0.26	0.46		
4	Portland, OR	0.86	0.86	0.86	0.86	0.63	0.71		
5	Phoenix, AZ	0.42	0.42	0.46	0.48	0.06	0.17		
6	Boston, MA	0.98	0.98	0.99	1.00	0.51	0.70		
7	Atlanta, GA	1.17	1.17	1.17	1.19	0.73	0.97	1.19	1.23

As shown in the above table, the estimated runoff results from direct determination, the Rational Method, and SWMM are relatively similar. Runoff volumes using TR-55 are lower than the other estimates. SWMM modeling results using NRCS 24-hour rainfall distributions were nearly identical to the results based on uniform distribution.

Table 16. Applicability of the methods for analyzing onsite control measures

Purpose	Direct Determination	Rational Method	TR-55*	SWMM
Planning Tool	Applicable	Applicable	Applicable	Applicable
Preliminary Design	Applicable	Applicable	Applicable	Applicable
Detailed Design	Not applicable	Not applicable	Not applicable	Applicable
Actual Assessment (Long-term)	Not applicable	Not applicable	Not applicable	Applicable
Water Quality	Not applicable	Not applicable	Not applicable	Applicable

*Use with caution when applying this method for small storms

CONCLUSIONS

Although sites varied in terms of climate and soil conditions, in all of the scenarios selected, the 95th percentile storm event could be managed onsite with green infrastructure systems. There are many more infiltration, evapotranspiration and capture and use stormwater management options available than used in these analyses giving site operators additional flexibility in managing wet weather.

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APPENDIX A: Modeling Parameter Assumptions

Runoff from each land cover was estimated by the following equation:

$$Runoff = Rainfall - Depression\ Storage - Infiltration\ Loss \quad (1)$$

Depression Storage

Reference depression storage (inches)

Reference	Impervious	Pervious
1	0.05 - 0.1	0.1 - 0.3
2	0.01 - 0.11	0.02 - 0.6
3	0.1	0.2

1. ASCE, (1992). *Design & Construction of Urban Stormwater Management Systems*. New York, NY.
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3. Walesh, S. G. (1989).*Urban Surface Water Management*. John Wiley & Sons, Inc.

Based on the above reference data, depression storage (or initial abstraction) to the direct determination method was assumed as follows:

- Rooftop: 0.1 inches
- Pavement: 0.1 inches
- Pervious area: 0.2 inches

Infiltration

Infiltration loss occurs only in pervious areas. In this analysis, infiltration was estimated by Horton's equation:

$$f = f_{min} + (f_{max} - f_{min})\, e^{-k\,t} \quad (2)$$

where, f = infiltration rate at time t (in/hr),
f_{min} = minimum or saturated infiltration rate (in/hr),
f_{max} = maximum or initial infiltration rate (in/hr),
k = infiltration rate decay factor (/hr), and
t = time (hr).

Reference infiltration parameters

Maximum infiltration rate (in.hr), f_{max}

Infiltration (in/hr)	Partially dried out with		Dry soils with	
	No vegetation	Dense vegetation	No vegetation	Dense vegetation
Sandy	2.5	5	5	10
Loam	1.5	3	3	6
Clay	0.5	1	1	2

Reference: Huber, W. C. and Dickinson, R. (1988). *Storm Water Management Model User's Manual, Version 4*. EPA/600/3-88/001a (NTIS PB88-236641/AS), U.S. Environmental Protection Agency, Athens, GA.

Minimum infiltration rate (in/hr), f_{min}

Hydrologic Soil Group	Infiltration (in/hr)
A	0.45 - 0.30
B	0.30 - 0.15
C	0.15 - 0.05
D	0.05 - 0

A: well drained sandy; D: poorly drained clay
Reference: Huber, W. C. and Dickinson, R. (1988). *Storm Water Management Model User's Manual, Version 4*. EPA/600/3-88/001a (NTIS PB88-236641/AS), U.S. Environmental Protection Agency, Athens, GA.

Decay coefficient, k

Soils	k (sec^{-1})	k (hr^{-1})
Sandy	0.00056	2
⇕	0.00083	3
	0.00115	4
Clay	0.00139	5

Reference: Huber, W. C. and Dickinson, R. (1988). *Storm Water Management Model User's Manual, Version 4*. EPA/600/3-88/001a (NTIS PB88-236641/AS), U.S. Environmental Protection Agency, Athens, GA.

Based on the above reference data, infiltration parameters to the direct determination method were assumed as follows:

- Hydrologic Soil Group B
  - Maximum infiltration rate: 5 in/hr
  - Minimum infiltration rate: 0.3 in/hr
  - Decay factor: 2 /hr
- Hydrologic Soil Group C
  - Maximum infiltration rate: 3 in/hr
  - Minimum infiltration rate: 0.1 in/hr
  - Decay factor: 3.5 /hr
- Hydrologic Soil Group D
  - Maximum infiltration rate: 1 in/hr
  - Minimum infiltration rate: 0.02 in/hr
  - Decay factor: 5 /hr

Infiltration loss for the 24-hr rainfall duration was estimated by the following equations with assumptions of a half hour Δt:

$$\textit{Infiltration Loss at the } n^{\text{th}} \textit{ time-step} = (f \cdot \Delta t) = \{(f_{n-1} + f_n)/2) \cdot \Delta t\} \quad (3)$$

$$\textit{Integrated Infiltration Loss for 24 hours} = \sum (f \cdot \Delta t) \quad (4)$$

Integrating infiltration loss during 24 hours with a half hour Δt

time-step	t (hr)	Infiltration rate (in/hr) [a]			Infiltration volume (inches) [b]		
		Soil B	Soil C	Soil D	Soil B	Soil C	Soil D
0	0	5	3	1	0	0	0
1	0.5	2.03	0.60	0.100	1.757	0.901	0.275
2	1	0.94	0.19	0.027	0.741	0.198	0.032
3	1.5	0.53	0.12	0.021	0.368	0.076	0.012
4	2	0.39	0.10	0.02	0.230	0.054	0.01
5	2.5	0.33	0.1	0.02	0.179	0.05	0.01
6	3	0.31	0.1	0.02	0.161	0.05	0.01
7	3.5	0.30	0.1	0.02	0.154	0.05	0.01
8	4	0.3	0.1	0.02	0.15	0.05	0.01
9	4.5	0.3	0.1	0.02	0.15	0.05	0.01
10	5	0.3	0.1	0.02	0.15	0.05	0.01
11	5.5	0.3	0.1	0.02	0.15	0.05	0.01
12	6	0.3	0.1	0.02	0.15	0.05	0.01
13	6.5	0.3	0.1	0.02	0.15	0.05	0.01
14	7	0.3	0.1	0.02	0.15	0.05	0.01
15	7.5	0.3	0.1	0.02	0.15	0.05	0.01
16	8	0.3	0.1	0.02	0.15	0.05	0.01
17	8.5	0.3	0.1	0.02	0.15	0.05	0.01
18	9	0.3	0.1	0.02	0.15	0.05	0.01
19	9.5	0.3	0.1	0.02	0.15	0.05	0.01
20	10	0.3	0.1	0.02	0.15	0.05	0.01
21	10.5	0.3	0.1	0.02	0.15	0.05	0.01
22	11	0.3	0.1	0.02	0.15	0.05	0.01
23	11.5	0.3	0.1	0.02	0.15	0.05	0.01
24	12	0.3	0.1	0.02	0.15	0.05	0.01
25	12.5	0.3	0.1	0.02	0.15	0.05	0.01
26	13	0.3	0.1	0.02	0.15	0.05	0.01
27	13.5	0.3	0.1	0.02	0.15	0.05	0.01
28	14	0.3	0.1	0.02	0.15	0.05	0.01
29	14.5	0.3	0.1	0.02	0.15	0.05	0.01
30	15	0.3	0.1	0.02	0.15	0.05	0.01
31	15.5	0.3	0.1	0.02	0.15	0.05	0.01
32	16	0.3	0.1	0.02	0.15	0.05	0.01
33	16.5	0.3	0.1	0.02	0.15	0.05	0.01
34	17	0.3	0.1	0.02	0.15	0.05	0.01
35	17.5	0.3	0.1	0.02	0.15	0.05	0.01
36	18	0.3	0.1	0.02	0.15	0.05	0.01
37	18.5	0.3	0.1	0.02	0.15	0.05	0.01
38	19	0.3	0.1	0.02	0.15	0.05	0.01
39	19.5	0.3	0.1	0.02	0.15	0.05	0.01
40	20	0.3	0.1	0.02	0.15	0.05	0.01
41	20.5	0.3	0.1	0.02	0.15	0.05	0.01
42	21	0.3	0.1	0.02	0.15	0.05	0.01
43	21.5	0.3	0.1	0.02	0.15	0.05	0.01
44	22	0.3	0.1	0.02	0.15	0.05	0.01

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45	22.5	0.3	0.1	0.02	0.15	0.05	0.01
46	23	0.3	0.1	0.02	0.15	0.05	0.01
47	23.5	0.3	0.1	0.02	0.15	0.05	0.01
48	24	0.3	0.1	0.02	0.15	0.05	0.01
Sum: Infiltration loss during 24 hours [c]					9.743	3.430	0.769

[a] Calculated infiltration rate at each time by Equation (2)
[b] Calculated infiltration volume from the previous time to the current time by Equation (3)
[c] Integrated infiltration volume for 24 hours with a half hour Δt by Equation (4)

Based on the above calculation, 24-hr infiltration losses for pervious areas and bioretentions were modeled as follows:

- Soil Group B: 9.743 inches
- Soil Group C: 4.430 inches
- Soil Group D: 0.769 inches

Infiltrations of underlying soils at paver blocks were modeled conservatively by applying the minimum infiltration rate for each soil type (Infiltration loss = $f_{min} \cdot 24$) because the soils under the paver blocks may require or be subjected to some compaction for engineering stability. The estimated infiltration losses for each soil are presented below:

- Soil Group B: (0.3 in/hr) · (24 hrs) = 7.2 inches
- Soil Group C: (0.1 in/hr) · (24 hrs) = 2.4 inches
- Soil Group D: (0.02 in/hr) · (24 hrs) = 0.48 inches

Design Storage of Management Practices

Bioretention

Reference	Ponding (inches)	Mulch (inches)	Soil media (ft)	Soil Media Porosity	Underdrain
1	up to 12	2 - 4 (optional)	1 - 1.5	about 40%	bioretention systems utilize infiltration rather than an underdrain
2	6 - 12	2 - 3	2.5 - 4	about 40%	recommended, especially if initial testing infiltration rate < 0.52 in/hr
3	6 - 12		2 - 4		
4		2 - 3	1.5 - 4		if necessary
5	up to 6		1.5 - 2	30 - 40%	Optional
6	6 - 18	as needed	2 - 4		if necessary

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Paver Blocks

Reference	Media (inches)	Void Space
1	12 or more	40%
2	9 or more	40%
3	12 - 36	40%

1. Univ. of California at Davis. (2008). Low Impact Development Techniques: Pervious Pavement. http://extension.ucdavis.edu/unit/center_for_water_and_land_use/pervious_pavement.asp
2. AMEC Earth and Environmental, Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, and Atlanta Regional Commission. (2001). Georgia Stormwater Management Manual Volume 2: Technical Handbook http://www.georgiastormwater.com/
3. Subsurface Infiltration Bed. http://www.tredyffrin.org/pdf/publicworks/CH2 - BMP4 Infiltration Bed.pdf

Green Roofs

Reference	Media (inches)
1	3 - 4
2	1 - 6
3	2 - 6

1. Charlie Miller. (2008). Extensive Green Roofs. Whole Building Design Guide (WBDG). http://www.wbdg.org/resources/greenroofs.php
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Based on the above reference data, design storages to the direct determination method were assumed as follows:

- Bioretention: up to 10 inches
- Green roof: 1 inch (2.5 inches deep media with 40% void space)
- Porous pavement: 4 inches (10 inches deep media with 40% void space)

State of North Carolina

Office of Administrative Hearings

County of Wake

NORTH CAROLINA WILDLIFE FEDERATION CENTRAL PIEDMONT GROUP OF THE NC SIERRA CLUB, Petitioner,
v.
N.C. DIVISION OF WATER QUALITY, Respondent.

05 EHR 2055, 06 EHR 0164

Hearing Dates: July 19 and 20, 2006
Decision Date: October 13, 2006

DECISION

This contested case was heard by Fred G. Morrison Jr., Senior Administrative Law Judge, on July 19 and 20, 2006, in Raleigh, North Carolina. The parties filed proposed Decisions and Memoranda of Law on September 15, 2006.

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Raleigh, North Carolina 27699-9001

ISSUES

This matter is an appeal by Petitioners of the National Pollutant Discharge Elimination System ("NPDES") Phase II stormwater permits issued to three local governments located in the Goose Creek watershed in Mecklenburg and Union Counties. The final NPDES Phase II stormwater permit for Mecklenburg County, including the Town of Mint Hill, was issued on June 15, 2005, with effective dates from July 1, 2005, through June 30, 2010. The final NPDES Phase II stormwater permit for the Town of Indian Trail was issued on September 1, 2005, with effective dates from October 1, 2005, through September 30, 2010. The final NPDES Phase II stormwater permit for the Town of Stallings was issued on September 7, 2005, with effective dates from October 1, 2005, through September 30, 2010.

The parties submitted a Pretrial Order that included their contentions regarding the issues to be decided. The undersigned determines that the issues to be decided are:

1. Whether Respondent exceeded its authority or jurisdiction, acted erroneously, failed to use proper procedure, acted arbitrarily and capriciously, or failed to act as required by law or rule (hereinafter "err") in issuing NPDES Permit Nos. NCS000453, NCS000454, and NCS000395 without ensuring the permits will comply with all applicable state water quality standards as required by 40 C.F.R. § 122.44(d) (2006) and N.C. Gen. Stat. § 143.215.1(a)(6)(2006)?

2. Whether Respondent erred in issuing NPDES Permit Nos. NCS000453, NCS000454, and NCS000395 without requiring measures that will reduce discharges of pollutants to the maximum extent practicable as required by 40 C.F.R. § 122.34(a) (2005)?

3. Whether Respondent erred in issuing NPDES Permit Nos. NCS000453, NCS000454, and NCS000395 without including effluent limitations and conditions necessary to meet the requirements of the waste load allocation in the Goose Creek Total Maximum Daily Load as required by 40 C.F.R. § 122.44(d)(1)(vii)(B) (2006)?

WITNESSES

For Petitioners: Thomas Stewart Blue and John Fridell

For Respondent: Michael F. Randall, Kenneth Bruce Pickle, Tilman Bradley Bennett, and Thomas Reeder

EXHIBITS RECEIVED INTO EVIDENCE

Petitioner: Note: Petitioners' exhibits were admitted into evidence without objection as four notebooks containing the documents listed below.

P-1 O5 EHR 2055 Petitioners' Prehearing Statement (Jan. 6, 2006)
P-2 06 EHR 0164 Petitioners' Prehearing Statement (Mar. 6, 2006)
P-3 05 EHR 2055 Respondent's Prehearing Statement (Jan. 6, 2006)
P-4 06 EHR 0164 Respondent's Prehearing Statement (Mar. 6, 2006)

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P-5 40 C.F.R. § 122.4 (2006)
P-6 40 C.F.R. § 122.21 (2006)
P-7 40 C.F.R. § 122.26 (2006)
P-8 40 C.F.R. § 122.34 (2006)
P-9 40 C.F.R. § 122.44 (2006)
P-10 40 C.F.R. § 122.32 (2006)
P-11 40 C.F.R. § 130.2 (2006)
P-12 40 C.F.R. § 130.12 (2006)
P-13 40 C.F.R. § 131.12 (2006)
P-14 38 Fed. Reg. 13,528 (May 22, 1973)
P-15 50 Fed. Reg. 1774 (Jan. 11, 1985)
P-16 52 Fed. Reg. 36,034 (Sept. 25, 1987)
P-17 58 Fed. Reg. 34,926 (June 30, 1993)
P-18 64 Fed. Reg. 235 (Dec. 8, 1999)
P-19 67 Fed. Reg. 127 (July 2, 2002)
P-20 58 Fed. Reg. 124 (June 30, 1993)
P-21 33 U.S.C. § 1251 (2006)
P-22 33 U.S.C. § 1311 (2006)
P-23 33 U.S.C. § 1313 (2006)
P-24 33 U.S.C. § 1342 (2006)
P-25 33 U.S.C. § 1362 (2006)
P-26 N.C. Gen. Stat. § 143-213 (2006)
P-27 N.C. Gen. Stat. § 143.215.1 (2006)
P-28 15A N.C. Admin. Code 2B.0110 (2006)
P-29 15A N.C. Admin. Code 2B.0201 (2006)
P-30 15A N.C. Admin. Code 2B.0202 (2006)
P-31 15A N.C. Admin. Code 2B.0211 (2006)
P-32 15A N.C. Admin. Code 2H.0112 (2006)
P-33 Haeuser v. Dept. of Law, Gov.'t of Guam, 97 F.3d 1152 (9th Cir. 1996)
P-34 Rybachek v. US EPA, 904 F.2d 1276 (9th Cir. 1989)
P-35 Association of Pacific Fisheries v. US EPA, 615 F.2d 794 (9th Cir. 1980)
P-36 Environmental Defense Center, Inc. v. US EPA, 319 F.3d 398 (9th Cir. 2001)
P-37 Arkansas v. Oklahoma, 112 S. Ct. 1046 (1991)
P-38 Champion International Corporation v. US EPA, 648 F.Supp. 1390 (D.N.C. 1986)
P-39 NPDES Phase II Stormwater Permit No. NCS000453 for Indian Trail (Sept. 1, 2005)
P-40 NPDES Phase II Stormwater Permit No. NCS000454 for Stallings (Sept. 7, 2005)
P-41 NPDES Phase II Stormwater Permit No. NCS000395 for Mecklenburg County, Towns of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, and Pineville (July 1, 2005)
P-42 NPDES Phase II Stormwater Permit Application for Indian Trail (Mar. 28, 2003)
P-43 NPDES Phase II Stormwater Permit Application for Stallings (Mar. 28, 2003)
P-44 NPDES Phase II Stormwater Permit Application for Mecklenburg County (March 4, 2003), including the attached Stormwater Management Program Report (Feb. 25, 2003)
P-45 Draft Technical Support Document for Consideration of Federally-listed Threatened or Endangered Aquatic Species in Water Quality Management Planning for the Goose Creek Watershed (July 2005)
P-46 N.C. Wildlife Resources Commission, Guidance Memorandum to Address and Mitigate Secondary and Cumulative Impacts to Aquatic and Terrestrial Wildlife Re-

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sources and Water Quality (Aug. 2002)

P-47 Total Maximum Daily Loads for Fecal Coliform for Goose Creek, North Carolina, Final Report, April 2005 (Approved July 08, 2005)

P-48 North Carolina Water Quality Assessment and Impaired Waters List (2002 Integrated 305(b) and 303(d) Report) (Feb. 2003)

P-49 N.C. Division of Water Quality, Review of Effectiveness of Coastal Stormwater Rules, PowerPoint Presentation (Nov. 2005)

P-50 N.C. Division of Water Quality, Universal Stormwater Management Program (UDPA1) Draft Rules, PowerPoint Presentation (Oct. 12, 2005)

P-51 Letter from P. Benjamin and B. Cole, U.S. Fish and Wildlife Service, to B. Bennett, NC Division of Water Quality (Dec. 29, 2004)

P-52 R.A. Fischer, C.O. Martin, and J.C. Fischenich, Improving riparian buffer strips and corridors for water quality and wildlife, in PROCEEDINGS OF THE AMERICAN WATER RESOURCES ASSOCIATION INTERNATIONAL CONFERENCE ON RIPARIAN ECOLOGY AND MANAGEMENT IN MULTI-LAND USE WATERSHEDS, 457-462, American Water Resources Association, Portland, Oregon (2000).

P-53 D.L. Correll., Buffer zones and water quality protection: general principles, in PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON BUFFER ZONES, Quest Environmental, Harpenden, Hertfordshire, UK (1997).

P-54 R.A. Fischer, C. O. Martin, D. Q. Barry, K. Hoffman, K. L. Dickson, E. G. Zimmerman, and D.A. Elrod, Corridors and Vegetated Buffer Zones: A Preliminary Assessment and Study Design, Technical Report EL-99-3. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS (1999).

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P-56 C.W. May, & R.R. Horner, The cumulative impacts of watershed urbanization on stream-riparian ecosystems, in PROCEEDINGS OF THE AMERICAN WATER RESOURCES ASSOCIATION INTERNATIONAL CONFERENCE ON RIPARIAN ECOLOGY AND MANAGEMENT IN MULTI-LAND USE WATERSHEDS, American Water Resources Association, Portland, Oregon (2000).

P-57 R.J. Naiman, H. Decamps, & M. Pollock., The role of riparian corridors in maintaining regional biodiversity, 3 ECOLOGICAL APPLICATIONS 209, 209-212 (1993).

P-58 G.J. Kauffman, & T. Brant, The role of impervious cover as a watershed-based zoning tool to protect water quality in the Christina River Basin of Delaware, Pennsylvania, and Maryland, Paper presented at Watershed 2000 Management Conference, Water Environment Federation, Alexandria, Virginia (2000).

P-59 C.L. Arnold, Jr., & J.C. Gibbons, Impervious surface coverage: the emergence of a key environmental indicator, 62 JOURNAL OF THE AMERICAN PLANNING ASSOCIATION 243, 243-258 (1996).

P-60 B.A. Doll, et. al., Hydraulic geometry relationships for urban streams throughout the piedmont of North Carolina, 38 JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION 641, 641-651 (2002).

P-61 A.J. Castelle, A.W. Johnson, & C. Conolly, Wetland and stream buffer size requirements: a review, 23 JOURNAL OF ENVIRONMENTAL QUALITY 878, 878- 882 (1994).

P-62 A E.H. Livingston, J.R. Maxted, R.R. Horner, & C.W. May, BMPs, impervious cover, and biological integrity of small streams (on file with the author) (1999).

P-63 Tom Schueler, The importance of imperviousness, 1 WATERSHED PROTECTION TECHNIQUES 100, 100-111 (1994).

P-64 Belinda Hatt, et. al., The Influence of Urban Density and Drainage Structure on the Concentrations and Loads of Pollutants in Small Streams, 34 ENVIRONMENTAL MANAGEMENT 1, 112-124 (2004).

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P-71 U.S. Environmental Protection Agency, Annotated Bibliography of Urban Wet Weather Flow Literature from 1996-2000.

P-72 Deposition of Thomas Reeder (July 7, 2006)

P-73 Deposition of Michael Randall (July 6, 2006)

P-74 Deposition of Kenneth Pickle (June 30, 2006)

P-75 Deposition of Bradley Bennett (June 30, 2006)

Respondent:

R-1 NPDES Permit No. NCS000395 for Mecklenburg County, Town of Cornelius, Davidson, Huntersville, Matthews, Mint Hill and Pineville (July 1, 2005)

R-2 NPDES Permit No. NCS000453 for Town of Indian Trail (Sept. 1, 2005)

R-3 NPDES Permit No. NCS000454 for Town of Stallings (Sept. 1, 2005)

R-4 July 2005 Review Draft Goose Creek Technical Support Document

R-5 Wildlife Resources Commission, Guidance Memorandum to Address and Mitigate Secondary and Cumulative Impacts to Aquatic and Terrestrial Wildlife Resources and Water Quality (Aug. 2002).

R-6 Total Maximum Daily Loads for Fecal Coliform for Goose Creek Final Report (Apr. 2004)

R-7 Response to Comments Summary, North Carolina MS4, Phase II Individual Permits

R-8 N.C. Admin. Code 02B Rules

STATUTES AND RULES IN ISSUE

33 U.S.C. § 1251 (2006)
33 U.S.C. § 1311 (2006)
33 U.S.C. § 1342 (2006)
33 U.S.C. § 1362 (2006)
40 C.F.R. § 122.21 (2006)
40 C.F.R. § 122.32 (2006)
40 C.F.R. § 122.34 (2006)
40 C.F.R. § 122.44 (2006)
40 C.F.R. § 130.2 (2006)
40 C.F.R. § 131.12 (2006)
N.C. Gen. Stat. 143-213 (2006)
N.C. Gen. Stat. 143-215.1 (2006)
N.C. Admin. Code 02B.0110 (2005)
N.C. Admin. Code 02B.0200 (2005)
N.C. Admin. Code 02B.0201 (2005)

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N.C. Admin. Code 02B.0211 (2005)
N.C. Admin. Code 02H.0112 (2005)

MOTIONS

On March 10, 2006, Petitioners and Respondent filed a Joint Motion to Consolidate Cases, Continue Hearing, and Amend Scheduling Order and Deadlines in 05 EHR 2055 and 06 EHR 0164. The two cases collectively involved Petitioners' appeals of three NPDES Phase II stormwater permits in the Goose Creek watershed. On March 23, 2006, Chief Administrative Law Judge Julian Mann granted the motion to consolidate and reassigned the cases to Senior Administrative Law Judge Fred G. Morrison Jr.

On June 1, 2006, Respondent filed a Motion to Join Additional Parties. Respondent requested that the County of Mecklenburg, North Carolina, and the Towns of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, Pineville, North Carolina; Indian Trial, North Carolina; and Stallings, North Carolina, be joined as necessary parties or, in the alternative, as permissive parties. In response, Petitioners opposed the motion and contended that the additional parties were not necessary parties. Petitioners also contended that the parties should not be joined as permissive parties because it would cause undue delay and prejudice to Petitioners. Of the proposed parties to be joined, only Mecklenburg County and the Town of Mint Hill filed a response. Both parties opposed the motion to be joined as additional parties to the litigation. Oral argument was held via teleconference on June 9, 2006. The undersigned denied the motion after considering written memos supporting and opposing the motion and at the conclusion of oral argument on July 5, 2006.

On June 30, Petitioners filed a Motion for Summary Judgment on Aggrieved Party Status. Following oral argument and prior to a ruling from the Court, Respondent agreed to stipulate to Petitioners' aggrieved party status in the Pretrial Order. Therefore, the undersigned did not rule on this motion.

Pursuant to N.C. Gen. Stat. § 150B-34 and-36, the ruling on the Motion to Join Additional Parties is a part of this Decision. All such rulings are hereby incorporated herein.

STIPULATIONS

In the Pretrial Order, the parties agreed to and the undersigned approved the following stipulations:

Procedural Stipulations from Pretrial Order:

1. North Carolina Wildlife Federation and Central Piedmont Group of the NC Sierra Club ("Petitioners") are entitled to bring these consolidated contested cases as "person[s] aggrieved" within the meaning of N.C. Gen. Stat. §§ 150B-2(6) and 23 (2006).

2. Petitioners timely filed Petitions for Contested Case Hearings to challenge three Phase II Stormwater Permits identified as NPDES Permit No. NCS000453 issued to the Town of Stallings, NPDES Permit No. NCS000454 issued to the Town of Indian

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Trail, and NPDES Permit No. NCS000395 issued to Mecklenburg County.

3. Petitioners have the burden of proof to establish facts that Respondent has erred in one or more of the ways set forth in N.C. Gen. Stat. § 150B-23(a).

4. Presentation of Evidence:
(a) Petitioners shall present evidence first to show that the three stormwater permits do not "reasonably ensure compliance with applicable water quality standards and regulations of all affected states." N.C. Admin. Code tit. 15A, r. 02H.0112(c) (2006).
(b) If necessary, Respondent may then present evidence to show that the three stormwater permits at issue "reasonably ensure compliance with applicable water quality standards and regulations of all affected states."

5. Each of the Exhibits identified above is an authentic copy of the original, is a public record or a business or agency record kept in the ordinary course of business, and may be introduced into evidence without further identification of proof, all subject to objections for relevance.

Factual Stipulations from Pretrial Order:

1. The federal Clean Water Act requires certain governmental entities to control stormwater pollution into public waters. 33 U.S.C. § 1342(p)(2) (2005).

2. These governmental entities are required to obtain National Pollutant Discharge Elimination System ("NPDES") permits to eliminate or reduce to the maximum extent practicable discharges of pollution from stormwater.

3. The permitting program for stormwater discharges has been implemented in two phases. In Phase II, certain municipalities designated as "urbanizing" that serve less than 100,000 are required to obtain NPDES Phase II stormwater permits.

4. To meet federal Clean Water Act and state law requirements, the Towns of Indian Trail and Stallings, and Mecklenburg County, including the town of Mint Hill, were required to obtain Phase II stormwater discharge permits.

5. The federal regulations governing Phase II require owners and operators of municipal storm sewer systems ("MS4s") to apply for NPDES permits which require the implementation of six minimum measures within their stormwater systems to control pollution. 40 C.F.R. § 122.21(a) (2005). The six minimum measures consist of: (1) public education and outreach on stormwater impacts; (2) public involvement and participation in program design; (3) illicit discharge detection and elimination; (4) construction site stormwater pollution control; (5) post-construction stormwater management; and (6) pollution prevention and good housekeeping measures. 40 C.F.R. § 122.34(b) (2005).

6. Respondent issued a final NPDES Phase II stormwater permit to Mecklenburg County, including the Town of Mint Hill, on June 15, 2005, with effective dates from July 1, 2005, through June 30, 2010.

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7. Respondent issued a final NPDES Phase II stormwater permit to the Town of Indian Trail on September 1, 2005, with effective dates from October 1, 2005, through September 30, 2010.

8. Respondent issued a final NPDES Phase II stormwater permit to the Town of Stallings on September 7, 2005, with effective dates from October 1, 2005, through September 30, 2010.

9. Goose Creek is a perennial stream fed by a number of perennial, intermittent and ephemeral tributaries. Goose Creek is a tributary to the Rocky River, which is in turn a tributary to the Pee Dee River (the lower portion of the Yadkin River). The Goose Creek watershed is located in southeastern Mecklenburg County and northwestern Union County, North Carolina. Portions of the Towns of Indian Trail, Stallings, and Mint Hill drain into the Goose Creek watershed.

10. The Carolina heelsplitter is a species of freshwater mussel. The U.S. Fish & Wildlife Service ("USFWS") listed the Carolina heelsplitter as endangered pursuant to the provisions of the Endangered Species Act on June 30, 1993. 58 Fed. Reg. 34,926 (June 30, 1993).

11. The Goose Creek watershed contains one of only seven remaining populations of the Carolina heelsplitter. In July 2002, the USFWS designated critical habitat for the Carolina heelsplitter, including portions of the main stems of Goose Creek and Duck Creek in Union County. 67 Fed. Reg. 44,502- 44,521 (July 2, 2002) Since the USFWS listed the Carolina heelsplitter as endangered, it has discovered two additional populations, raising the total to nine.

12. Goose Creek has its headwaters in southeastern Mecklenburg County within the jurisdiction of the Town of Mint Hill. Stormwater runoff from Mint Hill flows into Goose Creek at its headwaters and travels downstream into the critical habitat for the Carolina heelsplitter. Stormwater runoff from Indian Trail and Stallings flows into Goose Creek and travels downstream into the critical habitat for the Carolina heelsplitter.

13. The North Carolina Wildlife Resources Commission ("WRC") and the USFWS have jointly submitted to Respondent a draft technical support document containing their recommendations for a site-specific management plan to protect and preserve habitat for threatened or endangered species in Goose Creek.

14. The WRC, in coordination with the USFWS, also has issued guidance regarding water quality conditions required to sustain and recover federally listed endangered species, including the Carolina heelsplitter.

15.The NPDES Phase II stormwater permits Respondent issued to the Towns of Indian Trail and Stallings and Mecklenburg County, set the imperviousness threshold at twenty-four percent and require thirty-foot buffers on perennial and intermittent streams in the Goose Creek watershed.

16. Under the NPDES Phase II stormwater permits Respondent issued to the Towns of Indian Trail and Stallings and Mecklenburg County, developments with a built upon area less than twenty-four percent are not required to implement engineered storm-

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water management controls to treat stormwater pollution.

17. Goose Creek does not meet water quality standards for fecal coliform. In 1998, Respondent placed Goose Creek on the 303(d) list of impaired waters due to fecal coliform violations. According to Respondent's listing document, the causes of water quality impairment in Goose Creek include construction activities and urban runoff/storm sewers. Goose Creek remains on the 303(d) list of impaired waters through the present.

18. On April 20, 2005, Respondent finalized and submitted to the U.S. EPA Total Maximum Daily Loads ("TMDL") for Fecal Coliform for Goose Creek. The TMDL allocates allowable pollutant loads from known sources so that required actions may be taken to restore the water to its intended uses.

19. The U.S. EPA approved and finalized the Goose Creek TMDL without substantial change on July 8, 2005.

20. The waste load allocation in the Goose Creek TMDL requires a ninety-two point five percent reduction of fecal coliform discharges from existing MS4s. EPA approved and finalized the Goose Creek TMDL without substantial change on July 8, 2005.

21. The Goose Creek TMDL specifically requires a ninety-two point five percent reduction of fecal coliform discharges from the MS4s in Indian Trail, Stallings, and Mint Hill, in order to meet water quality standards.

22. Petitioners voluntarily agree to dismiss as a non-suit and without prejudice claims brought under Section 9 of the Endangered Species Act in these consolidated cases.

23. Each of the Exhibits identified above is an authentic copy of the original, is a public record or a business or agency record kept in the ordinary course of business, and may be introduced into evidence without further identification of proof, all subject to objections for relevance.

FINDINGS OF FACT

1. Petitioner Central Piedmont Group of the North Carolina Sierra Club is a non-profit organization. Central Piedmont Group is the local Sierra Club member group in Mecklenburg County. Central Piedmont Group members use, enjoy, and benefit aesthetically and recreationally from the Goose Creek watershed. Central Piedmont Group also has members who live within the Goose Creek watershed.

2. Petitioner North Carolina Wildlife Federation is a not-for-profit corporation founded in 1945. NCWF, which is an affiliate of the National Wildlife Federation ("NWF"), has 17,000 members in North Carolina. NWF has approximately 5 million members, including 25,000 members in North Carolina. NCWF has members who use, enjoy, and benefit aesthetically and recreationally from the Goose Creek watershed. NCWF also has members who live within the Goose Creek watershed.

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3. Respondent North Carolina Department of Environment and Natural Resources ("NCDENR") Division of Water Quality ("DWQ") is the state agency charged with protecting water quality and has been delegated the authority to issue NPDES permits under the Clean Water Act.

4. Petitioners' witness, Thomas Stewart Blue, is an expert in the field of stormwater engineering and hydrology with a particular expertise in engineered stormwater controls, impervious surface limits, land development, and water quality modeling related to developing Total Maximum Daily Loads ("TMDL").

5. Petitioners' witness, John Fridell, a wildlife biologist with the United States Fish and Wildlife Service ("USFWS"), is an expert in wildlife biology with a particular expertise in the protection and recovery of the federally endangered Carolina heelsplitter.

6. Respondent's witness, Michael F. Randall, is an environmental engineer with the Division of Water Quality's Stormwater Permitting Unit. Mr. Randall was involved in discussions regarding the development of the three challenged NPDES permits, but was not in charge of drafting any of them.

7. Respondent's witness, Kenneth Bruce Pickle, is an environmental engineer with the Division of Water Quality's Stormwater Permitting Unit. Mr. Pickle was involved in drafting and noticing the NPDES Phase II stormwater permits for the Town of Indian Trail and the Town of Stallings.

8. Respondent's witness, Tilman Bradley Bennett, is the supervisor of the Division of Water Quality's Stormwater Permitting Unit. Mr. Bennett's responsibilities include oversight for all of the state's stormwater permitting programs, including the NPDES Phase II program.

9. Respondent's witness, Thomas Reeder, is the manager of the Division of Water Quality's Wetlands and Stormwater Branch. Mr. Reeder's responsibilities include oversight of any programs that are associated with wetlands and stormwater management in the state.

10. None of Respondent's witnesses were offered as experts or qualified as experts in the field of stormwater management or wildlife biology.

11. Water quality degradation occurs when alterations are made to the natural character of the watershed. The natural character of a watershed includes its physical integrity, such as the way in which water travels downstream and the amount of groundwater recharging the stream's base flow; its biological integrity, such as the biological diversity of organisms living in the streams; and its chemical integrity, such as the distribution of chemicals in the water. A system is considered degraded when one of these characteristics is altered by non-natural activities. For example, a stream may no longer be able to support the natural biological diversity in the stream.

12. Land development is one type of non-natural activity that causes water quality degradation. In particular, increased stormwater runoff arising from construction and post-construction land development activities causes significant water

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quality degradation and aquatic habitat loss, resulting in lowered biological integrity for aquatic systems.

13. Stormwater runoff occurs when impervious surfaces increase within a watershed and rainfall can no longer infiltrate into soils. Surfaces that water cannot effectively pass through, such as asphalt, concrete, roof shingles, metal, gravel, and compacted soils.

14. Impervious surfaces collect pollutants, such as nutrients, sediment, petroleum products, and fecal coliform, deposited from other sources. During storm events, these collected pollutants are washed into aquatic systems as stormwater runoff.

15. Numerous scientific studies have shown that increased impervious surface in a watershed is correlated with water quality degradation. These studies have documented significant water quality degradation in streams draining watersheds with impervious surface area from zero to thirteen percent. One such study found that there is no safe threshold for impervious surface area because any increase in impervious surface results in detrimental impacts to sensitive aquatic species.

16. Increased stormwater runoff from impervious surfaces also causes increased runoff volume which detrimentally affects channel stability in aquatic systems. Stream channels will either widen their stream banks, down cut the stream bed, or do both to accommodate larger and more severe runoff events. The sediment from the eroded stream banks and bed will increase sediment loading in the stream.

17. Because increased impervious surfaces reduce the amount of natural infiltration in a watershed, groundwater recharge is also reduced. Groundwater contributes to a stream's base flow, which is the portion of water that comes from sources other than surface runoff. Thus, when groundwater recharge is reduced, base flow in streams is also reduced.

18. The NPDES Phase II stormwater permits at issue in these proceedings are intended to regulate new discharges of stormwater pollution from urban land development and to ameliorate the effects of stormwater pollution. Each permit contains six minimum measures consisting of: (1) public education; (2) public involvement in designing program; (3) illicit discharge detection and elimination; (4) construction site stormwater pollution control; (5) post-construction stormwater management; and (6) pollution prevention.

19. The NPDES Phase II stormwater permits at issue in these proceedings establish model practices for post-construction stormwater controls that constitute the minimum measures that must be implemented under the NPDES Phase II program. These model practices include a low-density option and a high-density option for stormwater controls in new development.

20. The low-density option applies to any new development that involves up to, but no more than, twenty-four percent impervious surface area or "built-upon area." Under this option, the only post-construction stormwater management measures are vegetated conveyances for transporting stormwater to the nearest stream and a thirty-foot setback from the stream for all impervious surfaces.

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21. The high-density option applies to any new development that involves more than twenty-four percent impervious surface area. Under this option, the stormwater measures require a thirty-foot setback from the stream for all impervious surfaces and require the installation of engineered structural controls. The structural controls must treat the difference between the pre-and post-development runoff for a certain design storm and remove eighty-five percent of all total suspended solids ("TSS"). The design storm included in the model practices is the one year, twenty-four hour storm.

22. All three of the challenged NPDES Phase II stormwater permits incorporate these model practices as the post-construction measures included in the permits themselves. These three NPDES Phase II stormwater permits authorize discharges of stormwater pollution into the Goose Creek watershed from the following sources: (1) Mecklenburg County, specifically as it includes discharges from the Town of Mint Hill; (2) the Town of Indian Trail; and (3) the Town of Stallings.

23. Goose Creek is a perennial stream with its watershed located in southeastern Mecklenburg County and northwestern Union County, North Carolina. Goose Creek has its headwaters in southeastern Mecklenburg County within the jurisdiction of the Town of Mint Hill. Stormwater runoff from portions of the Towns of Indian Trail, Stallings, and Mint Hill drains into Goose Creek. Duck Creek is the other main tributary in the Goose Creek watershed and is a perennial stream.

24. Goose Creek depends on base flow, particularly during dry or drought periods. Without adequate base flow, streams in the Goose Creek watershed will not be able to maintain adequate flows during dry or drought periods and will become an intermittent stream.

25. Stormwater runoff from Mint Hill flows into Goose Creek at its headwaters and travels downstream into the critical habitat for the Carolina heelsplitter. Stormwater runoff from Indian Trail and Stallings flows into Goose Creek and travels downstream into the critical habitat for the Carolina heelsplitter.

26. The Carolina heelsplitter is a species of mussel and was federally listed by the USFWS as endangered pursuant to the provisions of the Endangered Species Act on June 30, 1993. The Goose Creek watershed contains one of only nine remaining populations of the Carolina heelsplitter mussel.

27. Urban land development is the most significant land use change in the Goose Creek watershed.

28. As urban development and impervious cover increases in the Goose Creek watershed, the upper reaches of Goose and Duck Creeks have experienced significant stream bank and stream bed erosion due to increased stormwater runoff.

29. Increased urban development has also caused base flow in Goose and Duck Creeks to decline. The USFWS has seen portions of Duck Creek completely dry up during dry periods due to low groundwater recharge levels.

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30. Increased urban development has also caused the levels of several pollutants associated with stormwater to increase in the Goose Creek watershed. These pollutants include fecal coliform, ammonia, phosphorus, nitrate-nitrite, copper, and sediment. Although a TMDL has been developed to deal with fecal coliform issues, water quality standards are not in place for ammonia, phosphorus, nitrate-nitrite, copper, or sediment in the Goose Creek watershed.

31. As stated above, all three permits include the minimum model practices as the post-construction measures specified within the permits. Respondent issued the three NPDES Phase II stormwater permits with an imperviousness threshold for structural stormwater controls at twenty-four percent and a thirty-foot setback on perennial and intermittent streams in the Goose Creek watershed. For developments at or below twenty-four percent imperviousness, the only requirement beyond the thirty-foot setback is the use of vegetated conveyances. For developments above twenty-four percent imperviousness, the required measures include structural stormwater controls to treat the difference in pre-and post-development runoff for the one year, twenty-four hour storm and the controls must be designed to remove at least eighty-five percent TSS.

32. It is undisputed that water quality is degraded at impervious surface levels ranging between six to thirteen percent. It is also undisputed that there are many pollutant constituents in stormwater runoff beyond TSS. Those pollutants include nutrients, fecal coliform, pesticides, and petroleum products.

33. Because the permits do not adequately regulate impervious surfaces and pollutant constituents in stormwater runoff, the permits as drafted will not protect the biological integrity of the Goose Creek watershed and will result in water quality degradation.

34. Furthermore, it is undisputed that protection of biological integrity also requires the protection of the most sensitive species in a stream. It is also undisputed that protecting the biological integrity in the Goose Creek watershed includes protecting the Carolina heelsplitter.

35. The historic range of the federally endangered Carolina heelsplitter included wide portions of the Catawba, Pee Dee, Savannah, and Saluda river basins.

36. The current range of the Carolina heelsplitter is limited to nine surviving populations in the Catawba, Pee Dee, and Savannah river basins. One of the populations is found in the Goose Creek watershed.

37. Because the federally endangered Carolina heelsplitter is found in so few places today, the USFWS has determined that "any factors that adversely modify habitat or water quality in the stream reaches it now inhabits could further endanger the species."

38. The USFWS also has determined that "channel and streambank scouring associated with increased storm-water run-off; and the run-off of silt, fertilizers, pesticides, and other pollutants from various land disturbance activities with inadequate or poorly maintained erosion and stormwater control" are among the factors that adversely modify Carolina heelsplitter habitat.

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39. The USFWS has documented a correlation between increased urban development and Carolina heelsplitter habitat degradation in the Goose Creek watershed. As urban development has increased in the upper portion of the watershed, Carolina heelsplitter habitat is being eliminated. Surveys conducted by the USFWS of Carolina heelsplitter habitat from the time of listing through 2005 show that habitat has steadily decreased as urban development has increased in the watershed.

40. The federally endangered Carolina heelsplitter lives in the gravelly, rocky substrate found along the stream bed in Goose and Duck Creeks in the Goose Creek watershed. The majority of the substrate in the upper reaches of both creeks has been eroded away by increased stormwater runoff, thereby significantly reducing the available habitat for the endangered mussel.

41. Pollutants, such as sediment, ammonia, phosphorus, nitrate-nitrite, and copper, found in stormwater runoff have been determined to be harmful to the Carolina heelsplitter.

42. Sediment from stormwater runoff affects the Carolina heelsplitter in four ways. First, because the mussels are filter feeders, the increased sediment loading in stormwater runoff can clog their gills affecting their respiration and feeding. Increased sediment in the streams can ultimately suffocate the mussels by accumulating on top of the mussels' habitat and burying the mussels. Second, sediment affects the stability of the stream bottom and can result in mussels being washed out of their habitat because the substrate becomes unstable. Third, other pollutants bind to sediment particles and get carried down into the substrate as the sediment settles out of the water column, thereby increasing the mussels' exposure to the pollutant. Finally, sediment detrimentally affects the health of fish in streams. The mussels rely upon a fish host in order to reproduce by having mussel larvae attach to the fish's gill to mature.

43. Ammonia is a pollutant that has been associated with stormwater runoff and is of particular concern with regard to mussels. Ammonia is extremely toxic to freshwater mussels. Ammonia levels in the Goose Creek watershed have been identified as already exceeding the levels of concern for mussels and monitoring indicates that the levels are on an increasing trend in the watershed.

44. Phosphorus and nitrate-nitrite are also associated with stormwater runoff. Both pollutants are nutrients and at excessive levels in a watershed can lead to algal blooms, which deplete the oxygen levels in the streams. Low oxygen levels detrimentally affect the Carolina heelsplitter. Algal blooms from excessive nutrient levels have been documented in the Goose Creek watershed. Monitoring in the watershed also indicates that phosphorus and nitrate-nitrite levels in the watershed are on an increasing trend.

45. Copper is also a constituent in stormwater runoff and has been found harmful to mussels at high concentrations. Copper levels exceeding the concern level for mussels have been documented in the Goose Creek watershed.

46. The USFWS, in conjunction with the N.C. Wildlife Resources Commission and the N.C. Natural Heritage Program, has identified measures for controlling stormwater

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runoff and mitigating its detrimental impacts to the Carolina heelsplitter and its habitat in the Goose Creek watershed.

47. The USFWS provided Respondent with its determinations prior to the issuance of the three NPDES Phase II permits challenged in this proceeding, in the form of a letter and a draft site specific management plan.

48. Based on a review of scientific literature regarding appropriate buffer widths and on the field observations of the USFWS's own experts, the USFWS determined that two-hundred foot undisturbed riparian buffers on perennial streams and one-hundred foot undisturbed riparian buffers on intermittent streams are required to protect the Carolina heelsplitter in Goose Creek.

49. Based on a review of scientific literature regarding impervious surface or disturbance in the floodplain, and on the field observations of the USFWS's own experts, the USFWS determined that impervious surface, active management, and other land disturbances, such as sewer lines and water lines, should be prohibited in the Goose Creek floodplain.

50. Based on a review of scientific literature regarding impervious surface thresholds and on the field observations of the USFWS's own experts, the USFWS determined that any further increases in impervious surface in the Goose Creek watershed should be required to implement engineered stormwater controls to offset impacts to the stream.

51. Based on a review of scientific literature regarding impervious surface thresholds and on the field observations of the USFWS's own experts, the USFWS determined that water quality standards for phosphorus, nitrate-nitrite, copper, and ammonia should be in place in the Goose Creek watershed to protect the Carolina heelsplitter from toxic levels of these pollutants. For ammonia, the USFWS has determined that an acute water quality standard of 1.75 milligrams per liter and a chronic water quality standard of 0.50 milligrams per liter are necessary to protect the Carolina heelsplitter in the Goose Creek watershed. The USFWS has determined that a phosphorus water quality standard of 0.1 milligrams per liter and a nitrate-nitrite water quality standard of 0.4 milligrams per liter are necessary to protect the Carolina heelsplitter in the Goose Creek watershed. For copper, the USFWS has determined that an acute water quality standard of 3.6 micrograms per liter and a chronic water quality standard of 2.2 micrograms per liter are necessary to protect the Carolina heelsplitter in the Goose Creek watershed. Acute water quality standards constitute the level of a particular pollutant that can be tolerated for a short period of time. Chronic water quality standards constitute the level of a particular pollutant that can be tolerated repeatedly over time.

52. In issuing the three challenged NPDES Phase II permits, Respondent did not include the determinations made by the USFWS and did not include adequate protections for the federally endangered Carolina heelsplitter.

53. If development is allowed in the Goose Creek watershed pursuant to post-construction conditions and limitations in these three permits, the Carolina heelsplitter population in Goose Creek will be extirpated in two to five years.

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54. As noted above and not disputed by any of Respondent's witnesses, stormwater pollution causes water quality degradation by increasing the volume of water entering an aquatic system, decreasing groundwater recharge and base flow, increasing pollutant loadings to streams, and detrimentally impacting biological communities within the aquatic system.

55. As stated above, under the low-density development option, the permits allow development up to and including twenty-four percent impervious surface without any stormwater management measures other than a vegetated conveyance and a thirty-foot setback. Scientific studies documenting the correlation between increases in impervious surface area and decreases in water quality have shown that impervious surface areas between six and thirteen percent result in significant water quality degradation. Thus, the low-density option in the three challenged NPDES permits will also result in further water quality degradation in the Goose Creek watershed.

56. The permits state that vegetated conveyances must be used to the maximum extent practicable, but do not include any design requirements and are not required to be constructed as to remove any of the major pollutant constituents of stormwater (e.g., sediment, nutrients, fecal coliform, heavy metals, and pesticides).

57. Vegetated conveyances have been shown to cause a net increase in pollutant loading in streams from stormwater runoff. The grassed areas become an attractant for water fowl and other wildlife, which then defecate in the conveyances causing a net increase in fecal coliform, ammonia, and nitrogen loading.

58. Under the high-density development option (for development above twenty-four percent impervious surface), the permits require that new developments include stormwater structural controls designed to treat the difference in the pre-and post-development runoff for the one year, twenty-four hour storm event and remove eighty-five percent of total suspended solids.

59. TSS are particles of soil or sediment suspended in the water column. TSS have a variety of effects on water quality. TSS can transport into streams other pollutants that attach to the solids. When it settles out of the water column, TSS can settle out to the bottom of the stream affecting the stability of the stream bed. TSS also affects the health of fish and can impair the biological integrity of an aquatic system.

60. Although the structural controls are required to be designed to remove eighty-five percent TSS, the permits do not have any requirements to ensure that the structural controls actually continue to perform at an eighty-five percent removal rate during the terms.

61. The permits require that the structural controls be designed to treat the difference in pre-and post-development runoff for the one year, twenty-four hour storm event. In Goose Creek, the one year, twenty-four hour storm event is a rainfall event with about 2.9 inches of rain.

62. The structural controls will not be able to remove eighty-five percent TSS in storm events larger than the one year, twenty-four hour storm event.

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63. The one year, twenty-four hour storm event as a design standard is not sufficient to protect water quality in Goose Creek from degradation because it does not take into account antecedent conditions on a site, such as saturated soils from previous storm events.

64. The permits do not contain any volumetric requirements to protect channel stability, maintain base flow, or groundwater recharge for low-density or high-density development. Under the permits, the volume of stormwater during storm events will increase in the Goose Creek watershed and base flow to the watershed will be significantly reduced.

65. The three challenged NDPES stormwater permits do not have specific requirements directing how a structural control is to reduce the discharge of stormwater pollutants to the maximum extent practicable.

66. The three challenged NPDES Phase II stormwater permits do not require specific stormwater control measures to be in place for a particular development.

67. Rather than include specific requirements, the permits require the permittees to develop a stormwater management plan at some point in the future to reduce the discharge of pollutants to the maximum extent practicable.

68. The stormwater management plan is to contain more specific terms and provisions for controlling pollutants and can include additional measures to treat stormwater runoff. The terms include "effluent limitations" in the form of best management practices.

69. Although Respondent contends that the stormwater management plans are enforceable parts of the NPDES Phase II permits, the stormwater management plans are not attached or annexed to the NPDES Phase II stormwater permits.

70. Respondent did not include the stormwater management plans in the public notices for the draft permits.

71. When members of the public requested copies of the draft permits to comment upon, Respondent provided only the draft permit and not the stormwater management plan.

72. Goose Creek does not meet water quality standards for fecal coliform. In 1998, Respondent placed Goose Creek on the 303(d) list of impaired waters due to fecal coliform violations. According to Respondent's listing document, the causes of water quality impairment in Goose Creek include construction activities and urban runoff/storm sewers. Goose Creek remains on the 303(d) list of impaired waters through the present.

73. Respondent submitted the Total Maximum Daily Loads ("TMDL") for Fecal Coliform for Goose Creek to the U.S. Environmental Protection Agency ("EPA") for final approval on April 20, 2005. The TMDL allocates allowable fecal coliform loads from known sources so that remedial measures may be implemented to remove the water quality impairment.

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74. The EPA approved and finalized the Goose Creek TMDL without substantial change on July 8, 2005.

75. The finalized waste load allocation in the Goose Creek TMDL requires a ninety-two point five percent (92.5%) reduction of current fecal coliform discharges from existing municipal separate storm sewer systems

76. Indian Trail, Stallings, and Mecklenberg County own and operate MS4s in the Goose Creek watershed.

77. The Goose Creek TMDL specifically requires a ninety-two point five percent (92.5%) reduction of current fecal coliform discharges from Indian Trail, Stallings, and the portions of Mecklenburg County within the Goose Creek watershed, in order to meet water quality standards.

78. The three NPDES Phase II stormwater permits for Indian Trail, Stallings, and Mecklenburg County, do not contain terms and conditions that would require reductions from current loadings of fecal coliform from stormwater runoff.

79. If development continues in the Goose Creek watershed as permitted under these three NDPES Phase II stormwater permits, fecal coliform loading will increase.

BASED UPON the foregoing Stipulations and Findings of Fact, the undersigned makes the following:

CONCLUSIONS OF LAW

1. The Office of Administrative Hearings has jurisdiction to hear this case pursuant to N.C. Gen. Stat. § 150B-23 (2006).

2. Petitioners are persons aggrieved by the issuance of these three NPDES Phase II permits within the meaning of the Administrative Procedure Act.

3. All parties have been correctly designated and are properly before the Office of Administrative Hearings. The Office of Administrative Hearings has jurisdiction over the parties and the subject matter.

4. Petitioners bear the burden of proof on the issues.

5. Pursuant to the federal Clean Water Act, certain governmental entities are required to obtain NPDES Phase II stormwater permits to reduce and control stormwater pollution into public waters. 33 U.S.C. § 1342 (p)(2) (2006). In particular, with regard to the issues in this case, Mecklenburg County and the Towns of Mint Hill, Indian Trail, and Stallings are required to obtain NPDES Phase II stormwater permits for discharges of stormwater pollution from new development. 40 C.F.R. § 122.32 (2006).

Contested Issue No. 1:

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6. Pursuant to 40 C.F.R. § 122.44(d) (2006) and N.C. Gen. Stat. § 143.215.1(a)(6) (2006), Respondent was responsible for ensuring that the NPDES Phase II permits for Indian Trail, Stallings, and Mecklenburg County complied with all applicable state water quality requirements.

7. North Carolina's state water quality regulations recognize the protection of biological integrity as a state water quality standard and as a best usage of all freshwaters. 15A N.C. Admin. Code 02B.0211(1) (2006).

8. North Carolina regulations require that "[t]he water shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture. Sources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard." 15A N.C. Admin. Code 02B.0211(2) (2006).

9. Biological integrity is "the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms having species composition, diversity, population densities and functional organization similar to that of reference conditions." 15A N.C. Admin. Code 02B.0200(11) (2006). Respondent's legal obligation to protect biological integrity necessarily includes the protection of the most sensitive species within a watershed. Id. Therefore, in the Goose Creek watershed, biological integrity encompasses the ability of the watershed to maintain the federally endangered Carolina heelsplitter population.

10. Furthermore, North Carolina's antidegradation policy requires that "existing uses" of all waters must be maintained. 15A N.C. Admin. Code 02B.0201(b) (2006). North Carolina water quality standards recognize that an existing use of a water body includes providing habitat for endangered or threatened species. 15A N.C. Admin. Code 02B.0110 (2006). Since providing habitat for the Carolina heelsplitter is an existing use in the Goose Creek watershed, the NPDES Phase II stormwater permits must ensure that habitat for the Carolina heelsplitter is maintained and protected. 15A N.C. Admin. Code 02B.0201(b) (2006).

11. Respondent violated the Clean Water Act and N.C. Gen. Stat. § 143.215.1(a)(6) (2006) when it issued the permits without ensuring compliance with all applicable state water quality standards. This conclusion is supported by numerous Findings of Fact, which will not be recited again in detail here but which may be summarized as follows:

a. The USFWS determined that certain stormwater mitigation measures were necessary to protect the federally endangered Carolina heelsplitter in Goose Creek. These measures include two-hundred-foot buffers on perennial streams and one-hundred-foot buffers on intermittent streams, a zero to six percent impervious surface threshold for triggering the need for structural stormwater controls, and water quality standards for the major constituents of concern.

b. The USFWS provided its determinations to Respondent in the form of a draft Technical Support Document for the Goose Creek Site-Specific Management Plan well before the permits were issued.

c. Respondent issued the three challenged NPDES Phase II stormwater permits with measures that fall well short of the USFWS's determinations. The permits set the impervious surface threshold at twenty-four percent and only require a thirty-

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foot setback of impervious surfaces from streams. According to the USFWS, the Carolina heelsplitter population in Goose Creek will be extirpated within two to five years if development is allowed as permitted by the three challenged NPDES Phase II stormwater permits.

12. Respondent also violated the state antidegradation policy when it issued the permits without ensuring that the existing use of providing habitat for the federally endangered Carolina heelsplitter was adequately protected from stormwater discharges. Again, as detailed in the Findings of Fact, Respondent ignored the determinations made by the USFWS regarding stormwater measures that would be necessary to protect the Carolina heelsplitter population in Goose Creek.

13. Because Respondent violated its own rules in issuing the permits without ensuring compliance with all state water quality standards and the state antidegradation policy, Respondent acted arbitrarily and capriciously in issuing the three challenged NPDES stormwater permits. N.C. Gen. Stat. § 150B-23(a)(4) (2006). An agency action is arbitrary and capricious if it clearly shows "a lack of fair and careful consideration or want of impartial, reasoned decision-making." Comm'r. of Ins. v. Rate Bureau, 300 N.C. 381, 269 S.E. 2d 547 (1980). When an agency's decision is not in accordance with its own rules or policies, the agency has shown a lack of fair and careful consideration and has acted arbitrarily and capriciously. Joyce v. Winston-Salem State University, 91 N.C. App. 153 (1988).

14. Because Respondent violated its own regulations and the requirements of the federal Clean Water Act, Respondent also exceeded its statutory authority, failed to use proper procedure, and acted contrary to law. N.C. Gen. Stat. § 150B-23(a)(1)-(5) (2006).

Contested Issue No. 2:

15. The federal regulations implementing the Phase II permitting program require regulated entities to "develop, implement, and enforce a stormwater management program designed to reduce the discharge of pollutants ... to the maximum extent practicable, to protect water quality, and to satisfy the appropriate requirements of the Clean Water Act." 40 C.F.R. § 122.34(a) (2006).

16. The requirement to reduce discharges to the maximum extent practicable is distinct from other requirements under 40 C.F.R. § 122.34(a) (2006). Under this requirement, permittees may be required to go beyond compliance with state water quality standards and implement stormwater measures that are more than standard practice.

17. "Maximum extent practicable" means to the fullest degree technologically feasible for the protection of water quality, except where costs are wholly disproportionate to the potential benefits. See Haeuser v. Department of Law, 97 F.3d 1152, 1155 (9th Cir. 1996); Rybachek v. United States E.P.A., 904 F.2d 1276, 1289 (9th Cir. 1990); Ass'n of Pac. Fisheries v. United States E.P.A., 615 F.2d 794, 805 (9th Cir. 1980). This standard requires more of permittees than mere compliance with water quality standards or numeric effluent limitations designed to meet such standards. Envtl. Def. Center, Inc. v. United States E.P.A., 319 F.3d 398, 425-26 (9th Cir. 2003).

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18. The term "maximum extent practicable" in the stormwater context implies that the mitigation measures in a stormwater permit must be more than simply adopting standard practices. This definition applies particularly in areas where standard practices are already failing to protect water quality, such as the Goose Creek watershed.

19. Respondent violated 40 C.F.R. § 122.34(a) (2006) because it failed to require stormwater measures that achieve the maximum extent practicable standard. As set out more fully in the Findings of Fact, the permits set the impervious surface thresholds for structural controls at twenty-four percent and require only thirty-foot setbacks. These limits do not reduce discharge to the maximum extent practicable. The USFWS has provided Respondent with measures that, if implemented, would reduce stormwater pollution into Goose Creek to the maximum extent practicable. Those measures include a zero (or at a minimum a six percent) impervious surface threshold for structural stormwater controls, two-hundred foot undisturbed riparian buffers on perennial streams, one-hundred foot undisturbed riparian buffers on intermittent streams, setbacks on all new disturbances in the one-hundred year floodplain, and water quality standards for ammonia, phosphorus, nitrate-nitrite, and copper. Those measures constitute what is "technologically feasible" in Goose Creek and thus should have been incorporated into the permits. Furthermore, other types of structural controls are available, such as infiltration measures, which would reduce discharges more than the measures contained in the permits. The limits in the permits are no more than standard practice and as such do not meet the maximum extent practicable standard.

20. The Clean Water Act requires that all effluent limitations and pollution control terms or limitations must be included in the NPDES permit. See 33 U.S.C. §§ 1311(a)-(b), 1342(a) (2006).

21. An effluent limitation is "any restriction established by a State ... on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources." 33 U.S.C. § 1362(11) (2006).

22. The challenged permits require the permittees to develop and implement stormwater management plans "to reduce the discharge of pollutants ... to the maximum extent practicable, to protect water quality, and to satisfy the applicable water quality requirements of the Clean Water Act." As explained more fully in Findings of Fact 66-71, these stormwater management plans contain effluent limitations which are not a part of the NPDES permit because Respondent did not attach or annex the stormwater management plans to the permits. Therefore, Respondent violated 33 U.S.C. §§ 1311(a)-(b) and 1342(a) in issuing the NPDES Phase II stormwater permits to Indian Trail, Stallings, and Mecklenburg County.

23. The Clean Water Act further requires that state agencies issuing NPDES permits follow certain notice and comment procedures in developing new permits. "[P]ublic participation in the development, revision, and enforcement of any regulation, standard, effluent limitation, plan or program established by ... any State under this Act shall be provided for, encouraged, and assisted by ... the States." 33 U.S.C. § 1251(e) (2006).

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24. The Second Circuit Court of Appeals recently invalidated federal regulations governing NPDES permitting for confined animal operations that did not require nutrient management plans to be included in the permit and noticed to the public. Waterkeeper Alliance, Inc., et. al. v. EPA, 2005 U.S. App. LEXIS 6533, 6540 (2nd Cir. 2005). "Since nutrient management plans embody all the relevant 'site specific management practices,' it is clear that...nutrient management plans are a sine qua non of the 'regulation, standard, plan, or program' " under 33 U.S.C. § 1251(e) (2006). The Court held that because the management plans contained non-numerical effluent limitations in the form of best management practices, the rule "by failing to require that the terms of the nutrient management plans be included in NPDES permits - violates the Clean Water Act and is otherwise arbitrary and capricious in violation of the Administrative Procedure Act."

25. In the stormwater permitting context, stormwater management plans are equivalent to nutrient management plans. The stormwater management plans are supposed to contain "all relevant 'site specific management measures' " that will be implemented in the Goose Creek watershed to reduce the discharge of stormwater pollution. Waterkeeper Alliance, Inc, 2005 U.S. App. LEXIS at 43. Therefore, Respondent violated 33 U.S.C. §§ 1311(a)-(b) and 1342(a) by not including the plans in the NPDES Phase II stormwater permits.

26. As a necessary part of the NPDES permits, the stormwater management plans should also have been subject to the public participation requirement under 33 U.S.C. § 1251(e) (2006). Pursuant to 33 U.S.C. § 1342(j) (2006), "a copy of each permit application and each permit issued under this section shall be available to the public." Since the three challenged NPDES Phase II permits were noticed without including the stormwater management plans, Respondent violated 33 U.S.C. §§ 1251(e), 1311, 1342(a) (2006). Further, Respondent violated 33 U.S.C. § 1342(j) (2006) by failing to provide copies of the stormwater management plans to members of the public who requested copies of the draft permit.

27. Because Respondent violated the requirements of the federal Clean Water Act and the federal regulations implementing the Phase II program, Respondent exceeded its statutory authority, failed to use proper procedure, acted contrary to law, and acted arbitrarily and capriciously. N.C. Gen. Stat. § 150B-23(a)(1)-(5) (2006).

Contested Issue No. 3:

28. NPDES permits must contain "any more stringent limitation ... necessary to meet water quality standards." 33 U.S.C. § 1311(b)(1)(C) (2006). Pursuant to this requirement, NPDES permits for discharges to waters for which a TMDL has been established must be consistent with the waste load allocation in the TMDL. 40 C.F.R. §§ 122.44(d)(a)(vii)(B); 130.12(a) (2006).

29. As discussed more fully in the Findings of Fact 72-79, Goose Creek is subject to a final TMDL for fecal coliform discharges. The waste load allocation in the Goose Creek TMDL calls for a ninety-two point five percent (92.5%) reduction in current fecal coliform discharges.

30. The challenged permits do not contain limits and conditions that will reduce current discharges. The permits as written will in fact increase fecal coliform

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discharges.

31. By not including limits and conditions that will reduce current discharges of fecal coliform, Respondent has violated 33 U.S.C. § 1311(b)(1)(C) and 40 C.F.R. §§ 122.44 (d)(a)(vii)(B) and 130.12(a).

32. Because Respondent violated the requirements of the federal Clean Water Act, Respondent also exceeded its statutory authority, failed to use proper procedure, acted contrary to law, and acted arbitrarily and capriciously. N.C. Gen. Stat. § 150B-23(a)(1)-(5) (2006).

BASED UPON the foregoing Stipulations, Findings of Fact and Conclusions of Law, the undersigned renders the following:

DECISION

That Respondent must reopen, amend, and reissue the NPDES permits to incorporate the USFWS's determinations of measures necessary to protect the habitat for the Carolina heelsplitter. Those measures are two-hundred foot buffers for perennial streams, one-hundred foot buffers for intermittent streams, a zero percent impervious surface threshold for structural stormwater controls, no new impervious surface in the one-hundred year floodplain, and water quality standards for ammonia, copper, nitrate-nitrite, and phosphorus.

NOTICE

The agency making the final decision in this contested case is required to give each party an opportunity to file exceptions to this Decision and to present written arguments to those in the agency who will make the final decision. N. C. Gen. Stat. § 150B-36(a). In accordance with N.C. Gen. Stat. § 150B-36, the agency shall adopt each finding of fact contained in the Administrative Law Judge's decision unless the finding is clearly contrary to the preponderance of the admissible evidence, giving due regard to the opportunity of the Administrative Law Judge to evaluate the credibility of witnesses. For each finding of fact not adopted by the agency, the agency shall set forth separately and in detail the reasons for not adopting the finding of fact and the evidence in the record relied upon by the agency. Every finding of fact not specifically rejected as required by Chapter 150B shall be deemed accepted for purposes of judicial review. For each new finding of fact made by the agency that is not contained in the Administrative Law Judge's decision, the agency shall set forth separately and in detail the evidence in the record relied upon by the agency establishing that the new finding of fact is supported by a preponderance of the evidence in the official record.

The agency that will make the final decision in this case is the North Carolina Department of Environment and Natural Resources. The agency is required by N.C.G.S. 150B-36(b) to serve a copy of the final decision on all parties and to furnish a copy to the parties' attorneys of record and to the Office of Administrative Hearings.

This the 13th day of October, 2006.

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_____
Fred G. Morrison Jr.

Senior Administrative Law Judge

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STATE OF CALIFORNIA

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LOS ANGELES REGION

ORDER 09-xxx
NPDES PERMIT NO. CAS004002
WASTE DISCHARGE REQUIREMENTS
FOR
STORM WATER (WET WEATHER) AND NON-STORM WATER (DRY WEATHER) DISCHARGES FROM THE MUNICIPAL SEPARATE STORM SEWER SYSTEMS WITHIN THE VENTURA COUNTY WATERSHED PROTECTION DISTRICT, COUNTY OF VENTURA AND THE INCORPORATED CITIES THEREIN.

May 7, 2009



TENTATIVE

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STATE OF CALIFORNIA

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LOS ANGELES REGION

ORDER 08-xxx
NPDES PERMIT NO. CAS004002
WASTE DISCHARGE REQUIREMENTS
FOR
STORM WATER DISCHARGES FROM THE MUNICIPAL SEPARATE STORM SEWER SYSTEM WITHIN THE VENTURA COUNTY WATERSHED PROTECTION DISTRICT, COUNTY OF VENTURA AND THE INCORPORATED CITIES THEREIN

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FINDINGS

The California Regional Water Quality Control Board, Los Angeles Region (hereinafter called Regional Water Board), finds that:

A. Permit Parties and History

1. Ventura County Watershed Protection District (Principal Permittee), County of Ventura, cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura (Ventura), Santa Paula, Simi Valley and Thousand Oaks (hereinafter referred to separately as Permittees) have joined together to form the Ventura Countywide Storm Water Quality Management Program to discharge wastes. The Permittees discharge or contribute to discharges of storm water and non-storm water from municipal separate storm sewer systems (MS4s), also called storm drain systems, into the Watershed Management Areas of Ventura River, Santa Clara River, Calleguas Creek, Malibu Creek and Miscellaneous Ventura Coastal all within Ventura County and Los Angeles County (see Attachment "A").

2. Prior to the issuance of this permit, storm water discharges from the Ventura County MS4 were covered under the countywide waste discharge requirements contained in Order No. 00-108, adopted by the Regional Water Board on July 27, 2000, which replaced Order No. 94-082, adopted by the Regional Water Board on August 22, 1994. Order No. 00-108 also served as a National Pollutant Discharge Elimination System (NPDES) permit for the discharge of municipal storm water.

3. The Ventura County Board of Supervisors approved the concept of a countywide NPDES permit program and the use of the Flood Management District (presently the Watershed Protection District) benefit assessment authority to finance it on April 14, 1992. On June 30, 1992, the Ventura County Board of Supervisors adopted a benefit assessment levy for storm water and flood management in the unincorporated areas of Ventura County and the cities within the County, to be used in part to finance the implementation of a countywide NPDES municipal storm water

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permit program. The Ventura County MS4 Permittees have entered into an agreement with the Watershed Protection District to finance the activities related to the Ventura County MS4 Permit for shared and district wide expenses. The Permittees are also given the option to use the Benefit Assessment Program to finance their respective activities related to reducing the discharge of storm water pollutants under the MS4 Permit.

4. The Regional Water Board may require a separate NPDES permit for any entity that discharges storm water into the watersheds of Ventura County. Such an entity can be any State or Federal facility, special district or other public or private party.

B. Nature of Discharge

1. Storm water discharges consist of surface water runoff generated from various land uses in all the hydrologic drainage basins, which discharge into Waters of the State. The quality of these discharges varies and is affected by geology, land use, season, hydrology, and sequence and duration of hydrologic events. Based on the Ventura Countywide Storm Water Monitoring Program's Water Quality Monitoring Reports which were required under Order No. 00-108, the dry weather and wet weather Pollutants of Concern (POC) in urban stormwater include an anion, bacteria, conventional pollutants, metals, a nutrient, organic compounds, and pesticides. The POC are identified in Attachment "B" of this Order. Many of the POC listed are causing impairments identified on the federal Clean Water Act (CWA) § 303(d) list of impaired waterbodies.

   The State Water Board submits a report (a list of water quality limited segments (§ 303[d] list)) on the State's water quality to the U.S. EPA pursuant to § 305(b) of the 1972 CWA, and Title 40, CFR 130.7, every 2 years. The Report provides water quality information to the general public and serves as the basis for the U.S. EPA's National Water Quality Inventory Report to Congress. Section 303(d) requires that all waters that are not attaining standards after the implementation of those controls required by 1977, shall be included on the list. Title 40 CFR 130.7(b)(3) defines "water quality standard applicable to such waters" as "those water quality standards established under § 303 of the Clean Water Act, including numeric criteria, narrative criteria, waterbody uses, and antidegradation requirements."

2. Common pollutants in urban storm water and their respective sources are: bacteria from animal droppings and illegal discharges; Polycyclic Aromatic Hydrocarbons (PAHs) from the products of internal combustion engine operation and parking lot sealants wash off; nitrates from fertilizer application; pesticides from pest mitigating applications and from plant mitigating applications; bis (2-ethylhexyl) phthalate from the break down of plastic products; mercury from atmospheric fallout and improper disposal of mercury switches; lead from fuels, paints and automotive parts; copper

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from brake pad wear and roofing materials, zinc from tire wear and galvanized sheeting and fencing; sediment from land disturbance and erosion; and dioxins as products of combustion.

3. In general, the pollutants that are found in municipal storm water runoff can harm human health and aquatic ecosystems. In addition, the high volumes and high velocities of storm water discharged from MS4s into natural watercourses can adversely impact aquatic ecosystems and stream habitat and cause stream bank erosion and physical modifications. These changes are collectively termed hydromodification. Municipal point source discharges of runoff from urbanized areas remain a leading cause of impairment of surface waters in California.

4. Ammonia as Nitrogen, and Nitrate plus Nitrite as Nitrogen are biostimulatory substances that can cause or contribute to eutrophic effects such as low dissolved oxygen and algae growth impairing warm freshwater and wildlife habitats. Ammonia is highly toxic to fish and other aquatic life. Excessive ammonia can cause aquatic life toxicity.

5. Elevated bacterial indicator densities impair the water contact recreation (REC-1) beneficial use at beaches, creeks, estuaries, lagoons, and marinas. Swimming in waters with elevated bacterial indicator densities has been associated with adverse health effects. Specifically, local and national epidemiological studies indicate that there is a causal relationship between adverse health effects and recreational water quality, as measured by bacterial indicator densities. Sources of elevated bacteria to marine and fresh waters may also include illegal discharges from improperly maintained standard septic systems, onsite wastewater treatment systems (OWTS) and illicit discharges from private drains.

6. Pesticides are substances used to prevent, destroy, repel or mitigate pests such as insects, weeds, and microorganisms. Their effects can be direct (e.g. fish die from exposure to a pesticide entering waterways, or birds do not reproduce after ingesting contaminated fish), or indirect (a hawk becomes sick from eating a mouse dying from pesticide poisoning). Pesticide categories include: Organochlorine, Organophosphorus, Organophosphate, and Pyrethroid.

7. Polychlorinated Biphenyls (PCBs) are a subset of the synthetic organic chemicals known as chlorinated hydrocarbons. Concern over PCBs toxicity, persistence (chemical stability) in the environment and bioconcentration in aquatic organisms has led to prohibitions on PCBs.

8. Rising groundwater and swimming pool water have been found to be sources of pollutants such as salts (chloride). Salts increase the salinity of otherwise freshwater systems and disrupt physiological processes. The Regional Water Board has

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waterbodies listed on the CWA § 303(d) list for impairment due to salts and has adopted Basin Plan amendments to include Total Maximum Daily Loads (TMDLs) for salts. This Order includes provisions to control the discharges from these activities in order to directly or indirectly reduce or eliminate the discharge of salts to fresh water systems where salts may impair water quality and beneficial uses.

9. Trash and debris are pervasive pollutants which accumulate in streams, rivers, bays, and ocean beaches throughout Southern California. They pose a serious threat to our oceans and coasts, navigation, biological resources, recreation, human health and safety, aesthetics, and economies.

10. Municipal storm water (wet weather) and non-storm water (dry weather) discharges may contain pollutants that cause or threaten to cause an exceedance of the water quality standards, as outlined in the Los Angeles Region's Basin Plan. Wet weather and dry weather discharges from the MS4 are subject to conditions and requirements established in the Basin Plan for point source discharges. Discharges from the MS4 may not cause or contribute to exceedances of water quality standards.

11. Biological communities act to integrate the effects of water quality conditions in a stream by responding with changes in their population abundances and species composition over time. These populations are sensitive to multiple aspects of water and habitat quality, and provide expressions of ecological health easier to understand than the results of chemical and toxicity tests. Biological assessments and criteria address the cumulative impacts of all stressors, especially habitat degradation, and chemical contamination, which result in a loss of biological diversity. Biological information can help provide an ecologically based assessment of the status of a waterbody. Bioassessment is a cost-effective tool and protocol for assessing the biological and physical habitat conditions of streams and rivers for evaluation of the overall health of a watershed. The Principal Permittee consents to participate in the Southern California Storm Water Monitoring Coalition (SMC) Southern California Regional Bioassessment Monitoring Program.

12. The increased volume, increased velocity, and discharge duration of storm water runoff from developed areas has the potential to greatly accelerate downstream erosion and impair stream habitat in natural drainages. Studies have demonstrated a direct correlation between the degree of imperviousness of an area and the degradation of its receiving waters. Significant declines in the biological integrity and physical habitat of streams and other receiving waters have been found to occur with as little as 3-10 percent conversion from natural to impervious surfaces. Percentage impervious cover is a reliable indicator and predictor of potential water quality degradation expected from new development.

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13. Studies indicate that facilities with paved surfaces subject to frequent motor vehicular traffic (such as: strip malls, parking lots, commercial business parks, and fast food restaurants), or facilities that perform vehicle repair, maintenance, or fueling (automotive service facilities) are potential sources of POC in storm water.

14. Retail Gasoline Outlets (RGOs) are points of convergence for vehicular traffic and are similar to parking lots and urban roads. Studies indicate that storm water discharges from RGOs have high concentrations of hydrocarbons and heavy metals.

15. The industries and businesses listed in this Order that are to be inspected by Permittees have the potential to discharge contaminated storm water into the MS4. This storm water is an environmental threat because it can adversely impact public health and safety, and the quality of receiving waters. For example, pretreatment program compliance inspections and audits performed in the Los Angeles and Ventura Counties indicate that automotive service and food service facilities sometimes discharge polluted storm water to the MS4s. The POC in such wash waters include oil and grease, toxic chemicals, and food waste. Spills from clogged sanitary sewer lines have a high likelihood to reach the receiving waters via MS4s. Overall, the most common POC identified in storm water discharge to the MS4s are: (i) heavy metals, (ii) oil and grease/ PAHs, (iii) sediments, (iv) oxygen demanding substances, (v) litter/ trash/ debris, (vi) nutrients, (vii) other toxic materials, such as pesticides. Municipal storm water monitoring data and industrial storm water monitoring data indicate that industrial and commercial sites continue to contribute significant quantities of pollutants in storm water runoff.

16. Development and urbanization increase pollutant loads, volume, and discharge velocity. First, natural vegetated pervious ground cover is converted to impervious surfaces (paved) such as highways, streets, rooftops and parking lots. Natural vegetated soil can both absorb rainwater and remove pollutants providing an effective natural purification process. In contrast, impervious surfaces (such as pavement and concrete) can neither absorb water nor remove pollutants, and thus the natural purification characteristics are lost. Second, urban development creates new pollution sources as the increased density of human population brings proportionately higher levels of vehicle emissions, vehicle maintenance wastes, municipal sewage waste, pesticides, household hazardous wastes, pet wastes, trash, and other anthropogenic pollutants. Development and urbanization especially threaten environmentally sensitive areas. Such areas have a much lower capacity to withstand pollutant shocks than might be acceptable in the general circumstance. In essence, development that is ordinarily insignificant in its impact on the environment may become significant in a particularly sensitive environment. These environmentally sensitive areas (ESAs) designated by the State in the Ventura County watershed include:
    (a) Drainages to waters identified in the Basin Plan as supporting the "Rare, Threatened, or Endangered Species (RARE)" Beneficial Use; and

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(b) California Coastal Commission's Environmentally Sensitive Habitat Areas as delineated on maps in Local Coastal Plans (LCPs).
(c) Additional ESAs that may be identified by California Department of Fish and Game.

17. The implementation of Low Impact Development (LID) techniques across the United States and Canada has demonstrated that the proper implementation of LID techniques not only results in water quality protection benefits and in a reduction of the cost of land development and construction but also bears other positive attributes that go beyond economic benefits such as enhanced property values, improved habitat, aesthetic amenities, and improved quality of life. *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, USEPA Doc No. EPA 841-F-07-006, December 2007.* Further, properly implemented LID techniques reduce the volume of runoff leaving a newly developed or re-developed area thereby lowering the peak rate of runoff, and thus minimizing the adverse affects of hydromodification on stream habitat. *A Review of Low Impact Development Policies: Removing Institutional Barriers to Adoption, Low Impact Development Center and State of California, State Water Resources Control Board, December 2007.* The requirements of this Order facilitate the implementation of LID strategies to protect water quality, reduce runoff volume, and to benefit from these additional enhancements.

18. The Regional Water Board adopted a Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (Order No. R4-2005-0080) on November 3, 2005. The objective of the program is to monitor runoff from irrigated agriculture facilities in the coastal watersheds of Ventura and Los Angeles Counties. The Basin Plan, which designates beneficial uses and establishes water quality objectives for the Region, recognizes that agricultural activities can generate pollutants such as sediment, pesticides, and nutrients that upon discharge to receiving water, can degrade water quality and impair beneficial uses. A category identified by the Conditional Waiver as a source of pollutants is nursery operations. This Order includes requirements for the municipal operator to confirm that nursery operators implement pollutant reduction and control measures with the objective of reducing pollutants in storm water runoff discharges.

19. Research conducted on the contribution of aerial deposition of trace heavy metals in Los Angeles County watersheds indicates that dry indirect deposition may account for a significant load of pollutants into surface waters. Similar patterns of aerial deposition likely occur in Ventura County. Of the atmospherically deposited pollutants on the watersheds, ten to twenty percent may account for the total load for copper, zinc, nickel, lead, and chromium to the waterbodies. Land reservoirs and sequestration may account for the remaining eighty to ninety percent of the atmospherically deposited pollutants on the watersheds. Emissions of semi-volatile

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organics such as polycyclic aromatic hydrocarbons (PAHs) and pesticides and their subsequent deposition may contribute to the contamination of receiving waters but appear to be less significant. The remaining percentage is stored in land reservoirs and eventually shows up in receiving waters.

C. Permit Background

1. The essential components of the Storm Water Management Program, as required by the Code of Federal Regulations (CFR) [40 CFR122.26(d)] are:
   (a) Adequate Legal Authority.
   (b) Fiscal Resources.
   (c) Storm Water Quality Management Program (SMP)
      (1) Public Information and Participation Program
      (2) Industrial/ Commercial Facilities Program
      (3) Planning and Land Development Program
      (4) Development Construction Program
      (5) Public Agency Activities Program
      (6) Illicit Connection and Illicit Discharges Elimination Program
   (d) Reporting Program (Monitoring Report and Program Report)

2. The Ventura County SMP, dated November 2001 (revision 2) identifies seven program areas, which are listed below and were previously approved under Board Order No. 00-108. For purposes of consistency, they are titled as follows:
   (a) Ventura County SMP.
      (1) Program Management
      (2) Programs for Residents
      (3) Programs for Industrial/ Commercial Businesses
      (4) Programs for Planning and Land Development
      (5) Programs for Construction Sites
      (6) Programs for Public Agency Activities
      (7) Programs for Illicit Connections/ Illegal Discharges
   (b) For purposes of region-wide consistency, the program titles are revised and consolidated into the six areas listed in the preceding C.1(c). All Permittee storm water documents submitted to the Regional Water Board are to follow the organization enumerated in C.1(c).

3. The Permittees filed a Report of Waste Discharge (ROWD), dated January 26, 2005. The Permittees applied for renewal of their waste discharge requirements for a 5-year period, which serves as an NPDES permit to discharge wastes to surface waters.

4. The Regional Water Board reviewed the ROWD and determined it to be partially complete under the reapplication policy for MS4s issued by the United States Environmental Protection Agency (U.S. EPA) (61 Fed. Reg. 41697). The Regional

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Water Board has prepared this Order so that implementation of provisions contained in this Order by Permittees will meet the requirements of the federal NPDES regulations at 40 CFR122.26.

5. The Permittees ROWD contained a proposed Storm Water Management Program and a Monitoring Program to be considered by the Regional Water Board for incorporation into an MS4 NPDES Permit as permit conditions and to demonstrate compliance with federal law.

6. To-date, the monitoring program has consisted of mass emission, receiving water (tributaries), and land-use monitoring stations, toxicity testing, special studies for bioassessment of the Ventura River and hydrology, identification of ESAs, implementation of the Storm Water Quality Urban Impact Mitigation Plan (SQUIMP), and has provided support for volunteer monitoring programs. This Order requires a monitoring program consisting of mass emission, toxicity, TMDL storm water (wet weather) MS4 water quality-based effluent limits, TMDL non-storm water (dry weather) MS4 water quality-based effluent limits, trash and debris study, Pyrethroid assessment study, continuation of the hydromodification study, low impact development study, and participation in the Southern California Regional Bioassessment Program and Southern California Bight Project (SCBP).

7. The Principal Permittee is a member of the Southern California Coastal Water Research Project (SCCWRP) Commission. The Principal Permittee also participates in the Regional Monitoring Programs and research partnerships, such as the Southern California Storm Water Monitoring Coalition (SMC) and the Bioassessment Working Group.

D. Permit Coverage

1. The area covered by this Order includes all areas within Ventura County boundaries and all areas within each co-permittee's boundaries (see Figure 1) that drain into the MS4.

2. The Permittees covered under this Order were designated on a system-wide basis under Phase I of the CWA § 402(p)(3)(B)(i). The action of covering all Ventura County municipalities under a single MS4 permit on a system-wide basis was consistent with the provisions of 40 CFR122.26(a)(3)(iv), which states that one permit application may be submitted for all or a portion of all municipal separate storm sewers within adjacent or interconnected large or medium municipal separate storm sewer systems; and the Regional Water Board may issue one system-wide permit covering all, or a portion of all municipal separate storm sewers in adjacent or interconnected large or medium municipal separate storm sewer systems.

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3. Federal, State, Regional, or local entities within the Permittees' boundaries or in jurisdictions outside the Ventura County Watershed Protection District, and not currently named in this Order, may operate storm drain facilities and/ or discharge storm water to storm drains and watercourses covered by this Order. The Permittees may lack legal jurisdiction over these entities under State and Federal constitutions. The Regional Water Board will coordinate with these entities to implement programs that are consistent with the requirements of this Order. The Regional Board may consider such facilities for coverage under its NPDES permitting scheme pursuant to USEPA Phase II storm water regulations.
Permittees have expressed their intention to work cooperatively to control the contribution of pollutants from one portion of the MS4 to another portion of the system. Permittees shall make good faith efforts to control the contribution of pollutants to the MS4 from non-permittee dischargers such as Caltrans, the U.S. Department of Defense, and other state and federal facilities.

4. TMDLs are numerical calculations of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point sources (Waste Load Allocation (WLA) and non-point sources (Load Allocation (LA)). Discharges from the MS4s are considered point sources discharges, because the MS4 is a point source.

5. This Order incorporates applicable WLAs that have been adopted by the Regional Water Board and have been approved by the Office of Administrative Law and the U.S. EPA. The TMDL WLAs in the Order are expressed as water quality-based effluent limits in a manner consistent with the assumptions and requirements of the TMDL from which they are derived.

6. The CWA and the California Water Code contain specific provisions on how wastewater discharges from point sources are to be permitted. Urban non-storm water (dry weather) discharge is not considered a storm water (wet weather) discharge.

7. Permittees should work cooperatively to control the contribution of pollutants from one portion of the MS4 to another portion of the system through inter-agency agreements or other formal arrangements.

T E N T A T I V E

E. Federal, State and Regional Regulations

1. The Water Quality Act of 1987 added § 402(p) to the CWA (33U.S.C. § 1251-1387). This section requires the U.S. EPA to establish regulations setting forth NPDES requirements for storm water discharges in 2 phases.

(a) U.S. EPA Phase I storm water regulations were directed at MS4s serving a population of 100,000 or more, including interconnected systems and storm water discharges associated with industrial activities, including construction activities. The Phase 1 Final Rule was published on November 16, 1990 (55 Fed. Reg. 47990).

(b) U.S. EPA Phase II storm water regulations are directed at storm water discharges not covered in Phase I, including small MS4s (population of less than 100,000), small construction projects (less than 5 acres), municipal facilities with delayed coverage under the Intermodal Surface Transportation Efficiency Act of 1991, and other discharges for which the U.S. EPA Administrator or the State determines that the storm water discharge contributes to a violation of a water quality standard, or is a significant contributor of pollutants to waters of the U.S. The Phase II Final Rule was published on December 8, 1999 (64 Fed. Reg. 68722).

2. The U.S. EPA published an 'Interpretative Policy Memorandum on Reapplication Requirements for MS4 permits on August 9, 1996 (61 Fed. Reg. 41697). This policy requires that MS4 reapplication for reissuance for a subsequent five-year permit term contain certain basic information and information for proposed changes and improvements to the storm water management program and monitoring program.

3. The U.S. EPA has entered into a Memorandum of Agreement (MOA) with the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service for enhancing coordination regarding the protection of endangered and threatened species under section 7 of the Endangered Species Act, and the CWA's water quality standards and NPDES programs. Among other actions, the MOA establishes a framework for coordination of actions by the U.S. EPA, the Services, and CWA delegated States on CWA permit issuance under § 402 of the CWA [66 Fed. Reg. 11202-11217].

4. The CWA allows the U.S. EPA to authorize states with an approved environmental regulatory program to administer the NPDES program in lieu of the U.S. EPA. The State of California is a delegated State. The Porter-Cologne Water Quality Control Act (California Water Code) authorizes the State Water Resources Control Board (State Water Board), through the Regional Water Boards, to regulate and control the discharge of pollutants into all waters of the State, including waters of the United States, and tributaries thereto.

5. Under CWA § 303(d) of the CWA, States are required to identify a list of impaired water-bodies and develop and implement TMDLs for these waterbodies (33 USC § 1313(d)(1)). The most recent 303(d) list's U.S. EPA approval date was June 28, 2007. The U.S. EPA entered into a consent decree with the Natural Resources Defense Council (NRDC), Heal the Bay, and the Santa Monica BayKeeper on March 22, 1999, under which the Regional Water Board must adopt all TMDLs

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for the Los Angeles Region within 13 years from that date. This Order incorporates provisions incorporating approved WLAs for municipal storm water discharges and requires amending the SMP after subsequent pollutant loads have been allocated and approved.

6. Collectively, the restrictions contained in the TMDL Provisions for Storm Water (Wet Weather) Discharges and Non-Storm Water (Dry Weather) Discharges of this Order on individual pollutants are no more stringent than required to implement the provisions of the TMDL, which have been adopted and approved in a manner that is consistent with the CWA. Where a TMDL has been approved, NPDES permits must contain effluent limits and conditions consistent with the assumptions and requirements of the available WLAs in TMDLs (40 CFR122.44(d)(1)(vii)(B)).

7. This Order does not constitute an unfunded local government mandate subject to subvention under Article XIIIB, Section (6) of the California Constitution for several reasons, including, but not limited to, the following. This Order implements federally mandated requirements under CWA § 402, subdivision (p)(3)(B). (33 U.S.C. § 1342(p)(3)(B)) This includes federal requirements to effectively prohibit non-storm water discharges, to reduce the discharge of pollutants to the maximum extent practicable, and to include such other provisions as the Administrator or the State determines appropriate for the control of such pollutants. Federal cases have held these provisions require the development of permits and permit provisions on a case-by-case basis to satisfy federal requirements. (Natural Resources Defense Council, Inc. v. U.S. E.P.A. (9th Cir. 1992) 966 F.2d 1292, 1308, fn. 17.) The authority exercised under this Order is not reserved state authority under the Clean Water Act's savings clause (cf. Burbank v. State Water Resources Control Bd. (2005) 35 Cal.4th 613, 627-628 [relying on 33 U.S.C. § 1370, which allows a state to develop requirements which are not "less stringent" than federal requirements]), but instead, is part of a federal mandate to develop pollutant reduction requirements for municipal separate storm sewer systems. To this extent, it is entirely federal authority that forms the legal basis to establish the permit provisions. (See, City of Rancho Cucamonga v. Regional Water Quality Control Bd.-Santa Ana Region (2006) 135 Cal.App.4th 1377, 1389; Building Industry Ass'n of San Diego County v. State Water Resources Control Bd. (2004) 124 Cal.App.4th 866, 882-883.)

   Likewise, the provisions of this Order to implement TMDLs are federal mandates. The CWA requires TMDLs to be developed for waterbodies that do not meet federal water quality standards (33 U.S.C. § 1313(d)). Once the U.S. EPA or a state develops a TMDL, federal law requires that permits must contain effluent limitations consistent with the assumptions of any applicable wasteload allocation. (40 CFR122.44(d)(1)(vii)(B)).

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Second, the local agency Permittees' obligations under this Order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges. With a few inapplicable exceptions, the Clean Water Act regulates the discharge of pollutants from point sources (33 U.S.C. § 1342) and the Porter-Cologne regulates the discharge of waste (Wat. Code, § 13263), both without regard to the source of the pollutant or waste. As a result, the "costs incurred by local agencies" to protect water quality reflect an overarching regulatory scheme that places similar requirements on governmental and nongovernmental dischargers. (See *County of Los Angeles v. State of California* (1987) 43 Cal.3d 46, 57-58 [finding comprehensive workers compensation scheme did not create a cost for local agencies that was subject to state subvention].)

The Clean Water Act and the Porter-Cologne Water Quality Control Act largely regulate storm water with an even hand, but to the extent there is any relaxation of this even-handed regulation, it is in favor of the local agencies. Except for municipal separate storm sewer systems, the Clean Water Act requires point source dischargers, including discharges of storm water associated with industrial or construction activity, to comply strictly with water quality standards. (33 U.S.C. § 1311(b)(1)(C), *Defenders of Wildlife v. Browner* (1999) 191 F.3d 1159, 1164-1165 [noting that industrial storm water discharges must strictly comply with water quality standards].) As discussed in prior State Water Resources Control Board decisions, in many respects this Order does not require strict compliance with water quality standards. (SWRCB Order No. WQ 2001-15, p. 7.) The Order, therefore, regulates the discharge of waste in municipal storm water more leniently than the discharge of waste from non-governmental sources.

Third, the local agency Permittees have the authority to levy service charges, fees, or assessments sufficient to pay for compliance with this Order subject to certain voting requirements contained in the California Constitution. (See California Constitution XIII D, section 6, subdivision (c); see also *Howard Jarvis Taxpayers Association v. City of Salinas* (2002) 98 Cal. App. 4th 1351, 1358-1359.). The fact sheet demonstrates that numerous activities contribute to the pollutant loading in the municipal separate storm sewer system. Local agencies can levy service charges, fees, or assessments on these activities, independent of real property ownership. (See, e.g., *Apartment Ass'n of Los Angeles County, Inc. v. City of Los Angeles* (2001) 24 Cal.4th 830, 842 [upholding inspection fees associated with renting property].) The ability of a local agency to defray the cost of a program without raising taxes indicates that a program does not entail a cost subject to subvention. (*County of Fresno v. State of California* (1991) 53 Cal.3d 482, 487-488.)

Fourth, the Permittees have requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act section 301, subdivision (a) (33 U.S.C. § 1311(a)) and in lieu of numeric

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restrictions on their discharges. (See finding 5., supra.) To the extent, the local agencies have voluntarily availed themselves of the permit, the program is not a state mandate. (Accord *County of San Diego v. State of California* (1997) 15 Cal.4th 68, 107-108.) Likewise,where MS4 Permittees are regulated under a Best Management Practices (BMP) based storm water management program rather than end-of-pipe numeric limits, there exists no compulsion of a specific regulatory scheme that would violate the 10th Amendment to the United States Constitution. (See *City of Abilene v. U.S. E.P.A.* (5th Cir. 2003) 325 F.3d 657, 662-663 [noting that municipalities can choose between a management permit or a permit with numeric limits].) The local agencies' voluntary decision to file a report of waste discharge proposing a program-based permit is a voluntary decision not subject to subvention. (See *Environmental Defense Center v. USEPA* (9th Cir. 2003) 344 F.3d 832, 845-848.)

Fifth, the local agencies' responsibility for preventing discharges of waste that can create conditions of pollution or nuisance from conveyances that are within their ownership or control under state law predates the enactment of Article XIIIB, Section (6) of the California Constitution.

8. Under § 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Coastal States with approved coastal zone management programs are required to address non-point pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: 1) agriculture; 2) silviculture; 3) urban; 4) marinas; and 5) hydromodification. This Waste Discharge Requirement addresses the management measures required for the urban category and the hydromodification category, with the exception of septic systems.

9. The Regional Water Board addresses septic systems through the administration of non-Chapter 15 regulatory programs and the implementation of Regional Water Board Order No.R4-2004-0146. Septic systems are also addressed under State Assembly Bill (AB) 885 (2000). The Regional Water Board will implement and enforce regulations issued by the State Board pursuant to AB 885. Taken together, these State and Local agency requirements when imposed on septic system operators are expected to reduce the bacterial contamination of storm water from improperly maintained septic systems.

10. The State Water Board has issued waste discharge requirements for discharges from utility vaults (CAG990002). The Regional Water Board has issued waste discharge requirements for discharges from well heads and hydrostatic pipe testing (CAG674001). These discharges to the MS4 shall be conducted under coverage of a separate NPDES permit specific to that activity.

11. On May 18, 2000, the U.S. EPA established numeric criteria for priority toxic pollutants for the State of California (California Toxics Rule (CTR) 65 Fed. Reg.

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31682 (40 CFR131.38) for the protection of human health and aquatic life. These apply as ambient water quality criteria for inland surface waters, enclosed bays and estuaries.

12. The State Water Board adopted a revised Water Quality Control Plan for Ocean Waters of California (Ocean Plan) in 2005. The California Ocean Plan establishes water quality objectives for California's ocean waters and provides the basis for regulation of wastes discharged into the State's coastal waters. It applies to point and nonpoint source discharges. The Ocean Plan identifies the applicable beneficial uses of marine waters that include preservation and enhancement of designated Areas of Special Biological Significance (ASBS) (now called "State Water Quality Protection Areas") and establishes a set of narrative and numerical water quality objectives designed to protect beneficial uses. The SWRCB adopted the California Ocean Plan, and both the SWRCB and the six coastal Regional Water Quality Control Boards (RWQCBs) implement and interpret the California Ocean Plan.

13. This Regional Water Board adopted a revised Water Quality Control Plan (Basin Plan) for the Los Angeles Region on June 13, 1994. The Basin Plan specifies the beneficial uses of Ventura County waterbodies and their tributary streams, and contains both narrative and numerical water quality objectives for these receiving waters. The following beneficial uses identified in the Basin Plan apply to all or portions of each watershed covered by this Order:
    (a) Municipal and domestic supply
    (b) Agricultural supply
    (c) Industrial service supply
    (d) Industrial process supply
    (e) Ground water recharge
    (f) Freshwater replenishment
    (g) Navigation
    (h) Hydropower generation
    (i) Water contact recreation
    (j) Non-contact water recreation
    (k) Ocean commercial and sport fishing
    (l) Warm freshwater habitat
    (m) Cold freshwater habitat
    (n) Preservation of Areas of Special Biological Significance
    (o) Saline water habitat
    (p) Wildlife habitat
    (q) Preservation of rare and endangered species
    (r) Marine habitat
    (s) Fish migration
    (t) Fish spawning
    (u) Shellfish harvesting

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14. On March 22, 1999 the Consent Decree in Heal the Bay, Inc.; Santa Monica BayKeeper, Inc. v. Browner, Case No. 98-4825 SBA was approved. Under Establishment of TMDLs- The parties understand that California has the initial opportunity pursuant to § 303(d) of the CWA to adopt and submit to U.S. EPA for approval TMDLs to be established under this Consent Decree. TMDLs developed by Regional Water Boards are generally adopted through Basin Plan amendments. Basin plan amendments adopted by the State Board pursuant to Water Code section 13246, and the regulatory portions must be approved by the Office of Administrative Law pursuant to Government Code section 11353(b). TMDLs established pursuant to CWA section 303(d)(1) must be submitted to U.S. EPA for approval pursuant to section 303(d)(2), and incorporated into the state's water quality management plan

15. The Regional Water Board has adopted amendments to the Basin Plan, to incorporate TMDLs for the following:
    (a) The following TMDLs have been or will be incorporated into the Basin Plan within the term of the Order.
        (1) Santa Clara River - Nitrogen Compounds
            (A) Regional Water Board Resolution No. 2003-011
            (B) State Water Board Resolution No. 2003-0073
            (C) OAL file No. 04-0123-35
            (D) U.S. EPA approval date March 18, 2004
            (E) Final fee exemption date March 23, 2004 (effective date).
            (F) Compliance is 1 year after effective date (March 23, 2005)

        (2) Malibu Creek and Lagoon - Bacteria.
            (A) Regional Water Board Resolution No. 2004-019
            (B) State Water Board Resolution No. 2005-0072
            (C) OAL file No. 05-1018-03 S
            (D) U.S. EPA approval date January 10, 2006
            (E) Final fee exemption date January 24, 2006 (effective date)
            (F) Compliance for Summer Dry is 3 years after effective date (January 24, 2009)
            (G) Compliance for Winter Dry is 6 years after effective date (January 24, 2012)
            (H) Compliance for Wet Weather is 10 years after effective date (January 24, 2016), which is beyond the term of this Order

        (3) Toxicity, Chlorpyrifos and Diazinon in the Calleguas Creek, Its Tributaries and Mugu Lagoon.
            (A) Regional Water Board Resolution No. 2005-009
            (B) State Water Board Resolution No. 2005-0067
            (C) OAL file No. 05-1110-02 S

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(D) U.S. EPA approval date March 14, 2006
(E) Final fee exemption date March 24, 2006 (effective date)
(F) Compliance for Toxicity and Interim WLA is effective date (March 24, 2006)
(G) Compliance for Final WLA is 2 years after effective date (March 24, 2008)

(4) Organochlorine (OC) Pesticides, Polychlorinated Biphenyls (PCBs), and Siltation in Calleguas Creek, Its Tributaries and Mugu Lagoon.
(A) Regional Water Board Resolution No. 2005-010
(B) State Water Board Resolution No. 2005-0068
(C) OAL file No. 05-1206-03 S
(D) U.S. EPA approval date March 14, 2006
(E) Final fee exemption date March 24, 2006 (effective date)
(F) Compliance for Interim WLA is effective date (March 24, 2006)
(G) Compliance for Final WLA is 20 years after effective date (March 24, 2026), which is beyond the term of this Order

(5) Calleguas Creek Watershed Metals
(A) Regional Water Board Resolution No. 2006-012
(B) State Water Board Resolution No. 2006-0078
(C) OAL file No. 06-1222-015 S
(D) U.S. EPA approval date March 26, 2007
(E) Final fee exemption date March 27, 2007 (effective date)
(F) Compliance for Interim WLA is effective date (March 27, 2007)
(G) Compliance for Final WLA is Within 15 years after the effective date (March 27, 2022), which is beyond the term of this Order

(6) <u>Revolon Slough & Beardsley Wash Trash TMDL</u>
(A) Regional Water Board Resolution No. 2007-007
(B) State Water Board Resolution No 2007-0076
(C) OAL file No 2007-1227-05 S
(D) U.S. EPA approval date February 27, 2008
(E) Final fee exemption date March 6, 2008 (effective date)
(F) Compliance for Trash Monitoring & Reporting Plan Submittal is 6 months from effective date (September 6, 2008)
(G) Compliance for Final WLA is 8 years from effective date (March 6, 2016)

(7) <u>Ventura River Estuary Trash TMDL</u>
(A) Regional Water Board Resolution No. 2007-008
(B) State Water Board Resolution No 2007-0072
(C) OAL file No 2007-1227-01 S

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(D) U.S. EPA approval date February 27, 2008
(E) Final fee exemption date March 6, 2008 (effective date)
(F) Compliance for Trash Monitoring & Reporting Plan Submittal is 6 months from effective date (September 6, 2008)
(G) Compliance for Final WLA is 8 years from effective date (March 6, 2016)

(8) Harbor Beaches of Ventura County Bacteria TMDL
(A) Regional Water Board Resolution No. 2007-017
(B) State Water Board Resolution No 2008-0072
(C) OAL file No 2007-1023-01 S
(D) U.S. EPA approval date December 18, 2008
(E) Final fee exemption date January 17, 2009 (effective date)

16. The Regional Water Board adopted and approved requirements for new development and significant redevelopment projects in Ventura County to control the discharge of storm water pollutants in post-construction storm water, on January 26, 2000, in Board Resolution No. R-00-02. The Regional Water Board Executive Officer issued the approved Standard Urban Storm Water Mitigation Plans (SUSMPs) on March 8, 2000 for Los Angles County and the Cities in Los Angeles County. Since 2000, new development and redevelopment water quality criteria have been implemented by the Permittees to be consistent with SUSMP. The State Board affirmed the Regional Water Board action and SUSMPs in State Board Order No. WQ 2000-11, issued on October 5, 2000.
(a) A statewide policy memorandum (dated December 26, 2000), which interprets the Order to provide broad discretion to Regional Water Boards and identifies potential future areas for inclusion in SUSMPs and the types of evidence and findings necessary. Such areas include ministerial projects, projects in environmentally sensitive areas, and water quality design criteria for Retail Gasoline Outlets (RGOs, see part 7 for definition). The Regional Water Board properly justified the extensions of SUSMPs and water quality criteria to ministerial projects, projects in environmentally sensitive areas, and RGOs, during the adoption of Regional Water Board Order 01-182. The Regional Water Board's action was upheld by the County of Los Angeles Superior Court (In Re: *County of Los Angeles v. State Water Resources Control Board* (2006) 143 Cal.App.4th 985).
(b) The State Water Board's Chief Counsel interpreted the Order to encourage regional solutions and endorsed a mitigation fund or "bank" as alternatives for new development and significant redevelopment. The Regional Water Board has included provisions for regional solutions and the establishment of a mitigation bank in this Order.

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17. The Regional Water Board supports Watershed Management planning to address water quality protection in the region. The objective of the Watershed Management planning is to provide a comprehensive and integrated strategy towards water resource protection, enhancement, and restoration while balancing economic and environmental impacts within a hydrologically defined drainage basin or watershed. It emphasizes cooperative relationships between regulatory agencies, the regulated community, environmental groups, and other stakeholders in the watershed to achieve the greatest environmental improvements with available resources.

18. To facilitate compliance with federal regulations, the State Water Board has issued the following 4 Statewide General NPDES Permits associated with storm water:
    (a) Industrial General Permit (IASGP- Industrial Activities Storm Water General Permit), NPDES No. CAS000001, issued on November 19, 1991, reissued on September 17, 1992 and April 17, 1997, currently under review for reissuance.
    (b) Construction General Permit (CASGP- Construction Activities Storm Water General Permit), NPDES No. CAS000002, issued on August 20, 1992, reissued August 19, 1999, currently under review for reissuance.
    (c) Small Linear Underground/ Overhead Construction Projects General Permit (small LUPs), NPDES No. CAS000005, issued on June 18, 2003.
    (d) Small MS4 Permit WQ Order No. 2003-0005-DWQ, NPDES No. CAS000004, adopted on April 30, 2003.

19. Facilities discharging storm water associated with industrial activities, construction projects that disturb one or more acres of soil, or construction projects that disturb less than one acre but are part of a larger common plan of development or sale that in total disturbs 1 or more acres, and construction activities associated with small linear underground/ overhead projects that result in land disturbances greater than one acre, but less than five acres (small LUPs), are all required to obtain individual NPDES permits for storm water discharges, or be covered by the statewide General Permits by completing and filing a Notice of Intent (NOI) with the State Board. The U.S. EPA guidance anticipates coordination of the state-administered programs for industrial and construction activities with the local agency program to reduce pollutants in storm water discharges to the MS4.

20. State Water Board Resolution No. 68-16 contains the state Antidegradation Policy, titled "Statement of Policy with Respect to Maintaining High Quality Waters in California" (Resolution 68-16), which applies to all waters of the state, including ground waters of the state, whose quality meets or exceeds (is better than) water quality objectives. Resolution No. 68-16 is considered to incorporate the federal Antidegradation Policy (40 CFR131.12) where the federal policy applies, (State Water Board Order WQO 86-17). Administrative policies that implement both, federal and state antidegradation policies acknowledge that an activity that results in a minor water quality lowering, even if incrementally small, can result in violation of

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Antidegradation Policies through cumulative effects, for example, when the waste is a cumulative, persistent, or bioaccumulative pollutant.

(a) Federal Antidegradation Policy (40 CFR131.12) states that the State shall develop and adopt a statewide antidegradation policy and identify the methods for implementing such policy pursuant to this subpart. The antidegradation policy and implementation methods shall, at a minimum, be consistent with the following:
(1) Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
(2) Where the quality of the waters exceed levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the State finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses fully. Further, the State shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control.
(3) Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.
(4) In those cases where potential water quality impairment associated with a thermal discharge is involved, the antidegradation policy and implementing method shall be consistent with section 316 of the Act.

(b) State Water Board Resolution No. 68-16 establishes essentially a 2-step process for compliance with the policy.
  (1) Step 1- if a discharge will degrade high quality water, the discharge may be allowed if any change in water quality:
    (A) Will be consistent with maximum benefit to the people of the State.
    (B) Will not unreasonably affect present and anticipated beneficial use of such water.
    (C) Will not result in water quality less than that prescribed in state policies (e.g., water quality objectives in Water Quality Control Plans).
  (2) Step 2- any activities that result in discharges to high quality waters are required to:
    (A) Meet waste discharge requirements that will result in the best practicable treatment or control of the discharge necessary to avoid a pollution or nuisance.

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(B) Maintain the highest water quality consistent with the maximum benefit to the people of the State.

21. The State Water Board on June 17, 1999, adopted Order No. WQ 99-05, which specifies standard receiving water limitation language to be included in all municipal storm water permits issued by the State and Regional Water Boards.

22. Cal. Water Code § 13263(a) requires that waste discharge requirements issued by Water Boards shall implement any relevant water quality control plans that have been adopted; shall take into consideration the beneficial uses to be protected and the water quality objectives reasonably required for that purpose; other waste discharges; and the need to prevent nuisance.

23. Clean Water Act section 402(p)(3)(B)(iii) requires municipal separate storm sewer system (MS4) operators to control pollution in storm water to the "maximum extent practicable" (MEP). The MEP requirement is analogous to a technology-based requirement in that it focuses upon the feasibility of pollutant reduction measures rather than achievement of water quality standards in the receiving waters to achieve improvements in the quality of the storm water that is discharged. Compliance with the MEP requirement can range from implementation of structural and nonstructural best management practices to installation of end-of-pipe treatment systems. MEP generally provides the MS4 operators the flexibility to determine what controls should be implemented through the development of a storm water management plan, subject to the Regional Board's approval. Nevertheless, MEP does not define the limits of pollution control measures that may be required of MS4 operators, and the requirement to implement controls that reduce pollutants to the MEP is not limited by the goal of attaining water quality standards. In some circumstances, compliance with MEP may result in controls more stringent than applicable WQS, and in others, less stringent. The Regional Board may use its discretion to impose other provisions beyond MEP, as it determines appropriate for the control of pollutants, including ensuring strict compliance with water quality standards. (Defenders of Wildlife v. Browner (1999) 191 F.3d 1159, 1168.)

24. The California Supreme Court has ruled that although Water Code section 13263 requires the Water Boards to consider the factors set forth in Water Code section 13241 when issuing an NPDES permit, the Water Boards may not consider the factors to justify imposing pollutant restrictions that are less stringent than the applicable federal regulations require (City of Burbank v. State Water Resources Control Bd. (2005) 35 Cal.4th 613). However, when the pollutant restrictions in an NPDES are more stringent than federal law requires, Water Code section 13263 requires that the Water Boards consider the factors described in section 13241 as they apply to those specific restrictions.

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25 The City of Burbank case related to NPDES permits for publicly owned treatment works, not permits for municipal separate storm sewer systems (MS4s). Among other requirements, federal law requires MS4 permits to include requirements to effectively prohibit non-storm water discharges into the storm sewers, in addition to requiring controls to reduce the discharge of pollutants to the maximum extent practicable. Therefore, a 13241 analysis is not required for permit requirements that implement the effective prohibition on the discharge of non-storm water into the MS4, or for practicable controls to reduce the discharge of pollutants to the maximum extent, as those requirements are mandated by federal law.

26. The requirements in this Order may be more specific or detailed than those enumerated in federal regulations under 40 CFR122.26 or in U.S. EPA guidance. However, the requirements have been designed to be consistent with and within the federal statutory mandates described in CWA § 402(p)(3)(B)(ii) and (iii) and the related federal regulations. Consistent with federal law, all of the conditions in this permit could have been included in a permit adopted by U.S. EPA in the absence of the in lieu authority of California to issue NPDES permits.

27. The Board finds that all requirements in this order are practicable. Moreover, while commenters have alleged that the permit requirements are "beyond MEP," no commenter has presented evidence that demonstrates that any particular permit requirement that is not dedicated to the effective prohibition on non-storm water discharges into the MS4, is not actually practicable.

28. Notwithstanding findings 23 through 27, the Regional Board has developed an economic analysis of the permit's requirements, consistent with Water Code section 13241. That analysis is contained in the "Economic Considerations of the Proposed Storm Water (Wet Weather) and Non-Storm Water (Dry Weather) Discharges form the Municipal Spearate Storm Sewer Systems within the Ventura County Watershed Protection District, County of Ventura and the Incorporated Cities Therein , June 2, 2008, which is contained in the administrative record for this Order. The Regional Board has considered all of the evidence that has been presented regarding the 13241 factors in adopting this permit, both as contained in the economic analysis and as reflected in the fact sheet and comments (and responses thereto) submitted to the many drafts of this permit. The Regional Board finds that the requirements in this Order are reasonably necessary to protect beneficial uses identified in the Basin Plan, and the economic information related to costs of compliance and other 13241 factors are not sufficient to justify failing to protect those beneficial uses. Where appropriate, additional time to implement certain measures and achieve water quality objectives can be provided through the iterative storm water management plan process.

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F. Implementation

1. The California Environmental Quality Act (CEQA) (Cal. Pub. Resources Code § 2100 et seq.) requires that public agencies consider the environmental impacts of the projects they approve for development. CEQA applies to projects that are considered discretionary (a governmental agency can use its judgment in deciding whether and how to carry out or approve a project, § 15357) and does not apply to ministerial projects (the law requires a governmental agency to act on a project in a set way without allowing the agency to use its own judgment, § 15369). A ministerial project may be made discretionary by adopting local ordinance provisions or imposing conditions to create decision-making discretion in approving the project. In the alternative, Permittees may establish standards and objective criteria administratively for storm water mitigation for ministerial projects. For water quality purposes regardless of whether a project is discretionary or ministerial, the Regional Water Board considers that all new development and significant redevelopment activity in specified categories, that receive approval or permits from a municipality, are subject to storm water mitigation requirements in a manner that is consistent with and complies with the provisions of CEQA.

2. The objective of this Order is to ensure that discharges from the MS4 in Ventura County comply with water quality standards, including protecting the beneficial uses of receiving waters. To meet this objective, the Order requires that Best Management Practices (BMPs) will be implemented to reduce the discharge of pollutants in storm water to the maximum extent practicable (MEP), and achieve water quality objectives and standards. The U.S. EPA envisioned that municipal storm water programs would be implemented in an iterative manner and improved with each iteration by using information and experience gained during the previous permit term (*Interpretative Policy Memorandum on Reapplication Requirements for MS4 permits* - 61 Fed. Reg. 41697). Municipalities are required to evaluate what is effective and make improvements in order to protect beneficial uses of receiving waters. This Order requires implementation of an effective combination of pollution control and pollution prevention measures, education, public outreach, planning, and implementation of source control BMPs and Structural and Treatment Control BMPs. The better–tailored BMPs combined with the performance objectives outlined in this Order have the purpose of attaining water quality objectives and standards (*Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits*- 61 Fed. Reg. 43761). Where WLAs have been adopted for storm water (wet weather) and non-storm water (dry weather) discharges from MS4s, this Order requires Permittees to implement controls to achieve the WLAs within the compliance schedule provided in the TMDLs.

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3. The implementation of measures set forth in this Order are reasonably expected to reduce the discharge of pollutants conveyed in storm water discharges into receiving waters, and to meet the TMDL WLAs for discharges from MS4s that have been adopted by the Regional Water Board.

4. The U.S. EPA has recommended that all future TMDLs and TMDL amendments be expressed as daily increments consistent with a federal court ruling (*Friends of the Earth, Inc. v. EPA, et al*. No. 05-5015 (D.C. Cir. 2006)). However, this interpretation does not affect the discretionary authority of the Regional Water Board to express NPDES permit limits and conditions in non daily terms because there is no express or implied statutory limitation (CWA §502(11)) (*Establishing TMDL "Daily Loads" in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al. (April 2006) and Implications for NPDES Permits*, U.S. EPA Office of Water, memorandum, Nov 15, 2006). This Order translates MS4 TMDL WLAs adopted by the Regional Water Board into forms "consistent with the assumptions and requirements of the TMDL".

5. During the term of the Order, the Permittees shall implement all necessary control measures to reduce pollutant(s) which cause or continue to cause or contribute to water quality impairments, but for which TMDLs have not yet been developed or approved, to eliminate the water quality impairment(s). Successful efforts to reverse the wet weather impairments during the permit term for such pollutants, may avoid the need for a WLA for wet weather or the need to develop a TMDL in the future.

6. This Order promotes land development and redevelopment strategies that consider water quality and water management benefits associated with smart growth techniques. Such measures may include hydromodification mitigation requirements, minimization of impervious surfaces, integrated water resources planning, and low impact development guidelines. (Reference: *Protecting Water Resources with Smart Grow*th, EPA 231-R- 04-002, U.S. EPA 2004; *Using Smart Growth Techniques as Storm Water Best Management Practices,* EPA 231-B-05-002, U.S. EPA 2005; *Parking Spaces/Community Places: Finding the Balance through Smart Growth Solutions*, EPA 231-K-06-001, U.S. EPA 2006; *Protecting Water Resources with Higher-Density Development*, EPA 231-R-06-001, U.S. EPA 2006.)

7. The implementation of an effective Public Information and Participation Program is a critical component of a storm water management program. While commercial and industrial facilities are traditionally subject to multiple environmental regulations and receive environmental protection guidance from multiple sources, the general public, in comparison, receives significantly less education in environmental protection. An effective Public Information and Participation Program is required because:
   (a) Activities conducted by the public such as vehicle maintenance, improper household waste materials disposal, improper pet waste disposal and the improper

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application of fertilizers and pesticides have the potential to generate a significant amount of pollutants that could be discharged in storm water.

(b) An increase in public knowledge of storm water regulations, proper storage and disposal of household wastes, proper disposal of pet wastes and appropriate home vehicle maintenance practices can lead to a significant reduction of pollutants discharged in storm water.

8. This Order also provides flexibility for Permittees to seek authorization from the Regional Water Board Executive Officer to substitute a BMP under this Order with an alternative BMP, if they can provide information and documentation on the effectiveness of the alternative, equal to or greater than the prescribed BMP in meeting the objectives of this Order.

9. This Order contemplates that the Permittees are responsible for considering potential storm water impacts when making planning decisions in order to fulfill the Permittees' CWA requirement to reduce the discharge of pollutants in municipal storm water to the MEP and attain water quality objectives from new development and redevelopment activities. However, the Permittees retain authority to make the final land-use decisions and retain full statutory authority for deciding what land uses are appropriate at specific locations within each Permittee's jurisdiction. This Order and its requirements are not intended to restrict or control local land use decision-making authority.

10. The State Water Board amended the Policy for the Implementation of Toxics Standards In Inland Surface Waters, Enclosed Bays and Estuaries of California (State Implementation Policy – SIP) on February 24, 2005. The SIP does not apply directly to the stormwater discharges. However, this Order includes a Monitoring Program that incorporates Minimum Levels (MLs) established under the State Implementation Policy. The MLs represent the lowest quantifiable concentration for priority toxic pollutants that is measurable with the use of proper method-based analytical procedures and factoring out matrix interference. The SIP's MLs therefore represent the best available science for determining MLs and are appropriate for a storm water monitoring program. The use of MLs allows the detection of toxic priority pollutants at concentrations of concern using recent advances in chemical analytical methods.

11. This Order establishes Municipal Action Levels (MALs) for selected pollutants based on regional Phase I MS4 monitoring data for pollutants in storm water. (http://unix.eng.ua.edu/~rpitt/Research/Research.shtml, last visited on August 14, 2007). The MALs were computed using one of three approaches recommended by the California Water Board's Storm Water Panel in its report, 'The Feasibility of Numerical Effluent Limits Applicable to Discharges of Storm Water Associated with Municipal, Industrial and Construction Activities (June 2006). MALs

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are identified in Attachment "C". Permittees shall utilize the MALs to identify subwatersheds that require additional action to reduce the discharge of pollutants.

12. The International Storm Water Best Management Practices (BMP) Database was established in 1996 as a cooperative initiative between the U.S. EPA and the American Society of Civil Engineers (ASCE) to provide scientifically sound information to improve the design, selection and performance of storm water BMPs. The BMP database includes standardized BMP monitoring and reporting protocols, a storm water BMP database, BMP performance evaluation protocols, and BMP monitoring guidance. The storm water BMP database is updated approximately semi-annually to add new BMP studies and performance data. The International Storm Water Database is now maintained by the Water Environment Research Foundation (WERF).

13. This Order is not intended to prohibit the inspection for or abatement of vectors by the State Department of Public Health or local vector agencies in accordance with CA Health and Safety Code, § 116110 et seq. Certain Treatment Control BMPs if not properly designed, operated or maintained may create habitats for vectors (e.g. mosquitoes and rodents). This Order contemplates that the Permittees will closely cooperate and collaborate with local vector control agencies and the State Department of Public Health for the implementation, operation, and maintenance of Treatment Control BMPs in order to minimize the risk to public health from vector borne diseases.

14. This Order contemplates that Permittees will ensure that implemented Treatment Control BMPs will not pose a safety or health hazard to the public. This Order contemplates that Permittees will ensure that the maintenance of implemented Treatment Control BMPs will comply with all applicable health and safety regulations, such as, but not limited to requirements for worker entry into confined spaces under OSHA Safety and Training education, § 1926.21(b)(6)(i).

15. This Order incorporates presumptive BMPs to reduce pollutants in storm water discharges from construction sites to the MEP. The BMPs are identified in Table 6 (BMPs at Construction sites less than 1 acre), Table 7 (BMPs at Construction Sites 1 acre or greater but less than 5 acres), and Table 8 (BMPs at Construction sites 5 acres or greater). These BMPs include erosion control, sediment control, and construction site waste management practices. The BMPs listed in part 5.F of the Order were selected based on the Water Boards' experience of regulating such sites since 1992, and are referenced in the *California Stormwater Quality Association (CASQA) Storm Water Best Management Practice Handbook Construction (January 2003)* and from the *Stormwater Quality Handbooks, Project Planning and Design Guide, Stormwater Pollution Prevention Plan (SWPPP) and Water Pollution Control Plan (WPCP) Preparation Manual, Construction Site Best Management Practices (BMPs)*

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Reference Manual, March 2007 (Caltrans Document Number CTSW-RT-06-171.11-1) which serve as an industry standard for California. The BMPs identified in the Tables are technically feasible, practicable, and cost-effective. Where an identified BMP may be impracticable on a particular site, this Order includes a provision to select and implement an alternative BMP, through the BMP substitution provisions in subpart 5.A.2.

16. This Order incorporates presumptive BMPs to reduce pollutants in storm water discharges from commercial and industrial sites to the MEP. The BMPs are identified in Table 2 (BMPs at Restaurants), Table 3 (BMPs at Automotive Service Facilities), Table 4 (BMPs at Retail Gasoline Outlets), and Table 5 (BMPs at Nurseries). These BMPs include the implementation of good housekeeping practices designed to control pollutants at the source, promote the use of proper waste management practices, and implement control practices to keep pollutants away from any entrance to the storm drainage system. The BMPs listed in part 5.D of the Order were selected based on the Water Boards' experience of regulating such sites since 1992 and referenced in the California Stormwater Quality Association (CASQA) Storm Water Best Management Practice Handbook Commercial/Industrial Activity (January 2003) and from the Caltrans Storm Water Quality Handbook Maintenance Staff Guide May 2003 (Caltrans Document Number CTSW-RT-02-057), which serve as an industry standard for California. The BMPs identified in the Tables are technically feasible, practicable, and cost-effective. Where an identified BMP may be impracticable, this Order includes a provision to select and implement an alternative BMP, through the BMP substitution provisions in subpart 5.A.2.

17. This Order incorporates presumptive BMPs to reduce pollutants in storm water discharges from Public Agency Activities to the MEP. The BMPs are identified in Table 9 (BMPs at Vehicle Maintenance/ Material Storage Facilities/ Corporation Yards). These BMPs include the implementation of good housekeeping practices designed to control pollutants at the source, promote the use of proper waste management practices, implement control practices to keep pollutants away from any entrance to the storm drainage system and from being deposited or discharged directly into waters of the U.S. The BMPs listed in part 5.G of the Order were selected based on the Water Boards' experience of regulating such sites since 1990, and are referenced in the Caltrans Storm Water Quality Handbook Maintenance Staff Guide May 2003 (Caltrans Document Number CTSW-RT-02-057), which serves as a statewide standard for the California Department of Transportation (Caltrans). The BMPs identified in the Table are technically feasible, practicable, and cost-effective, and are the standard of practice for Caltrans sites statewide. Where an identified BMP may be impracticable, this Order includes a provision to select and implement an alternative BMP, through the BMP substitution provisions in subpart 5.A.2.

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18. This Order incorporates BMPs to ensure that authorized Non-Storm Water Discharges are not a source of pollutants to the MS4, Table 1 (Required Conditions for Non-Storm Water Discharges). The BMPs included are for the purpose of dechlorination and/or for prevention of erosion and sediment loss, or to reduce other harmful pollutants during the discharge of authorized non-storm water discharges to the MS4. The BMPs listed in part 1.B of the Order were selected from the *American Water Works Association AWWA Guidelines For The Development Of Your Best Management Practices (BMP) Manual For Drinking Water System Releases Developed by the CA-NV AWWA Environmental Compliance Committee (2005)* which serves as an industry standard for California, from the results of studies directed by the Los Angeles Water Board, - *Evaluation of Non-Storm Water Discharges to California Storm Drains and Potential Policies for Effective Prohibition Methods, Final Report*, University of California, Los Angeles, Contract No. 5-104-140-0 (1997), and *Water Quality Concerns and Regulatory Controls for Non Storm Water Discharges to Storm Drains*, Duke L.D. and M. Kihara, Journal of the American Water Resources Association, Vol. 34: 661-676, (1998), and from the Water Boards' experience of controlling authorized non-storm discharges to the MS4 since 1990. The BMPs identified in the Table are technically feasible, practicable, and cost-effective. Where an identified BMP may be impracticable, this Order includes a provision to select and implement an alternative BMP, through the BMP substitution provisions in subpart 5.A.2.

19. In accordance with Federal regulations at 40 CFR 124.8, a Fact Sheet has been prepared to explain the principal facts and the significant factual, legal, methodological, policy, and economic matters considered in preparing the Tentative Order. Also included are the analyses of factors required under Cal. Water Code 13241. This Fact Sheet has been made a part of the Administrative Record.

20. The State Water Board adopted statewide General Waste Discharge Requirements for Sanitary Sewer Systems, (WQ Order No. 2006-0003) on May 2, 2006, to provide a consistent, statewide regulatory framework to address sanitary sewer overflows ("SSO Orders"). The SSO Order establishes requirements for public agencies that own or operate sanitary sewer systems to develop and implement sewer system management plans and to report SSOs. SSOs that enter MS4s have the potential to impair the recreational use of receiving waters, and to harm public health. This Order establishes coordination, response, and notification requirements for MS4 Permittees when SSOs result in a discharge to the MS4 system.

21. This Order takes into consideration the housing needs in the area under the Permittees' jurisdiction by balancing the implementation of Smart Growth and Low Impact Development techniques with the protection of the water resources of the region. Although not required, the Regional Water Board considered the need for

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housing and the appropriate techniques to allow for reasonable development while protecting the receiving waters from degradation.

22. This Order may have an effect on costs required for compliance with the provisions contained herein. Although not required, the Regional Water Board has considered costs in preparing this Order. Though also not required, the Regional Water Board has also considered the factors set forth in Water Code section 13241.

G. Public Notification

1. The issuance of waste discharge requirements pursuant to California Water Code section 13370 et seq. is exempt from the California Environmental Quality Act in accordance with California Water Code section 13389. *County of Los Angeles et al., v. California Water Boards et al.*, (2006), 143 Cal.App.4th 985.

2. The Regional Water Board has notified the Permittees, and interested agencies and persons of its intent to issue waste discharge requirements for this discharge, and has provided them with an opportunity to make statements and submit their comments.

3. The Regional Water Board staff has conducted more than 35 meetings from February 9, 2007 through December 19, 2008, with Permittees, their representatives (Larry Walker and Associates, and Somach, Simmons & Dunn), and various stakeholders (Building Industry Association of Southern California/ Greater Los Angeles Ventura Chapter (BIAGLA/ VC), California State Dept. of Health Services, Calleguas Water District, California Stormwater Quality Association (CASQA), City of Downey, City of Los Angeles-EMD, Collation for Practical Regulation (CPR), Construction Industry Coalition on Water Quality (CICWQ), County of Orange, Geosyntec Consultants, Golden State, Heal The Bay; Local Government commission, Los Angeles City; Los Angeles County Department of Public Works, Los Angeles County-SD, Los Angeles Department of Water & Power, Metropolitan Water District, Natural Resources Defense Council (NRDC), Richard Watson Association, San Bernardino Flood Control District, Santa Monica Bay Restoration Commission, Southern California Coastal Water Research Project, University of California Sea Grant, Ventura CoastKeeper). On April 5, 2007 and September 20, 2007 the Regional Water Board conducted workshops to discuss drafts of the NPDES Order and received input from the Permittees and the public regarding proposed changes.

4. This Order shall serve as a NPDES permit, pursuant to CWA § 402, and shall take effect 90 days from Order adoption date provided the Regional Administrator of the U.S. EPA has no objections.

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5. Pursuant to Cal. Water Code § 13320, any aggrieved party may seek review of this Order by filing a petition with the State Board within 30 days of the date of adoption of the Order by the Regional Water Board. A petition must be sent to:

   State Water Resources Control Board
   Office of the Chief Counsel
   P.O. Box 100
   Sacramento, CA 95812-0100

6. This Order may be modified or alternatively revoked or reissued prior to its expiration date or any administrative extension thereto, in accordance with 40 CFR122.41(f) and 122.62.

IT IS HEREBY ORDERED that the Permittees, in order to meet the provisions contained in Division 7 of the Cal. Water Code and regulations adopted thereunder, and the provisions of the CWA and regulations adopted thereunder, shall comply with the following:

PART 1 - DISCHARGE PROHIBITIONS

A. Prohibitions - Non-Storm Water Discharges

1. The Permittees shall, within their respective juridictions, effectively prohibit non-storm discharges into the MS4 and watercourses, except where such discharges:
   (a) Originate from a State, Federal, or other source for which they are pre-empted from regulating by State or Federal law; or
   (b) Are covered by a separate individual or general NPDES permit, or conditional waiver for irrigated lands; or
   (c) Fall within one of the categories below, are not a source of pollutants that exceed water quality standards, and meet all conditions where specified by the Regional Water Board Executive Officer:
      (1) Category A – Natural flows
         (A) Stream diversions authorized by the State Water Board
         (B) Natural springs and rising ground water
         (C) Uncontaminated ground water infiltration [as defined by 40 CFR35.2005(20)][1]
         (D) Flows from riparian habitats or wetlands
      (2) Category B – Flows from emergency fire fighting activities.
      (3) Category C – Flows incidental to urban activities, providing conditions listed in table below:
         (A) Flows from non-emergency fire fighting activities
         (B) Discharges from potable water sources[2]

[1] NPDES permit for ground water dewatering is required within the Los Angeles Region including Ventura County.
[2] The term applies to low volume, incidental and infrequent releases that are innocuous from a water quality perspective. Those releases for dewatering or hydro-testing or flushing of water supply and distribution mains and

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(C) Gravity flow from foundation, footing and crawl space drains.
(D) Air conditioning condensate
(E) Reclaimed and potable landscape irrigation runoff
(F) Dechlorinated/ debrominated swimming pool discharges [see def. part 7]
(G) Non-commercial car washing by residents or non-profit organizations
(H) Sidewalk rinsing
(I) Pooled storm water from treatment BMPs[1]

Table 1 – Required Conditions for Non-Storm Water Discharges

Type of Discharges:	Conditions under which allowed:	Required conditions for discharge to occur:
Stream diversions permitted by the State Board;	**Authorization by the State Water Board**	**Permittees shall comply with all conditions in the authorization.**
Natural springs and rising ground water	**1. Ground water dewatering requires a separate NPDES permit. 2. Segregate flow to prevent introduction of pollutants.**	**Permittees shall comply with all conditions in the authorization.**
Uncontaminated ground water infiltration [as defined by 40 CFR 35.2005(20)] (Utility vault dewatering requires a separate NPDES permit.)	**NPDES permit for ground water dewatering is required within the Los Angeles Region including Ventura County**	**Permittees shall comply with all conditions in the authorization.**
Flows from riparian habitats or wetlands	**Provided that all necessary permits or authorizations are received prior to diverting the stream flow.**	**Permittees shall comply with all conditions in the authorization.**
Flows from emergency fire fighting activity	**Pooled water after fire must be controlled.**	
Discharges from potable water sources[1]	**See Footnote #1.** **Provided discharges from water lines and**	**See Footnote #2. To be discharged, this type of water shall be dechlorinated using**

incidental and infrequent releases from well heads shall be allowed with the implementation of appropriate BMPs until such time as a new General Permit is adopted that addresses those types of releases. Discharges from hydrostatic pipe testing shall be subject to separate NPDES general permit coverage (CAG674001) and discharges from utility vaults shall be conducted under coverage of a separate NPDES permit specific to that activity.
2 All storm water BMPs shall at a minimum be maintained at a frequency as specified by the manufacturer, and designed to drain within 72 hours of the end of a rain. Storm water treatment BMPs may be drained to the MS4 under this Order if the discharge is not a source of pollutants. Sediments shall be disposed of properly, in compliance with all applicable local, state, and federal policies, acts, laws, regulations, ordinances, and statutes.

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Type of Discharges:	Conditions under which allowed:	Required conditions for discharge to occur:
	potable water sources shall be dechlorinated, pH adjusted if necessary, reoxygenated, and volumetrically and velocity controlled to prevent resuspension of sediments.	**aeration and/ or sodium thiosulfate and/ or other appropriate means and/or be allowed to infiltrate to the ground. BMPs such as sand bags or gravel bags, or other appropriate means shall be utilized to prevent sediment transport. All sediments shall be collected and disposed of in a legal and appropriate manner.**
Drains for foundation, footing and crawl drains	**Dewatering requires a separate NPDES permit.**	**Permittees shall comply with all conditions in the authorization.**
Air conditioning condensate	**Segregation of flow to prevent introduction of pollutants. Percolation whenever possible.**	**Permittees shall comply with all conditions in the authorization.**
Water from crawl space pumps	**Dewatering requires a separate NPDES permit within the Los Angeles Region including Ventura County**	**Permittees shall comply with all conditions in the authorization.**
Reclaimed and potable landscape irrigation runoff	**Segregation of flow to prevent introduction of pollutants.**	**Implement conservation programs to minimize this type of discharge by using less water.**
Dechlorinated/ debrominated swimming pool discharges [see definition Part 8]	**Where the discharge is not excepted by the sanitary sewer operator. Swimming pool discharges are to be dechlorinated, pH adjusted if necessary, aerated to remove chlorine if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments.** **Cleaning waste water and filter back wash**	**Pool water may be dechlorinated using time, aeration, and/ or sodium thiosulfate.**

[1] The term applies to low volume, incidental and infrequent releases that are innocuous from a water quality perspective. Those releases for dewatering or hydro-testing or flushing of water supply and distribution mains and incidental and infrequent releases from well heads shall be allowed with the implementation of appropriate BMPs until such time as a new General Permit is adopted that addresses those types of releases. Discharges from hydrostatic pipe testing shall be subject to separate NPDES general permit coverage (CAG674001) and discharges from utility vaults shall be conducted under coverage of a separate NPDES permit specific to that activity.

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Type of Discharges:	Conditions under which allowed:	Required conditions for discharge to occur:
	shall not be discharged to municipal separate storm sewers. **No discharges are allowed containing salts in excess of Water Quality Standards.** **Chlorine residual in discharge shall not exceed 0.1mg/L.**	
Non-commercial car washing by residents or non-profit organizations	**Preferably at a commercial carwash or designated area where wash water can percolate. Pumps or vacuums may be used to direct water to pervious areas.**	**Permittees shall comply with all conditions in the authorization.**
Sidewalk rinsing	**This may be undertaken only if high pressure low volume is used as described in the glossary under "Sidewalk Rinsing".**	
Pooled storm water from treatment BMPs[1]	**All storm water BMPs shall at a minimum be maintained at a frequency as specified by the manufacturer. All storm water BMPs shall be designed to drain within 72 hours of the end of the rain event to avoid the breeding of vectors. Storm water treatment BMPs may be drained to the MS4 under this Order if the discharge is not a source of pollutants. The discharge shall cease before the discharge has become a source of a pollutant(s), (bottom sediment included). Sediments shall be disposed of properly, in compliance with all applicable local, state, and federal policies, acts, laws, regulations, ordinances, and statutes.**	

2. If the Regional Water Board Executive Officer determines that any of the preceding categories of non-storm water discharges are a source of pollutants that exceed water quality standards, the Permittee(s) shall either:
   (a) Prohibit the discharge from entering the MS4; or
   (b) Authorize the discharge category and require implementation of appropriate or additional BMPs to ensure that the discharge will not be a source of pollutants; or

[1] All storm water BMPs shall at a minimum be maintained at a frequency as specified by the manufacturer, and designed to drain within 72 hours of the end of a rain. Storm water treatment BMPs may be drained to the MS4 under this Order if the discharge is not a source of pollutants. Sediments shall be disposed of properly, in compliance with all applicable local, state, and federal policies, acts, laws, regulations, ordinances, and statutes.

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(c) Require or obtain coverage under a separate RWQCB or SWRCB permit for discharge into the MS4.

3. The following BMPs for non-stormwater discharges are required pursuant to this Order:
   (a) Flows from non-emergency fire fighting activity: Implement a program to reduce pollutants from non-emergency activities such as controlled or practice blazes and maintenance activities identified to be significant sources of pollutants.
   (b) Discharges from potable water system releases: Water shall be dechlorinated using aeration and/or sodium thiosulfate and/or other appropriate means and/or be allowed to infiltrate to the ground. BMPs such as sand bags or gravel bags shall be utilized to prevent sediment transport. All sediments shall be collected and disposed of in a legal and appropriate manner.
   (c) Swimming pool discharges: Swimming pool discharges are to be dechlorinated, pH adjusted if necessary, aerated to remove chlorine if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments.
   (d) Sidewalk rinsing: Sidewalk rinsing in commercial areas may be undertaken only if high pressure low volume is used as described in the glossary under "sidewalk rinsing."

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PART 2 – MUNICIPAL ACTION LEVELS

1. This Order establishes Municipal Action Levels (MALs) to identify subwatersheds requiring additional Best Management Practices (BMPs) to reduce pollutant loads and prioritize implementation of additional BMPs. MALs for selected pollutants based on a Climate Zone 6 subset of nationwide Phase I MS4 monitoring data for pollutants in storm water. (http://unix.eng.ua.edu/~rpitt/Research/Research.shtml, last visited on August 14, 2007). The MALs were obtained by computing the 80th percentile for selected pollutants. MALs are identified in Attachment "C".

2. Under this Order, the Municipal Action Levels (MALs) shall be utilized by Permittees to identify subwatersheds discharging pollutants at levels in excess of the MALs. Within those subwatersheds where pollutant levels in the discharge are in excess of the MALs, Permittees shall implement controls and measures necessary to reduce the discharge of pollutants.

3. In order to determine if MS4 discharges are in excess of the MALs, Permittees shall conduct outfall monitoring as required in the Monitoring and Reporting Program (MRP). A MAL Assessment Report shall be submitted to the Executive Officer as part of the Annual Report. The Report shall present the monitoring data in comparison to the applicable MALs, and identify those subwatersheds with a running average of twenty percent or greater of exceedances of the MALs listed in Attachment "C" in discharges of storm water from the MS4 to waters of the U.S..

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4. Beginning Year 3 after Order adoption date, each Permittee shall submit a MAL Action Plan with the Annual Report (first MAL Action Plan due with Dec. 15, 2011 Annual Report) to the Executive Officer, for those subwatersheds with a running average of twenty percent or greater of exceedances of the MALs in any discharge of storm water from the MS4 to waters of the U.S.. The plan is to include an assessment of the sources responsible for the MAL exceedances, the existing stormwater programs and BMPs that address those sources, an assessment of potential program enhancements, alternative BMPs and actions the Permittee shall implement to reduce discharges to a level that is equivalent to or below the MALs, and an implementation schedule for such actions for Executive Officer approval. The MAL Action Plan shall provide the technical rationale to demonstrate the proposed measures and controls will attain the MALs. If the MAL Action Plan is not approved within 90 days of the due date, the Executive Officer may establish an appropriate plan with at least 90 day notification and consultation to the Permittees.

5. Within 90 days of the plan approval by the Regional Board Executive Officer, the Permittee shall initiate the BMPs and actions proposed in the MAL Action Plan, together with any other practicable BMPs or actions that the Executive Officer determines to be necessary to meet the MALs. The Permittee shall complete the proposed actions in accordance with the approved implementation schedule.

6. Upon completion of the actions specified in the approved MAL Action Plan, the Permittee shall re-monitor the subject subwatershed in accordance with the MRP, and submit a Post-Project MAL Assessment Report to the Executive Officer.

7. As additional data become available through the MRP or from the Regional Subset of the National Dataset, MALs may be revised annually by the Executive Officer in accordance with an equivalent statistical method as that used to establish the MALs in Attachment C of this order with at least 90 day notification and consultation to the Permittees.

PART 3 – RECEIVING WATER LIMITATIONS

1. Discharges from the MS4 that cause or contribute to a violation of water quality standards are prohibited.

2. Discharges from the MS4 of storm water, or non-storm water, for which a Permittee is responsible, shall not cause or contribute to a condition of nuisance.

3. The Permittee shall comply with Receiving Water Limitations 1 and 2 through timely implementation of control measures and other actions to reduce pollutants in the storm water discharges in accordance with the requirements of this Order including any modifications. The Permittees' Program shall be designed to achieve compliance with Receiving Water Limitations 1 and 2. If exceedance(s) of water quality

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objectives or water quality standards (collectively WQS) persist, notwithstanding implementation of this permit, the Permittees shall ensure compliance with Receiving Water Limitations 1 and 2 by complying with the following procedure:

(a) Upon determination by either the Permittees or the Regional Water Board that discharges are causing or contributing to an exceedance of an applicable WQS, the Permittee(s) upstream of the point of discharge shall promptly notify and thereafter submit a report to the Regional Water Board Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of WQSs. The report may be included with the Annual Report, unless the Regional Water Board Executive Officer directs an earlier submittal. The Regional Water Board Executive Officer may require modifications to the report.

(b) Submit any modifications to the report required by the Regional Water Board Executive Officer within 30 days of notification.

(c) Within 30 days following approval of the Report described above by the Regional Water Board Executive Officer, the Permittees shall revise their Program and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required.

(d) Implement the revised Program and monitoring program according to the approved schedule.

4. Permittees shall annually report the effectiveness of BMPs in reducing exceedances of receiving water limitations. The Regional Board Executive Officer may direct implementation of additional BMPs if there are continuing or recurring exceedances of the same receiving water limitation.

PART 4 - STORM WATER QUALITY MANAGEMENT PROGRAM IMPLEMENTATION

A. General Requirements

1. Each Permittee shall, at a minimum, adopt and implement applicable terms of this Order within its jurisdictional boundary. The Principal Permittee shall be responsible for program coordination as described in this Order as well as compliance with applicable portions of the permit within its jurisdiction. This Order shall be implemented no later than (90 days after Order adoption date), unless a later date has been specified for a particular provision in this Order and provided the Regional Administrator of the U.S. EPA has no objections.

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2. Each Permittee shall comply with the requirements of 40 CFR122.26(d)(2) and implement programs and control measures so as to reduce the discharges of pollutants in storm water to the MEP and achieve water quality standards.

3. Each Permittee shall require that treatment control BMPs being implemented under the provisions of this Order shall be designed, at a minimum, to achieve the BMPperformance criteria for storm water pollutants likely to be discharged as identified in Attachment "C", Table 3. Expected BMP pollutant removal performance for effluent quality was developed from the WERF-ASCE/ U.S. EPA International BMP Database. Permittees shall select Treatment BMPs based on the primary class of pollutants likely to be discharged from the site/facility (e.g. metals from an auto repair shop). Permittees may develop guidance for appropriate Treatment BMPs for project type based on Attachment "C". For the treatment of pollutants causing impairments within the drainage of the impaired waterbody, permittees shall select BMPs from the top three performing BMP categories or alternative BMPs that are designed to meet or exceed the performance of the highest performing BMP for the pollutant causing impairment.

4. Each Permittee shall implement programs and measures to comply with the TMDLs' WLAs for the MS4 as specified in Part 6.

5. If TMDL requirements, including Implementation Plans and Reports, address substantially similar requirements as the MS4 permit, the Executive Officer may approve the applicable reports, plans, data or submittals under the applicable TMDL as fulfilling requirements under the MS4.

B. Legal Authority

1. Permittees shall possess the necessary legal authority to prohibit, including, but not limited to:
   (a) Illicit connections and illicit discharges, and to remove illicit connections.
   (b) The discharge of non-storm water to the MS4 from:
      (1) Washing or cleaning of gas stations, auto repair garages, or other types of automotive service facilities
      (2) Mobile auto washing, carpet cleaning, steam cleaning, sandblasting and other such mobile commercial and industrial operations
      (3) Areas where repair of machinery and equipment which are visibly leaking oil, fluid or antifreeze, is undertaken
      (4) Storage areas for materials containing grease, oil, or other hazardous substances, and uncovered receptacles containing hazardous materials
      (5) Swimming pools[1] that have a concentration greater than:
         (A) Chlorine/ bromine- 0.1mg/L

[1] MS4s discharging directly to the ocean are not subject to this prohibition.

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(B) Chloride- 250mg/L
(6) Swimming pool filter backwash
(7) Decorative fountains and ponds
(8) Industrial/ Commercial areas, including restaurant mats
(9) Concrete truck cement, pumps, tools, and equipment washout
(10) Spills, dumping, or disposal of materials other, such as:
(A) Litter, landscape and construction debris, garbage, food, animal waste, fuel or chemical wastes, batteries, and any other materials which have the potential to adversely impact water quality; and
(B) Any pesticide, fungicide or herbicide
(11) Stationary and mobile pet grooming facilities
(12) Trash container leachate

2. The Permittees shall possess adequate legal authority to:
(a) Control through interagency agreement, the contribution of pollutants from one portion of the MS4 to another portion of the MS4.
(b) Require persons within their jurisdiction to comply with conditions in the Permittees' ordinances, permits, contracts, model programs, or orders (i.e. hold dischargers to its MS4 accountable for their contributions of pollutants and flows).
(c) Utilize enforcement measures (e.g., stop work orders, notice of violations, fines, referral to City, County, and/ or District Attorneys, referral to strikeforces, etc.) by ordinances, permits, contracts, orders, administrative authority, and civil and criminal prosecution.[1]
(d) Control pollutants, including potential contribution[2] in discharges of storm water runoff associated with industrial activities, including construction activities to its MS4, and control the quality of storm water runoff from industrial sites, including construction sites.
(e) Carry out all inspections, surveillance and monitoring procedures necessary to determine compliance and non-compliance with permit conditions including the prohibition on illicit discharges to the MS4.
(f) Require the use of control measures to prevent or reduce the discharge of pollutants to achieve water quality objectives.
(g) Require that Treatment Control BMPs be properly operated and maintained.

3. Each Permittee has adopted a Storm Water Quality Ordinance based upon a countywide model. Each Permittee shall ensure, no later than (one year after Order adoption date), that its Storm Water Quality Ordinance authorizes the Permittee to enforce all requirements of this Order.

[1]In the case of private responsible parties such as, HOAs, the Permittee must retain enforcement authority.
[2] "Potential contributions" and "potential to discharge," means adequate legal authority to prevent an actual discharge of pollutants to the municipal separate storm sewer system.

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4. Each Permittee shall submit no later than two years after Order adoption date, a statement by its legal counsel that the Permittee has obtained and possesses all necessary legal authority to comply with this Order through adoption of ordinances and/ or municipal code modifications.

C. Fiscal Resources

1. The Permittees shall implement the activities required to comply with the provisions of this Order.[1] Each Permittee shall:
   (a) Submit an Annual Budget Summary that shall include:
      (1) Budgets for the upcoming report year (estimated expenditure) for the following specific categories (estimated percentages and written explanations where necessary):
         (A) Program Management Activities.
            (i) Overall Administrative costs
         (B) Program Implementation Activities (storm water related activities only). Provide figures breakdown of expenditures for the categories below:
            (i) Illicit connection/ illicit discharge program.
            (ii) Development planning and approval
            (iii) Construction program including inspection activities
            (iv) Industrial/ Commercial program including inspection activities
            (v) Public Agency Activities
               (I) Maintenance and inspection of Treatment Control BMPs
               (II) Municipal Street Sweeping
               (III) Municipal Drainage Maintenance including catch basin clean-outs
               (IV) Other costs associated with storm water management (describe)
            (vi) Public Information and Participation.
            (vii) Monitoring Program
            (viii) Miscellaneous Expenditures (describe)

D. Modifications/ Revisions

1. No later than two years after the Order adoption date, each Permittee shall modify its storm water management programs, protocols, practices, and municipal codes to make them consistent with the requirements herein.

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[1] The sources of funding may be the general funds, and/or Benefit Assessment, plan review fees, permit fees, industrial/ commercial user fee, revenue bonds, grants or other similar funding mechanism.

E. Designation and Responsibilities of the Principal Permittee

1. The Ventura County Watershed Protection District is hereby designated as the Principal Permittee. The Principal Permittee shall:
   (a) Participate in the County Environmental Crimes Task Force
   (b) Coordinate and facilitate activities necessary to comply with the requirements of this Order, but the Principal Permittee is not responsible for ensuring compliance of any other individual Permittee
   (c) Coordinate permit activities among Permittees and act as liaison between the Permittees and the Regional Water Board on permitting issues
   (d) Provide technical and administrative support for committees that will be organized to implement this Order and its requirements
   (e) Evaluate, assess, and synthesize the results of the monitoring program and the effectiveness of the implementation of BMPs
   (f) Convene the Committee Meetings constituted pursuant to subpart 4.F.1., below, upon designation of representatives
   (g) Implement the Countywide Monitoring Program required under the Order and evaluate, assess and synthesize the results of the monitoring program
   (h) Provide personnel and fiscal resources for the collection, processing and submittal to the Regional Water Board of monitoring and annual reports, and summaries of other reports required under this Order
   (i) Comply with the "Responsibilities of the Permittees" in part 4.F. below

F. Responsibilities of the Permittees

1. Each Permittee is required to comply with the requirements of this Order applicable to discharges within its boundaries (see Findings- Permit Coverage D.1 and D.2). Permittees are not responsible for the implementation of the provisions applicable to the Principal Permittee or other Permittees. Each Permittee shall:
   (a) Comply with the requirements of this Order and any modifications thereto
   (b) Coordinate among its internal departments and agencies, as necessary, to facilitate the implementation of the requirements of this Order applicable to such Permittees in an efficient and cost-effective manner
   (c) Participate in intra-agency coordination (e.g., Planning Department, Fire Department, Building and Safety, Code Enforcement, Public Health, Parks and Recreation, and others) necessary to successfully implement the provisions of this Order
   (d) Report, in addition to the Budget Summary, any supplemental dedicated budgets for the same categories
   (e) Participate in Committee Meetings, as necessary

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PART 5 - SPECIAL PROVISIONS (BASELINE)

A. General Requirements

1. This Order and the provisions herein, are intended to develop, achieve, and implement a timely, comprehensive, cost-effective storm water pollution control program to reduce the discharge of pollutants in storm water to the MEP and not cause or contribute to exceedances of water quality standards for the permitted areas in the County of Ventura.

2. Best Management Practice Substitution
   (a) The Regional Water Board Executive Officer may approve any site-specific BMP substitution upon written request by a Permittee(s) and after public notice, if the Permittee can document that:
      (1) The proposed alternative BMP or program will meet or exceed the objective of the original BMP or program in the reduction of storm water pollutants.
      (2) The fiscal burden of the original BMP or program is greater than the proposed alternative and does not achieve a greater improvement in storm water quality.
      (3) The proposed alternative BMP or program will be implemented within a similar period of time.
      (4) BMP substitution will be in accordance with the public review provisions of the Order (Part 8C.1 and Part 8C.2).

B. Watershed Initiative Participation

1. The Principal Permittee shall participate in water quality meetings for watershed management and planning, including but not limited to the following:
   (a) Southern California Stormwater Monitoring Coalition (SMC)
   (b) Other Watershed planning groups as appropriate

2. The Principal Permittee shall participate in the following regional water quality programs, and projects for watershed management and planning:
   (a) SMC Regional Monitoring Programs
      (1) Southern California Regional Bioassessment
         (A) Level of effort per watershed
            (i) Probabilistic sites per watershed
               (I) Ventura River - Six
               (II) Santa Clara River - Three
               (III) Calleguas Creek - Six

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(ii) Integrator sites per watershed
(I) Ventura River - One
(II) Santa Clara River - One
(III) Calleguas Creek – One
(iii) Fixed bioassessment sites
(I) The Permittees shall perform bioassessment at one fixed urban site in each major watershed. Site selection shall be determined by the results of the first year SMC results, as approved by the Executive Officer.

(b) Southern California Bight Projects
(1) Regional Monitoring Survey – 2008, and successive years.

C. Public Information and Participation Program (PIPP)

1. The Principal Permittee shall implement a Public Information and Participation Program (PIPP) that includes, but is not limited to, the requirements listed in this part. The Principal Permittee shall coordinate with Permittees to implement specific PIPP requirements. The objectives of the PIPP are as follows:

(a) To increase the knowledge of the target audience about the MS4, the adverse impacts of storm water pollution on receiving waters and potential solutions to mitigate the impacts

(b) To change the waste disposal and storm water pollution generation behavior of target audiences by encouraging implementation of appropriate solutions

(c) To involve and engage communities in Ventura County to participate in mitigating the impacts of storm water pollution

2. Residential Program
(a) "No Dumping" Message
Each Permittee shall label all storm drain inlets that they own with a legible “no dumping” message. In addition, signs with prohibitive language discouraging illegal dumping shall be posted at designated public access points to creeks, other relevant waterbodies, and channels. Signage and storm drain messages shall be legible and maintained.
(b) Public Reporting
Each Permittee shall identify staff who will serve as the contact person(s) for reporting clogged catch basin inlets and illicit discharges/dumping, faded or missing catch basin labels, and general storm water management information. Permittees shall include this information, updated by July 1 of each year, in public information media such as the government pages of the telephone book, and internet web sites. The Principal Permittee shall compile a list of the general public reporting contacts submitted by all Permittees and make this information available on the web site (http://www.vcstormwater.org/contact.htm) and upon

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request. Each Permittee is responsible for providing current, updated information to the Principal Permittee.

(c) Outreach and Education

(1) Collaboratively, the Permittees shall implement the following activities:

(A) Conduct a Storm Water pollution prevention advertising campaign.

(B) Conduct Storm Water pollution prevention public service announcements.

(C) Distribute storm water pollution prevention public education materials to:

(i) Automotive parts stores

(ii) Home improvement centers/ lumber yards/ hardware stores

(iii) Pet shops/ feed stores

(D) Public education materials shall include, but are not limited to information on the proper disposal, storage, and use of:

(i) Vehicle waste fluids

(ii) Household waste materials

(iii) Construction waste materials

(iv) Pesticides and fertilizers (including integrated pest management practices-IPM)

(v) Green waste (including lawn clippings and leaves)

(vi) Animal wastes

(E) Work with existing local watershed groups or organize watershed Citizen Advisory Groups/ Committees to develop effective methods to educate the public about storm water pollution no later than (365 days after Order adoption date).

(F) Organize events targeted to residents and population subgroups; and

(G) Maintain the Countywide storm water website (www.vcstormwater.org), which shall include educational material listed in the preceding subpart C.1(c)(1)(C).

(2) The Principal Permittee shall develop a strategy to educate ethnic communities through culturally effective methods. Details of this strategy should be incorporated into the PIPP, and implemented, no later than (365 days after Order adoption date).

(3) Each Permittee shall continue the existing outreach program to residents on the proper disposal of litter, green waste, pet waste, proper vehicle maintenance, lawn care and water conservation practices.

(4) Each Permittee shall conduct educational activities within its jurisdiction and participate in countywide events.

(5) The Permittees shall make a minimum of 5 million impressions per year to the general public related to storm water quality, with a minimum of 2.5 million impressions via newspaper, local TV access, local radio and/ or internet access.

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(6) The Principal Permittee, in cooperation with the Permittees, shall provide schools within each School District in the County with materials, including, but not limited to, videos, live presentations, and other information necessary to educate a minimum of 50 percent of all school children (K-12) every 2 years on storm water pollution. Alternatively, a Permittee may submit a plan to the Regional Water Board Executive Officer for consideration no later than (90 days after adoption of the Order), to provide outreach in lieu of the school curriculum. Pursuant to Water Code section 13383.6, the Permittees, in lieu of providing educational materials/ funding to School Districts in the County, may opt to provide an equivalent amount of funds or fraction thereof to the Environmental Education Account established within the State Treasury.

(7) Each Permittee shall provide the contact information for their appropriate staff responsible for storm water public education activities to the Principal Permittee and contact information changes no later than 30 days after a change occurs.

(8) The Permittees shall develop and implement a behavioral change assessment strategy no later than (365 days after Order adoption date), in order to determine whether the PIPP is demonstrably effective in changing the behavior of the public. The strategy shall be developed based on current sociological data and studies.

(d) Pollutant-Specific Outreach

The Principal Permittee, in cooperation with the Permittees, shall coordinate to develop outreach programs that focus on metals, urban pesticides, bacteria and nutrients as the pollutants of concern no later than (365 days after Order adoption date). Metals may be appropriately addressed through the Industrial/ Commercial Facilities Program (e.g. the distribution of educational materials on appropriate BMPs for metal fabrication and recycling facilities that have been identified as a potential source). Region-wide pollutants may be included in the Principal Permittee's mass media outreach program.

3. Businesses Program

(a) Corporate Outreach

(1) The Permittees shall work with other regional or statewide agencies and, associations such as the California Storm Water Quality Association (CASQA), to develop and implement a Corporate Outreach program to educate and inform corporate franchise operators and/or local facility managers about storm water regulations and BMPs. Once developed, the program shall target a minimum of four Retail Gasoline Outlets (RGO) franchisers and cover a minimum of 80% of RGO franchisees in the county, four retail automotive parts franchisers, two home improvement center franchisers and six restaurant franchisers. Corporate outreach for all target facilities shall be conducted not less than twice during the term of this

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Order, with the first outreach contact to begin no later than two years after Order adoption date. At a minimum, this program shall include:

(A) Confer with franchise operators and/or local facility managers to explain storm water regulations.

(B) Distribution and discussion of educational material regarding storm water pollution and BMPs, and provide managers with recommendations to facilitate employee and facility compliance with storm water regulations.

(b) Business Assistance Program

(1) The Permittees shall implement a Business Assistance Program to provide technical information to small businesses to facilitate their efforts to reduce the discharge of pollutants in storm water. The Program shall include:

(A) On-site, telephone or e-mail consultation regarding the responsibilities of businesses to reduce the discharge of pollutants, procedural requirements, and available guidance documents.

(B) Distribution of storm water pollution prevention education materials to operators of auto repair shops, car wash facilities (including mobile car detailing), mobile carpet cleaning services, commercial pesticide applicator services and restaurants.

D. Industrial/ Commercial Facilities Program

Each Permittee shall require implementation of pollutant reduction and control measures, unless precluded by local ordinances, at industrial and commercial facilities, with the objective of reducing pollutants in storm water. Except where specified otherwise in this Order, pollutant reduction and control measures may be used alone or in combination, and may include Treatment Control, Source Control BMPs, and operation and maintenance procedures, which may be applied before, during, and/ or after pollutant generating activities. At a minimum, the Industrial/ Commercial Facilities Control Program shall include requirements to:

(a) Track

(b) Inspect

(c) Ensure compliance with municipal ordinances at industrial and commercial facilities that are critical sources of pollutants in storm water

1. Inventory of Critical Sources

(a) Each Permittee shall maintain a watershed-based inventory or database of all facilities within its jurisdiction that are critical sources of storm water pollution. Critical Sources to be tracked are summarized below, and specified in Attachment "D":

(1) Commercial Facilities

(A) Restaurants

(B) Automotive service facilities

(C) RGOs and automotive dealerships

(D) Nurseries and nursery centers

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(2) U.S. EPA Phase I, II Facilities
(3) Other Federally-mandated Facilities [as specified in 40 CFR122.26(d)(2)(iv)(C)]
(A) Municipal landfills
(B) Hazardous waste treatment, disposal, and recovery facilities
(C) Facilities subject to SARA Title III (also known as the Emergency Planning and Community Right-to-Know Act (EPCRA))

(b) Each Permittee shall include the following minimum fields of information for each critical source industrial and commercial facility
(1) Name of facility and name of owner/ operator.
(2) Address of facility
(3) Coverage under the IASGP or other individual or general NPDES permits or any applicable waiver issued by the Regional or State Board pertaining to runoff discharges.
(4) A narrative description including Standard Industrial Classification (SIC) System/ North American Industry Classification System (NAICS) codes that best describe the industrial activities performed and principal products used at each facility and status of exposure to storm water.

(c) The Regional Water Board recommends that Permittees include additional fields of information, such as material usage and/ or industrial output, and discrepancies between SIC System/ NAICS Code designations (as reported by facility operators) and identify the actual type of industrial activity that has the potential to pollute storm water. In addition, the Regional Water Board recommends the use of an automated database system, such as a Geographical Information System (GIS) or Internet-based system.

(d) Each Permittee shall update its inventory of critical sources at least annually. The update may be accomplished through collection of new information obtained through field activities or through other readily available inter and intra-agency informational databases (e.g. business licenses, pretreatment permits, sanitary sewer hook-up permits, and similar information).

2. Inspect Critical Sources

(a) Commercial Facilities

Permittee shall inspect all facilities identified in subpart 5.D.2. twice during the 5-year term of the Order, provided that the first inspection occurs no later than (2 years after Order adoption date). A minimum interval of 6 months between the first and the second mandatory compliance inspection is required. In addition, each Permittee shall implement the activities outlined in the following subparts. At each facility, inspectors shall verify that the operator is implementing the source control BMPs. The Permittees may require implementation of additional BMPs where storm water flows from the MS4 discharge to an environmentally sensitive area (ESA, see part 7 for definition) or a CWA § 303(d) listed waterbody (see subpart 3(b) below).

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(1) Restaurants-

Level of inspections: Each Permittee, in cooperation with its appropriate department (such as health or public works), shall inspect all restaurants within its jurisdiction to confirm that storm water BMPs are being effectively implemented in compliance with State law, County and municipal ordinances. BMPs in Table 2 (BMPs at Restaurants) shall be implemented, unless the pollutant generating activity does not occur.

Table 2 - BMPs at Restaurants

Pollutant-Generating Activity	BMP Narrative Description	2003 California Stormwater BMP Handbook Industrial and Commercial BMP Identification #
Waste/ Hazardous Materials Storage, Handling and Disposal	Implementation of effective storage, handling and disposal procedures for hazardous materials.	By Municipality
Unauthorized Non-Storm Water Discharges	Effective elimination of non-storm water discharges.	SC-10
Accidental Spills/ Leaks	Implementation of effective spills/ leaks prevention and response procedures.	SC-11
Outdoor Storage of Raw Materials	Implementation of effective source control practices and structural devices.	SC-33
Storage and Handling of Solid Waste	Implementation of effective solid waste storage/ handling practices and appropriate control measures	SC-34
Parking/ Storage Area Maintenance	Implementation of effective parking/ storage area designs and housekeeping/ maintenance practices	SC-43
Storm Water Conveyance System Maintenance	Implementation of proper conveyance system operation and maintenance protocols.	SC-44

(2) Automotive Service Facilities-

Level of Inspection: Each Permittee shall confirm that BMPs are being effectively implemented at each facility within its jurisdiction, in compliance with County and municipal ordinances. The inspections shall verify that BMPs in Table 3 (BMPs at Automotive Service Facilities) are being implemented, unless the pollutant generating activity does not occur.

Table 3 - BMPs at Automotive Service Facilities

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Pollutant-Generating Activity	BMP Narrative Description	2003 California Stormwater BMP Handbook Industrial and Commercial BMP Identification #
Unauthorized Non-Storm Water Discharges	Effective elimination of non-storm water discharges.	SC-10
Accidental Spills/ Leaks	Implementation of effective spills/ leaks prevention and response procedures.	SC-11
Vehicle/ Equipment Fueling.	Implementation of effective fueling source control devices and practices.	SC-20
Vehicle/ Equipment Cleaning.	Implementation of effective equipment/ vehicle cleaning practices and appropriate wash water management practices	SC-21
Vehicle/ Equipment Repair	Implementation of effective vehicle/ equipment repair practices and source control devices.	SC-22
Outdoor Liquid Storage	Implementation of effective outdoor liquid storage source controls and practices.	SC-31
Outdoor Storage of Raw Materials	Implementation of effective source control practices and structural devices.	SC-33
Storage and Handling of Solid Waste	Implementation of effective solid waste storage/ handling practices and appropriate control measures	SC-34
Parking/ Storage Area Maintenance	Implementation of effective parking/ storage area designs and housekeeping/ maintenance practices	SC-43
Storm Water Conveyance System Maintenance Practices	Implementation of proper conveyance system operation and maintenance protocols.	SC-44

(3) Retail Gasoline Outlets and Automotive Dealerships-

Level of Inspections: Each Permittee shall confirm that BMPs are being effectively implemented at each facility within its jurisdiction, in compliance with County and municipal ordinances. The inspections shall verify that BMPs in Table 4 (BMPs at Retail Gasoline Outlets) are being implemented, unless the pollutant generating activity does not occur.

Table 4 - BMPs at Retail Gasoline Outlets

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Pollutant-Generating Activity	BMP Narrative Description	2003 California Stormwater BMP Handbook Industrial and Commercial BMP Identification #
Unauthorized Non-Storm Water Discharges	Effective elimination of non-storm water discharges.	SC-10
Accidental Spills/ Leaks	Implementation of effective spills/ leaks prevention and response procedures.	SC-11
Vehicle/ Equipment Fueling	Implementation of effective fueling source control devices and practices.	SC-20
Vehicle/ Equipment Cleaning	Implementation of effective wash water control devices.	SC-21
Outdoor Storage of Raw Materials	Implementation of effective source control practices and structural devices.	SC-33
Storage and Handling of Solid Waste	Implementation of effective solid waste storage/ handling practices and appropriate control measures	SC-34
Building and Grounds Maintenance	Implementation of effective facility maintenance practices.	SC-41
Parking/ Storage Area Maintenance	Implementation of effective parking/ storage area designs and housekeeping/ maintenance practices	SC-43

(4) Commercial Nurseries and Nursery Centers (Merchant Wholesalers, Nondurable Goods, and Retail Trade)-

Level of Inspection: Each Permittee shall confirm that BMPs are being effectively implemented at each facility within its jurisdiction, in compliance with County and municipal ordinances. The inspections shall verify that BMPs in Table 5 (BMPs at Nurseries) are being implemented, unless the pollutant generating activity does not occur.

Table 5 - BMPs at Nurseries

Pollutant-Generating Activity	BMP Narrative Description	2003 California Stormwater BMP Handbook Industrial and Commercial BMP Identification #
Unauthorized Non-Storm Water Discharges	Effective elimination of non-storm water discharges.	SC-10
Outdoor Loading/ Unloading	Implementation of effective outdoor loading/ unloading practices.	SC-30

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Pollutant-Generating Activity	BMP Narrative Description	2003 California Stormwater BMP Handbook Industrial and Commercial BMP Identification #
Outdoor Liquid Storage	Implementation of effective outdoor liquid storage source controls and practices.	SC-31
Outdoor Equipment Operations	Implementation of effective outdoor equipment source control devices and practices.	SC-32
Outdoor Storage of Raw Materials	Implementation of effective source control practices and structural devices.	SC-33
Building and Grounds Maintenance	Implementation of effective facility maintenance practices.	SC-41

(b) Industrial Facilities

Each Permittee shall conduct compliance inspections as specified below.

(1) **Frequency of Inspection**

(A) Each Permittee shall perform an initial inspection at all industrial facilities identified by the U.S. EPA in 40 CFR122.26(c) no later than 2 years after Order adoption date. After the initial inspection, all facilities determined as having exposure of industrial activities to storm water are subject to a second mandatory compliance inspection. A minimum interval of 6 months between the first and the second compliance inspection is required.

(B) Following the first mandatory compliance inspection, a Permittee shall perform a second mandatory compliance inspection yearly at a minimum of 20% of the facilities determined not to have exposure of industrial activities to storm water. The purpose of this inspection is to verify the continuity of the no exposure status. Facilities determined as having exposure will be notified that they must obtain coverage under the IASGP. A facility need not be inspected more than twice during the term of the Order unless subject to an enforcement action. A minimum interval of 6 months in between the first and the second compliance inspection is required.

(C) Applicable to all facilities: A Permittee need not inspect facilities that have been inspected by the Regional Water Board within the previous 24 month interval. However, if the Regional Water Board performed only one inspection, the Permittee shall conduct the second required mandatory compliance inspection.

(2) **Level of Inspection:** Each Permittee shall confirm that each operator:

(A) Has a current Waste Discharge Identification (WDID) number for facilities discharging storm water associated with industrial activity,

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and that a Storm Water Pollution Prevention Plan (SWPPP) is available on-site.

(B) Is effectively implementing BMPs in compliance with County and municipal ordinances. Facilities must implement the source control BMPs identified in subpart 5.D.3. and Appendix D, *California Stormwater Industrial and Commercial BMP Handbook (2003)*. The Permittees shall require implementation of additional BMPs where the storm water from the MS4 discharges to a CWA § 303(d) listed waterbody; or

(C) Has applied and has a current No Exposure Certification (and WDID number) for facilities subject to this requirement.

3. Ensure Compliance of Critical Sources

(a) **BMP Implementation:** Facilities must implement the source control BMPs identified in Part 5. D. 3. and, as applicable, Appendix D, *California Stormwater Industrial and Commercial BMP Handbook (2003).*In the event that a Permittee determines that a BMP is infeasible at any site, the Permittee shall require implementation of similar BMPs that will achieve the equivalent reduction of pollutants in the storm water discharges. Likewise, for those BMPs that are not protective of water quality standards, Permittees may require additional site-specific controls.

(b) **Environmentally Sensitive Areas (ESAs) and Impaired Waters:** For critical sources that discharge to MS4s that directly discharge to ESAs or to CWA § 303(d) listed impaired waterbodies, the Permittees shall require operators to implement additional pollutant specific controls to reduce pollutants in storm water runoff that are causing or contributing to exceedances of water quality objectives. A Regional Board approved TMDL Implementation Plan for the receiving water will substitute for this requirement.

(c) **Progressive Enforcement:** Each Permittee shall implement a progressive enforcement policy to ensure that facilities are brought into compliance with all storm water requirements within a reasonable time period as specified below.

(1) In the event that a Permittee determines, based on an inspection conducted, that an operator has failed to adequately implement all necessary BMPs, that Permittee shall take progressive enforcement actions which, at a minimum, shall include a follow-up inspection within 4 weeks from the date of the initial inspection.

(2) In the event that a Permittee determines that an operator has failed to adequately implement BMPs after a follow-up inspection, that Permittee shall take further enforcement action as established through authority in its municipal code and ordinances or through the judicial system.

(3) Each Permittee shall maintain records and make them available on request to the Regional Water Board, including inspection reports, warning letters,

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notices of violations, and other enforcement records, demonstrating a good faith effort to bring facilities into compliance.

4. Interagency Coordination

(a) **Referral of Violations of the Municipal Storm Water Ordinances and California Water Code § 13260:** A Permittee may refer a violation(s) of § 13260 by Industrial and Commercial facilities to the Regional Water Board provided that under its municipal storm water ordinance the Permittee has made a good faith effort of progressive enforcement. At a minimum, a Permittee's good faith effort must be documented with:

(1) Two follow-up inspections
(2) Two warning letters or notices of violation

(b) **Referral of Violations of the Industrial Activities Storm Water General Permit (IASGP), including Requirements to File a Notice of Intent or No Exposure Certification:** For those facilities in violation of the municipal storm water ordinance and subject to the IASGP, Permittees may escalate referral of such violations to the Regional Water Board (electronically on a quarterly basis to the Regional Water Board's Storm Water Site at MS4stormwaterrb4@waterboards.ca.gov) after one inspection and one written notice (copied to the Regional Water Board) to the operator regarding the violation. In making such referrals, Permittees shall include, at a minimum, the following documentation:

(1) Name of the facility
(2) Operator of the facility
(3) Owner of the facility
(4) WDID Number (if applicable)
(5) Industrial activity being conducted at the facility that is subject to the IASGP
(6) Records of communication with the facility operator regarding the violation, which shall include at least an inspection report
(7) The written notice of the violation copied to the Regional Water Board

(c) **Investigation of Complaints Regarding Facilities – Transmitted by the Regional Water Board Staff:** Each Permittee shall initiate, within one business day,[1] investigation of complaints of non-storm water discharges to the MS4 from facilities within its jurisdiction (other than non-storm water discharges). The initial investigation shall include, at a minimum, a limited inspection of the facility to confirm the complaint to determine if the facility is effectively complying with the municipal storm water urban runoff ordinances, and, if necessary, to oversee corrective action.

[1] Permittees may comply with the Permit by taking initial steps (such as logging, prioritizing, and tasking) to "initiate" the investigation within that one business day. However, the Regional Water Board would expect that the initial investigation, including a site visit, to occur within four business days.

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(d) **Assistance of Regional Water Board Enforcement Actions:** As directed by the Regional Water Board Executive Officer, Permittees shall assist Regional Water Board enforcement actions by: helping in identification of current owners, operators, and lessees of facilities; providing staff, when available, for joint inspections with Regional Water Board inspectors; appearing as witnesses in Regional Water Board enforcement hearings; and providing copies of inspection reports and other progressive enforcement documentation.

(e) **Participation in a Task Force:** The Permittees shall participate with the Regional Water Board, and other public agencies on an enforcement task force such as the Storm Water Task Force, to communicate concerns regarding special cases of storm water violations by industrial and commercial facilities and to develop a coordinated approach to enforcement action.

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E. Planning and Land Development Program

I. Purpose

1. The Permittees shall implement a Planning and Land Development Program pursuant to part 5.E. for all New Development and Redevelopment projects subject to this Order to:
   (a) Minimize the adverse impacts from storm water runoff on the biological integrity of Natural Drainage Systems and the beneficial uses of waterbodies in accordance with requirements under CEQA (Cal. Pub. Resources Code § 21100).
   (b) Minimize the percentage of impervious surfaces on land developments to mimic predevelopment water balance through infiltration, evapotranspiration and reuse.
   (c) Minimize pollutant loadings from impervious surfaces such as roof-tops, parking lots, and roadways through the use of properly designed, technically appropriate BMPs (including Source Control BMPs such as good housekeeping practices), Low Impact Development Strategies, and Treatment Control BMPs.
   (d) Properly select, design and maintain Treatment Control BMPs and Hydromodification Control BMPs to address pollutants that are likely to be generated, assure long-term function, and to avoid the breeding of vectors.[1]
   (e) Prioritize the selection of BMPs suites to remove storm water pollutants, reduce storm water runoff volume, and beneficially reuse storm water to support an integrated approach to protecting water quality and managing water resources in the following order of preference:
      (1) Infiltration BMPs
      (2) BMPs that store and reuse storm water runoff.
      (3) BMPs that incorporate vegetation to promote pollutant removal and runoff volume reduction and integrate multiple uses

[1] Treatment BMPs when designed to drain within 48 hours of the end of rainfall minimize the potential for the breeding of vectors.

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(4) BMPs which percolate runoff through engineered soil and allow it to discharge downstream slowly
(5) Approved modular/ proprietary treatment control BMPs that are based on LID concepts and that meet pollution removal goals

II. Applicability

1. New Development Projects.
   (a) Development projects subject to Permittee conditioning and approval for the design and implementation of post-construction controls to mitigate storm water pollution, prior to completion of the project(s), are:
      (1) All development projects equal to 1 acre or greater of disturbed area and adding more than 10,000 square feet of impervious surface area
      (2) Industrial park 10,000 square feet or more of impervious surface area
      (3) Commercial strip mall 10,000 square feet or more of impervious surface area
      (4) Retail gasoline outlet 5,000 square feet or more of impervious surface area
      (5) Restaurant (SIC 5812) 5,000 square feet or more of impervious surface area
      (6) Parking lot 5,000 square feet or more of impervious surface area, or with 25 or more parking spaces
      (7) Streets, roads, highways, and freeway construction of 10,000 square feet or more of impervious surface area shall incorporate USEPA guidance regarding Managing Wet Weather with Green Infrastructure: Green Streets to the maximum extent practicable.
      (8) Automotive service facilities (SIC 5013, 5014, 5511, 5541, 7532-7534 and 7536-7539) [5,000 square feet or more of impervious surface area]
      (9) Redevelopment projects in subject categories that meet Redevelopment thresholds (identified in subpart E.II.2 below)
      (10) Projects located in or directly adjacent to, or discharging directly to an Environmentally Sensitive Area (ESA), where the development will:
         (A) Discharge storm water runoff that is likely to impact a sensitive biological species or habitat; and
         (B) Create 2,500 square feet or more of impervious surface area
      (11) Single-family hillside homes. To the extent that a Permittee may lawfully impose conditions, mitigation measures or other requirements on the development or construction of a single-family home in a hillside area as defined in the applicable Permittee's Code and Ordinances, each Permittee shall require that during the construction of a single-family hillside home, the following measures to be implemented:
            (A) Conserve natural areas
            (B) Protect slopes and channels
            (C) Provide storm drain system stenciling and signage

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(D) Divert roof runoff to vegetated areas before discharge unless the diversion would result in slope instability
(E) Direct surface flow to vegetated areas before discharge unless the diversion would result in slope instability

2. Redevelopment Projects
   (a) Redevelopment projects subject to Permittee conditioning and approval for the design and implementation of post-construction controls to mitigate storm water pollution, prior to completion of the project(s), are:
      (1) Land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site on development categories identified in subpart 5.E.II.1.
      (2) Where Redevelopment results in an alteration to more than fifty percent of impervious surfaces of a previously existing development, and the existing development was not subject to post development storm water quality control requirements, the entire project must be mitigated.
      (3) Where Redevelopment results in an alteration to less than fifty percent of impervious surfaces of a previously existing development, and the existing development was not subject to post development storm water quality control requirements, only the alteration must be mitigated, and not the entire development.
   (b) Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of facility or emergency redevelopment activity required to protect public health and safety. Impervious surface replacement, such as the reconstruction of parking lots and roadways which does not disturb additional area and maintains the original grade and alignment, is considered a routine maintenance activity. Redevelopment does not include the repaving of existing roads to maintain original line and grade.
   (c) Existing single-family dwelling and accessory structures are exempt from the Redevelopment requirements unless such projects create, add, or replace 10,000 square feet of impervious surface area.

3. Effective Date –The New Development and Redevelopment requirements contained in Section E of the Order shall begin 90 calendar days after Regional Board Executive Officer approval of the changes to the Technical Guidance Manual needed to comply with this permit. After that date all discretionary permit projects or project phases that have not been deemed complete for processing, or discretionary permit projects without vesting tentative maps that have not requested and received an extension of previously granted approvals must comply with the requirements in Section E. Projects that have been deemed complete prior to the update of the technical design manual are not subject to this section. For Permittee's projects the effective date shall be the date the governing body approves authorization to advertize to bid the project.

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III. New Development/ Redevelopment Performance Criteria

1. Integrated Water Quality/ Flow Reduction/ Resources Management Criterion
   (a) Permittees shall establish standards for all New Development and Redevelopment projects identified in subpart 5.E.II to control pollutants, pollutant loads, and runoff volume emanating from impervious surfaces through percolation, infiltration, storage, or evapo-transpiration, by reducing the percentage of Effective Impervious Area (EIA). The standards shall be based on the type of development, site conditions (including soils and groundwater), community constraints, and shall consider USEPA's "Managing Wet Weather with Green Infrastructure, Action Strategy, 2008".
   (b) The goal of the New Development and Redevelopment standards shall be to reduce the effective impervious area (EIA) to 5% or less. This goal may be implemented through use of site features, a Redevelopment Project Area Master Plan (RPAMP), payment of an in-lieu fee, or use of stormwater mitigation credits as described in this section. For development projects in undeveloped areas, the project shall comply with the goal of 5% EIA or less. For redevelopment projects, or development projects that can be demonstrated that the 5% EIA goal is infeasible, the project shall comply with the surface discharge requirements of 5.E.III.4
   (c) All features structured constructed to render impervious surfaces "ineffective" as described in provision (b), above, shall be properly sized to infiltrate or store for beneficial reuse at least the volume of water that meets the criteria in subpart 5.E.III.3.
   (d) Impervious surfaces may be rendered "ineffective" if the storm water runoff is:
      (1) Drained into a vegetated cell, over a vegetated surface, or through a vegetated swale, having soil characteristics either as native material or amended medium using approved soil engineering techniques; or
      (2) Collected and stored for beneficial use such as irrigation, or other reuse purpose; or
      (3) Discharged into an infiltration trench
   (e) Any excess surface discharge of the storm water runoff shall be mitigated in accordance with subpart 5.E.III.3

2. Hydromodification (Flow/ Volume/ Duration) Control Criteria
   (a) Each Permittee shall require all New Development and Redevelopment projects identified in subpart 5.E.II to implement hydrologic control measures, to prevent accelerated downstream erosion and to protect stream habitat in natural drainage systems. The purpose of the hydrologic controls is to minimize changes in post-development hydrologic storm water runoff discharge rates, velocities, and

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duration. This shall be achieved by maintaining the project's pre-project storm water runoff flow rates and durations.

(1) Description

(A) Hydromodification control in natural drainage systems shall be achieved by maintaining the Erosion Potential (E_p) in streams at a value of 1, unless an alternative value can be shown to be protective of the natural drainage systems from erosion, incision, and sedimentation that can occur as a result of flow increases from impervious surfaces and damage stream habitat (see Attachment "E" - Determination of Erosion Potential)

(B) Hydromodification control may include one, or a combination of on-site, regional subregional hydromodification control BMPs, LID strategies, or stream restoration measures, with preference given to LID strategies and hydromodification control BMPs. Any in-stream restoration measure shall not adversely affect the beneficial uses of the natural drainage systems

(C) Natural drainage systems, which include unlined or unimproved (not engineered) creeks, streams, rivers and their tributaries, are located in the following watersheds:
(i) Ventura River
(ii) Santa Clara River
(iii) Calleguas Creek
(iv) Miscellaneous Ventura Coastal

(D) The Southern California Storm Water Monitoring Coalition (SMC) is developing a regional methodology to eliminate or mitigate the adverse impacts of hydromodification as a result of urbanization, including hydromodification assessment and management tools.
(i) The SMC has identified the following objectives for the Hydromodification Control Study (HCS):
(I) Establishment of a stream classification for Southern California streams
(II) Development of a deterministic or predictive relationship between changes in watershed impervious cover and stream-bed/ stream bank enlargement
(III) Development of a numeric model to predict stream-bed/ stream bank enlargement and evaluate the effectiveness of mitigation strategies

(E) The Permittees shall participate in the SMC HCS to develop:
(i) A regional stream classification system
(ii) A numerical model to predict the hydrological changes resulting from new development
(iii) A numerical model to identify effective mitigation strategies

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(F) Until the completion of the SMC HCS, Permittees shall implement the Interim Hydromodification Control Criteria, described in subpart 5.E.III.3(a)(2) below, to control the potential adverse impacts of changes in hydrology that may result from new development and redevelopment projects identified in subpart 5.E.II

(G) Existing single-family structures are exempt from the Hydromodification control requirements unless such projects disturb one acre or more of land or create, add, or replace 10,000 square feet or more of impervious surface area

(2) Exemptions to Hydromodification Controls. Permittees may exempt the following New Development and Redevelopment projects from implementation of Hydromodification controls where assessments of downstream channel conditions and proposed discharge hydrology indicate that adverse Hydromodification effects to present and future beneficial uses of Natural Drainage Systems are unlikely:

(A) All projects that disturb less than one acre.

(B) Projects that are replacement, maintenance or repair of a Permittee's existing flood control facility, storm drain, or transportation network.

(C) Redevelopment Projects in the Urban Core that do not increase the effective impervious area or decrease the infiltration capacity of pervious areas compared to the pre-project conditions.

(D) Projects that have any increased discharge go directly or via a storm drain to a sump, lake, area under tidal influence, into a waterway that has a 100-year peak flow (Q100) of 25,000 cfs or more, or other receiving water that is not susceptible to Hydromodification impacts;

(E) Projects that discharge directly or via a storm drain into concrete or improved (not natural) channels (e.g., rip rap, sackcrete, etc.), which, in turn, discharge into receiving water that is not susceptible to Hydromodification impacts (as in D above).

(3) Interim Hydromodification Control Criteria

(A) The Interim Hydromodification Control Criteria to protect natural drainage systems until Permittees complete Hydromodification Control Plans (HCPs), described in subpart 5.E.III.3(a)(3) below, are as follows:

(i) **Projects disturbing land area of less than fifty acres** will be subject to LID and/or source or treatment BMPs as addressed in this permit. The combined effects of LID and the

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treatment BMPs are considered adequate for Hydromodification control for projects that disturb less than 50 acres.

(ii) **Projects disturbing land areas of fifty acres or greater**
Projects in this category shall develop and implement a Hydromodification Analysis Study (HAS) that demonstrates that post development conditions are expected to approximate the pre-project erosive effect of sediment transporting flows in receiving waters. The HAS must lead to the incorporation into the project design features intended to approximate, to the extent feasible, an Erosion Potential value of 1 or any alternative value that can be shown to be protective of the natural drainage systems from erosion, incision, and sedimentation that can occur as a result of flow increases from impervious surfaces and damage stream habitat in natural drainage systems, or

(4) Alternatively, project proponents in this category may elect to develop, in partnership with Permittees, an equivalent implementation method based on flow duration control in the form of nomographs relating planned impervious area and local soil type (infiltration rates) to determine hydromodification control BMP volume and land area requirements for the proposed project. The nomographs shall be derived from continuous simulation modeling using Ventura County specific rain gauge records and soil types, and calibrated using data from a local undeveloped watershed with similar conditions; or

(5) Alternatively, the Co-Permittees may revise the Ventura County Technical Guidance Manual for Stormwater Quality Control Measures to address projects that disturb more than 50 acres.

(4) Final Criteria

(A) The Permittees shall develop and implement watershed specific HCPs no later than 180 days after the completion of the SMC HCS.

(i) The HCP shall identify:

(I) Stream classifications

(II) Flow rate and duration control methods

(III) Sub-watershed mitigation strategies

(IV) Stream restoration measures, which will maintain the stream and tributary Erosion Potential at 1 unless an alternative value can be shown to be protective of the natural drainage systems from erosion, incision, and sedimentation that can occur as a result of flow increases from impervious surfaces and damage stream habitat in natural drainage system tributaries

(B) The HCP shall contain the following elements:

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(i) Hydromodification Management Standards
(ii) Natural Drainage Areas and Hydromodification Management Control Areas
(iii) New Development and Redevelopment Projects subject to the HCP
(iv) Description of authorized Hydromodification Management Control BMPs
(v) Hydromodification Management Control BMP Design Criteria.
(vi) For flow duration control methods, the range of flows to control for, and goodness of fit criteria
(vii) Allowable low critical flow, Q_c, which initiates sediment transport
(viii) Description of the approved Hydromodification Model.
(ix) Any alternate Hydromodification Management Model and Design
(x) Stream Restoration Measures Design Criteria
(xi) Monitoring and Effectiveness Assessment
(xii) Record Keeping

3. Water Quality Mitigation Criteria
   (a) Each Permittee shall require all New Development and Redevelopment projects identified in subpart 5.E.II to implement post-construction storm water treatment BMPs and control measures to mitigate storm water pollution as follows:
      (1) Projects disturbing land areas less than 50 acres
         (A) Volumetric Treatment Control BMP
            (i) The 85th percentile 24-hour runoff event determined as the maximized capture storm water volume for the area using a 48 to 72-hour draw down time, from the formula recommended in *Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998*); or
            (ii) The volume of annual runoff based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment by the method recommended in the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures (July 2002 and its revisions); or
            (iii) The volume of runoff produced from a 0.75 inch storm event, prior to its discharge to a storm water conveyance system;[1] and/ or
         (B) Flow Based Treatment Control BMP
            (i) The flow of runoff produced from a rain event equal to at least 0.2 inches per hour intensity; or

[1] This option is available only for construction projects that disturb land area less than 5 acres.

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(ii) The flow of runoff produced from a rain event equal to at least 2 times the 85th percentile hourly rainfall intensity as determined from local rainfall records; or

(iii) Eight percent of the 50-year storm design flow rate as determined from the method recommended in the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures (July 2002 and its revisions)

(2) Projects disturbing land area of 50 acres or greater

(A) Eighty percent of the average runoff volume using an appropriate public domain continuous flow model (such as Storm Water Management Model (SWMM) or Hydrologic Engineering Center – Hydrologic Simulation Program – Fortran (HEC-HSPF), using the local rainfall record and relevant BMP Performance data.

IV. Implementation

1. Maintenance Agreement and Transfer

(a) Prior to issuing approval for final occupancy each Permittee shall require that all new development and redevelopment projects subject to post-construction BMP requirements provide an operation and maintenance plan and verification of ongoing maintenance provisions for LID practices, Treatment Control BMPs, and Hydromodification Control BMPs including but not limited to: final map conditions, legal agreements, covenants, conditions or restrictions, CEQA mitigation requirements, conditional use permits, and/ or other legally binding maintenance agreements.

(1) Verification at a minimum shall include the developer's signed statement accepting responsibility for maintenance until the responsibility is legally transferred; and either

(A) A signed statement from the public entity assuming responsibility for BMP maintenance; or

(B) Written conditions in the sales or lease agreement, which require the property owner or tenant to assume responsibility for BMP maintenance and conduct a maintenance inspection at least once a year; or

(C) Written text in project covenants, conditions, and restrictions (CCRs) for residential properties assigning BMP maintenance responsibilities to the Home Owners Association (HOA); or

(D) Any other legally enforceable agreement or mechanism that assigns responsibility for the maintenance of BMPs.

(b) Each Permittee shall require all development projects subject to post-construction BMP requirements to provide a plan for the operation and maintenance of all structural and treatment controls. The Operation and Maintenance plan shall follow the Technical Guidance Manual Appendix D

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"Maintenance Plan Guidance" (or subsequent guidance manual) for each BMP component. The plan shall be submitted for examination of relevance to keeping the BMPs in proper working order. Where BMPs are transferred to Permittee for ownership and maintenance, the plan shall also include all relevant costs for upkeep of BMPs in the transfer. Operation and Maintenance plans for private BMPs shall be kept on site for periodic review by Permittee inspectors.

2. Tracking, Inspection, and Enforcement of Post-Construction BMPs
   (a) Each Permittee shall implement a tracking system, and an inspection and enforcement program for new development and redevelopment post-construction storm water BMPs as set fort in part 5.E no later than (365 days after Order adoption date).
      (1) Implement a GIS or other electronic system for tracking projects that have been conditioned for post-construction BMPs. The electronic system, at a minimum, should contain the following information:
         (A) Municipal Project ID
         (B) State WDID No
         (C) Project Acreage
         (D) BMP Type and Description
         (E) BMP Location (coordinates)
         (F) Date of Acceptance
         (G) Date of Maintenance Agreement
         (H) Maintenance Records
         (I) Inspection Date and Summary
         (J) Corrective Action
         (K) Date Certificate of Occupancy Issued
         (L) Replacement or Repair Date
   (b) Inspect all development sites upon completion of construction and prior to the issuance of occupancy certificates to ensure proper installation of LID measures, structural BMPs, treatment control BMPs and Hydromodification control BMPs. The inspection may be combined with other inspections provided it is conducted by trained personnel.
   (c) Verify proper maintenance and operation of post-construction BMPs previously approved for new development and redevelopment and operated by the Permittees. The post construction BMP maintenance inspection program shall incorporate the following elements:
      (1) Post-construction BMP Maintenance Inspection checklist.
      (2) Inspection at least once every 2 years, beginning (365 days after Order adoption date), of post-construction BMPs to assess operation conditions with particular attention to:
      (3) Criteria and procedures for post construction Treatment Control and Hydromodification Control BMP repair, replacement, or re-vegetation.

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(d) For post construction BMPs operated and maintained by parties other than the Permitees the Permittees shall require annual reports by the other parties demonstrating proper maintenance and operations.

(e) Undertake enforcement as appropriate based on the results of the inspection.

3. Alternative Post Construction Storm Water Mitigation Programs

(a) A Permittee or a coalition of Permittees may apply to the Regional Water Board for approval of a Redevelopment Project Area Master Plan (RPAMP) for redevelopment projects within the Redevelopment Project Areas, in consideration of exceptional site constraints that inhibit site-by-site or project-by-project implementation of post-construction requirements.

(b) Upon review and a determination by the Regional Water Board Executive Officer that the proposal is technically valid and appropriate, the Regional Water Board may consider for approval such a program if its implementation will:

(1) Result in equivalent or superior reduction of storm water pollutant loads in comparison to individual projects regulated by this permit.

(2) Satisfy, on a Redevelopment Project Area-wide basis, the hydromodification criteria of this section.

(3) Reduce the percentage of Effective Impervious Area (EIA) to a target of less than 5 percent of the Redevelopment Project Area, using properly sized storm water treatment/collection features, as described in this Section.

(4) Be fiscally sustainable and have secure funding; and

(5) Be completed in four years of the adoption date of this permit.

(c) The RPAMP should prioritize the implementation of LID storm water mitigation measures, as described in this section.

(d) A Permittee or a coalition of Permittees may apply to the Regional Water Board for approval of a Redevelopment Project Area Master Plan (RPAMP) that takes into consideration the balancing of water quality protection with the needs for adequate housing, population growth, public transportation and management, land recycling, and urban revitalization.

(e) For the RPAMP to be considered, a technical panel of the Local Government Commission or an equivalent state or regional planning agency must have reviewed and approved the proposed RPAMP, prior to its submittal to the Regional Water Board. The Regional Water Board Executive Officer may then consider the RPAMP for approval, or elect to submit it to the Regional Water Board for consideration.

(f) The RPAMP, on approval, may substitute in part or wholly for post-construction requirements.

(g) Redevelopment Project Areas include the following:

(1) City Center areas

(2) Historic District areas

(3) Brownfield areas

(4) Infill Development areas

(5) Urban Transit Villages

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(6) Any other redevelopment area so designated by the Regional Water Board

(h) Nothing in these provisions shall be construed as to delay the implementation of post-construction control requirements, as approved in this Order.

4. Mitigation Funding

(a) The Principal Permittee or a coalition of Permittees shall create a management framework to fund regional or subregional solutions to storm water pollution, where any of the following situations occur:

(1) A waiver for impracticability is granted
(2) Funds become available
(3) Off-site mitigation is required because of loss of environmental habitat; or
(4) An approved watershed management plan, or an integrated water resources management plan, or a regional storm water mitigation plan, or a wetlands recovery plan exists that incorporates an equivalent or improved strategy for storm water pollution mitigation

5. Developer Technical Guidance and Information

(a) The Permittees shall update the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures to include, at a minimum, the following:

(1) Hydromodification Control criteria described in this Order, including numerical criteria.
(2) Expected BMP pollutant removal performance including effluent quality (ASCE/ U.S. EPA International BMP Database, CASQA New Development BMP Handbook, technical reports, local data on BMP performance, and the scientific literature appropriate for southern California geography and climate).
(3) Selection of appropriate BMPs for storm water pollutants of concern.
(4) Data on Observed Local Effectiveness and performance of implemented BMPs.
(5) BMP Maintenance and Cost Considerations.
(6) Guiding principles to facilitate integrated water resources planning and management in the selection of BMPs, including water conservation, groundwater recharge, public recreation, multipurpose parks, open space preservation, and redevelopment retrofits.
(7) LID principles and specifications, including the objectives and specifications for integration of LID strategies in the areas of:

(A) Site Assessment.
(B) Site Planning and Layout.
(C) Vegetative Protection, Revegetation, and Maintenance.
(D) Techniques to Minimize Land Disturbance.
(E) Techniques to Implement LID Measures at Various Scales
(F) Integrated Water Resources Management Practices.
(G) LID Design and Flow Modeling Guidance.

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(H) Hydrologic Analysis.
(I) LID Credits.

(b) Permittees shall update the Technical Guidance Manual within 365 days of the adoption of this Order.

(c) The Permittees shall facilitate implementation of LID by providing key industry, regulatory, and other stakeholders with information regarding LID objectives and specifications contained in the LID Technical Guidance Section through a training program. The LID training program will include the following:
(1) LID targeted sessions and materials for builders, design professionals, regulators, resource agencies, and stakeholders
(2) A combination of awareness on national efforts and local experience gained through LID pilot projects and demonstration projects
(3) Materials and data from LID pilot projects and demonstration projects including case studies
(4) Guidance on how to integrate LID requirements into the local regulatory program(s) and requirements
(5) Availability of the LID Technical Guidance regarding integration of LID measures at various project scales
(6) Guidance on the relationship among LID strategies, Source Control BMPs, Treatment Control BMPs, and Hydromodification Control requirements

6. Project Coordination
(a) Each Permittee shall facilitate a process for effective approval of post-construction storm water control measures. The process shall include:
(1) Detailed BMP review including BMP sizing calculations, BMP pollutant removalperformance, and municipal approval; and
(2) An established structure for communication and delineated authority between and among municipal departments that have jurisdiction over project review, plan approval, and project construction through memoranda of understanding (MOU) or an equivalent agreement.

V. State Statute Conformity

1. California Environmental Quality Act (CEQA) Document Update
(a) Each Permittee shall incorporate into its CEQA process no later than (6 months from Order adoption date), those additional procedures necessary for considering potential storm water quality impacts and providing for appropriate mitigation when preparing and reviewing CEQA documents.
(1) The procedures shall require consideration of the following:
(A) Potential impact of project construction on storm water runoff.
(B) Potential impact of project post-construction activity on storm water runoff.

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(C) Potential for discharge of storm water from areas from material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas or loading docks, or other outdoor work areas.
(D) Potential for discharge of storm water to impair the beneficial uses of the receiving waters.
(E) Potential for the discharge of storm water to cause significant harm on the biological integrity of the waterways and waterbodies.
(F) Potential for significant changes in the flow velocity or volume of storm water runoff to cause harm to or impair the beneficial uses of natural drainage systems.
(G) Potential for significant increases in erosion at the project site or surrounding areas.

2. General Plan Update
(a) Each Permittee shall amend, revise or update its General Plan to include watershed and storm water quality and quantity management considerations and policies when any of the following General Plan elements are updated or amended:
(1) Land Use
(2) Housing
(3) Conservation
(4) Open Space
(b) Each Permittee shall provide the Regional Water Board with the draft amendment or revision when a listed General Plan element or General Plan is noticed for comment in accordance with Cal. Govt. Code § 65350 *et seq*.

F. Development Construction Program

I. Each Permittee shall implement a construction program that prevents illicit construction-related discharges of pollutants into the MS4, implements and maintains structural and non-structural BMPs to reduce pollutants in stormwater runoff from construction sites, reduces construction site discharges of pollutants from the MS4 to the MEP, and prevents construction site discharges from the MS4 from causing or contributing to a violation of water quality standards.

1. BMP Implementation - Construction Sites Less Than One Acre

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(a) Each Permittee shall require the implementation of an effective combination of erosion and sediment control BMPs from Table 6 to prevent erosion and sediment loss, and the discharge of construction wastes.[1]

Table 6 - BMPs at Construction sites less than 1 acre

Minimum Set of BMPs for All Construction Sites	CASQA Handbook	Caltrans Handbook
For Erosion Control		
Scheduling	EC-1	SS-1
Preservation of Existing Vegetation	EC-2	SS-2
Sediment Controls		
Silt Fence	SE-1	SC-1
Sand Bag Barrier	SE-8	SC-8
Stabilized Construction Site Entrance/Exit	TC-1	TC-1
Non-Storm Water Management		
Water Conservation Practices	NS-1	NS-1
Dewatering Operations (Groundwater dewatering only under NPDES Permit No. CAG994004).[2]	NS-2	NS-2
Waste Management		
Material Delivery and Storage	WM-1	WM-1
Stockpile Management	WM-3	WM-2
Spill Prevention and Control	WM-4	WM-4
Solid Waste Management	WM-5	WM-5
Concrete Waste Management	WM-8	WM-8
Sanitary/ Septic Waste Management	WM-9	WM-9

2. BMP Implementation - Construction Sites One Acre but Less than 5 acres.
   (a) Each Permittee shall require the implementation of an effective combination of appropriate erosion and sediment control BMPs from Table 7 in addition to the ones identified in Table 6 to prevent erosion and sediment loss, and the discharge of construction wastes:

Table 7 - BMPs at Construction sites 1acre or greater but less than 5 acres

BMPs	CASQA Handbook	Caltrans Handbook
For Erosion Control		
Hydraulic Mulch	EC-3	SS-3
Hydroseeding	EC-4	SS-4
Soil Binders	EC-5	SS-5
Straw Mulch	EC-6	SS-6
Geotextiles and Mats	EC-7	SS-7
Wood Mulching	EC-8	SS-8

[1] The BMPs are taken from the *California BMP Handbook, Construction, January 2003* and the *Caltrans Stormwater Quality Handbooks, Construction Site Best Management Practices (BMPs) Manual, March 2003*, and addenda.
[2] Ponded storm water may be discharged at a concentration of Total Suspended Solids (TSS) of 100mg/L or less.

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Sediment Controls		
Fiber Rolls	SE-5	SC-5
Gravel Bag Berm	SE-6	SC-6
Street Sweeping and/ or Vacuum	SE-7	SC-7
Storm Drain Inlet Protection	SE-10	SC-10
Additional Controls		
Wind Erosion Controls	WE-1	WE-1
Stabilized Construction Entrance/ Exit	TC-1	TC-1
Stabilized Construction Roadway	TC-2	TC-2
Entrance/ Exit Tire Wash	TC-3	TC-3
Non-Storm Water Management		
Vehicle and Equipment Washing	NS-8	NS-8
Vehicle and Equipment Fueling	NS-9	NS-9

3. BMP Implementation - Construction Sites 5 acres and Greater
   (a) Each Permittee shall require the implementation of an effective combination of the following BMPs in Table 8 (BMPs at Construction sites 5 acres or greater) in addition to the ones identified in Table 6 (BMPs at Construction sites less than 1 acre) and Table 7 (BMPs at Construction sites 1acre or greater but less than 5 acres) at all construction sites 5 acres and greater to prevent erosion and sediment loss, and the discharge of construction wastes. Erosion control BMPs shall be preferred to sediment control BMPs.

Table 8 - BMPs at Construction sites 5 acres or greater

BMPs	**CASQA Handbook**	**Caltrans Handbook**
Sediment Controls		
Sediment Basin	SE-2	SC-2
Check Dam	SE-4	SC-4
Tracking Control BMPs		
Stabilized Construction Entrance/ Exit	TR-1	TC-1
Non-Storm Water Management		
Vehicle and Equipment Maintenance	NS-10	NS-10
Waste Management		
Material Delivery and Storage	WM-1	WM-1
Spill Prevention and Control	WM-4	WM-4
Concrete Waste Management	WM-8	WM-8
Sanitary/ Septic Waste Management	WM-9	WM-9

4. Enhanced Construction BMP Implementation.
   (a) Each Permittee shall implement, or require implementation of, enhanced practices that preclude impacts to water quality posed by all construction sites on hillsides as defined in this Order and construction sites that directly discharge to a waterbody listed on the CWA § 303 (d) list for siltation or sediment, or that occur within or directly adjacent to an Environmentally Sensitive Area (ESAs).

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Construction sites located on hillsides, adjacent to CWA 303(d) listed waters for siltation or sediment, and directly adjacent to ESAs are termed "High risk sites."

(b) Each Permittee shall require implementation of enhanced practices for high risk sites which shall include increased BMP inspection and maintenance requirements.

(1) Each Permittee shall require that high risk sites shall be inspected by the project proponent's Qualified SWPPP Developer or Qualified SWPPP Practitioner or personnel or consultants who are Certified Professionals in Erosion and Sediment Control (CPESC) at the time of BMP installation, at least weekly during the wet season, and at least once each 24 hour period during a storm event that generates runoff from the site, to identify BMPs that need maintenance to operate effectively, that have failed or could fail to operate as intended.

(2) During the wet season, the area of disturbance shall be limited to the area that can be controlled with an effective combination of erosion and sediment control BMPs. Enhanced sediment controls should be used in combination with erosion controls and should target portions of the site that cannot be effectively controlled by standard erosion controls described above. Effective sediment and erosion control BMPs proposed by the proponent shall include the BMPs listed in Table 9 below. The project proponents are responsible to implement the BMPs below unless shown unnecessary. The Permittee shall require that the project proponent retain records of the inspection and a determination and rationale of the BMPs selected to control runoff.

Table 9 Enhanced Construction BMP Implementation.

Construction Site BMPs	**CASQA Handbook[17]**	**Caltrans Handbook[18]**
Erosion Controls		
Scheduling	EC-1	SS-1
Preservation of Existing Vegetation	EC-2	SS-2
Hydraulic Mulch	EC-3	SS-3
Hydroseeding	EC-4	SS-4
Soil Binders	EC-5	SS-5
Straw Mulch	EC-6	SS-6
Geotextiles and Mats	EC-7	SS-7
Wood Mulching	EC-8	SS-8
Slope Drains	EC-11	SS-11
Sediment Controls		
Silt Fence	SE-1	SC-1
Fiber Rolls	SE-5	SC-5

17 BMPs of equivalent effectiveness may also be utilized.
18 BMPs of equivalent effectiveness may also be utilized.

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Construction Site BMPs	CASQA Handbook17	Caltrans Handbook18
Sediment Basin	SE-2	SC-2
Check Dam	SE-4	SC-4
Gravel Bag Berm	SE-6	SC-6
Street Sweeping and/or Vacuum	SE-7	SC-7
Sand Bag Barrier	SE-8	SC-8
Storm Drain Inlet Protection	SE-10	SC-10
Additional Controls		
Wind Erosion Controls	WE-1	WE-1
Stabilized Construction Entrance/Exit	TC-1	TC-1
Stabilized Construction Roadway	TC-2	TC-2
Entrance/Exit Tire Wash	TC-3	TC-3
Advanced Treatment Systems[1]		
Non-Storm Water Management		
Water Conservation Practices	NS-1	NS-1
Dewatering Operations (Groundwater dewatering only under NPDES Permit No. CAG994004).19	NS-2	NS-2
Vehicle and Equipment Washing	NS-8	NS-8
Vehicle and Equipment Fueling	NS-9	NS-9
Vehicle and Equipment Maintenance	NS-10	NS-10
Waste Management		
Material Delivery and Storage	WM-1	WM-1
Stockpile Management	WM-3	WM-2
Spill Prevention and Control	WM-4	WM-4
Solid Waste Management	WM-5	WM-5
Concrete Waste Management	WM-8	WM-8
Sanitary/Septic Waste Management	WM-9	WM-9

(c) The Permittees shall require the project proponent to collect representative samples during wet weather events in accordance with the SWRCB general construction permit or equivalent monitoring program as developed by the Permittees on approval by the Executive Officer.

5. Local Agency Requirements
   (a) Each Permittee shall require for all construction sites 1 acre or greater, compliance with all conditions identified in the preceding subparts F.1 - F.5, and the following requirements:
      (1) Local Storm Water Pollution Prevention Plan (Local SWPPP),
         (A) Each Permittee shall require the preparation and submittal of a Local SWPPP, for the Permittee's review and written approval prior to issuance of a grading or construction permit for construction or

[1] If appropriate given natural background stormwater runoff and receiving water quality conditions.

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demolition projects. The Permittees' approval signature shall be contained within the first pages of the Local SWPPP

(i) The Permittee shall not approve any Local SWPPP unless it contains appropriate site-specific construction site BMPs, specific locations, and maintenance schedules.

(ii) The Local SWPPP must include the rationale used for selecting or rejecting BMPs for various construction phases and weather conditions. The project architect, or engineer of record, or authorized qualified designee, must sign a statement on the Local SWPPP to the effect:

(I) *"As the architect/ engineer of record, I have selected appropriate BMPs to effectively minimize the negative impacts of this project's construction activities on storm water quality. The project owner and contractor are aware that the selected BMPs must be installed, monitored, and maintained to ensure their effectiveness. The BMPs not selected for implementation are redundant or deemed not applicable to the proposed construction activity."*

(2) Certification Statement

(A) Each Permittee shall require that each landowner or the landowner's agent sign a statement on the Local SWPPP to the effect:

(i) *"I certify that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, to the best of my knowledge and belief, the information submitted is true, accurate, and complete. I am aware that submitting false and/ or inaccurate information, failing to update the Local SWPPP to reflect current conditions, or failing to properly and/ or adequately implement the Local SWPPP may result in revocation of grading and/ or other permits or other sanctions provided by law."*

(ii) The Local SWPPP certification shall be signed by the property owner or owner's representative/designee. If the Local SWPPP or SWPPP is being prepared by the local agency then the appropriate authority of the local agency shall sign the document.

6. Roadway Paving or Repaving Operations (For Private or Public Projects)

(a) Each Permittee shall require that for any project that includes roadbed or street paving, repaving, patching, digouts, or resurfacing roadbed surfaces, that the following BMPs be implemented for each project.

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(b) Restrict paving and repaving activity to exclude periods of rainfall or predicted rainfall unless required by emergency conditions
(c) Install sand bags or gravel bags and filter fabric at all susceptible storm drain inlets and at manholes to prevent spills of paving products and tack coat
(d) Prevent the discharge of release agents including soybean oil, other oils, or diesel to the storm water drainage system or watercourses
(e) Minimize non storm water runoff from water use for the roller and for evaporative cooling of the asphalt
(f) Clean equipment over absorbent pads, drip pans, plastic sheeting or other material to capture all spillage and dispose of properly
(g) Collect liquid waste in a container, with a secure lid, for transport to a maintenance facility to be reused, recycled or disposed of properly
(h) Collect solid waste by vacuuming or sweeping and securing in an appropriate container for transport to a maintenance facility to be reused, recycled or disposed of properly
(i) Cover the "cold-mix" asphalt (i.e., pre-mixed aggregate and asphalt binder) with protective sheeting during a rainstorm
(j) Cover loads with tarp before haul-off to a storage site, and do not overload trucks
(k) Minimize airborne dust by using water spray during grinding
(l) Avoid stockpiling soil, sand, sediment, asphalt material and asphalt grindings materials or rubble in or near storm water drainage system or watercourses
(m) Protect stockpiles with a cover or sediment barriers during a rain

7. Electronic Site Tracking System
   (a) Each Permittee shall use an electronic system to track grading permits, encroachment permits, demolition permits, building permits, or construction permits (and any other municipal authorization to move soil and/ or construct or destruct that involves land disturbance) issued by each Permittee. To satisfy this requirement, the use of a database or GIS system is encouraged, but not required.

8. Inspections
   (a) Each Permittee shall inspect all construction sites for the implementation of storm water quality controls a minimum of once during the wet season. Concurrently, each Permittee shall ensure that:
      (1) The Local SWPPP is reviewed for compliance with local codes, ordinances, and permits.
      (2) A follow-up inspection takes place within two weeks for inspected sites that have not adequately implemented their Local SWPPP.
   (b) Each Permittee shall take additional enforcement actions to achieve compliance as specified in municipal codes, if compliance with municipal codes, ordinances, or permits has not been attained.
   (c) Each Permittee can refer sites to the Regional Water Board for further joint enforcement actions for violation of municipal storm water ordinances and the

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Construction Activities Storm Water General Permit (CASGP), or Small Linear Underground/ Overhead Construction Projects General Permit (small LUPs), after conducting a minimum of 2 site inspections and issuing a minimum of 2 written notices to the operator regarding the violation (copied to the Regional Water Board). In making such referrals, Permittees shall include, at a minimum, the following documentation:

(1) Name of the site
(2) WDID number
(3) Site developer
(4) Site owner
(5) Records of communication with the site operator regarding the violation(s), which shall include at least an inspection report
(6) Written notice of the violation copied to the Regional Water

(d) Prior to approving and/ or signing off for occupancy and issuing the Certificate of Occupancy for all construction projects subject to post-construction controls, each Permittee shall inspect the constructed site design, source control and treatment control BMPs to verify that they have been constructed in compliance with all specifications, plans, permits, ordinances, and this Order. The initial/ acceptance BMP verification inspection does not constitute a maintenance and operation inspection, as required in the preceding subpart E.IV.2(c).

9. State Conformity Requirements

(a) Each Permittee shall ensure that no grading permit, encroachment permit, demolition permit, building permit, electrical permit, or construction permit (or any other municipal authorization to move soil and/ or construct or destruct that involves land disturbance) is issued for any project requiring coverage under the CASGP or Small LUP General Permit[1] unless:

(1) Proof of filing a Notice of Intent for coverage under a State NPDES permit is demonstrated).
(2) Demonstration or Certification that a SWPPP has been prepared by the project developer.
(3) Proof of Change of Information form (COI) and a copy of the modified SWPPP(s) at any time a transfer of ownership takes place for the entire development or portions of the common plan of development where construction activities are still on-going.

10. Interagency Coordination

(a) **Referral of Violations:**

[1] NPDES Permit No. CAS000005, Waste Discharge Requirements For Discharges of Storm Water Runoff Associated with Small Linear Underground/ Overhead Construction Projects (Small LUP General Permit) for any linear land disturbing activity or activities (cumulatively) that will cause one acre or more of land disturbance but not more than 5 acres.

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A Permittee may refer a violator of the municipal storm water ordinance and CWC § 13260 to the Regional Water Board provided that the Permittee has made a good faith effort at progressive enforcement consistent with the preceding subpart F.8(c). At a minimum, the Permittee's good faith effort shall be documented with:

(1) A minimum of 2 follow-up inspection reports (inspections completed within 3 months).
(2) A minimum of two warning letters or NOVs.

(b) **Referral of Non-filers under the CASGP or the Small LUP General Permit:** Each Permittee shall refer non-filers (i.e., those projects which cannot demonstrate that they have a WDID number) under the CASGP or Small LUP General Permit, to the Regional Water Board, no later than 15 days after making a determination of failure to file. In making such referrals, Permittees shall include, at a minimum, the following documentation:
(1) Project location address
(2) Project description
(3) Developer or owners name with complete mailing address
(4) Project size
(5) Records of communication with the developer or owner regarding filing requirements

(c) **Investigation of Complaints Regarding Facilities – Transmitted by the Regional Water Board Staff:**
(1) Each Permittee shall initiate, within one business day,[1] an initial investigation of complaint(s) (other than non-storm water discharges) on the construction site(s) within its jurisdiction.
(A) The initial investigation shall include, at a minimum, an inspection on the facility and its perimeter to confirm the complaint and to determine if the site operator is effectively complying with the municipal storm water/ urban runoff ordinances, and to oversee corrective action.

(d) **Support of Regional Water Board Enforcement Actions – As directed by the Regional Water Board Executive Officer:**
(1) Each Permittee shall support Regional Water Board enforcement actions by:
(A) Assisting in identification of current owners, operators, and lessees of properties and sites.
(B) Providing staff, when available, for joint inspections with Regional Water Board inspectors.
(C) Appearing to testify as witnesses in Regional Water Board enforcement hearings.
(D) Providing copies of inspection reports and other progressive enforcement documentation.

[1] Permittees may comply with the Permit by taking initial steps (such as logging, prioritizing, and tasking) to "initiate" the investigation within that one business day. However, the Regional Water Board would expect that the initial investigation, including a site visit, to occur within four business days.

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G. Public Agency Activities Program

I. Each Permittee shall implement a Public Agency Activities Program to minimize storm water pollution impacts from public agency activities. Public Agency requirements consist of:
   i. Public Construction Activities Management.
   ii. Vehicle Maintenance/ Material Storage Facilities/ Corporation Yards Management/ Municipal Operations.
   iii. Vehicle and Equipment Wash Areas
   iv. Landscape and Recreational Facilities Management
   v. Storm Drain Operation and Management
   vi. Streets and Roads Maintenance
   vii. Public Industrial Activities Management
   viii. Emergency Procedures
   ix. Employee Training
   x. Infrastructure Maintenance

1. Public Construction Activities Management
   (a) Each Permittee shall implement and comply with the Planning and Land Development Program requirements in part 5.E. of this Order at Permittee owned or operated public construction projects for project types identified in part 5.E of this Order.
   (b) Each Permittee shall implement and comply with the appropriate Development Construction Program requirements in part 5.F. of this Order at Permittee owned or operated construction projects as applicable.
   (c) For public projects including those under a Capital Improvement Project Plan that disturb less than one acre of soil the Permittees shall require the development and implementation of a Storm Water Pollution Control Plan. The SWPCP shall include BMPs as identified in Tables 5, 9 and 10.
2. Vehicle Maintenance/ Material Storage Facilities/ Corporation Yards Management/ Long Term Maintenance Programs
   (a) Each Permittee shall implement the activity specific BMPs[1] listed in Table 9 when such activities occur at Permittee owned/leased facilities and job sites including but not limited to vehicle/ equipment maintenance facilities, material storage facilities, and corporation yards, and at any area that includes the activities as described in the following Tables. Additionally, for any activity or area

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[1] These BMPs are identified in Appendix B of the *Caltrans Storm Water Quality Handbook Maintenance Staff Guide, May 2003*, and its addenda. Other BMPs may be substituted upon approval by the Executive Officer.

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described in the footnote below,[1] each Permittee shall also implement the BMPs in the Caltrans Storm Water Quality Handbook Maintenance Staff Guide described as B-4 in Table 10 (BMPs at Vehicle Maintenance/ Material Storage Facilities/ Corporation Yards).

Table 10 - BMPs at Vehicle Maintenance/ Material Storage Facilities/ Corporation Yards

From the Caltrans Storm Water Quality Handbook Maintenance Staff Guide	**Appendix B**
Activity Specific BMPs	**Page**
General BMPs	B-4
Flexible Pavement	B-9
Asphalt Cement Crack and Joint Grinding/ Sealing	B-9
Asphalt Paving	B-10
Structural Pavement Failure (Digouts) Pavement Grinding and Paving	B-11
Emergency Pothole Repairs	B-13
Sealing Operations	B-14
Rigid Pavement	B-15
Portland Cement Crack and Joint Sealing	B-15
Mudjacking and Drilling	B-16
Concrete Slab and Spall Repair	B-17
Slope/ Drains/ Vegetation	B-19
Shoulder Grading	B-19
Nonlandscaped Chemical Vegetation Control	B-21
Nonlandscaped Mechanical Vegetation Control/ Mowing	B-23
Nonlandscaped Tree and Shrub Pruning, Brush Chipping, Tree and Shrub Removal	B-24
Fence Repair	B-25
Drainage Ditch and Channel Maintenance	B-26
Drain and Culvert Maintenance	B-28
Curb and Sidewalk Repair	B-30
Litter/ Debris/ Graffiti	B-32
Sweeping Operations	B-32
Litter and Debris Removal	B-33
Emergency Response and Cleanup Practices	B-34
Graffiti Removal	B-36
Landscaping	B-37
Chemical Vegetation Control	B-37
Manual Vegetation Control	B-39
Landscaped Mechanical Vegetation Control/ Mowing	B-40
Landscaped Tree and Shrub Pruning, Brush Chipping, Tree and Shrub Removal	B-41
Irrigation Line Repairs	B-42
Irrigation (Watering), Potable and Nonpotable	B-43
Environmental	B-44

[1] Scheduling and Planning; Spill Prevention and Control; Sanitary/ Septic Waste Management; Material Use; Safer Alternative Products; Vehicle/ Equipment Cleaning, Fueling, and Maintenance; Illicit Connections Detection, Reporting and Removal; Illegal Spill / Discharge Control and Maintenance Facility Housekeeping Practices.

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Activity Specific BMPs	**Page**
Storm Drain Stenciling	B-44
Roadside Slope Inspection	B-45
Roadside Stabilization	B-46
Storm Water Treatment Devices	B-48
Traction Sand Trap Devices	B-49
Public Facilities	B-50
Public Facilities	B-50
Bridges	B-52
Welding and Grinding	B-52
Sandblasting, Wet Blast with Sand Injection and Hydroblasting	B-54
Painting	B-56
Bridge Repairs	B-57
Other Structures	B-59
Pump Station Cleaning	B-59
Tube and Tunnel Maintenance and Repair	B-61
Tow Truck Operations	B-63
Toll Booth Lane Scrubbing Operations	B-64
Electrical	B-65
Sawcutting for Loop Installation	B-65
Traffic Guidance	B-67
Thermoplastic Striping and Marking	B-67
Paint Striping and Marking	B-68
Raised/ Recessed Pavement Marker Application and Removal	B-70
Sign Repair and Maintenance	B-71
Median Barrier and Guard Rail Repair	B-73
Emergency Vehicle Energy Attenuation Repair	B-75
Snow and Ice Control	B-76
Snow Removal	B-76
Ice Control	B-77
Storm Maintenance	B-78
Minor Slides and Slipouts Cleanup/ Repair	B-78
Management and Support	B-80
Building and Grounds Maintenance	B-80
Storage of Hazardous Materials (Working Stock)	B-82
Material Storage Control (Hazardous Waste)	B-84
Outdoor Storage of Raw Materials	B-85
Vehicle and Equipment Fueling	B-86
Vehicle and Equipment Cleaning	B-87
Vehicle and Equipment Maintenance and Repair	B-88
Aboveground and Underground Tank Leak and Spill Control	B-90

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3. Vehicle and Equipment Wash Areas
   (a) Each Permittee shall eliminate discharges of wash waters from vehicle and equipment washing no later than (365 days after Order adoption date) by

implementing any of the following measures at existing facilities with vehicle or equipment wash areas:
(1) Self-contain, and haul off for disposal
(2) Equip with a clarifier
(3) Equip with an alternative pre-treatment device; or
(4) Plumb to the sanitary sewer

(b) Each Permittee shall ensure that any municipal facilities constructed, redeveloped, or replaced has all vehicle and equipment wash areas plumbed to the sanitary sewer or be self contained and all wastewater/ washwater hauled for legal disposal.

4. Landscape, Park, and Recreational Facilities Management

(a) Integrated Pest Management (IPM)
IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Each Permittee shall implement an IPM program that includes the following:
(1) Pesticides are used only if, after monitoring indicates they are needed according to established guidelines.
(2) Treatments are made with the goal of removing only the target organism.
(3) Pest controls are selected and applied in a manner that minimizes risks to human health, beneficial, non-target organisms, and the environment.
(4) Its use of pesticides, including Organophosphates and Pyrethroids do not threaten water quality.
(5) Partner with other agencies and organizations to encourage the use of IPM.
(6) Adopt and verifiably implement policies, procedures, and/ or ordinances requiring the minimization of pesticide use and encouraging the use of IPM techniques (including beneficial insects) in the Permittees' overall operations and on municipal property.
(7) Policies, procedures, and ordinances shall include commitments and timelines to reduce the use of pesticides that cause impairment of surface waters by implementing the following procedures:
(A) Quantify pesticide use by its staff and hired contractors.
(B) Prepare and annually update an inventory of pesticides used by all internal departments, divisions, and other operational units.
(C) Demonstrate reductions in pesticide use.

(b) Each Permittee shall implement the following requirements no later than (180 days after Order adoption date):
(1) Use a standardized protocol for the routine and non-routine application of pesticides (including pre-emergents), and fertilizers.

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(2) Ensure no application of pesticides or fertilizers are applied to an area immediately prior to, during, or immediately after a rain event, or when water is flowing off the area.
(3) Ensure that no banned or unregistered pesticides are stored or applied.
(4) Ensure that all staff applying pesticides are certified in the appropriate category by the California Department of Pesticide Regulation, or are under the direct supervision of a pesticide applicator certified in the appropriate category.
(5) Implement procedures to encourage the retention and planting of native vegetation to reduce water, pesticide and fertilizer needs; and
(6) Store pesticides and fertilizers indoors or under cover on paved surfaces or use secondary containment.
    (A) Reduce the use, storage, and handling of hazardous materials to reduce the potential for spills.
    (B) Regularly inspect storage areas.
(7) Comply with the provisions and the monitoring requirements for application of aquatic pesticides to surface waters (WQ Order No. 2004-0008-DWQ).

5. Storm Drain Operation and Management
(a) Catch Basin Cleaning
(1) Each Permittee shall designate catch basin inlets within its jurisdiction as one of the following:
    Priority A: Catch basins that are designated as consistently generating the highest volumes of trash.
    Priority B: Catch basins that are designated as consistently generating moderate volumes of trash.
    Priority C: Catch basins that are designated as generating low volumes of trash.
    Within one year of Order adoption, Permittees shall submit a map or list of Catch Basins with their GPS coordinates and their designations. The map or list shall contain the rationale or data to support designations.
(2) Each Permittee shall inspect catch basins according to the following schedule:
    Priority A: A minimum of 3 times during the wet season and once during the dry season every year.
    Priority B: A minimum of once during the wet season and once during the dry season every year.
    Priority C: A minimum of once per year.
    Catch basins shall be cleaned as necessary on the basis of inspections. Permittees shall maintain inspection records for Regional Board review.
(3) In addition to the preceding schedule, Permittees shall ensure that any catch basin that is determined to be at least 25% full of trash shall be cleaned out.
(b) Trash Management at Public Events

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(1) Each Permittee shall require for any event in the public right of way or wherever it is foreseeable that substantial quantities of trash and litter may be generated, the following measures:
(A) Proper management of trash and litter generated; and
(B) Arrangement for temporary screens to be placed on catch basins; or
(C) Provide clean out of catch basins, trash receptacles, and grounds in the event area within 24 hours subsequent to the event.

(c) Trash Receptacles
(1) Each Permittee shall install trash receptacles, or equivalent trash capturing devices in areas subject to high trash generation within its jurisdiction no later than (one year after Order adoption date).
(2) Each Permittee shall ensure that all trash receptacles are cleaned out and maintained as necessary to prevent trash overflow.

(d) Catch Basin Labels
(1) Each Permittee shall inspect the legibility of the catch basin stencil or label nearest each catch basin and inlet before the rainy season begins.
(2) Each Permittee shall record and re-stencil or re-label within 15 days of inspection, catch basins with illegible stencils.

(e) Additional Trash Management Practices
(1) Each Permittee shall install trash excluders, or equivalent devices on or in catch basins or outfalls to prevent the discharge of trash to the storm drain system or receiving water no later than two years after Order adoption date in areas defined as Priority A (Provision 1a(2)) except in sites where the application of such BMP(s) alone will cause flooding. Lack of maintenance that causes flooding is not an acceptable exception to the requirement to install BMPs. Alternatively the Permittee may implement alternative or enhanced BMPs beyond the provisions of this permit (such as but not limited to increased street sweeping, adding trash cans near trash generation sites, prompt enforcement of trash accumulation, increased trash collection on public property, increased litter prevention messages or trash nets within the MS4) that provide substantially equivalent removal of trash. Permittees shall demonstrate that BMPs, which substituted for trash excluders provide equivalent trash removal performance as excluders. When outfall trash capture is provided, revision of the schedule for inspection and cleanout of catch basins in task (a) may be proposed by the Permittee for approval by the Executive Officer.

(f) Storm Drain Maintenance
(1) Each Permittee shall implement a program for Storm Drain Maintenance no later than (180 days after Order adoption date) that includes the following:
(A) Visual monitoring of Permittee-owned open channels and other drainage structures for debris at least annually.
(B) Remove trash and debris from open channel storm drains a minimum of once per year before the storm season.

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(C) Eliminate the discharge of contaminants during MS4 maintenance and clean outs.
(D) Quantify the amount of materials removed using techniques appropriate for quantifying solid waste and ensure the materials are properly disposed of.

(g) Spill Response Plan
(1) Each Permittee shall implement a response plan for spills to the MS4 within their respective jurisdiction. The response Plan shall clearly identify agencies responsible and telephone numbers and e-mail address for contact and shall contain at a minimum the following:
(A) Investigation of all complaints received within 24 hours of the incident report.
(B) Response within 2 hours to spills for containment upon notification, except where such overflows occur on private property, in which case the response should be within 2 hours of gaining legal access to the property.
(C) Notification to appropriate public health agencies and the Office of Emergency Services (OES).

(h) Permittee Owned Treatment Control BMPs
(1) Each Permittee shall implement an inspection and maintenance program for all Permittee owned treatment control BMPs, including post-construction treatment control BMPs.
(2) Each Permittee shall ensure proper operation of all treatment control BMPs and maintain them as necessary for proper operation, including all post-construction treatment control BMPs.
(3) Any residual water produced by a treatment control BMP and not being internal to the BMP performance when being maintained shall be:
(A) Hauled away and legally disposed of; or
(B) Applied to the land without runoff; or
(C) Discharged to the sanitary sewer system (with permits or authorization); or
(D) Treated or filtered to remove bacteria, sediments, nutrients, and meet the limitations set in Table 11 (Discharge Limitations for Dewatering Treatment BMPs) prior to discharge to the MS4.

Table 11 - Discharge Limitations for Dewatering Treatment BMPs[1]

Parameter	Units	Limitation
Total Suspended Solids	mg/L	100
Turbidity	NTU	50
Oil and Grease	mg/L	10

[1] Technology based effluent limits.

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6. Streets and Roads Maintenance
   (a) Maintenance
      (1) Each Permittee shall perform street sweeping of curbed streets in commercial areas and areas subject to high trash generation to control trash and debris at least two times per month.
   (b) Road Reconstruction
      (1) Each Permittee shall require that for any project that includes roadbed or street paving, repaving, patching, digouts, or resurfacing roadbed surfaces, that the following BMPs be implemented for each project.
         (A) Restrict paving and repaving activity to exclude periods of rainfall or predicted rainfall[1] unless required by emergency conditions.
         (B) Install sand bags or gravel bags and filter fabric at all susceptible storm drain inlets and at manholes to prevent spills of paving products and tack coat;
         (C) Prevent the discharge of release agents including soybean oil, other oils, or diesel to the storm water drainage system or watercourses.
         (D) Minimize non storm water runoff from water use for the roller and for evaporative cooling of the asphalt.
         (E) Clean equipment over absorbent pads, drip pans, plastic sheeting or other material to capture all spillage and dispose of properly.
         (F) Collect liquid waste in a container, with a secure lid, for transport to a maintenance facility to be reused, recycled or disposed of properly.
         (G) Collect solid waste by vacuuming or sweeping and securing in an appropriate container for transport to a maintenance facility to be reused, recycled or disposed of properly.
         (H) Cover the "cold-mix" asphalt (i.e., pre-mixed aggregate and asphalt binder) with protective sheeting during a rainstorm.
         (I) Cover loads with tarp before haul-off to a storage site, and do not overload trucks.
         (J) Minimize airborne dust by using water spray during grinding.
         (K) Avoid stockpiling soil, sand, sediment, asphalt material and asphalt grindings materials or rubble in or near storm water drainage system or watercourses.
         (L) Protect stockpiles with a cover or sediment barriers during a rain.

7. Emergency Procedures
   (a) Each Permittee may conduct repairs of essential public service systems and infrastructure in emergency situations with a self-waiver of the provisions of this Order.
      (1) Where the self-waiver has been invoked, the Permittee shall submit to the Regional Water Board Executive Officer a statement of the occurrence of

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[1] A probability of precipitation (POP) of 50% is required.

the emergency, an explanation of the circumstances, and the measures that were implemented to reduce the threat to water quality, no later than 30 business days after the situation of emergency has passed.

(2) Minor repairs of essential public service systems and infrastructure in emergency situations (can be completed in less than one day) are not subject to the notification provisions. Appropriate BMPs to reduce the threat to water quality shall be implemented.

8. Municipal Employee and Municipal Contractor Training

(a) Each Permittee shall, no later than (12 months after Order adoption date and annually thereafter before June 30), train all of their employees and contractors in targeted positions (whose interactions, jobs, and activities affect storm water quality) on the requirements of the overall storm water management program to:
   (1) Promote a clear understanding of the potential for activities to pollute storm water.
   (2) Identify opportunities to require, implement, and maintain appropriate BMPs in their line of work.

(b) Each Permittee shall, no later than (12 months after Order adoption date and annually thereafter before June 30), train all of their employees and contractors who use or have the potential to use pesticides or fertilizers (whether or not they normally apply these as part of their work). Training programs shall address:
   (1) The potential for pesticide-related surface water toxicity.
   (2) Proper use, handling, and disposal of pesticides.
   (3) Least toxic methods of pest prevention and control, including IPM.
   (4) Reduction of pesticide use.

(c) Each Permittee shall, no later than (12 months after Order adoption date) and annually thereafter before June 30, train all of their employees and contractors who are responsible for illicit connections and illicit/ illegal discharges. Training programs shall address:
   (1) Identification
   (2) Investigation
   (3) Termination
   (4) Cleanup
   (5) Reporting of Incidents
   (6) Documentation of Incidents

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H. Illicit Connections and Illicit Discharges Elimination Program

I. Each Permittee shall implement an Illicit Connections and Illicit Discharges (IC/ IDs) program to eliminate IC/IDs to the storm drain system, and shall document, track, and report all such cases in accordance with the elements and performance measures specified in the following subsections.

1. General

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(a) Implementation - Each Permittee shall implement an IC/ ID Program. The IC/ ID procedures shall be documented and made available for public review.
(b) Tracking - All Permittees shall, no later than (3 years after Order adoption date), map at a scale and in a format specified by the Principal Permittee all known connections to their storm drain system. All Permittees shall map at a scale and in a format specified by the Principal Permittee incidents of illicit connections and discharges since January 2009 on their baseline maps, and shall transmit this information to the Principal Permittee no later than (3 years after Order adoption date). Permittees shall use this information to identify priority areas for further investigation and elimination of IC/ ID.

2. Public Reporting
(a) Permittees shall establish and maintain a phone hotline and internet site to receive all reports of IC/ ID complaints.
(b) Permittees shall document the location of the reported IC/ ID and the actions undertaken in response to all IC/ ID complaints.

3. Illicit Connections
(a) Screening for Illicit Connections
(1) Each Permittee shall submit to the Principal Permittee:
(A) A map at a scale and in a format specified by the Principal Permittee showing the location and length of underground pipes 18 inches and greater in diameter, and channels within their permitted area and operated by the Permittee in accordance with the following schedule:
(i) All channeled portions of the storm drain system no later than (365 days after Order adoption date).
(ii) All portions of the storm drain system consisting of storm drain pipes 36 inches in diameter or greater, (no later than 3 years after Order adoption date).
(iii) All portions of the storm drain system consisting of storm drain pipes 18 inches in diameter or greater, (no later than 5 years after Order adoption date).
(B) The status of suspected, confirmed, and terminated illicit connections.
(2) Permittees shall conduct field screening of their storm drain systems in accordance with screening procedures described in the Illicit Discharge Detection and Elimination, A Guidance Manual for Program Development and Technical Assessments (2004)[1]. Permittees shall conduct field screening of their storm drain system that has not been previously screened and reported to the Regional Board, for illicit connections in accordance with the following schedule:

[1] *Illicit Discharge Detection and Elimination, A Guidance Manual for Program Development and Technical Assessments*. The Center for Watershed Protection, Pitt R., October 2004. Chapter 13, 13.1,13.2, 13.3, 13.4

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(A) All portions of the storm drain system consisting of storm drain pipes 36 inches in diameter or greater, no later than (3 years after Order adoption date).
(B) High priority areas identified during the mapping of illicit connections and discharges, no later than (3 years after Order adoption date).
(C) All portions of storm drain systems 50 years or older in age, no later than (3 years after Order adoption date).

(3) Each Permittee shall maintain a list containing all connections under investigation for possible illicit connection and their status.

(b) Response to Illicit Connections

(1) Investigation -
Each Permittee, upon discovery or upon receiving a report of a suspected illicit connection, shall complete an investigation within 21 days, to determine the following:
(A) Source of the connection.
(B) Nature and volume of discharge through the connection.
(C) Responsible party for the connection.

(2) Termination -
Each Permittee, upon confirmation of an illicit storm drain connection, shall ensure the following:
(A) Termination of the connection within 180 days of completion of the investigation, using formal enforcement authority to eliminate the illicit connection.

(3) Documentation -
Each Permittee shall keep records of all illicit connection investigations and the formal enforcement taken to eliminate all illicit connections.

4. Illicit Discharges

(a) Investigation -
Each Permittee shall investigate an illicit/ illegal discharge during or immediately following containment and cleanup activities, and shall take appropriate enforcement action to eliminate the illegal discharge.

(b) Abatement and Cleanup -
Each Permittee shall respond, within 1 business day of discovery or a report of a suspected illicit/ illegal discharge, with actions to abate, contain, and/or clean up all illegal discharges, including hazardous waste.

(c) Documentation -
Each Permittee shall maintain records of all illicit/ illegal discharge discoveries, reports of suspected illicit/ illegal discharges, their response to the illicit/ illegal discharges and suspected illicit/ illegal discharges, and the formal enforcement taken to eliminate all illicit/ illegal discharges.

I. REPORTING PROGRAM

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1. The Principal Permittee in consultation with the Permittees and Regional Water Board staff shall convene an adhoc working group to develop an Electronic Reporting Program, the basis of which shall be the requirements in this Order. The Committee shall no later than (12 months after Order adoption date) submit the electronic reporting form in each subsequent year.

2. Each Permittee shall submit information required in the Reporting Program in a method as appropriate to the format approved by the Regional Water Board Executive Officer.

3. The Principal Permittee shall submit by December 15th of each year, an Annual Report to the Regional Water Board Executive Officer in the form one hard copy and three compact disk (CD) copies (or an electronic equivalent).

4. The Annual Report shall document the status of the Municipal Storm Water Program, an integrated summary of the results of analyses from:
   (a) The monitoring program described under Part 1- Monitoring Report.
   (b) The requirements described under Part 2- Program Report.

5. Plans shall be submitted to the Regional Water Board Executive Officer in the form of one hard copy and three compact disk (CD) copies (or an electronic equivalent).

6. Study Reports shall be submitted to the Regional Water Board Executive Officer in the form of one hard copy and three compact disk (CD) copies (or an electronic equivalent).

7. Progress Reports shall be submitted to the Regional Water Board Executive Officer in the form of one hard copy and three compact disk (CD) copies (or an electronic equivalent).

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PART 6 - TOTAL MAXIMUM DAILY LOAD PROVISIONS

I. Part 6 of this Order incorporates provisions to assure that Ventura County MS4 permittees comply with WLAs and other requirements of TMDLs covering impaired waters impacted by the permittees' discharges.

II. Each permittee shall attain the storm water WLAs incorporated into this Order by implementing BMPs in accordance with the MS4 effluent quality workplan and source identification approved by the Executive Officer.

III. TMDLs in effect and covered in this Order are the following:

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1. TMDL for Nitrogen Compounds for the Santa Clara River - (Effective date: March 23, 2004).
2. TMDL for Toxicity, Chlorpyrifos and Diazinon in the Calleguas Creek, its Tributaries and Mugu Lagoon - (Effective date: March 24, 2006).
3. TMDL for Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation in Calleguas Creek, its Tributaries and Mugu Lagoon - (Effective date: March 24, 2006).
4. TMDL for Bacteria in Malibu Creek and Lagoon – (Effective date: January 24, 2006).
5. TMDL for Metals and Selenium in the Calleguas Creek, its Tributaries and Mugu Lagoon (Effective date: March 26, 2007)
6. TMDL for Trash in Revolon Slough and Beardsley Wash (Effective date: March 6, 2008).
7. TMDL for Trash in the Ventura River Estuary (Effective date: March 6, 2008).
8. TMDL for Bacteria in Harbor Beaches of Ventura County (Effective date: September 23, 2008).

IV. TMDL Interim WLAs incorporated into this Order due to compliance dates which exceed the term of this Order are the following:
1. Final Wet Weather Bacteria WLAs for Malibu Creek and Lagoon – (Compliance date: January 24, 2016).
2. Final Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation WLAs for Calleguas Creek, its Tributaries and Mugu Lagoon – (Compliance date: March 24, 2026).
3. Final Metals and Selenium WLAs for Calleguas Creek, its Tributaries and Mugu Lagoon (Compliance date: March 26, 2022)

V. TMDL WLAs and Other TMDL Provisions Incorporated into this Order are as follows:

1. TMDL for Nitrogen Compounds in the Santa Clara River
   (a) Waste Load Allocations:
      (1) The Ventura County MS4 permittees discharging to the Santa Clara River (the cities of Fillmore and Santa Paula) ("Santa Clara MS4 permittees") shall implement BMPs to achieve the following MS4 wasteload allocations applicable to River Reach 3:

Ammonia nitrogen 30-day average	2.0 mg/L
Ammonia nitrogen 1-hour average	4.2 mg/L
Nitrate + Nitrite nitrogen 30-day average	8.1 mg/L

   (b) Compliance Monitoring:
      (1) Compliance with the WLAs is to be determined through receiving water monitoring conducted in accordance with the Santa Clara River Nitrogen TMDL Monitoring Program approved by the Executive Officer.

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(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Santa Clara MS4 permittees:

(1) Annual Progress Reports. Santa Clara River MS4 permittees, either independently or in conjunction with other stakeholders, shall submit an annual progress report with respect to achievement of the WLAs.

2. TMDL for Toxicity, Chlorpyrifos, and Diazinon in the Calleguas Creek, its Tributaries and Mugu Lagoon.

(a) Waste Load Allocations:

(1) MS4 permittees discharging to Calleguas Creek, its tributaries and Mugu Lagoon (Ventura County Watershed Protection District, County of Ventura and the cities of Camarillo, Moorpark, Oxnard, Simi Valley and Thousand Oaks) ("Calleguas MS4 permittees") shall implement BMPs to achieve the following MS4 WLAs:

Toxicity WLA	1.0 TUc
Chlorpyrifos WLA	0.014 ug/L
Diazinon WLA	0.10 ug/L

(2) Pursuant to the TMDL, the final storm water WLAs for Toxicity, Chlorpyrifos and Diazinon, listed above, are receiving water concentrations measured in-stream at the base of each subwatershed within the Calleguas Creek watershed.

(b) Compliance Monitoring:

(1) Compliance with the WLAs is to be determined through the measurement of in-stream water quality at the base of each of the Calleguas Creek subwatersheds, in accordance with the Calleguas Creek Watershed TMDL Monitoring Program approved by the Executive Officer.

(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(3) If as a result of compliance monitoring and subsequent investigations it is determined that a Calleguas MS4 permittee is responsible for exceedance of the in-stream Toxicity WLA, that permittee shall initiate the TRE/TIE process as outlined in U.S. EPA's "Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System Program" (2000) or the approved Toxicity TMDL monitoring plan, and take appropriate action to eliminate the identified source of the toxicity.

(c) Actions and Special Studies required of Calleguas MS4 permittees:

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(1) Special Study #1. Together with Calleguas POTW permittees, investigate the pesticides that will replace diazinon and chlorpyrifos in the urban environment, their potential impact on receiving waters and potential control measures. Special Study #1 was completed by March 24, 2008.
(2) Special Study #2. Together with Calleguas Agricultural Dischargers, consider results of monitoring of sediment concentrations by source/land use type through the special study required in the Calleguas OC Pesticide, PCB and Siltation TMDL Implementation Plan. Complete within 6 months of completion of the OCs TMDL special study #1.
(3) Pesticide Collection Program. Together with Calleguas POTW permittees, develop and implement a collection program for diazinon and chlorpyrifos and an educational program. Collection and education could occur through existing programs such as household hazardous waste collection events. The Pesticide Collection Program is to be implemented by March 24, 2009.
(4) Special Study #3. Together with Calleguas Agricultural Dischargers, consider the findings of transport rates developed through the OC Pesticide, PCB and Siltation TMDL Implementation Plan. Complete within 6 months of completion of the OCs TMDL special study #1.

3. TMDL for Organochlorine (OC) Pesticides, Polychlorinated Biphenyls (PCBs) and Siltation in the Calleguas Creek, its Tributaries and Mugu Lagoon.
(a) Waste Load Allocations:
(1) MS4 permittees discharging to Calleguas Creek, its tributaries or Mugu Lagoon (Ventura County Watershed Protection District, County of Ventura and the cities of Camarillo, Moorpark, and Simi Valley) ("Calleguas MS4 permittees") shall implement BMPs to achieve the interim WLAs listed in Table 11.

Table 12. Interim Sediment Concentration WLAs (ng/g)

Constituent	Subwatershed					
	Mugu Lagoon	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek
Chlordane	25	17	48	3.3	3.3	3.4
4,4-DDD	69	66	400	290	140	5.3
4,4-DDE	300	470	1600	950	170	20
4.4-DDT	39	110	690	670	25	2
Dieldrin	19	3	5.7	1.1	1.1	3
PCBs	180	3800	7600	25700	25700	3800
Toxaphene	22900	260	790	230	230	260

(2) Pursuant to the TMDL, the interim storm water WLAs for OC Pesticides, PCBs and Siltation, listed above, are annual average, sediment-based

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concentrations measured in surface waters at the base of each subwatershed within the Calleguas Creek watershed.

(b) Compliance Monitoring:

(1) Compliance with the WLAs is to be determined through the measurement of in-stream water quality at the base of each of the Calleguas Creek subwatersheds, in accordance with the Calleguas Creek Watershed TMDL Monitoring Program approved by the Executive Officer.

(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Calleguas MS4 permittees:

(1) Pesticide Collection Program. Together with Calleguas POTW permittees, implement a collection program and source control measures pursuant to a work plan approved by the Executive Officer. The Pesticide Collection Program is to be implemented by March 24, 2011.

(2) Special Study #1. Together with Calleguas POTW permittees, Calleguas Agricultural Dischargers, and the Point Mugu Naval Base, submit a work plan to quantify sedimentation in the Calleguas Creek Watershed, evaluate management methods to control siltation and contaminated sediment transport to Calleguas Creek, identify appropriate BMPs to reduce sediment loadings and evaluate the effect of sediment on habitat preservation in Mugu Lagoon for approval by the Executive Officer. This special study is also to evaluate the concentration of OC pesticides and PCBs in sediments from various sources/land use types. Special Study #1 is to be completed by March 24, 2014.

(3) Special Study #2. Together with Calleguas Agricultural Dischargers, identify areas of high OC concentrations and evaluate the effects of watershed protection and land use practices on water quality. Such practices include but are not limited to management of sediment reduction practices and structures, streambank stabilization, and other projects related to stormwater conveyance and flood control improvements in the Calleguas Creek watershed. Special Study #2 is to be completed based on the schedule provided in the workplan, submitted in March, 2007

(4) Special Study #3 – Together with Calleguas POTW permittees, Calleguas Agricultural Dischargers, and the Point Mugu Naval Base, evaluate natural attenuation rates and evaluate methods to accelerate organochlorine pesticide and polychlorinated biphenyl attenuation and examine the attainability of wasteload and load allocations in the Calleguas Creek Watershed. Special Study #3 is to be completed by March 24, 2016.

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4. TMDL for Metals and Selenium in the Calleguas Creek, its Tributaries and Mugu Lagoon.
   (a) Waste Load Allocations:
      (1) MS4 permittees discharging to Calleguas Creek, its tributaries or Mugu Lagoon (Ventura County Watershed Protection District, County of Ventura and the cities of Camarillo, Moorpark, Oxnard, Simi Valley and Thousand Oaks) ("Calleguas MS4 permittees") shall implement BMPs to achieve the interim WLAs listed in Table 12 and Table 13.

Table 13. Interim WLAs for Copper, Nickel and Selenium (ug/L)

Constituent	Calleguas and Conejo Creek (a)			Revolon Slough		
	Dry Daily Maximum (ug/L)	Dry Monthly Average (ug/L)	Daily Maximum (ug/L)	Dry Daily Maximum (ug/L)	Dry Monthly Average (ug/L	Daily Maximum (ug/L)
Copper	23	19	204	23	19	204
Nickel	15	13	(a)	15	13	(a)
Selenium	(b)	(b)	(b)	14(c)	13(c)	(a)

      (A) The current loads do not exceed the TMDL under wet conditions, interim limits are not required
      (B) Selenium allocations have not been developed for this reach as it is not on the 303(d) list
      (C) Attainment of interim limits will be evaluated in consideration of background loading data, if available
      (2) Pursuant to the TMDL, the interim storm water WLAs for copper, nickel, and selenium are receiving water concentrations measured in-stream at the base of Calleguas Creek and Revolon Slough and in Mugu Lagoon.

Table 14. Mass-based WLAs for copper, nickel and selenium

Annual Cumulative Flow (million gallons per year)	Calleguas Creek (lbs/yr)	Revolon Slough (lbs/yr)
0-15,000	3.3	1.7
15,000-25,000	10.5	4
Above 25,000	64.6	10.2

      (3) Pursuant to the TMDL, the interim storm water WLAs for mercury are suspended sediment loads measured in-stream at the base of Calleguas Creek and Revolon Slough and in Mugu Lagoon.
      (4) Determination of the applicable interim WLA will be determined by calculating the total annual flow (October 1-September 30) in the Calleguas Creek watershed as measured by the flow gage at CSUCI.

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(b) Compliance Monitoring:
   (1) Compliance with the WLAs is to be determined through the measurement of in-stream water quality and total suspended solids (TSS) at the base of Calleguas Creek, Revolon Slough and in Mugu Lagoon, in accordance with the Calleguas Creek Watershed TMDL Monitoring Program approved by the Executive Officer.
   (2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Calleguas MS4 permittees:
   (1) Conduct a source control study, develop and submit an Urban Water Quality Management Program (UWQMP) for copper, mercury, nickel, and selenium. Complete by March 26, 2009.
   (2) Implement the UWQMP within one year of approval by Executive Officer.
   (3) In cooperation with agricultural dischargers, evaluate the results of the OCs TMDL special study on sediment transport rates for applicability to the metals and selenium TMDL. Complete within 6 months of completion of the OCs TMDL special study #1.
   (4) In cooperation with agricultural dischargers, include monitoring for copper, mercury, nickel and selenium in the OC pesticides TMDL special study – Monitoring of Sediment by Source and Land Use Type. The special study is to be completed by March 26, 2014.
   (5) Evaluate the results of the OC Pesticides TMDL Special Study – Effects of BMPs on Sediment and Siltation, to determine the impacts on metals and selenium. Complete within 6 months of completion of the OC Pesticides special study #1.
   (6) Evaluate the effectiveness of BMPs implemented under the UWQMP in controlling metals and selenium discharges. This is to be completed by March 26, 2013.
   (7) Re-evaluate agricultural and urban waste load allocations for copper, mercury, nickel and selenium based on the evaluation of BMP effectiveness. By March 26, 2012, urban dischargers will have a required 25% reduction in the difference between the loadings at the time of the TMDL preparation and the final WLAs effective in 2022.
   (8) In cooperation with POTW permittees and agricultural dischargers, conduct a study to identify selenium contaminated groundwater sources. Special Study is to be completed within one year of the approval of the workplan.
   (9) In cooperation with agricultural dischargers, conduct a study to investigate metals “hot spots” and natural soils concentrations. This special study is to be completed within 2 years of the approval of the workplan.

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5. TMDL for Bacteria in Malibu Creek and Lagoon

(a) Waste Load Allocations:

(1) MS4 permittees discharging to Malibu Creek or its tributaries (Ventura County Watershed Protection District, County of Ventura and the cities of Thousand Oaks and Simi Valley) ("Malibu MS4 permittees") shall achieve the WLAs identified in Resolution 2004-19. . These WLAs are expressed as the number of daily or weekly sample days that may exceed the single sample limits or 30-day geometric mean bacteria targets in Resolution 2004-19.

Table 15 - Bacteria Targets

Parameters	Unit	Fresh Water Targets	
		Geometric Mean	Single Sample
E. coli	mg	126/ 100	235/ 100
Fecal coliform	mg	200/ 100	400/ 100

(2) The wasteload allocations are to be achieved no later than January 26, 2012.

(b) Compliance Monitoring:

(1) Achievement of the WLAs is to be determined through receiving water monitoring conducted in accordance with the Santa Monica Bacteria TMDL Compliance Monitoring Program approved by the Executive Officer.

(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Malibu MS4 permittees:

(1) If TMDL compliance monitoring indicates that the Malibu MS4 permittees are causing or contributing to an exceedance of the WLAs in the receiving waters, the permittees shall conduct a source identification study and implement additional controls sufficient to achieve the WLAs in the receiving waters.

6. TMDL for Trash in Revolon Slough and Beardsley Wash

(a) Wasteload Allocations

(1) MS4 permittees discharging to Revolon Slough and Beardsley Wash (Ventura County Watershed Protection District, County of Ventura and the cities of Camarillo and Oxnard) shall implement BMPs to achieve the WLAs of zero trash.

(b) Compliance Monitoring

(1) Responsible jurisdictions will develop a TMRP for Executive Officer approval that describes the methodologies that will be used to assess and monitor trash in Revolon Slough and Beardsley Wash and/or within

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responsible jurisdiction land areas. The TMRP shall include a plan to establish the trash Baseline WLAs.

(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Revolon Slough and Beardsley Wash MS4 permittees

(1) Per the adopted Basin Plan Amendment, compliance with the TMDL may be either through a progressive implementation schedule of full capture devices or implementation of other measures to attain the required trash reduction.

7. TMDL for Trash in the Ventura River Estuary

(a) Wasteload Allocations

(1) MS4 permittees discharging to the Ventura River Estuary (Ventura County Watershed Protection District, County of Ventura and the City of Ventura) shall implement BMPs to achieve the WLAs of zero trash.

(b) Compliance Monitoring

(1) Responsible jurisdictions will develop a TMRP for Executive Officer approval that describes the methodologies that will be used to assess and monitor trash in the Ventura River Estuary and/or within responsible jurisdiction land areas. The TMRP shall include a plan to establish the trash Baseline WLAs.

(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Revolon Slough and Beardsley Wash MS4 permittees

(1) Per the adopted Basin Plan Amendment, compliance with the TMDL may be either through a progressive implementation schedule of full capture devices or implementation of other measures to attain the required trash reduction.

8. TMDL for Bacteria in Harbor Beaches of Ventura County

(a) Waste Load Allocations

(1) MS4 permittees discharging to the Channel Islands Harbor Beaches (the County of Ventura, the Ventura County Watershed Protection District (VCWPD) and associated Municipal Separate Storm Sewer System (MS4) permittees in the Channel Islands Harbor subwatershed, and the City of

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Oxnard shall implement BMPs to achieve the interim WLAs listed in Table 15. All WLAs for summer dry-weather single sample bacteria densities at the Harbor Beaches of Ventura County are zero (0) days of allowable exceedances; winter dry weather and wet weather final WLAs are listed in Table 17 below.

The Basin Plan objectives that serve as the numeric targets for this TMDL are (single sample limits):
a. Total coliform density shall not exceed 10,000/100 ml.
b. Fecal coliform density shall not exceed 400/100 ml.
c. Enterococcus density shall not exceed 104/100 ml.
d. Total coliform density shall not exceed 1,000/100ml, if the ratio of fecal-to-total coliform exceeds 0.1.

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Table 16. Interim WLAs for Single Sample Exceedance Days

Location	Summer Dry Weather		Winter Dry Weather		Wet Weather	
	Daily Sampling	Weekly Sampling	Daily Sampling	Weekly Sampling	Daily Sampling	Weekly Sampling
Kiddie Beach	54	8	23	4	32	5
Hobie Beach	40	6	25	4	38	6

Table 17. Final Allowable Exceedance Days by Location

Location	Summer Dry-weather		Winter Dry-weather		Wet-weather	
	Daily Sampling	Weekly Sampling	Daily Sampling	Weekly Sampling	Daily Sampling	Weekly Sampling
Hobie Beach	0	0	3	1	17	3
Kiddie Beach	0	0	3	1	17	3

(2) Pursuant to the TMDL, the interim storm water WLAs for bacteria are from samples taken at existing monitoring sites in ankle to knee- high depths.

(b) Compliance Monitoring

(1) Compliance and monitoring for Harbor Beaches of Ventura County is based on existing monitoring protocols and locations. Monitoring shall continue at sampling locations (VCEHD 36000 and VCEHD37000) and at the current weekly monitoring frequency, consistent with AB411 compliance monitoring. Monitoring shall be conducted on a year-round basis at the current monitoring locations including the summer months (i.e., April to October) and winter months (i.e., November to March).

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Bacteria sampling shall be conducted in ankle- to knee-high water, consistent with AB411. However, if additional monitoring stations are added or if changes are made to the sampling frequencies or existing monitoring locations, then submittal of a monitoring plan is required for Executive Officer approval.

(2) If any WLA is exceeded at a compliance monitoring site, permittees shall implement BMPs in accordance with the TMDL Technical Reports, Implementation Plans or as identified as a result of TMDL special studies identified in the Basin Plan Amendment. Following these actions, Regional Water Board staff will evaluate the need for further enforcement action.

(c) Actions and Special Studies required of Harbor Beaches of Ventura County MS4 permittees

(1) Per the adopted Basin Plan Amendment, compliance with the TMDL may be either through structural and non-structural BMPs or implementation of other measures to attain the required source control.

(2) Special studies are not required for implementation of the TMDL though conducting special studies is within the discretion of the responsible parties.

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PART 7 - DEFINITIONS

The following are definitions for terms in this Order:

Adverse Impact - means a detrimental effect upon water quality or beneficial uses caused by a discharge or loading of a pollutant or pollutants.

Agriculture - means the science, art, and business of cultivating the soil, producing crops, and raising livestock.

Antidegradation Policies - means policies which protect surface and ground waters from degradation, and federal policies, which protect high quality surface waters. In particular, this policy protects waterbodies where existing quality is higher than that necessary for the protection of beneficial uses including the protection of fish and wildlife propagation and recreation on and in the water (*Statement of Policy with Respect to Maintaining High Quality Water in California*, State Board Resolution No. 68-16; 40 CRF 131.12).

Applicable Standards and Limitations - means all State, interstate, and Federal standards and limitations to which a "discharge" or a related activity is subject under the CWA, including effluent limitations, water quality standards, standards of performance, toxic effluent standards or prohibitions, best management practices, and pretreatment standards under § 301, § 302, § 303, § 304, § 306, § 307, § 308, § 403, and § 404 of CWA.

Areas of Special Biological Significance (ASBS) - means all those areas of this state listed as ASBS, listed specifically within the California Ocean Plan or so designated by the State Board which, among other areas, includes the area from Mugu Lagoon to Latigo Point: Oceanwater within a line originating from Laguna Point at 34° 5' 40" north, 119° 6'30" west, thence southeasterly following the mean high tideline to a point at Latigo Point defined by the intersection of the mean high tide line and a line extending due south of Benchmark 24; thence due south to a distance of 1000 feet offshore or to the 100 foot isobath, whichever distance is greater; thence northwesterly following the 100 foot isobath or maintaining a 1,000-foot distance from shore, whichever maintains the greater distance from shore, to a point lying due south of Laguna Point, thence due north to Laguna Point.

Authorized Discharge - means any discharge that is authorized pursuant to an NPDES permit, waste discharge requirement, conditional waiver from waste discharge requirements, or meets the conditions set forth in this Order.

Automotive Repair Shop - means a facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

Automotive Service Facilities - means a facility that is categorized in any one of the following Standard Industrial Classification (SIC) and North American Industry Classification System (NAICS) codes. For inspection purposes, Permittees need not inspect facilities with SIC codes 5013, 5014, 5541, 5511, provided that these facilities have no outside activities or materials that may be exposed to storm water.

SIC Code	Corresponding NAICS Code
5013	425120, 441310, 425110, & 423120
5014	425120, 425110, 423130, & 441320
5511	441110
5541	447110, & 447190
7532	811121
7533	811112
7534	326212, & 811198
7536	811122
7537	811113
7538	811111
7539	811198, & 811118

Bacteria Total Maximum Daily Load (TMDL) Dry Weather - defined in the Bacteria TMDLs as those days with less than 0.1 inch of rainfall and those days occurring more than 3 days after a rain.

Bacteria Total Maximum Daily Load (TMDL) Wet Weather - defined in the Bacteria TMDLs as a day with 0.1 inch or more of rain and 3 days following the rain event.

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Basin Plan - means the Water Quality Control Plan, Los Angeles Region, Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties, adopted by the Regional Water Board on June 13, 1994 and subsequent amendments.

Beneficial Uses - means the existing or potential uses of receiving waters in the permit area as designated by the Regional Water Board in the Basin Plan.

Best Management Practices (BMPs) - means methods, measures, or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and nonpoint source discharges including storm water. BMPs include structural and nonstructural controls, and operation and maintenance procedures, which can be applied before, during, and/or after pollution producing activities.

California Environmental Quality Act (CEQA) - means a California statute that requires state and local agencies to identify significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible (Reference: California Public Resources Code § 21000 et seq.)

Channel - means an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two waterbodies.

Chronic Toxicity - means a measurement of a sublethal effect (e.g., reduced growth, reproduction) to experimental test organisms exposed to an effluent or ambient waters compared to that of the control organisms.

Commercial Area(s) - means any geographic area of the Permittees' jurisdiction that is not heavy industrial or residential. A commercial area includes, but is not limited to areas surrounding: commercial activity, hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

Commercial Development - means any development on private land that is not heavy industrial or residential. The category includes, but is not limited to: hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

Construction - Construction activity includes any construction or demolition activity, clearing, grading, grubbing, or excavation or any other activity that results in a land disturbance. Construction does not include emergency construction activities required to immediately protect public health and safety or routine maintenance activities required to maintain the integrity of structures by performing minor repair and restoration work, maintain original line and grade,

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hydraulic capacity, or original purpose of the facility. See "Routine Maintenance" definition for further explanation. Where clearing, grading or excavating of underlying soil takes place during a repaving operation, State General Construction Permit coverage is required if more than one acre is disturbed or the activities are part of a larger plan.

Construction Activities Storm Water General Permit (CASGP) - means the general NPDES permit adopted by the State Board, which authorizes the discharge of storm water from construction activities under certain conditions.

Control - means to minimize, reduce, eliminate, or prohibit by technological, legal, contractual or other means, the discharge of pollutants from an activity or activities.

Critical Sources - means commercial facilities and businesses that have a potential to contribute pollutants to stormwater runoff if effective BMPs are not implemented. Attachment "D" specifies the commercial facilities and businesses that have been identified as Critical Sources.

Dechlorinated/ Debrominated Swimming Pool Discharge - means any swimming pool discharge with a residual chlorine or bromine level of 0.1mg/L or less; and does not contain any detergents, wastes, algaecides, or cyanuric acid in excess of 50 ppm, or any other chemicals including salts from pools commonly referred to as "salt water pools". The term does not include swimming pool filter backwash or swimming pool water containing bacteria.

Development - means any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and any other non-residential projects, including public agency projects; or mass grading for future construction.

Directly Adjacent - means situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of the environmentally sensitive area.

Directly Discharging - means outflow from a drainage conveyance system that is composed entirely or predominately of flows from the subject, property, development, subdivision, or industrial facility and not commingled with the flows from adjacent lands.

Discharge - means when used without qualification the "discharge of a pollutant."

Discharging Directly - means outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge of a Pollutant - means any addition of any "pollutant" or combination of pollutants to "waters of the United States" from any "point source" or, any addition of any pollutant or

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combination of pollutants to the waters of the "contiguous zone" or the ocean from any point source other than a vessel or other floating craft, which is being used as a means of transportation. The term discharge includes additions of pollutants into waters of the United States from: surface runoff which is collected or channeled by man; discharges through pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works.

Disturbed Area - means any area that is altered as a result of land disturbance. Examples include but are not limited to: clearing, grading, grubbing, stockpiling and/ or excavation, etc...

Dry Day - means a non-wet day for Malibu Creek and Lagoon Bacteria TMDL WLA. A wet day is defined as a day with a 0.1 inch or more of rain and 3 days following the rain event is a non-wet day for Bacteria TMDL WLA.

Effect Concentration (EC) is a point estimate of the toxicant concentration that would cause an observable adverse effect (e.g., death, immobilization, or serious incapacitation) in a given percent of the test organisms, calculated from a continuous model (e.g., Probit Model). EC_{25} is a point estimate of the toxicant concentration that would cause an observable adverse effect in 25 percent of the test organisms.

Effective Impervious Surface - means that portion of the surface area that is hydrologically connected via sheet flow over a hardened conveyance or impervious surface without any intervening medium to mitigate flow volume.

Effluent limitation - means any restriction imposed by the Permitting Authority (PA) on quantities, discharge rates, concentrations, and/ or mass loadings of "pollutants" which are "discharged" from "point sources" into "waters of the United States," the waters of the "contiguous zone," or the ocean.

Emergency - means a sudden, unexpected occurrence, involving a clear and imminent danger, demanding immediate action to prevent or mitigate loss of, or damage to, life, health, property, or essential public services. "Emergency" includes such occurrences as fire, flood, earthquake, or other soil or geologic movements, as well as such occurrences as riot, accident, or sabotage. (Reference: California Public Resources Code § 21060.3. Emergency).

End-of-Pipe - means the end of the major outfall as defined in 40 CFR122.26 (b)(5) and 40 CFR122.26 (b)(6).

Endpoint - means a biological measurement used to quantify the results obtained from analytical methods such as whole effluent toxicity testing [e.g., lethal concentration (LC_{50}); inhibition concentration (IC_{25}); and no observed effect concentration (NOEC)]. Such endpoints are quantitative measurements of the responses of test organisms (e.g., survival, growth, mobility,

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reproduction, and weight gain or loss) in response to exposure to a serial dilution of effluent.

Environment - means the physical conditions, which exist within the area and which will be affected by a proposed project including land, air, water, minerals, flora, fauna, ambient noise, and objects of historical or aesthetic significance. The area involved shall be the area in which significant effects would occur either directly or indirectly as a result of the project. The "environment" includes both natural and man-made conditions.

Environmentally Sensitive Area (ESA) - means an area "in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments" (Reference: California Public Resources Code § 30107.5). ESAs will include Clean Water Act 303d Listed Water Bodies in all reaches that are unimproved, all California Coastal Commission's Environmentally Sensitive Habitat Areas as delineated on maps in Local Coastal Plans and Regional Water Quality Control Board's Basin Plan Rare, Threatened or Endangered Species (RARE) and Preservation of Biological Habitats (BIOL) designated waterbodies. The California Department of Fish and Game's Significant Natural Areas map will be considered for inclusion as the department field verifies the designated locations. Watershed restoration projects will be considered for inclusion as the department field verifies the designated locations.

Erosivity Factor - The Erosivity Factor is a criterion that to assess the risk of erosion on disturbed land. It is described in "Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE), Agricultural Handbook 703, USDA-ARS, U.S. Government Printing Office, Washington, D.C., 1997 by Renard, K.C., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder.

Federal Clean Water Act (CWA) - means (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Public Law 92—500, as amended by Public Law 95—217, Public Law 95—576, Public Law 96—483 and Public Law 77—117, codified at 33 U.S.C. 1251 et seq.

First Storm Event - means the first storm event of the wet season that produces at least 0.25 inches of rain.

Forest Land - means land at least 10 percent stocked with live trees, or land that had this minimum tree stocking in the past and is not currently developed for nonforest use. The minimum area recognized is 1 acre.

Groundwater Dewatering - means the active practice of removing standing water from soil excavations using a pump(s) or other means.

Hillside - means property located in an area with known erosive soil conditions, where the

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development will result in grading on any slope that is 20% or greater or an area designated by the Municipality under a General Plan or ordinance as a "hillside area".

Horse Stables - means a property where at least one horse is stabled at least part of the year.

Hydromodification - means the alteration away from a natural state of stream flows or the beds or banks of rivers, streams, or creeks, including ephemeral washes, which results in hydrogeomorphic changes.

Illegal Discharge - means any discharge to the municipal separate storm sewer (storm drain system) that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illegal discharge includes all non-storm water discharges not composed entirely of storm water except discharges pursuant to an NPDES permit, discharges that are identified in part 1, "Discharge Prohibitions" of this order, or discharges authorized by the Regional Water Board Executive Officer.

Illicit Connection - means any engineered conveyance that is connected to the storm drain system without a permit or municipal authorization. It also means any engineered conveyance through which discharges of pollutants to the separate storm drainage systems, which are not composed entirely of storm water or are not authorized by an NPDES permit, may occur.

Illicit Discharge - means any discharge to a municipal separate storm sewer (storm drain system) that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all non-storm water discharges not composed entirely of storm water except discharges pursuant to a NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges that are identified in part 1, "Discharge Prohibitions" of this order, or authorized by the Regional Water Board Executive Officer.

Illicit Disposal - means any disposal, either intentionally or unintentionally, of material(s) or waste(s) that can pollute storm water.

Industrial/ Commercial Facility - means any facility involved and/ or used in the production, manufacture, storage, transportation, distribution, exchange or sale of goods and/ or commodities, and any facility involved and/ or used in providing professional and non-professional services. This category of facilities includes, but is not limited to, any facility defined by either the Standard Industrial Classifications (SIC) or the North American Industry Classification System (NAICS). Facility ownership (federal, state, municipal, private) and profit motive of the facility are not factors in this definition.

Industrial Activities Storm Water General Permit (IASGP) - means the general NPDES permit adopted by the State Board, which authorizes the discharge of storm water from certain industrial activities under certain conditions.

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Industrial Park - means a land development that is set aside for industrial development. Industrial parks are usually located close to transport facilities, especially where more than one transport modalities coincide: highways, railroads, airports, and navigable rivers. It includes office parks, which have offices and light industry.

Inhibition Concentration (IC) - means a point estimate of the toxicant concentration that would cause a given percent reduction in a non-lethal biological measurement (e.g., reproduction or growth), calculated from a continuous model (i.e., Interpolation Method). IC25 is a point estimate of the toxic concentration that would cause a 25-percent reduction in a non-lethal biological measurement.

Inspection - means entry and the conduct of an on-site review of a facility and its operations, at reasonable times, to determine compliance with specific municipal or other legal requirements. The steps involved in performing an inspection, include, but are not limited to:

1. Pre-inspection documentation research
2. Request for entry
3. Interview of facility personnel
4. Facility walk-through
5. Visual observation of the condition of facility premises
6. Examination and copying of records as required
7. Sample collection (if necessary or required)
8. Exit conference (to discuss preliminary evaluation)
9. Report preparation, and if appropriate, recommendations for coming into compliance

Integrated Pest Management (IPM) - means a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks.

Large Municipal Separate Storm Sewer System (MS4) - means all MS4s that serve a population greater than 250,000 (1990 Census) as defined in 40 CFR122.26 (b)(4). The Regional Water Board designated Ventura County as a large MS4 in 1990, based on: (i) the U.S. Census Bureau 1990 population count of 669,016 thousand, and (ii) the interconnectivity of the MS4s in the incorporated and unincorporated areas within the County.

Local SWPPP - means the Local Storm Water Pollution Prevention Plan (LSWPPP) required by the local agency for a project that disturbs one or more acres of land. Shall mean a plan identifying potential pollutant sources from a construction site and describing proposed design, placement and implementation of BMPs, to effectively prevent non-storm water discharges and reduce pollutants in storm water discharges to the storm drain system, during construction activities. Also referred as a Storm Water Pollution Control Plan (SWPCP).

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Low Impact Development (LID) – means a design strategy with the goal of maintaining or replicating the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic site design. Hydrologic functions of storage, infiltration and ground water recharge, as well as the volume and frequency of discharges are maintained through the use of integrated and distributed micro-scale storm water retention and detention areas, reduction of impervious surfaces, and the lengthening of runoff flow paths and flow time. Other strategies include the preservation/protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands, and highly permeable soils.

Major Municipal Separate Storm Sewer Outfall ("or major outfall") - means a major municipal separate storm sewer outfall that discharges from a single pipe with an inside diameter of 36 inches or more or its equivalent (discharge from a single conveyance other than circular pipe which is associated with a drainage area of more than 50 acres); or for municipal separate storm sewers that receive storm water from lands zoned for industrial activity (based on comprehensive zoning plans or the equivalent), an outfall that discharges from a single pipe with an inside diameter of 12 inches or more or from its equivalent (discharge from other than a circular pipe associated with a drainage area of 2 acres or more), as defined in 40 CFR122.26 (b)(5).

Major Outfall - means a major municipal separate storm sewer outfall, as defined in 40 CFR122.26 (b)(6).

Maximum Extent Practicable (MEP) – The technology-based permit requirement established by Congress in CWA section 402(p)(3)(B)(iii) that municipal dischargers of storm water must meet. Technology-based requirements, including MEP, establish a level of pollutant control that is derived from available technology or other controls. MEP requires municipal dischargers to perform at maximum level that is practicable. Compliance with MEP may be achieved by emphasizing pollution prevention and source control BMPs in combination with structural and treatment methods where appropriate. The MEP approach is an ever evolving and advancing concept, which considers technical and economic feasibility.

Method Detection Limit (MDL) - means the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, as defined in 40 CFR136, Appendix "G" of this Order.

Minimum Level (ML) - means the concentration at which the entire analytical system must give a recognizable signal and acceptable calibration point. The ML is the concentration in a sample that is equivalent to the concentration of the lowest calibration standard analyzed by a specific analytical procedure, assuming that all the method specified sample weights, volumes, and processing steps have been followed. The ML value represents the lowest quantifiable concentration in a sample based on the proper application of all method-based analytical procedures and the absence of any matrix interferences. Assuming that all method-specific

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analytical steps are followed, the ML value will also represent, after the appropriate application of method-specific factors, the lowest standard in the calibration curve for that specific analytical technique.

Minimum Significant Difference (MSD) - means a measure of test sensitivity that establishes the minimum difference required between a control and a test treatment in order for that difference to be considered statistically significant.

Municipal Action Levels (MALs) – means an action level that is derived from a statistical analysis of relevant data that is utilized to identify areas and subwatersheds that require additional or improved BMPs to reduce the discharge of pollutants to the maximum extent practicable. MALs may be revised as additional data are obtained so that MALs can continue to be used to effectively prioritize BMP implementation as the storm water program progresses. MALs are one measure of the effectiveness of the storm water program. MALs are not effluent limitations as defined by this Order, and/or as defined by Water code section 13385.1(c).

Municipal Separate Storm Sewer System (MS4) - means a conveyance or system of conveyances (including roads w/ drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains), as defined in 40 CFR122.26(b)(8):

1. Owned or operated by a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under § 208 of the Federal Clean Water Act (CWA) that discharges into waters of the United States
2. Designed or used for collecting or conveying storm water
3. Which is not a combined sewer
4. Which is not part of a Publicly Owned Treatment Works (POTW), as defined in 40 CFR122.2

NAICS - means North American Industry Classification System.

National Pollutant Discharge Elimination System (NPDES) - means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under CWA § 307, 402, 318, and 405.

Natural Drainage Systems - means unlined or unimproved (not engineered) creeks, streams, rivers or similar waterways.

New Development - means land disturbing activities; structural development, including construction or installation of a building or structure, creation and replacement of impervious surfaces; and land subdivision.

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Non-Storm Water Discharge - means any discharge to a storm drain that is not composed entirely of storm water.

No Observed Effect Concentration (NOEC) - means the highest tested concentration of an effluent or toxicant that causes no observable adverse effect on the test organisms (i.e., the highest concentration of toxicant at which the values for the observed responses are not statistically different from the controls).

Nuisance - means anything that meets all of the following requirements: (1) is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property; (2) affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted upon individuals may be unequal.; (3) occurs during, or as a result of, the treatment or disposal of wastes.

Nursery - means NAICS classification to describe nursery operations and determine the type of operations covered under this Order and those covered under the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (Conditional Waiver).

1. There are 3 broad NAICS sectors available to classify nurseries:
   (1) 111xxx - Crop Production - Agriculture
   (a) 424xxx - Merchant Wholesalers, Nondurable Goods
   (b) 44xxxx - Retail Trade
      (1) **Nursery (Agricultural Facilities - Crop Production) -** means Nursery and Floriculture Production under NAICS Code 11142x. These operations are subject to the **Conditional Waiver**. This industry comprises establishments primarily engaged in (1) growing nursery and floriculture products (e.g., nursery stock, shrubbery, cut flowers, flower seeds, foliage plants, sod) under cover or in open fields and/ or (2) growing short rotation woody trees with a growing and harvesting cycle of 10 years or less for pulp or tree stock (e.g., cut Christmas trees, cottonwoods).
      (2) **Nursery (Commercial Facilities - Merchant Wholesalers, Nondurable Goods, and Retail Trade) -** means industries Flower, Nursery Stock, and Florists' Supplies Merchant Wholesalers under NAICS Code 424930; and Nursery, Garden Center, and Farm Supply Stores under NAICS Code 444220. This Order covers these types of operations. The industry in NAICS Code 424930 comprises establishments primarily engaged in the merchant wholesale distribution of flowers, florists' supplies, and/ or nursery stock (except plant seeds and plant bulbs). The industry in NAICS Code 444220 comprises establishments primarily engaged in retailing nursery and garden products, such as trees, shrubs, plants, seeds, bulbs, floriculture products and sod, which are predominantly grown elsewhere. These establishments may sell a limited amount of a product they grow themselves.

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Open Channel - means a storm drainage channel that is not a natural water course.

Parking Lot - means land area or facility for the parking or storage of motor vehicles used for businesses, commerce, industry, or personal use.

Percent Minimum Significant Difference (PMSD) - means the minimum significant difference divided by the control mean, expressed as a percent (see minimum significant difference).

Permit - means an authorization, license, or equivalent control document issued by U.S. EPA or an "approved State" to implement the requirements of 40 CFR Parts 122, 123, and 124. "Permit" includes an NPDES "general permit" (§ 122.28). Permit does not include any permit, which has not yet been the subject of final agency action, such as a "draft permit" or a "proposed permit."

Permittee(s) - means co-permittee(s) and any agency named in this Order as being responsible for permit conditions within its jurisdiction, as defined by Federal Regulation. Permittees to this Order include the Ventura Water Protection District, Ventura County, and the cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley and Thousand Oaks.

Point Source - means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Point Zero - means in the context of the TMDLs, the point at which water from the storm drain or creek initially mixes with water. Point zero has been selected as the compliance point for the TMDL numeric target because access to these drains is, on the whole, not restricted.

Pollutants - means those "pollutants" defined in CWA § 502(6) (33.U.S.C.§ 1362(6)), and incorporated by reference into California Water Code § 13373.

Pollutants of Concern - means constituents that have exceeded Basin Plan Objectives, and CTR- Chronic or Acute Objectives during monitoring at Mass Emission, Receiving Water, and Land Use stations.

Potable Water Sources - means the potable water system for the treatment, distribution, and provision of water for residential, commercial, industrial, or institutional use that meets all California safe drinking water regulatory standards for human consumption.

Pre-Developed Condition - means native vegetation and soils that existed at a site prior to first development. The pre-developed condition may be assumed to be an area with the typical

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vegetation, soil, and storm water runoff characteristics of open space areas in coastal Southern California unless reasonable historic information is provided that the area was atypical.

Priority Pollutants - means those constituents referred to in 40 CFR401.15 and listed in the U.S. EPA NPDES Application Form 2C, pp. V-3 through V-9.

Project - means all development, redevelopment, and land disturbing activities. The term is not limited to "Project" as defined under CEQA (Reference: California Public Resources Code § 21065).

Qualified SWPPP Developer or Qualified SWPPP Practitioner – refer to State of California General Construction Stormwater Permit for definition.

Rare, Threatened, or Endangered Species (RARE) - means a beneficial use for waterbodies in the Los Angeles Region, as designated in the Basin Plan (Table 2-1), that supports habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.

Redevelopment - means land-disturbing activity that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site. Redevelopment includes, but is not limited to: the expansion of a building footprint; addition or replacement of a structure; replacement of impervious surface area that is not part of a routine maintenance activity; and land disturbing activities related to structural or impervious surfaces. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

Regional Administrator - means the Regional Administrator of the Regional Office of the U.S. EPA or the authorized representative of the Regional Administrator.

Report of Waste Discharge (ROWD) - means an application for renewal of the NPDES Permit for Waste Discharge Requirements for Municipal Separate Storm Sewer Discharges Within the Ventura County Watershed Protection District, County of Ventura and the Incorporated Cities Therein.

Restaurant - means a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC Code 5812).

Restoration - means the reestablishment of predisturbance aquatic functions and related physical, chemical and biological characteristics (Reference: National Research Council. 1992. Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. National Academy Press, Washington, D.C.).

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Retail Gasoline Outlet (RGO) - means any facility engaged in selling gasoline and lubricating oils- SIC 5541 and NAICS 447110 & 447190.

1. RGOs: 447190 Other Gasoline Stations:
   This industry comprises establishments known as gasoline stations (except those with convenience stores) primarily engaged in one of the following: (1) retailing automotive fuels (e.g., diesel fuel, gasohol, gasoline) or (2) retailing these fuels in combination with activities, such as providing repair services; selling automotive oils, replacement parts, and accessories; and/ or providing food services.
2. RGOs: 447110 Gasoline Stations with Convenience Stores:
   Retailing automotive fuels in combination with a convenience store or food mart.

Routine Maintenance –Routine maintenance projects include, but are not limited to projects conducted to:

1. Maintain the original line and grade, hydraulic capacity, or original purpose of the facility.
2. Perform as needed restoration work to preserve the original design grade, integrity and hydraulic capacity of flood control facilities.
3. Includes road shoulder work, regrading dirt or gravel roadways and shoulders and performing ditch cleanouts.
4. Update existing lines* and facilities to comply with applicable codes, standards, and regulations regardless if such projects result in increased capacity.
5. Repair leaks

Routine maintenance does not include construction of new** lines or facilities resulting from compliance with applicable codes, standards and regulations.

* Update existing lines includes replacing existing lines with new materials or pipes.

** New lines are those that are not associated with existing facilities and are not part of a project to update or replace existing lines.

Screening - means using proactive methods to identify illicit connections through a continuously narrowing process. The methods may include: performing baseline monitoring of open channels, conducting special investigations using a prioritization approach, analyzing maintenance records for catch basin and storm drain cleaning and operation, and verifying all permitted connections into the storm drains. Special investigation techniques may include: dye testing, visual inspection, smoke testing, flow monitoring, infrared, aerial and thermal photography, and remote control camera operation.

Sidewalk Rinsing - means only sidewalk rinsing using high pressure and low volume of water with no additives and at an average usage of 0.006 gallons per square foot of surface area to be rinsed. Any waste generated from the activity must be collected and properly and legally disposed of. It does not mean hosing of any sidewalk or street with a garden hose with a pressure nozzle.

Site - means the land or water area where any "facility or activity" is physically located or conducted, including adjacent land used in connection with the facility or activity.

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Small Construction - means any soil disturbing activities less than 5 acres.

Source Control BMP - means any schedules of activities, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent storm water pollution by reducing the potential for contamination at the source of pollution.

Southern California Stormwater Monitoring Coalition (SMC) - means the Stormwater Monitoring Coalition, which is a collaborative research/ monitoring partnership of the Southern California Water Boards, Municipal Storm Water Agencies, and municipalities to develop the methodologies and assessment tools to more effectively understand urban storm water and non-storm water (anthropogenic) impacts to receiving waters and to conduct research/ monitoring through Subsequent Research Implementation Agreements. The first original cooperative agreement was entered into on February 8, 2001.

Stream - means a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal (Reference: US Geological Survey).

Strip Mall - means a commercial development that is a shopping center where the stores are arranged in a row, with a sidewalk in front. Strip malls are typically developed as a unit and have large parking lots in front. They face major traffic arterials and tend to be self-contained with few pedestrian connections to surrounding neighborhoods. It is also called a plaza.

Storm Event Monitoring- means a rainfall event that produces more than 0.25 inch of precipitation and is separated from the previous storm event by at least 1 week of dry weather, for the purpose of monitoring.

Storm Water - means storm water runoff, snow melt runoff, and surface runoff and drainage, as defined in 40 CFR122.26(b)(13).

Storm Water Discharge Associated with Industrial Activity - means industrial discharge, as defined in 40 CFR122.26(b)(14).

Storm Water Quality Management Program - means the Ventura Countywide Storm Water Quality Management Plan, which includes descriptions of programs, collectively developed by the Permittees in accordance with provisions of the NPDES Permit, to comply with applicable federal and state law, as the same is amended from time to time.

Structural BMP - means any structural facility designed and constructed to mitigate the adverse impacts of storm water runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

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Summer Dry Weather - means dry weather days occurring from April 1 through October 31 of each year.

t-Test (formally Student's t-test) - means a statistical analysis comparing two sets of replicate observations, in the case of WET, only two test concentrations (e.g., a control and 100% effluent). The purpose of this test is to determine if the means of the two sets of observations are different [e.g., if the 100% effluent concentration differs from the control (i.e., the test pass or fails)].

Targeted Employees - means management and staff who perform or direct activities that directly or indirectly have an effect of storm water quality. The employees generally are employed in the following areas: department of public works, engineering, sanitation, storm water maintenance, drainage and flood control, transportation, streets and roads, parks and recreation, public landscaping and corporation yards, planning or community development, code enforcement, building and safety, harbor or port departments, airports, or general services and fleet services.

Total Maximum Daily Load (TMDL) - means the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background.

Toxicity Identification Evaluation (TIE) - means a set of procedures to identify the specific chemical(s) responsible for toxicity through a process of chemical/ physical manipulations of samples followed by toxicity tests. These procedures are performed in 3 phases (Phase I- Toxicity Characterization Procedure, Phase II- Toxicity Identification Procedure, and Phase III- Toxicity Confirmation Procedure) using aquatic organism toxicity tests.

Toxicity Reduction Evaluation (TRE) - means a study conducted in a step-wise process to identify the causative agents of effluent or ambient toxicity, isolate the sources of toxicity, evaluate the effectiveness of toxicity control options, and then confirm the reduction in toxicity.

Toxicity Test - means a procedure using living organisms to determine whether a chemical or an effluent is toxic. A toxicity test measures the degree of the effect of a specific chemical or effluent on exposed test organisms.

Toxic Unit (TU) - means a measure of toxicity in an effluent as determined by the acute toxicity units (TUa) or chronic toxicity units (TUc) measured. The larger the TU, the greater the toxicity.

Toxic Unit - Chronic (TUc) - means 100 times the reciprocal of the effluent concentration that causes no observable effect on the test organisms in a chronic toxicity test (TUc = 100/NOEC or 100/EC25*)* (see NOEC).

Treatment - means the application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to,

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filtration, gravity settling, media absorption, biodegradation, biological uptake, chemical oxidation and UV radiation.

Treatment Control BMP - means any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media absorption or any other physical, biological, or chemical process.

Urbanization - means the process of changing of land use and land patterns from rural characteristics to urban (city-like) characteristics. These changes include (i) the replacement of pervious surfaces with impervious surfaces such as rooftops and buildings, and impervious materials such as asphalt and concrete; and (ii) the conversion of rural land to house new residents, support new businesses, and facilitate vehicular traffic flow.

U.S. EPA Phase I Facilities - means facilities in specified industrial categories that are required to obtain an NPDES permit for storm water discharges, as required by 40 CFR122.26(c). These categories include:

1. Facilities subject to storm water effluent limitation guidelines, new source performance standards, or toxic pollutant effluent standards (40 CFR N)
2. Manufacturing facilities
3. Oil and gas/ mining facilities
4. Hazardous waste treatment, storage, or disposal facilities
5. Landfills, land application sites, and open dumps
6. Recycling facilities
7. Steam electric power generating facilities
8. Transportation facilities
9. Sewage of wastewater treatment works
10. Light manufacturing facilities

Vehicle Maintenance/ Material Storage Facilities/ Corporation Yards - means any Permittee owned or operated facility or portion thereof that:

1. Conducts industrial activity, operates or stores equipment or materials, and provides services similar to Federal Phase I facilities;
2. Performs fleet vehicle service/ maintenance including repair, maintenance, washing, or fueling;
3. Performs maintenance and/ or repair of machinery/ equipment; or
4. Stores chemicals, raw materials, or waste materials.

Waste Load Allocations (WLAs) - means a portion of a receiving water's Total Maximum Daily Pollutant Load (TMDL) that is allocated to one of its existing or future point sources of pollution (Reference: 40 CFR130.2(h)).

Water Quality Objectives - means water quality criteria contained in the Basin Plan, the California Ocean Plan, the National Toxics Rule, the California Toxics Rule, and other state or

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federally approved surface water quality plans. Such plans are used by the Regional Water Board to regulate all discharges, including storm water discharges.

Water Quality Standards - means the State Water Quality Standards, which are comprised of beneficial uses, water quality objectives and the State's Antidegradation Policy.

Waters of the State - means any surface water or groundwater, including saline waters, within boundaries of the state (Reference: California Water Code § 13050).

Waters of the United States or Waters of the US - means:

1. All waters that are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;
2. All interstate waters, including interstate "wetlands";
3. All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, "wetlands," sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds where the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters:
   a. Which are or could be used by interstate or foreign travelers for recreational or other purposes
   b. From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or
   c. Which are used or could be used for industrial purposes by industries in interstate commerce
4. All impoundment's of waters otherwise defined as waters of the United States under this definition;
5. Tributaries of waters identified in the preceding paragraph (1) through (4) of this definition;
6. The territorial sea; and
7. "Wetlands" adjacent to waters (other than waters that are themselves wetlands) identified in the preceding paragraph (1) through (6) of this definition. (Reference: 33 CFR328)

Watercourse - means any natural or artificial channel for passage of water, including the VCFCD jurisdictional channels included in the List of Channels within the Comprehensive Plan of the VCFCD, as approved by the Board of Supervisors of the VCFCD on October 4, 1993, and any amendments thereto.

Watershed Management - means approach for water resources protection. It is a strategy for integrating and managing resources, both human and fiscal that focuses on regulation of point sources, to a more regional approach that acknowledges environmental impacts from other activities.

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Watershed Management Areas (WMA) - means the geographically-defined watershed areas where the Regional Water Board will implement the watershed approach. These generally involve a single large watershed within which exists smaller subwatersheds but in some cases may be an area that does not meet the strict hydrologic definition of a watershed e.g., several small Ventura coastal waterbodies in the region are grouped together into one WMA.

Wet Season - means the calendar period beginning October 1 through April 15.

Winter Dry Weather - means dry weather days occurring from November 1 - March 31 of each year.

Whole Effluent Toxicity - means the aggregate toxic effect of an effluent measured directly by a toxicity test.

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PART 8 - STANDARD PROVISIONS

A. General Requirements

1. The Permittee shall comply with all provisions and requirements of this Order.

2. Should the Permittee discover that it failed to submit any relevant facts or that it submitted incorrect information in a report it shall promptly submit the missing or correct information.

3. The Permittee shall report all instances of non-compliance not otherwise reported at the time monitoring reports are submitted.

4. This Order includes Attachment "H", the Reporting Program, which is a part of this Order and must be complied with.

B. Regional Water Board Review

1. The Regional Water Board may review any formal determinate or approval made by the Regional Water Board Executive Officer pursuant to the provisions of this Order.
   (a) Permittee(s) or a member of the public may request such review upon petition within 30 day of the effective date of the notification of such decision to the Permittee(s) and interested parties on file at the Regional Water Board.

C. Public Review

1. All documents submitted to the Regional Water Board in compliance with the terms and conditions of this Order shall be made available to members of the public

pursuant to the Freedom of Information Act (5 U.S.C. § 552), as amended, and the Public Records Act (California Government Code § 6250 et seq.).

2. All documents submitted to the Regional Water Board Executive Officer for approval shall be made available to the public for a 30-day period to allow for public comment.

D. Duty to Comply [40 CFR122.41(a)]

1. Each Permittee must comply with all of the terms, requirements, and conditions of this Order. Any violation of this order constitutes a violation of the Clean Water Act, its regulations and the California Water Code, and is grounds for enforcement action, Order termination, Order revocation and reissuance, denial of an application for reissuance, or a combination thereof [40 CFR122.41(a), CAL. WATER CODE § 13261, 13263, 13265, 13268, 13300, 13301, 13304, 13340, 13350].
2. A copy of these waste discharge specifications shall be maintained by each Permittee so as to be available during normal business hours to Permittee employees and members of the public.

3. Any discharge of wastes at any point(s) other than specifically described in this Order is prohibited, and constitutes a violation of the Order.

E. Duty to Mitigate [40 CFR122.41 (d)]

1. Each Permittee shall take all reasonable steps to minimize or prevent any discharge that has a reasonable likelihood of adversely affecting human health or the environment.

F. Inspection and Entry; Investigations; Responsibilities [40 CFR122.41(i), Cal. Water Code § 13225 and § 13267]

1. The Regional Water Board, U.S. EPA, and other authorized representatives shall be allowed:
   (a) Entry upon premises where a regulated facility is located or conducted, or where records are kept under conditions of this Order;
   (b) Access to copy any records, at reasonable times that are kept under the conditions of this Order;
   (c) To inspect at reasonable times any facility, equipment (including monitoring and control equipment), practices, or operations regulated or required under this Order;
   (d) To photograph, sample, and monitor at reasonable times for the purpose of assuring compliance with this Order, or as otherwise authorized by the CWA and the CAL. WATER CODE;

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(e) To review any water quality control plan or waste discharge requirements, or in connection with any action relating to any plan or requirement to investigate the quality of any waters of the state within its region; and,
(f) To require as necessary any state or local agency to investigate and report on any technical factors involved in water quality control or to obtain and submit analyses of water.

G. Proper Operation and Maintenance [40 CFR122.41 (e), Cal. Water Code § 13263(f)]

1. The Permittees shall at all times properly operate and maintain all facilities and systems of treatment (and related appurtenances) that are installed or used by the Permittees to achieve compliance with this Order. Proper operation and maintenance includes:
   (a) adequate laboratory controls; and
   (b) appropriate quality assurance procedures.
2. This provision requires the operation of backup or auxiliary facilities or similar system that are installed by a Permittee only when necessary to achieve compliance with the conditions of this Order.

H. Signatory Requirements [40 CFR122.41(k) & 122.22]

1. Except as otherwise provided in this Order, all applications, reports, or information submitted to the Regional Water Board shall be signed by the City Manager or Mayor, or authorized designee and certified as set forth in 40 CFR122.22.

I. Reopener and Modification [40 CFR122.41(f) & 122.62]

1. This Order may only be modified, revoked, or reissued, prior to the expiration date, by the Regional Water Board, in accordance with the procedural requirements of the CAL. WATER CODE and CCR Title 23 for the issuance of waste discharge requirements, 40 CFR122.62, and upon prior notice and hearing, to:
   (a) Address changed conditions identified in the required reports or other sources deemed significant by the Regional Water Board;
   (b) Incorporate applicable requirements or statewide water quality control plans adopted by the State Board or amendments to the Basin Plan, including TMDLs;
   (c) Comply with any applicable requirements, guidelines, and/ or regulations issued or approved pursuant to CWA § 402(p); and/ or,
   (d) Consider any other federal, or state laws or regulations that became effective after adoption of this Order.

2. After notice and opportunity for a hearing, this Order may be terminated or modified for cause, including, but not limited to:
   (a) Violation of any term or condition contained in this Order;

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(b) Obtaining this Order by misrepresentation, or failure to disclose all relevant facts; or,
(c) A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge.

3. The filing of a request by the Principal Permittee or Permittees for a modification, revocation and re-issuance, or termination, or a notification of planned changes or anticipated noncompliance does not stay any condition of this Order.

4. This Order may be modified to make corrections or allowances for changes in the permitted activity listed in this section, following the procedures at 40 CFR122.63, if processed as a minor modification. Minor modifications may only:
(a) Correct typographical errors; or
(b) Require more frequent monitoring or reporting by the Permittee.

J. Severability

1. The provisions of this Order are severable; and if any provision of this Order or the application of any provision of this Order to any circumstance is held invalid, the application of such provision to other circumstances and the remainder of this Order shall not be affected.

K. Duty to Provide Information [40 CFR122.41(h)]

1. The Permittees shall furnish, within a reasonable time, any information the Regional Water Board or U.S. EPA may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this Order.

2. The Permittees shall also furnish to the Regional Water Board, upon request, copies of records required to be kept by this Order.

L. Twenty-Four Hour Reporting [40 CFR122.41(l)(6)][1]

1. The Permittees shall report to the Regional Water Board any noncompliance that may endanger health or the environment. Any information shall be provided orally within 24 hours from the time any Permittee becomes aware of the circumstances. A written submission shall also be provided within 5 days of the time the Permittee becomes aware of the circumstances. The written submission shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times and, if the noncompliance has not been corrected, the anticipated time it is

[1] This provision applies to incidents where effluent limitations (numerical or narrative) as provided in this Order or in the Ventura County SMP are exceeded, and which endanger public health or the environment.

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expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance.

2. The Regional Water Board may waive the required written report on a case-by-case basis.

M. Bypass [40 CFR122.41(m)][1]

1. Bypass (the intentional diversion of waste streams from any portion of a treatment facility) is prohibited. The Regional Water Board may take enforcement action against Permittees for bypass unless:
   (a) Bypass was unavoidable to prevent loss of life, personal injury or severe property damage. (Severe property damage means substantial physical damage to property, damage to the treatment facilities that causes them to become inoperable, or substantial and permanent loss of natural resources that can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.);
   (b) There were no feasible alternatives to bypass, such as the use of auxiliary treatment facilities, retention of untreated waste, or maintenance during normal periods of equipment down time. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass that could occur during normal periods of equipment downtime or preventive maintenance;
   (c) The Permittee submitted a notice at least ten days in advance of the need for a bypass to the Regional Water Board; or,
   (d) Permittees may allow a bypass to occur that does not cause effluent limitations to be exceeded, but only if it is for essential maintenance to assure efficient operation. In such a case, the above bypass conditions are not applicable. The Permittee shall submit notice of an unanticipated bypass as required.

N. Upset [40 CFR122.41(n)][2]

1. Upset means an exceptional incident in which there is unintentional and temporary noncompliance with technology based permit effluent limitations because of factors beyond the reasonable control of the Permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

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[1] This provision applies to the operation and maintenance of storm water controls and BMPs as provided in this Order or in the Ventura County SMP.
[2] This provision applies to incidents where effluent limitations (numerical or narrative) as provided in this Order or in the Ventura County SMP are exceeded, and which endanger public health or the environment.

2. A Permittee that wishes to establish the affirmative defense of an upset in an action brought for non compliance shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:
   (a) An upset occurred and that the Permittee can identify the cause(s) of the upset;
   (b) The permitted facility was being properly operated by the time of the upset;
   (c) The Permittee submitted notice of the upset as required; and,
   (d) The Permittee complied with any remedial measures required.
3. No determination made before an action for noncompliance, such as during administrative review of claims that non-compliance was caused by an upset, is final administrative action subject to judicial review.

4. In any enforcement proceeding, the Permittee seeking to establish the occurrence of an upset has the burden of proof.

O. Property Rights [40 CFR122.41(g)]

1. This Order does not convey any property rights of any sort, or any exclusive privilege.

P. Enforcement

1. Violation of any of the provisions of the NPDES permit or any of the provisions of this Order may subject the violator to any of the penalties described herein, or any combination thereof, at the discretion of the prosecuting authority; except that only one kind of penalties may be applied for each kind of violation. The CWA provides the following:
   (a) Criminal Penalties for:
      (1) Negligent Violations [CWA 309 (c)(1)(B)]:
      The CWA provides that any person who negligently violates permit conditions implementing CWA § 301, 302, 306, 307, 308, 318, or 405 is subject to a fine of not less than $2,500 nor more than $25,000 per day for each violation, or by imprisonment for not more than 1 year, or both.
      (2) Knowing Violations [CWA 309 (c)(2)(B)]:
      The CWA provides that any person who knowingly violates permit conditions implementing CWA § 301, 302, 306, 307, 308, 318, or 405 is subject to a fine of not less than $5,000 nor more than $50,000 per day of violation, or by imprisonment for not more than 3 years, or both.
      (3) Knowing Endangerment [CWA 309 (c)(3)(A)]:
      The CWA provides that any person who knowingly violates permit conditions implementing CWA § 301, 302, 307, 308, 318, or 405 and who knows at that time that he is placing another person in imminent danger of death or serious bodily injury is subject to a fine of not more than $250,000, or by imprisonment for not more than 15 years, or both.

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(4) False Statement [CWA 309 (c)(4)]:
The CWA provides that any person who knowingly makes any false material statement, representation, or certification in any application, record, report, plan, or other document filed or required to be maintained under the Act or who knowingly falsifies, tampers with, or renders inaccurate, any monitoring device or method required to be maintained under the Act, shall upon conviction, be punished by a fine of not more than $10,000 or by imprisonment for not more than two years, or by both. If a conviction is for a violation committed after a first conviction of such person under this paragraph, punishment shall be by a fine of not more than $20,000 per day of violation, or by imprisonment of not more than four years, or by both.

(b) Civil Penalties [[CWA 309 (d)]
The CWA provides that any person who violates a permit condition implementing CWA § 301, 302, 306, 307, 308, 318, or 405 is subject to a civil penalty not to exceed $27,500 per day for each violation.

2. Violation of any of the provisions of the NPDES permit or any of the provisions of this Order may subject the violator to any of the penalties described herein, or any combination thereof, at the discretion of the prosecuting authority; except that only one kind of penalties may be applied for each kind of violation. The Cal Water Code § 13885 provides the following:
   (a) Any person who violates any of the following shall be liable civilly in accordance with this section:
      (1) Section 13375 or 13376.
      (2) Any waste discharge requirements or dredged or fillmaterial permit issued pursuant to this chapter or any water quality certification issued pursuant to Section 13160.
      (3) Any requirements established pursuant to Section 13383.
      (4) Any order or prohibition issued pursuant to Section 13243 or Article 1 (commencing with Section 13300) of Chapter 5, if the activity subject to the order or prohibition is subject to regulation under this chapter.
      (5) Any requirements of Section 301, 302, 306, 307, 308, 318, 401, or 405 of the Clean Water Act, as amended.
      (6) Any requirement imposed in a pretreatment program approved pursuant to waste discharge requirements issued under Section 13377 or approved pursuant to a permit issued by the administrator.

Q. Need to Halt or Reduce Activity not a Defense [40 CFR122.41(c)]

1. It shall not be a defense for a Permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this Order.

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R. Termination~~Rescission~~ of Board Order

1. Regional Water Board Order No. 00-108 is hereby terminated~~rescinded~~.

S. Board Order Expiration Date

1. This Order expires on ~~XX~~May 7-, 2014. The Permittees must submit a Report of Waste Discharge (ROWD) and a proposed Storm Water Quality Management Program in accordance with CCR Title 23 as application for reissuance of waste discharge requirements no later than 180 days in advance of such date.

T. MS4 Annual Reporting Program [40 CFR122.42(c)]

1. The Annual Program Reporting shall include the following information:
   (a) *Municipal separate storm sewer systems.*
   The operator of a large or medium municipal separate storm sewer system or a municipal separate storm sewer that has been designated by the Director under 40 CFR122.26(a)(1)(v) of this part must submit an annual report by the anniversary of the date of the issuance of the permit for such system. The report shall include:
   (1) The status of implementing the components of the storm water management program that are established as permit conditions;
   (2) Proposed changes to the storm water management programs that are established as permit condition. Such proposed changes shall be consistent with 40 CFR122.26(d)(2)(iii) of this part;
   (3) Revisions, if necessary, to the assessment of controls and the fiscal analysis reported in the permit application under 40 CFR122.26(d)(2)(iv) and (d)(2)(v) of this part;
   (4) A summary of data, including monitoring data that is accumulated throughout the reporting year;
   (5) Annual expenditures and budget for year following each annual report;
   (6) A summary describing the number and nature of enforcement actions, inspections, and public education programs; and
   (7) Identification of water quality improvements or degradation.

TENTATIVE

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I, Tracy J. Egoscue, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Los Angeles Region, on mm dd, 2009.

_____

Tracy J. Egoscue
Executive Officer

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Hydrology [H]

H52D MW:2020 Friday

Impacts of Urbanization on Hydrologic Processes and Regional Climate II

Presiding: T S Hogue, University of California, Los Angeles; E Stein, Southern California Coastal Water Resources Project; D Booth, Stillwater Sciences and University of Washington

H52D-01

Urban Effects on Stream Hydrology and Geomorphology: Variations, Magnitudes and Implications for Stream Protection and Restoration

Brown, S (sbrown@balancehydro.com), Balance Hydrologics, 841 Folger Ave, Berkeley, CA 94710, United States Hecht, B (bhecht@balancehydro.com), Balance Hydrologics, 841 Folger Ave, Berkeley, CA 94710, United States * Gartner, J D (jgartner@balancehydro.com), Balance Hydrologics, 841 Folger Ave, Berkeley, CA 94710, United States Owens, J (jowens@balancehydro.com), Balance Hydrologics, 841 Folger Ave, Berkeley, CA 94710, United States

The hydrologic and geomorphic response to urbanization has become an increasing concern for regulatory agencies and practitioners of stream protection and restoration. However, there has been comparatively less attention to this topic in the research community. In his classic diagram of the effect of urbanization, Leopold (1968) illustrated how increases in impervious area and degree of &#65533;improved' storm drainage tend to shorten lag times and increase peak flows. This response, sometimes termed hydrograph modification or hydromodification, can have dramatic effects on stream morphology, inducing both accelerated erosion and/or deposition. We present field data for case studies in California that contrast hydrologic and geomorphic responses in sandy versus clay-rich soils with different underlying geology. The first case study compares the urban effect in paired watersheds with relatively sandy terrain in Southern California. Annual peak flows, measured by indirect methods, increased by up to an order of magnitude in catchments with urbanization compared to adjacent catchments without urbanization. Morphologic responses have included significant incision plus natural-levee deposition from overbank flows. The second case study, in areas with clay-rich soils in the San Francisco Bay Area, examines hydrographs in watersheds with and without urbanization. Watersheds with urbanized areas showed significant increases in stream flow in early season storms and moderate mid-winter storms, but less of an urban effect in large mid-winter storms. Near bankfull flow events capable of sediment transport also became more frequent following urbanization, especially early in the rainfall season and following mid-winter dry spells. Channel response to hydromodification included increases in bank recession and collapse associated with the early-season storms. A third case study, in the East San Francisco Bay Hills shows how even minor (approximately 1 percent) increase in impervious area, an index of urbanization, can cause up to an order of magnitude increases in early season storm flow peaks. In summary, these case studies illustrate variation in both the magnitude and type of responses due to site conditions, which can be used to guide methods of stream restoration and protection to the local setting.

Los Angeles County
Department of Regional Planning

Planning for the Challenges Ahead

Bruce W. McClendon FAICP
Director of Planning

January 10, 2008

TO: Harold V. Helsley, Chair
Leslie G. Bellamy, Vice Chair
Esther L. Valadez, Commissioner
Wayne Rew, Commissioner
Pat Modugno, Commissioner

FROM: Karen Simmons
Section Head, Ordinance Studies

SUBJECT: Green Building Program
Project Nos. R2007-02988, R2007-02985, R2007-02984

Agenda of January 23, 2008 – Item Nos. 5, 6, 7

EXECUTIVE SUMMARY

On January 16, 2007, the Los Angeles County Board of Supervisors (Board) instructed the Directors of Regional Planning (DRP) and Public Works (DPW) to investigate and report back to the Board on opportunities to incorporate green building principles into the County's development standards for all appropriate industrial, commercial and residential development within unincorporated areas and to develop an implementation program that includes modifications to building and zoning codes. The report was presented to the Board of Supervisors on October 23, 2007. The report can be found in its entirety at http://planning.lacounty.gov/doc/green/ReportBOS.pdf.

As a result of the report, on October 23, 2007 the Board made 15 motions directed towards the Internal Services Department, Chief Executive Office, Department of Public Works and the Department of Regional Planning. Attached is a chart (**Attachment 1**) that clarifies the motions made by the Supervisors.

The Board's actions requested DRP and DPW to prepare three draft ordinances (i.e. green building, drought-tolerant landscaping and low impact development) and present them to the Regional Planning Commission for public hearing in 90 days.

Green Building - establishes minimum requirements that maximize the positive impacts that incorporating green building techniques into the construction of buildings have on the community and the natural environment. (**Attachment 2**)

Part 19 (Green Building) of Chapter 22.52
The proposed Part 19 applies to all new construction, remodels and additions10,000 gross square feet or greater. These regulations will be phased in based on type of use and building size, as depicted in Table 22.52.1920 -1.

Use Exceptions: The Director of Planning may grant an exemption for a temporary project or for any project where an application for a building permit was accepted by the Department of Public Works for a building permit prior to the effective date of this ordinance.

Requirements: This section establishes what standards apply and when, depending on the building's type of use and size.

Drought-Tolerant Landscaping - establishes minimum standards for the design and installation of landscaping using drought-tolerant and native plants that require minimum water and ensure that the County will continue to realize the benefits of landscaping that is appropriate to the particular project and the region's climate. (**Attachment 3**)

Part 5 of Chapter 21.24 (Special Requirements) Addition of Section 21.24.430 – Drought-Tolerant
The proposed Section references compliance with Part 20 of Chapter 22.52.

Part 20 (Drought-Tolerant Landscaping) of Chapter 22.52
The proposed Part 20 applies to on-site landscaping for new construction. Part 20 applies to development on private property and does not apply to construction by a public agency within public easements and road rights-of-way.

Part 20 applies to expansion of existing buildings, additional structures, additions to structures and accessory buildings any of which are 2,500 square feet or larger.

Use Exceptions: registered historical sites, golf courses, cemeteries or landscaping for a manufactured cut or fill slope exceeding a gradient of 3:1.

Development Standards: This section establishes the minimum percentages of drought-tolerant plants and the maximum percentages of turf permitted.

Low Impact Development (LID) – establishes minimum standards which incorporate LID principles that provide on-site stormwater and runoff management for development on private property. (**Attachments 4 and 5**)

Part 5 of Chapter 21.24 (Special Requirements) Addition of Section 21.24.420 – Low Impact Development
The proposed Section references compliance with Chapter 12.84 of Title 12.

Part 21 (Low Impact Development) of Chapter 22.52
The proposed Section references compliance with Chapter 12.84 of Title 12.

Chapter 12.84 (Low Impact Development) of Title 12
The proposed Chapter applies to development on private property; and applies to all new parking lots, nonresidential projects, mixed use projects, multi- family residential projects of five or more units, and residential subdivisions of five or more units and redevelopments where fifty-percent or more of impervious surfaces are altered shall fully comply with development standards. Redevelopments that result in alterations of less than fifty-percent, only the altered portion shall comply with development standards.

Development Standards: This section references that urban and stormwater runoff quantity and quality control standards to be applied to development will be established by April 2008 in the Low Impact Development Standards Manual, which shall be updated as deemed necessary.

PROPOSED ORDINANCE FRAMEWORK

The proposed ordinances are designed to work in conjunction with community-level provisions in Title 21 (Subdivisions) and Title 22 (Zoning). Special Districts, such as the Community Standards Districts (CSDs) and Transit Oriented Districts (TODs), and Specific Plans (Chapter 22.46) supersede the provisions of the proposed ordinances – in some cases, imposing more restrictive, and in some cases less-restrictive, standards and requirements.

COST BENEFIT ANALYSIS

There are several factors that determine the different costs and benefits associated with constructing green buildings. These factors include first costs, operating costs, other economic factors, health and productivity, and environmental factors. A more extensive discussion of the costs and benefits of building green can be found in **Attachment 6**. The following summarizes some of the more easily quantifiable first costs and operating costs for the builder, owner and occupants of green buildings. Typical costs and savings are provided for new residential and nonresidential buildings.

Residential

Building Construction:

- A green home's up-front costs are typically 3-4% more than a conventional building.
- If a house costs $200,000 to build, the "green premium" is an extra $6,000 to $8,000.

For the Buyer:

- With a 3-4% cost increase passed directly on to the homebuyer, with an average median home price in Los Angeles County at $547,500, the price increase for a green home would be approximately $16,000; bringing the home price up to $564,000.

Cost Savings:

- LEED constructed homes save 35% on energy costs

- LEED constructed homes save 40% on water costs

Nonresidential

Building Construction:

- A green building costs on average less than 2% of standard building costs or $3 -$5 per square foot to build.

Operating Costs:

- Energy bills are typically 30% less
- Water bills are typically 30-50% less

ENVIRONMENTAL DOCUMENTATION

The Department of Regional Planning has determined that the project is categorically exempt (Class 8 – Actions by Regulatory Agencies for Protection of the Environment) from CEQA requirements. Class 8 consists of actions taken by regulatory agencies, as authorized by state or local ordinance, to assure the maintenance, restoration, enhancement, or protection of the environment where the regulatory process involves procedures for protection of the environment.

PUBLIC COMMENT

The notice of public hearing was sent to approximately 700 interested persons and organizations, and advertised in 11 newspapers throughout the County. The staff report and draft ordinances were distributed to all County libraries and to several public agencies. We have received letters from individuals, organizations and agencies regarding the draft ordinances. Public comments are included as **Attachment 7.**

RECOMMENDATION

Staff recommends that the Regional Planning Commission continue the public hearing for 60 days, until March 26, 2008, so that Regional Planning can complete the following:

- Outreach to town councils and homeowners within the communities
- Outreach to maintenance and/or building engineers that have been maintaining green buildings
- Present to the Housing Advisory Committee in February of 2008
- Provide additional time for public review of the three draft ordinances
- Prepare the Departments' Green Guideline Technical Manual that includes the various checklists and guidelines
- Expand Regional Planning's Green Program website
- Revise the draft ordinances, based on the feedback from additional outreach and the public hearing
- Complete any additional requests, as directed by the Commission

SUGGESTED MOTION

"I MOVE THE PUBLIC HEARING REMAIN OPEN AND THAT THE REGIONAL PLANNING COMMISSION CONTINUE PROJECT NOS. R2007-02988, R2007-02984, R2007-02984 TO MARCH 26, 2008 IN ORDER TO GIVE THE COUNTY OF LOS ANGELES TIME TO COMPLETE THE REQUESTED ADDITIONAL TASKS."

Attachments

1) Green Building Motion Chart
2) Draft Green Building Ordinance
3) Draft Drought-Tolerant Landscaping Ordinance
4) Draft Low Impact Development Ordinance (Title 21 and Title 22)
5) Draft Low Impact Development Ordinance (Title 12)
6) Cost Benefit Discussion
7) Public Comments
8) Background/Discussion
9) Public Meeting Recap
10) Public Meeting Handouts
11) Public Hearing Notice

KMS 1-10-08

	MADE BY	DESCRIPTION	TIMELINE	DEPT
1	Burke (motion)	(1) Develop methodology for calculating the quantifiable savings and effectiveness of the polices and action plans as they relate to satisfying the goals of AB 32	April 15, 2008	CEO/ISD
2	Burke (motion)	(2) Develop strategy for ensuring that the ordinance and/or programs and accompanying guidelines and checklists will be "living documents" and may be revised as needed	April 15, 2008	
		Include "living documents" provisions in amendments to Zoning and Subdivision Ordinances		DRP/ County Counsel
		Include "living documents" provisions in guidelines and checklists		CEO
3	Burke (motion)	(3) Report back on the impact of the policies and action plans in satisfying the goals of AB 32	Quarterly (beginning August 15, 2008)	CEO/ISD/ DPW/DRP
4	Burke (motion)	Report back on the feasibility of requiring that all computer products to meet EPEAT (Electronic Products Environmental Assessment Tool) standards	45 days (December 7, 2007)	CEO/ISD/CIO
5	Burke (transcripts)	Report to the Board the advisability of exempting single-family residences from green building and LID standards	Prior to 2010	
		Analyze potential impacts of green building and LID standards on housing costs; submit analysis/recommendation to CEO		DRP/DPW
		Prepare report and recommendations to Board		CEO
6	Burke (transcripts)	Report back on all aspects of the County's Energy Policy, including LEED, Purchasing, public outreach, and leasing of buildings	Quarterly (Beginning February 2008)	CEO/ISD
7	Yaroslavsky Molina (motion)	(1a) Prepare ordinance for green building as reflected in staff's recommendations	90 days to RPC (January 23, 2008)	
		Prepare amendments to the Zoning Ordinance implementing green building standards		DRP
		Prepare amendments to the Building Code implementing green building standards		DPW
	Staff	Prepare Initial Studies/Negative Declarations, one for each of the three ordinances	90 days to RPC (January 23, 2008)	DRP
	Staff	County Counsel Review of all ordinances	90 days to RPC (January 23, 2008)	County Counsel
	Staff	Develop inter-departmental Task Force to review project status, the draft ordinances and cost-benefit analysis	Bi-weekly meetings	Task Force (DRP/DPW/CEO/ISD)

	MADE BY	DESCRIPTION	TIMELINE	DEPT
8	Yaroslavsky Molina (motion)	(1b) Prepare ordinance for Low Impact Development as reflected in staff's recommendations **and** (2) add provisions for adding LID for non-discretionary projects **and** consider developing menu-based approach for LID for private development **and** consider how new LID standards could be applied to urban infill and redevelopment projects	90 days to RPC (January 23, 2008)	
		Prepare amendments to the Zoning and Subdivision Ordinances implementing LID standards		DRP (counsel with DPW)
9	Yaroslavsky Molina (motion)	(3) Incorporate LID standards into Public Works Road and Flood Design and Manuals as soon as possible	By 2009	
10	Yaroslavsky Molina (motion)	(4) Conduct outreach with property owners associations, homeowners groups, town councils, building industry representatives, utilities and environmental groups, ownership and environmental groups	Prior to RPC hearing (Prior to January 23, 2008)	
		Organize and coordinate outreach program meetings		DRP
		Attend meetings to provide input on areas of expertise		DRP & Task Force
11	Yaroslavsky Molina (motion)	(5) Prepare a cost benefit analysis of the various LID requirements that will be included in the draft ordinances, prior to RPC	Prior to RPC hearing (Prior to January 23, 2008)	
		Analyze potential impacts LID standards in Zoning and Subdivision Ordinances		DRP
		Analyze potential impacts LID standards in Building Code		DPW
12	Yaroslavsky Molina (motion)	(6) Incorporate the Board's previously requested drought tolerant landscaping ordinance into the draft ordinance	90 days to RPC (January 23, 2008)	DRP
13	Yaroslavsky Molina (motion)	(1) Evaluate the economic impacts of green building and LID for small non-discretionary projects, particularly single-lot sfrs. This should include evaluating additional review fees and permit processing time.	Prior to RPC (Prior to January 23, 2008)	
		Identify economic impacts of Zoning and Subdivision Ordinance amendments		DRP
		Identify economic impacts of Building Code amendments		DPW

	MADE BY	DESCRIPTION	TIMELINE	DEPT
14	Antonovich Knabe (motion)	(2) Evaluate the economic impacts of green building and LID for small discretionary projects, including projects subject to plot plan review, Director's Review, CSD modification, Minor CUP, parcel maps. This should include evaluating additional review fees and permit processing time.	Prior to RPC (January 23, 2008)	
		Evaluate Zoning and Subdivision Ordinance impacts		DRP
		Evaluate Building Code impacts		DPW
15	Antonovich Knabe (motion)	(3) Prepare a cost benefit analysis of proposed green building and LID development standards to quantify the additional costs of such standards to future home-buyers	Prior to RPC (January 23, 2008)	
		Evaluate Zoning and Subdivision Ordinance impacts		DRP
		Evaluate Building Code impacts		DPW

ORDINANCE NUMBER ___DRAFT___

An ordinance amending Title 22 of the Los Angeles County Code relating to Green Building.

The Board of Supervisors of the County of Los Angeles ordains as follows:

SECTION 1. Part 19 of Section 22.52 is hereby added to read as follows:

Part 19

GREEN BUILDING

22.52.1900 Purpose.

A. The purpose of Part 19 is to establish minimum requirements that maximize the positive impacts that incorporating green building techniques into the construction of residential and non-residential buildings have on the community and the natural environment. Incorporating green building measures into the design, construction and maintenance of buildings will enhance the health and well-being of occupants and the surrounding community, introduce less toxins and other harmful pollutants into the environment, improve long-term economic performance, conserve energy, water and other resources, and minimize impacts to existing infrastructure.

B. This Part 19 shall not be construed to supersede any state or federal law. Where conflict may be deemed to exist, the stricter shall apply.

22.52.1910 Definitions. The following definitions apply to this Part 19:

A. "Commissioning" means that the process of verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the project's requirements.

B. “GPR” means GreenPoint Rated which is a residential green building rating system developed and administered by the non-profit organization Build It Green.

C. “GPR Checklist” means a checklist provided by Build It Green that lists various features that may be incorporated into a home and is the basis for the GreenPoint Rated Program. The checklist also includes the number of points required in each category as well as the number of points that must be attained for different levels of GPR certification.

D. “Green Building Technical Manual (Manual)” means a document prepared by the County that includes the following:

1. Copies of the most recent versions of established third-party green building guidelines, standards and rating systems that have been approved by the director of planning and the director of public works that are required in order to comply with requirements laid forth in Table 22.52.1930-1.

2. Detailed applicant submittal requirements for all projects subject to this Part 19.

3. Other pertinent information necessary to assist applicant in complying with the green building requirements.

E. “LEED” means the Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ which is a system established by the USGBC as an independent means to verify the sustainable qualities of different building types. Buildings pursuing LEED certification are rated at four different levels: Certification, Silver, Gold and Platinum.

F. “LEED Checklist” means a checklist provided by the USGBC for each LEED

program that contains a list of various features that must be incorporated into a project as prerequisites and other various design features that will achieve credits. The checklist also includes the number of points required in each category and the number of points that must be attained for different levels of LEED certification.

G. "MEP" means Mechanical, Electrical, and Plumbing work.

H. "Temporary Project" means a temporary project that is a building constructed for a short term, such as a construction trailer or festival tent.

I. "U.S. Green Building Council (USGBC)" means a non-profit organization that works to promote structures that are environmentally responsible, profitable, and healthy places to live and work.

22.52.1920 Applicability.

A. Projects meeting the following thresholds shall comply with the provisions of this chapter; refer to Table 22.52.1930-1 for the timeline of when these standards are required and the specific requirements for applicable projects:

1. New high-rise buildings that are greater than 75 feet in height as defined in Title 26 of the Los Angeles County Code.

2. Hotels or nonresidential or mixed use buildings greater than or equal to 25,000 square feet of gross floor area; including any additions with a gross floor area of 25,000 square feet or more and, spaces of remodels within a building with a gross floor area of 25,000 square feet or more that include mechanical, electrical and plumbing work.

3. Hotels or nonresidential or mixed use buildings greater than or equal to 10,000 square feet and less than 25,000 square feet of gross floor area; including

any additions with a gross floor area greater than or equal to 10,000 square feet and less than 25,000 square feet and, spaces of remodels within a building with a gross floor area greater than or equal to 10,000 square feet and less than 25,000 square feet that include mechanical, electrical and plumbing work.

4. New residential buildings including single-family dwellings, two-family dwellings, multi-family dwellings, parcel maps and tract maps.

B. If a building or a project may be defined by more than one category in Table 22.52.1930-1, the more stringent requirement shall apply.

C. Exemptions.

1. The director of planning may grant an exemption from this chapter for a temporary project.

2. Any project where an application for a building permit was accepted by the department of public works for a building permit prior to the effective date of this ordinance.

22.52.1930 Requirements.

A. The applicable standard from Table 22.52.1930-1 for a building or structure shall be based on the date of the building permit application as provided by the applicant to the Department of Public Works.

B. Table 22.52.1930-1.

TABLE22.52.1930-1 REQUIREMENTS FOR GREEN BUILDING STANDARDS NONRESIDENTIAL AND RESIDENTIAL CONSTRUCTION					
	TITLE 22 (ZONING)	**2008**	**2009**	**2010**	**2011**
1	New High-Rise buildings > 75 Feet in Height	**LEED Checklist**	**LEED – Silver**	**LEED – Silver**	**LEED – Silver**
2	Hotels or nonresidential or mixed use buildings ≥ 25,000 square feet of gross floor area (includes additions or remodels with MEP work)	**LEED Checklist**	**LEED – Certified**	**LEED - Silver**	**LEED – Silver**
3	Hotels or nonresidential or mixed use buildings ≥ 10,000 to 25,000 square feet of gross floor area (includes Additions or Remodels with MEP work)	**Voluntary**	**LEED Checklist**	**LEED Checklist**	**LEED – Certified**
4	New Residential buildings including single-family dwellings, two-family dwellings, multi-family dwellings, parcel maps and tract maps	**Voluntary**	**GPR Checklist**	**GPR**	**GPR**

1. Compliance with this ordinance to a standard other than a LEED or GPR Checklist requires the applicant to obtain third-party certification from a recognized and approved green building guideline, rating system, or standard.

2. Whenever a building or project demonstrates compliance with this ordinance through a Checklist, the applicant must complete a Checklist as provided in the County Green Building Technical Manual that identifies measures that shall be incorporated with the building or project.

3. The most recent version of the third-party guidelines and rating systems available at the time of project submittal shall be used, and shall be made available in the Green Building Technical Manual.

4. Although Table 22.52.1930-1 refers to LEED and GPR, applicants may submit an equivalent third-party industry standard; standard to be approved by the director of planning and the director of public works.

22.52.1940 Compliance.

A. The applicant for any building or project applicable to this ordinance shall provide to the departments of regional planning and public works documents demonstrating compliance to this ordinance prior to approval of the project or prior to issuance of a building permit.

B. The applicant, builder or authorized representative shall demonstrate compliance with the provisions of this Part 19 through the erection, construction, and if applicable, commissioning and certification of the green building measures provided by the applicant prior to final approval of the building permit.

ORDINANCE NUMBER ___DRAFT___

An ordinance amending Titles 21 and 22 of the Los Angeles County Code relating to drought-tolerant and native landscaping standards.

The Board of Supervisors of the County of Los Angeles ordains as follows:

SECTION 1. Section 21.24.430 of Title 21 is hereby added to read as follows:

Section 21.24.430 Drought-tolerant landscaping. All projects, including common areas, shall comply with the landscaping requirements as outlined in Part 20 of Chapter 22.52 of Title 22.

SECTION 2. Part 20 of Chapter 22.52 of Title 22 is hereby added to read as follows:

Part 20

DROUGHT-TOLERANT LANDSCAPING

22.52.2110 Purpose

A. The purpose of Part 20 is to establish minimum standards for the design and installation of landscaping using drought-tolerant plants and native plants that require minimum water and ensure that the County will continue to realize the benefits of landscaping that is appropriate to the particular project and the region's climate.

B. This Part 20 shall not be construed to supersede any state or federal law. Where conflict may be deemed to exist, the stricter shall apply.

22.52.2120 Definitions. The following definitions apply to this Part 20 of chapter 22.52:

A. “Drought-tolerant approved plant list” means a listing of plant species that is organized by ecological zones within the County unincorporated areas and approved by the Director for use in landscaped areas.

B. “Ecological zone” means a zone that is organized by plants indigenous to that area.

C. “Hydrozone” means a portion of the landscaped area having plants with similar water needs that are served by a valve or set of valves with the same schedule.

D. “Landscaped area” means any area covered with turf, shrubbery, flowers or trees.

E. “Native plants” means indigenous plants that are naturally found in one of the ecological zones in the County.

F. “Turf” means a surface layer of earth containing mowed grass.

22.52.2130 Applicability.

A. This Part 20 shall apply to on-site landscaping for all new construction. This Part 20 applies to development on private property and does not apply to construction by a public agency within public easements and road rights-of-way.

B. This Part 20 applies to expansion of existing buildings, additional structures, additions to structures and accessory buildings any of which are 2,500 square feet or larger.

C. Exception: Landscaping plan shall not be required for projects that are a part of:

1. Registered historical site, golf course facility or cemetery may be exempted from the provisions of this chapter when deemed necessary and appropriate by the director of planning.

2. Landscaping for a manufactured cut or fill slope exceeding a gradient of 3:1 may be exempted from the provisions of this chapter when deemed necessary and appropriate by the building official in order to comply with the requirements of the Building Code regulating engineered grading.

D. In addition to compliance with this Part 20, the applicant must also conform to Title 26 of the Los Angeles County Code, Chapter 71 – Water Efficient Landscaping.

22.52.2140 General landscaping development standards. Any landscaped area shall comply with the following:

A. A minimum of 70 percent of any landscaped area shall be plants as specified within the Drought-Tolerant Approved Plant List.

B. Turf shall not exceed 30 percent of landscaped area.

C. Any plant listed on the “Undesirable Plant Species (Invasive Species)” published by the county fire department may not be planted in any zone.

D. Plants shall be grouped in hydrozones in accordance with their respective water, cultural (soil, climate, sun and light) and maintenance needs.

ORDINANCE NUMBER ___DRAFT___

An ordinance amending Titles 21 and 22 of the Los Angeles County Code relating to Low Impact Development.

The Board of Supervisors of the County of Los Angeles ordains as follows:

SECTION 1. Section 22.21.420 of Title 21 is hereby added to read as follows:

Section 21.24.420 LOW IMPACT DEVELOPMENT

A. Regulations — Department of public works authority. The director of public works of the county of Los Angeles shall prescribe, by uniform rule or regulation, minimum standards which incorporate Low Impact Development principles that provide on-site stormwater and runoff management for development on private property; and shall also have the power to prescribe any and all other rules and regulations, uniform in their operation, necessary for the carrying out of the purposes of this Section and of Chapter 12.84 or as required by the director of public works.

B. Applicability. All projects, as defined in Chapter 12.84 or as required by the director of public works, shall comply with this Section.

SECTION 2. Part 21 of Chapter 22.52 is hereby added to read as follows:

Part 21

LOW IMPACT DEVELOPMENT

22.52.2210 Regulations — Department of public works authority. The director of public works of the county of Los Angeles shall prescribe, by uniform rule or regulation, minimum standards which incorporate Low Impact Development principles that provide on-site stormwater and runoff management for development on private property; and shall also have the power to prescribe any and all other rules and

regulations, uniform in their operation, necessary for the carrying out of the purposes of this Part 21 and of Chapter 12.84 or as required by the director of public works.

22.52.2210 Applicability. All projects, as defined in Chapter 12.84 or as required by the director of public works, shall comply with this Part 21.

TITLE 12
ENVIRONMENTAL PROTECTION

Chapter 12.84 Low Impact Development (LID) Standards

12.84.410 Purpose

A. The purpose of this chapter is to require the use of LID principles in development projects. LID encourages site sustainability and smart growth in a manner that respects and preserves the characteristics of the County's watersheds, drainage paths, water supplies and natural resources. LID builds on conventional design strategies by exploiting every surface in the development—softscape and hardscape—to perform a beneficial hydrologic function. The surfaces are used to retain, detain, store, change the timing of, or filter runoff in a number of different configurations and combinations.

B. This chapter shall not be construed to supersede any local, state or federal law. Where conflict may be deemed to exist, the stricter shall apply.

12.84.420 Definitions

The following definitions apply to this chapter:

A. "Beneficial Use" means the existing or potential uses of receiving waters as designated by the Los Angeles or Lahontan Regional Water Quality Control Boards in their respective Basin Plans for Los Angeles County.

B. "Best Management Practices (BMP)" means methods, measures or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and nonpoint source discharge, including storm water.

C. "Drainage System" means a conveyance or system of conveyances, including paths, drives, roads, streets, alleys, catch basins, curbs, gutters, ditches, manmade channels, or storm drains, designed or used to collect or convey urban runoff and stormwater.

D. "Development" means land disturbing activity that results in the creation, addition, modification, or replacement of impervious surface area. Development includes, but is not limited to: land subdivision and single-lot projects requiring discretionary or non-discretionary land use approval; the construction, installation, addition, or replacement of a building or structure; expansion of a building footprint; replacement of impervious surface area that is not part of a routine maintenance activity; and land disturbing activities related to structural or impervious surfaces. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

E. “Effective Impervious Area” means that portion of the total impervious area that is hydraulically connected to a drainage system or receiving water body. Impervious surfaces may be rendered “ineffective” if the runoff is dispersed through properly designed vegetated filters or infiltration areas using approved dispersion techniques.

F. “Hardscape” means any durable surface material (both pervious and impervious) used as paving by pedestrians or vehicles

G. “Hydromodification” means alteration of flow characteristics

H. “Low Impact Development” means LID is a sustainable storm water management strategy that controls rainfall and runoff at the source. It is a decentralized system that distributes stormwater across a project site in order to replenish groundwater supplies rather than sending it into a system of storm drain pipes and channelized networks that control water downstream in a large storm water management facility. The LID approach promotes the use of various devices that filter water and infiltrate water into the ground. It promotes the use of roofs of buildings, parking lots, and other horizontal surfaces to convey water to either distribute it into the ground or collect it for reuse. LID encompasses the use of structural devices (engineered systems) and non-structural devices (vegetated, natural systems). It uses a combination of these technologies to maintain or restore the natural hydrologic functions on a site with the goal of reducing the impact of development. Of particular concern are the rate and volume of storm water runoff, the pollutants in the runoff, and recharge of rainfall and runoff into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and to stabilize the flow rates of nearby streams. The LID approach differs from conventional storm water treatment systems as it promotes the highest and best use of the intrinsic land form and built structure(s) to both distribute storm water and collect rainwater. It capitalizes on the integration of infrastructure, architecture, and landscape in order to create a balanced, hydrologically functional and sustainable site.

I. “Natural Drainage System” means any unlined or unimproved (not engineered) creek, stream, river, or similar waterway.

J. “Pollutants of Concern” means chemical, physical, or biological components of storm water that impair the beneficial uses of receiving waters, including those defined in CWA §502(6) (33.U.S.C.§1362(6)), and incorporated by reference into California Water Code §13373.

K. “Softscape” means the horticultural elements of a landscape, such as soil and plants.

L. “Stormwater” means runoff that occurs as the result of rainfall.

M. “Urban Runoff” means dry weather surface flows emanating from urban development.

N. “Water Quality Design Storm Event” means standard storm event for designing wet weather BMPs, such as the Weighted Average Storm Event (WASE) or 85th percentile, 24-hour storm.

12.84.430 Applicability

A. This chapter applies to development on private property. The minimum site design features shall be installed and maintained in accordance with the standards and requirements of this Chapter, which shall apply to all new parking lots, nonresidential projects, mixed use projects, multi-family residential projects of 5 or more units, and residential subdivisions of 5 or more units.

B. If development results in an alteration to fifty percent or more of the impervious surfaces of a previously existing development, the entire project must meet the standards and requirements of this chapter. Where development results in an alteration to less than fifty percent of impervious surfaces of a previously existing development, only the alteration must meet the standards and requirements of this chapter, and not the entire development.

C. An applicant proposing to deviate from the standards of this chapter due to technical infeasibility, while still meeting the intent of the chapter, may submit a proposal for approval by the Director of Public Works.

12.84.440 Low Impact Development (LID) Objectives

A. Minimize hydromodification such that the post-developed urban and stormwater runoff rates and volumes match undeveloped conditions in any storm event up to and including the 50 year capital design storm event.

B. Eliminate pollutants of concern from leaving the site in stormwater as the result of storms up to and including the water quality design storm event.

12.84.450 Submittal Requirements

A. Under the discretion of the Director of Public Works, a comprehensive LID Plan that addresses drainage, hydromodification and water quality may be required. Fees to recover costs associated with this plan review will be required. The Department of Public Works shall review the plan and shall approve it if it is in accordance with criteria specified in this chapter.

B. The LID plan must be approved prior to the site plan or subdivision tentative map.

C. The grading and/or site plan shall incorporate the features of the approved documents referenced in 12.84.450(B) above.

12.84.460 Low Impact Development Standards

A. Urban and stormwater runoff quantity and quality control standards to be applied to development will be established by April 2008 in the LID Standards Manual, which shall be updated as deemed necessary. The LID Standards manual will incorporate many of the elements from the "Standard Urban Storm Water Mitigation Plan" and the "Stormwater Best Management Practice Design and Maintenance Manual". The LID Standards Manual will establish criteria for effective impervious area and impacts to the natural drainage system.

GREEN BUILDING PROGRAM
STAFF REPORT TO REGIONAL PLANNING COMMISSION
COST BENEFIT ANALYSIS

There is a common misconception among developers, contractors and building owners that green buildings are significantly more expensive than conventional buildings and don't yield long-term savings. Several studies break down the conceptions and misconceptions of green building, with particular attention to the economic realities of green building and the costs and benefits of such designs. The costs and benefits of green building have been broken down into five categories: First costs, operating costs, other direct economic factors, health and productivity, and environmental factors. The differentiation between these factors is always not clear as some are easily quantifiable while others are externalities or more abstract. Within each of the five categories, staff has highlighted some of the costs and benefits that were identified in the literature reviewed.

First Costs. First costs include the soft costs and hard costs of development. Soft costs are expenditures that take place away from the building site such as design and engineering consultants, financing and transaction costs, insurance, permit fees, third-party certification fees (if applicable), mortgages and legal fees. Hard costs are those costs directly related to the building site, such as land, building materials, the labor necessary to install those materials, contingency costs, furniture, fixtures, and equipment.

- **Certification.** Some prototypical costs for attaining certification through the staff-recommended GreenPoint Rated Third-Party Certification system for homes are shown below. These costs include program ratings and certificates, as well as a series of inspections and tests that provide construction quality assurance:

One Home:	$500-1,500
Subdivision - 60 units:	$3,300-$19,000
Multifamily (30 units/bldg):	$3,250-5,000[1]

- **Building Costs.** In a study comparing the construction of 33 green non-residential buildings from across the United States compared to conventional designs for those same buildings, the average construction premium has been slightly less than 2%, or $3-5/ ft^2.[2]

  Assuming a cost increase of $5/ ft^2, the total financial benefits of green buildings are over ten times the average initial investment, attaining a savings of $50/ ft^2 in a LEED building.[3]

[1] California BIA, http://www.cbia.org/go/cbia/government-affairs/green-building/ (January 2008).
[2] Greg Kats, "The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force" (October 2003), 3.
[3] Kats, 3.

For residential buildings, many experts in the field have stated that green construction can be successfully completed with no extra cost; however, according to a study by the Urban Land Institute, practitioners estimate a cost premium of 3-4% for green rather than conventional construction materials."[4]

Assuming a 3-4% increase, if a house costs $200,000 to build, the "green premium" is an extra $6,000 to $8,000, a number consistent with findings of the California Building Industry Association (BIA).[5]

Assuming that this 3-4% cost is passed directly onto the homebuyer, and the average median home price in Los Angeles County is $547,500 (July 2007), the price increase for a green home would be approximately $16,000; bringing the home price up to $564,000.[6]

- **Energy Efficient Mortgages (EEMs).** EEMs are available for new and existing homes.
  - Energy Improvement Mortgage - Finances the energy upgrades of an existing home in the mortgage loan using monthly energy savings.
  - Energy Efficient Mortgage - Uses the energy savings from a new energy efficient home to increase the home buying power of consumers and capitalizes the energy savings in the appraisal.

EEMs are currently available as Conventional Energy Efficient Mortgages, Federal Housing Authority (FHA) Energy Efficient Mortgages, and Veteran's Administration (VA) Energy Efficient Mortgages.[7]

Example: Assuming a Mortgage Rate of 7.5%, Down Payment of 10%, and a 30 Year Term Principal and Interest Only, and monthly incomes of $3,000 and $5,000, the added borrowing power due to an energy efficient mortgage would be $9,500 and $15,800, respectively.[8]

Operating Costs. Operating costs occur after a building is completed and include utilities, maintenance and waste removal, replacement costs, rentals and vacancies, and insurance.

- **Energy.** Green Buildings are on average 25-30% more energy efficient than conventional buildings.[9]
  Assuming energy costs are $1.47/ft^2 per year, an average savings of $0.44/ft^2 per year leads to a 20 year present value for that property's energy efficiency of $5.48/ft^2 beyond what conventional buildings can offer.[10]

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[4] Jeff Martin, Brian Swett, Doug Wein. "Residential Green Building Report: A Marketing Engagement Framework for Developers and Builders" (May 2007), 9.
[5] California BIA.
[6] US Census Bureau, *Housing Topics,* http://www.census.gov/hhes/www/housing.html (January 2008).
[7] Residential Energy Services Network, *Energy Efficient Mortgages,* http://www.resnet.us/ratings/mortgages/default.htm (January 2008).
[8] Residential Energy Services Network.
[9] Kats, 19.

Energy consumption also has larger environmental and economic impacts through emissions costs that are not included in the initial costs of the energy. Assuming the same base costs as above, an energy efficient building can save $1.18/ft^2, over a 20 year lifespan, as the need to mitigate its emissions impacts are much less than a conventional building.[11]

- **Water.** The long-term cost of water is somewhat hard to calculate, but with very conservative estimates, a green building can save $0.51/ft^2 over a 20 year lifetime. This estimate does not include the total economic and environmental costs, but simply the water itself.[12]

- **Waste.** Although there is still a cost premium for recycling services for regular waste, oftentimes the cost of recycling construction and demolition waste can be less than half of the cost of disposal.[13]

- **Homes.** The following table highlights the most significant costs benefits of home built to LEED standards. As summarized in this table, the net cost of building and owning a LEED Home is roughly $1 per day less than the cost of building and owning a conventional home.[14]

Type of Resource	**Monthly Cost** *($/Month)*	**Monthly Savings** *($/Month)*	**Net Cost of Measures** *($/Month)*	*($/Day)*
Energy: 35% savings	$20	-$70	-$50	-$1.70
Water 40% savings	$5	-$15	-$10	-$0.30
Indoor Environment	$15	0	$15	$0.50
Materials 50% Waste Reduction	$15	-$15	0	$0.00
Building Site	$15	?	$15	$0.50
Overall	**$70**	**-$100**	**-$30**	**-$1.00**

Other Economic Factors. Other economic factors include property resale value and length of resale time and lease and rental of commercial buildings and residential units.

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[10] Kats, 27.
[11] Kats, 39.
[12] Kats, 46.
[13] Kats, 49.
[14] Davis Energy Group, LEED for Homes Provider in California, http://www.davisenergy.com/publications/index.php (December 2007).

Other business factors include employee recruitment and turnover, liability associated with sick buildings, marketing and public relations and retail sales.

- **Increased retail sales.** A 2005 study prepared by Heschong Mahone Group (HMG) of a retailer's 74 stores in California found that daylighting alone increased sales by 1-6%.[15]

- **Increased property value.** Lower operating costs increase the building's net operating income (NOI). Increasing the NOI increases the building's appraised value by ten times the annual cost savings. For example, a 75,000 ft^2 office building that saves \$0.50/ft^2 per year in operating costs will have an increased value of \$375,000.[16]

- **Increased sales and rentals.** Green buildings enjoy more rapid lease-out of commercial buildings and residential rentals and often at higher rates.[17]

  For green subdivision development, Terramor Village in southern California, home prices had a 5-10% price premium over homes in the neighboring non-green subdivision development, Ladera villages. Terramor Village also enjoyed an overall interest of 32% more than its non-green counterpart.[18]

  Even in a down-turn market, lower utility bills and healthier indoor environment give the developer a way to differentiate the product in the marketplace.[19]

Health and Productivity. Health and productivity factors include worker and resident health, comfort and quality of life, worker absenteeism and productivity, learning capacity in schools, and healing rates for patients in health care facilities.

- EPA studies have shown that on average indoor levels of pollutants may be two to five times higher than those outdoors, with some reaching 100 times the outdoor levels.[20]

- A study aimed at pinpointing the connection between healthy buildings and productivity found that improvements to indoor ventilation systems could reduce health care costs and work losses from communicable respiratory diseases by 9-20%; from allergies and asthma by 18-25%; and from other unspecified health and discomfort by 20-50%.[21]

[15] Alex Wilson, "Making the Case for Green Building", *Environmental Building News* (April 2005), 14.
[16] Wilson, 5.
[17] Wilson, 5.
[18] Martin, Swett & Wein, 14.
[19] Martin, Swett & Wein, 14.
[20] US Green Building Council, "Making the Business Case for High Performance Green Buildings" (November 2005).
[21] USGBC.

- A collection of studies noted that worker productivity is increased because of tenant control over ventilation, temperature and lighting, with an aggregate increase anywhere from 0.5%-34%. Respectively, productivity gains averaged with 7.1% for improved lighting control, 1.8% with ventilation control and 1.2% with thermal control.[22]

- Nationwide, the estimated value of improved productivity from office workers as a result of indoor environmental improvements is $20 to $160 billion.[23]

Environmental factors. Environmental factors include the waste entering landfills, off-gassing of volatile organic compounds, formaldehyde, and other toxic chemicals, impacts of resource extraction, transportation of materials, urban heat island affect, indoor and outdoor air quality, wasted resources, loss of biodiversity, the costs of global climate change.

- The UN estimates the potential costs for global warming at over $300 billion a year, worldwide.[24]

- The cost of urban water conservation programs can range from $500-$750/acre-foot of water conserved, which is only about 325,000 gallons.[25]

- A study found that the environmental benefit of recycling versus disposal could be quantified at $63 per ton.[26]

- Many of the true costs for utilities such as water and electricity cannot be accurately estimated as the costs for emissions mitigation, habitat replacement, erosion control and various other environmental protection measures are not included and are often hard to approximate.

[22] Kats, 61.
[23] USGBC.
[24] Kats, 35.
[25] Kats 41.
[26] Kats 52.

PROJECT NOS. R2007-02988, R2007-02985, R2007-02984

Draft Ordinances: Green Building, Drought-Tolerant Landscaping, Low Impact Development

PUBLC COMMENTS

Sierra Club Angeles Chapter
3435 Wilshire Boulevard, Suite 320
Los Angeles, CA 90010-1904
213-387-4287
www.Angeles.SierraClub.org

January 6, 2008

Karen Simmons, Department of Regional Planning
County of Los Angeles
320 West Temple Street, Room 1355
Los Angeles, California 90012

Re: County of Los Angeles – Recommendations for Green Building Standards: Nonresidential and Residential Construction

Dear Ms. Simmons:

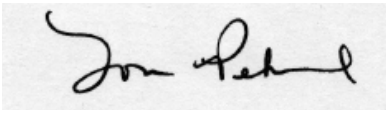
We are writing to comment on the County of Los Angeles Green Building Standards as set forth in draft format as of December 10, 2007. While we are truly encouraged by the County's intent to move forward with green building standards, we believe these standards can and should be upgraded significantly. The County must take a leadership role in mandating green building standards resulting in immediate diminution of global warming effects. In particular, we strongly support residential green building mandates—as opposed to voluntary residential standards as proposed for 2008. Mandated residential standards of any meaningful effect should also be positioned at the high end of the GPR scores, at least over 100.

New green building programs have appeared across this country in quick succession over the past several years—and often in forms surpassing previous best examples. Each new program expands the green building marketplace as well as the general knowledge base. Green building costs move downward accordingly. We ask the County of Los Angeles to mandate green building standards given the number of exemplary programs now in existence. The City of West Hollywood's new green building program provides one excellent example, among others. Similarly, the *Report and Recommendations of the Mayor's Task Force on Green Building for the City of and County of San Francisco* (which is currently moving through the review process by both City and County) provides another template on which to base an enhanced set of standards. We particularly applaud San Francisco's estimation of the cumulative effect of certain of its proposed standards as pertains to electrical savings and CO2 reduction, among other categories. Quantification of such improvements provides a coherent means by which to base cost/benefit decision-making.

We also are pleased with the inclusion of Low Impact Development Standards, and again urge strong mandates, especially maximum feasible on-site water retention, with the goal of 100% retention of normal rainfall (e.g. less than a half-inch per 24 hours).

We look forward to providing further input and support to the County of Los Angeles with respect to Green Building Standards. Approval and implementation of a strong set of standards is an important step forward in the fight against global warming.

Respectfully yours,



Lore Pekrul, Chair, Green Building Committee
310-306-2428 Email: elpe1@earthlink.net Cell: 310-529-2026



Jim Stewart, PhD, Co-chair, Global Warming, Energy & Air Quality Committee
213-487-9340 Fax: 310-362-8400 Cell: 213-820-4345

cc: Angeles Chapter Green Building Committee

Stewart, Alyson

From: Stewart, Alyson
Sent: Thursday, January 10, 2008 8:31 AM
To: ZOUP
Subject: FW: Los Angeles County Green Building Ordinance

From: SSL [mailto:steve_lamb57@sbcglobal.net]
Sent: Friday, December 14, 2007 2:01 PM
To: Adams, Marshall; Alexanian, Sorin; Brizee, Melissa; Charles Bryant; Chung, Connie; Franchino, Nick; Franco-Rogan, Susana; a. Gentry; Glaser, Mitch; Glaser, Rob; Lori Glasgow; Hamilton, Rose; Hand, Gunnar; Herwick, Mark; Hoffman, Dan; Hua, Thuy; McClendon, Bruce; McDonald, David; Ng, Adrienne; Bart Prince; Vivian Rescalvo; Russett, Anne; Seawards, Travis; Siemers, Gretchen; Sinclair, Lisbeth; Siranosian, Veronica; Stewart, Alyson; Veronica Tam; Hannah Wear; Eric Lloyd Wright
Cc: Sussy Nemer; Paul Novak; organicus@gmail.com; Stefanos Polyzoides
Subject: Los Angeles County Green Building Ordinance

Dear Sirs;

It is my understanding that the Los Angeles County Department of Regional Planning has been instructed by the Los ANgeles County Board of Supervisors to prepare a Green Building Ordinance. I have been both a builder and residential designer frot he last thirty years. Throughout that entire time I have attempted to build green buildings with the best available technology. Most of the builders, designers and Architects I have known have done the same. Throughout this entire time, our major obsticles have not been our clients, the educational and willingness level of contractors or the lack of available technology. Our major obsticles in building green buildings have been the local Buildiong departments, the code itself, and the unthinking unreasonable fundamentalist attitudes of the people who enforce the Building Codes.

Below are a few examples of recent denials of the use of the best available technologies by local agencies:

Both Los Angeles County and the City of Pasadena refuse to approve site built skylights for daylighting. Until five years ago, I was allowed to use my own design and Polygal or GE Thermoclear with refridgerator gaskets and wood hold downs. These skylights are inexpensive, and in thirty years I have never had a single one leak or fail. They are superior in both light transmission and U value to anything available commercially on the market. They have regularly been denied because they dont have a City of LA approval number. The Polygal/Thermoclear material do not have approval here, but they have it in Europe,Asia, South America, and the Atlantic states in the US. This gives my clients the choice of low performing leaking skylights or no daylighting at all.

Recently I designed a cathederal ceiling. Instead of using the existing 2x8 rafters with sprayed in foam insulation resulting in a R value of R56, I was required to remove the existing rafters and sheathing, replace them with 2 x 12 rafters and inferior R30 insulation. The additional thrust of the larger rafters required many many new steel connectors. Of course my client could have in the interest of being green, given up the cathedral ceiling, but getting it was the whole point of the job.....

Last year I designed a small house. I wanted to use Structural Insulated Panelized System (SIPS) for the walls and roof. This technology is well known and has been in use since Alden Dow invented it in 1942. It offers superior insulation values, better earthquake resistance, and less wood usage. Not allowed period. After months of endless calcs, consultants and consternation, client abandonded the project.

In the last four years I have attempted to use LED lighting in my kitchens to radically reduce energy use. In each case the building department has insisted that certian percentage of the total wattage had to come from a different ancient out of date but early low wattage lighting system. My clients are using more energy than they need as a result of the code, but they are getting a lower quality of light in the bargan.

I think what I'm trying to say is that we have codes that are stuck back in the past and people implementing them who are an impedence to progress.

Whatever we do regarding green building, I would like to say that the answer is not in new or more or better regulation, but in more freedom. Were Architects, Residential Designers and Builders not shackled with various mandates and limited choices, America would be much farther along in reducing energy and materials consumption per square foot of building.

One of the things that is leading to high energy use in the American home is the HUGE size house we have undertaken to build. In 1900 the average American house was 1100 Sq Ft. In 1948 it was 1400 SqFt, in the 1980's it was looming up in the 1650 range. Today the average new american home is 3,400 Sq Ft and many existing homes are being remodeled to almost double their existing square feet. If we have cut the energy usage per square foot by 30% since the late 1970's, but doubled the total number of square feet, we are way way behiend not ahead of the game. This is in fact where we are.While reduction in the number of square feet per household is a excellent answer, mandating maximum house size is not a fair or just solution, compared to education, and is one that will probably make the County more wealthy through an increase of CUP applications, but not actually lead to reduction in square footage per house.

Additionally, we now to build a house that meets the "minimum" standard for safety under the code use 100% more board feet of structural lumer than we did in 1975 and 400% more steel, and 20% more concrete. We require so many nails in shear panels that framing members often shatter when placed under relatively slight stress. What has been our answer to that? Requiring larger members, thicker shear panels and yet MORE NAILS. This has not, in spite of all of the engeneering studies, made most families in earthquakes any safer than they were in a 1975 house, but it hase used tremendous additional uneccesary natural materials and gallons of fuel in production.

The answer is not more mandates on buildings, but smaller buildings, and more freedom for builders and designers, not less.

Steve Lamb
President, Society of Organic Architects

Stewart, Alyson

From: Alpat62@aol.com
Sent: Monday, December 31, 2007 7:05 PM
To: ZOUP
Cc: Jim@EarthDayLA.org
Subject: Say "No" to sod lawns

Say No To Sod Lawns!!
By Alan Pollack, M.D.

On December 8, a photo of the Tujunga Wash Greenway Project in the Daily News depicted the effort to restore the LA River and its tributaries to something resembling their natural state. Somewhat puzzling, though, were the large swaths of sod lawn in the photo. Apparently, not all the agencies responsible for overseeing restoration attempts are aware that sod lawns are totally inappropriate in a restored, natural area in semi-arid Southern California.

The expansive, manicured lawn tradition found its way to this country from soggy old England, where it evolved as a status symbol. Back then, the more acres of sod lawn you had, the richer you were. Los Angeles is not soggy old England and has been suffering seven years of drought, with no end in sight, according to many experts. Now consider that in most cities in the U.S., lawns consume between 30-60% of municipal water supplies and, in our San Fernando Valley, that figure is probably closer to 80%.

The lawn story gets worse: in addition to water gluttony, lawns are often doused with millions of pounds of synthetic insecticides and herbicides which negatively affect the eco-system in our soil. Furthermore, any critter further up the food chain that happens to feed on a poisoned lawn pest can perish, too. Compounding these problems are toxic chemical fertilizers that are applied to lawns, which percolate into our ground water or run-off and ultimately end up in the ocean, damaging it's eco-system. And let's not forget the large amount of CO2 that is pumped into the atmosphere from all those gasoline powered mowers used to manicure those lawns.

Fortunately, there are good alternatives to growing a traditional sod lawn. If an area is to be used for children to play on or for relaxing adults, consider a low growing, low water using and low maintenance native ground cover. For more vigorous recreation, think about creating an unplanted area of decomposed granite. If an area is simply decorative, consider meadows of native grasses, perennials, or beds for native plants that are connected by paths of decomposed granite. Yet another option is to create a rock or succulent garden. The use of a mulch over any bare soil will enhance moisture retention in the soil.

Any of these choices will not only conserve water, but will also be saving time, energy and money while reducing air pollution. By eliminating sod lawn and restoring native plant habitat in our restoration projects, we will also be providing a welcoming home for our wildlife friends. Of course, these conservation measures go beyond large restoration projects and also apply to homes, schools and businesses. Say "NO" to sod lawns!!!

Alan Pollack, M.D. is Audubon at Home Chair of the San Fernando Valley Audubon Society and Wildlife Habitat Steward for the National Wildlife Federation.

See AOL's top rated recipes and easy ways to stay in shape for winter.

Stewart, Alyson

From: Richard Seeley [dick.seeley@juno.com]
Sent: Monday, January 07, 2008 2:25 PM
To: ZOUP
Subject: Waterand energy conservation

To: Department of regional Planning

Gentlemen:

The Los Angeles County Board of Supervisors should be commended for their efforts to address global warming, water shortages, and drought.
With respect to their comprehensive Green Building program, the Board needs to adopt an ordinance similar to that of West Hollywood which requires strict energy and water use standards for all new developments, remodels, and tenant improvements.

To merely request that the public conserve energy and water without controlling and limiting their use by developers, landlords and others is self defeating well as discriminatory.

It is imperative that you follow through with this program of conservation of energy and water, especially the latter. And see to it that the standards you adopt are strictly enforced without any "exemptions." Thank you.

Richard Seeley
3924 El Caminito
La Crescenta, CA 91214-1026

Stewart, Alyson

From: JOANNE N NAGY [jnn@juno.com]
Sent: Monday, January 07, 2008 4:09 AM
To: ZOUP
Subject: Require water and energy efficiency for all new development

Dear Department of Regional Planning.

We recommend the Los Angeles County Board of Supervisors' efforts to address global warming and drought issues through a comprehensive Green Building program.

We urge the Board to adopt an ordinance (perhaps similar to that of West Hollywood), which requires strict energy and water use standards for all new development, remodels, and tenant improvements.

We do what we can at home. One little thing: we use liquid hand soap and so we do not turn on the water to rinse until we have done our 15 second wash. We only wish there were a simple device so that we could get warm water quickly without running off gallons of cold water first.

Thanks you for your concern about global warming and water and energy conservation.

Sincerely,

Ted and Joanne Nagy
16500 Simonds Street
Granada Hills, CA 91344-3730

jnn@juno.com

Stewart, Alyson

From: Sandra Trutt [s.trutt@verizon.net]
Sent: Sunday, January 06, 2008 8:53 PM
To: ZOUP
Subject: Green Building Standards

Department of Regional Planning

Hello,
I understand that there is an opportunity to formulate new standards for building with the environment in mind. This is good news. I do support new regulations on energy use and water use in new construction and refurbishment. What a wonderful way to make a measurable difference by building energy and water efficiency right into the building from the ground up. Something which is vital to avert the climate crisis at our door.
Please do all you can to help bring this about for all new development, remodeling projects and also in apartment buildings.
You help is most appreciated. Thank you.

Sandra Trutt
19549 Crystal Ridge Lane
Northridge, CA 9l326
(818) 360-1020

Stewart, Alyson

From: Linda Kline [lkline@qagc.com]
Sent: Sunday, January 06, 2008 3:46 PM
To: ZOUP
Cc: Jim@EarthDayLA.org; Elpe1@earthlink.net
Subject: FW:Green Building Ordinance

Hi,

This is a big topic, and so important. Who knew buildings were the big bad wolves of global warming!

Energy consumption can be cut dramatically by a simple duct leakage test and strict standards of 1/2 to 2% allowance of duct leakage.

I have the privilege of working with five companies that routinely achieve this tight allowance.

They do not actually seal the sheet metal or systems components.

They test for leakage, locate the leaks and stay in communication with the mechanical contractors(sheet metal installers) until the 1/2 to 2% duct leakage is reached.

Certified the by the Associated Air Balance Council, they follow their guidelines for testing and cannot sign off on the test until the strict standards of AABC are in effect.

The challenge is not only in new construction. Existing buildings may have as much as 30% duct leakage. No system can run efficiently under that condition.

The good news is there is an immediate
remedy with knowledgeable and reputable companies prepared to tackle the problem.

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Regards,
Linda
(714) 356- 6387

Linda Kline

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Stewart, Alyson

From: Candace Haskell Swirkal [candy@swirkal.com]
Sent: Saturday, January 05, 2008 8:56 PM
To: ZOUP
Subject: requiring water and energy efficiciency for ALL new devlop.

Dear Dept of Regional Planning,

Please adopt an ordiance which requires strict energy and water use standards for ALL new development, remodels and tenant improvements. We need a comprehensive Grreen Building program.

Please consider for Los Angeles County what Orange County did with re-using all their water, including sewage water. We need vision for the future because we won't have water or freeways enough for the future at the rate we're growing.

Thank you.

Candace Haskell Swirkal

Candace Haskell Swirkal Massage
310-451-1636



Stewart, Alyson

From: thedes4@aol.com
Sent: Saturday, January 05, 2008 2:12 PM
To: ZOUP
Subject: Energy efficincy for all new devleopment

Dear Department of Regional Planning,

I would like to thank the LA County Board of Supervisors for the efforts in addressing global warming and drought issues by a Green Building Program

I am urging the Board to adopt and ordinance that requires strict energy and water use standards for all new developments, tenant improvements and remodels.

Thank you very much for your concern about water and energy conservation as well as global warming.

Eileen Daniels

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Stewart, Alyson

From: Doug Goosey [dgoosey@hotmail.com]
Sent: Saturday, January 05, 2008 1:38 PM
To: ZOUP
Subject: Require water and energy effciency for all new development..

Dear Department of Regional Planing
We commend the Los Angels county board of supervisors efforts to address global warming and drought issues through a comprehensive green building program.
We urge the board to adopt an ordinance which requires strict energy and water use standards for all new development, remodels and tenant improvements.
Thank you for your concern about global warming and water and enegy conservation.

Doug Goosey

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Stewart, Alyson

From: Patricia Larkin [larkinss@socal.rr.com]
Sent: Saturday, January 05, 2008 11:24 AM
To: ZOUP
Subject: Require water and energy efficiency for all new devlopment

Dear Department of Regional Planning,

We commend the Los Angeles County Board of Supervisors' efforts to address global warming and drought issues through a comprehensive Green Building program.

We urge the Board to adopt an ordinance (perhaps similar to that of West Hollywood), which requires strict energy and water use standards for all new development, remodels and tenant improvements.

Thank you for your concern about global warming and water and energy conservation.

Sincerely,

Pat and Paul Larkin

SARB_016770

Stewart, Alyson

From: Susan Moore [drsmoore01@ca.rr.com]
Sent: Saturday, January 05, 2008 11:13 AM
To: ZOUP
Subject: Green Building Ordinance

Department of Regional Planning,

Thank you for your good work in addressing the global warming and drought issues in LA County to date.

I am writing as a concerned citizen of LA County to request that the board adopt an ordinance that requires strict energy and water use standards for all new development, remodels, and tenant improvements. The West Hollywood ordinance is a good example.

I appreciate your continued support of the environmental issues in LA County through imposing strict controls on water and energy efficiency. Regards,

Susan Moore, Ph.D.
DrSMoore01@ca.rr.com
310.305.9928

Stewart, Alyson

From: Dorrit Ragosine [Dorrit.Ragosine@fox.com]
Sent: Saturday, January 05, 2008 8:55 AM
To: ZOUP
Subject: Green Building Program

How exciting that the Los Angeles County Board of Supervisor's is considering adopting a Green Building program ordinance. This is the kind of forward/long term thinking that will benefit our local economy and quality of life.

I strongly urge the Board to make strict energy and water use standards for all new development, remodels and tenant improvments to insure this county's future. It is too important not too.

Let's be the leaders in the country!

Thank you.

Dorrit Ragosine

Stewart, Alyson

From: Julia Stein [juliast@earthlink.net]
Sent: Thursday, January 03, 2008 7:51 PM
To: ZOUP
Subject: re: green building ordinance

Hi

Please support the green building ordinance for L.A. County, which is badly needed right now.
Sincerely,

Julia Stein

SARB_016773

Stewart, Alyson

From: Graham Elwood [grahamelwood@verizon.net]
Sent: Thursday, January 03, 2008 5:27 PM
To: ZOUP
Subject: Green Building

Dear Dept. of Regional Planning,

We commend the LA County Board of Supervisors' efforts to address global warming and drought issues through a comprehensive Green Building program.

We urge the Board to adopt an ordinance (maybe similar to West Hollywood), which requires strict energy and water use standards for all new developement, remodels and tenant improvements.

Thank you for your concern about global warming and water and energy conservation.

Graham Elwood
www.grahamelwood.com

Stewart, Alyson

From: Rachel Young [reuyoung@gmail.com]
Sent: Thursday, January 03, 2008 9:35 AM
To: ZOUP
Subject: Require water and energy efficiency for all new development

Dear Department of Regional Planning,

We commend the Los Angeles County Board of Supervisors' efforts to address global warming and drought issues through a comprehensive Green Building program.

We URGE the Board to adopt an ordinance (perhaps similar to that of West Hollywood's) that requires strict energy and water use standards for all new developments, remodels and tenant improvements.

We can't wait any longer. NOW is the time. We are completely in support of any such ordinance.

Thank you for your concern.

Sincerely,
Rachel and Patrick Young

Stewart, Alyson

From: Rebecca Barker [barker450000@hotmail.com]
Sent: Thursday, January 03, 2008 3:00 PM
To: ZOUP
Subject: Please Require Water & Energy Efficiency

To The Department of Regional Planning:

I write to urge the Board to adopt an ordinance which requires strict energy and water use standards for all new developments, remodels and tenant improvements. West Hollywood has already implemented similar requirements and may serve as a template or guide to creating such an ordinance.

Thank you for your time and consideration!
Sincerely,

Rebecca Barker
222 W. Duell Street
Glendora, Ca. 91740
L.A. County

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GREEN BUILDING PROGRAM **ATTACHMENT 8**
STAFF REPORT TO REGIONAL PLANNING COMMISSION
BACKGROUND/DISCUSSION

Since the Board motions on October 23, 2007, Regional Planning developed an inter-departmental Task Force that met bi-weekly to develop and review the draft ordinances and project status. The Task Force included members of Regional Planning, Public Works, Internal Services and Parks and Recreation.

Green Building

The draft ordinance utilizes a third-party system that verifies that a development's location and design meet accepted high standards for environmentally responsible and sustainable development. DRP is not recommending the adoption of a specific system, but adoption of a Green Building Technical Manual that includes rating systems checklists and standards that are recognized and approved by the County. The Manual will be updated as the systems are revised and additional equivalent systems may be added as they are developed and approved by the Director of Planning and the Director of Public Works.

As building green involves different architectural and site design standards than currently used by developers and builders, the green building requirements will be phased in from the date of the ordinance adoption. This phase in period will allow for the education of the developers and builders of how to build green and education of homeowners on the benefits of building green. The timeline can be found within the draft ordinance at Table 22.52.1930-1.

As all of the systems reviewed for this report are used nationwide, staff has explored developing a green building review system that is unique to Los Angeles County. This customized system would address building materials and climate conditions that are distinctive of this region. Additionally, the costs to the applicant for a third-party certification would not be required. However, the development of a customized system is time-intensive and could not be completed within the time period provided by the Board. A system for the County could be completed in a second phase of this project, if requested by the Commission and Board.

Although the State of California has not adopted any required green building standards, research has shown that a State Green Building Committee is in the process of preparing regulations that will be placed within the State Building Code in 2009 or 2010. Public Works is in favor of the recommendations in the draft ordinance, as these regulations could be the minimum recommendations recommended by the State.

The Board's motions on October 23, 2007 instructed Regional Planning and Public Works to prepare ordinances as reflected in staff's recommendations within the report. Planning staff believes the recommendations within the report are a minimum baseline the ordinance should work from, and increasing the development standards where additional research shows it would be recommended is appropriate.

For clarification in the below discussion the systems standards refer to:

LEED: The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ is a system established by the United States Green Building Council (USGBC) as an independent means to verify the sustainable qualities of different building types. The levels of standards within LEED are checklist, certified, silver, gold and platinum.
Where a LEED checklist is required, the applicant must fill out the checklist, as provided by the County, and identify green building measures that are planned to be incorporated into the project. The applicant shall work with County staff to identify further green building measures that may be incorporated into the project.
Whenever LEED - Certified or LEED - Silver are used, the applicant is required to obtain third-party certification from the USGBC.
GPR: GreenPoint Rated is a residential green building rating system administered by the non-profit organization Build It Green (BIG).
Whenever **GPR** is used, the applicant is required to obtain third-party certification from a certified GreenPoint Rater.
Whenever LEED or GPR are used, any other appropriate guideline, rating system or standard that is recognized and approved by the County may be used to meet the requirement, and the applicant shall be required to obtain certification from a certified third-party rater.
Staff provides these additional recommendations to the Regional Planning Commission for consideration.

High Rise Buildings

The draft green building ordinance incorporates high rise buildings greater than 75 feet in height, while all other applicable standards refer to gross square footage. The standards for high rise buildings are the most stringent. Regional Planning believes a structure 75 feet in height would automatically fall into one of the other categories of gross square footage. In this case the more stringent regulation would apply. The Department of Public Works prefers the 75 foot height category as DPW already has more stringent standards that they apply to high rises. Whereas, DRP would prefer all regulations be in gross square footage for consistency. If this size of building is a concern, another classification for buildings over 100,000 square feet can be added.

County Buildings

On January 16, 2007 the Board of Supervisors made a motion that required all new county buildings of at least 10,000 gross square feet in size that are authorized and fully funded on or after February 15, 2007 to achieve at lease the Leadership in Energy and Environmental Design (LEED) Silver level of certification (or a successor, equivalent standard established by the U.S. Green Building Council).

This requirement is not within the Zoning Ordinance. This requirement should be added to the text of the green ordinance, as well as within Table 22.52.1920 -1. The county will be leading in green development by codifying this requirement, as a 10,000 square

foot private development is not required to build at a LEED – Silver level until after 2011.

Smaller Scale Buildings

The proposed draft ordinance does not address any hotels, nonresidential or mixed use buildings under 10,000 gross square feet. Staff is concerned that many buildings could be constructed at 9,900 gross square feet to avoid this requirement; or several buildings constructed as a project add up to 10,000 gross square feet or more when calculated together. Therefore, we recommend adding these buildings at a minimal level of voluntary compliance in 2008, and LEED checklist through 2011.

Mid Size Buildings

Staff feels the requirement timeline for hotels, nonresidential or mixed use buildings ≥ 10,000 to 25,000 square feet of gross floor area (includes additions or remodels with mechanical, electrical and plumbing work) is too conservative. The draft ordinance only requires these buildings to be LEED Certified in 2011; DRP recommends LEED Certified in 2010 and LEED Silver in 2011.

Residential

Residential within the draft ordinance is as follows:

TITLE 22	2008	2009	2010	2011
New residential buildings including single-family dwellings, two-family dwellings, multi-family dwellings, parcel maps and tract maps	Voluntary	GPR Checklist	GPR	GPR

All residential is exempt until 2010, except for filing of a checklist. While this ordinance protects the single-family homeowner from any additional costs related to building green, it also exempts subdivisions of any size. Larger developments, which will have a larger effect on the environment, should be treated differently. Residential can be broken down into several categories, with a different timeline relating to each.

TITLE 22 (ZONING)	2008	2009	2010	2011
Residential I: one to, and including four residential units, including single-family residential, two-family residential and apartments	Voluntary	GPR Checklist	GPR	GPR
TITLE 21 (SUBDIVISIONS)				
Residential II: two to, and including four residential units with a parcel map	Voluntary	GPR Checklist	GPR	GPR
Residential III: five to 50 residential units	Voluntary	GPR	GPR	GPR
Residential IV: 51 or more residential units	Voluntary	GPR with additional measures for sustainable communities	GPR with additional measures for sustainable communities	GPR with additional measures for sustainable communities

The breakdown of residential into these categories was presented at the public meetings; refer to the Public Meetings Recap (**Attachment 8)** for input regarding residential classifications.

The green building standards apply to all discretionary and non-discretionary projects; plot plans, director's reviews, minor conditional use permits, conditional use permits, parcel maps and tract maps. In-house training will be required to teach planners the concepts of the third-party systems, checklists and guidelines, and how to process these permits.

Future Review of Ordinance

The report presented to the Board and the proposed green building ordinance only goes through 2011. Although the Green Building Technical Manual will be kept current on system checklists and guidelines, not all structures will have the same requirements in 2011. Perhaps the ordinance should be revisited every several years to determine if the requirements need to be updated. A suggestion at the public meetings was that all new construction must comply with the same requirements in a given year (i.e. All new construction must be LEED – Silver by 2015).

Incentives

The draft ordinance, as written, does not include any incentives to build green. However, after input from the public meetings and additional research on incentives provided by other jurisdictions; staff would recommend a combination of incentives, some within the ordinance and some as policy, which would be defined within the Technical Manual.

According to *Green Building Incentives That Work: A Look at How Local Governments are Incentivizing Green Development* (Yudelson, 2007), with a lack of substantial federal and state green building legislation, locally-based, market-driven incentives are sprouting up in municipalities across the country. Many jurisdictions offer direct monetary payment from a city or county; a direct grant, rebate or reimbursement for achieving LEED status, property or sales tax rebates or abatements, or full or partial refunds of development fees.

Incentive payments from utility energy-efficient programs are common. The Department can post all such existing utility refunds on the Green Program website to encourage participation in such programs.

Density bonuses written into a local ordinance allows a project to build at a higher density if certain green criteria are met. This allows the developer to expect more rent from the building site and increases it's valuation. A local example of this is the City of West Hollywood. For LEED Certification for multi-family residential or mixed-use projects the City allows one additional residential unit, not to exceed 700 square feet, without additional parking required. For LEED Certification for commercial or mixed-use projects 0.1 floor-to-area ratio (FAR) increase is permitted.

Expedited permit processing has been successful in jurisdictions where permit processing is complicated and/or time extensive. Regional Planning would be able to expedite permit processing only if the Board approves additional staffing to perform these duties.

A policy incentive that can be implemented is marketing and good publicity of buildings that are being built green and/or awards for green buildings. Also, builders and developers have noted that additional education is required so the benefits are recognized and desired by developers and tenants. Most larger multinational corporations do not have a green component; free technical assistance and project guidebooks should be provided.

Drought-Tolerant Landscaping

Drought-tolerant and native landscaping programs combine various landscaping techniques to create areas that are more resilient during periods of drought and better equipped to the local climate. Some of the techniques used to meet these goals are: the use of native and other climactically suitable plants, the creation of "hydrozones", which group plants with similar watering, lighting and other maintenance needs and setting minimum allowable areas of high-water use plants, such as turf.

While preparing the draft Drought – Tolerant Landscaping ordinance Staff noted the following issues should be discussed further:

- The ordinance applies to on-site landscaping for all new construction; it applies to development on private property and does not apply to construction by a public agency within public easements and road rights-of-way.

  Should parkways adjacent to sidewalks be included in the applicability? Parkways can range from three to ten feet (if not more). Although these are county right-of-way they are often planted, irrigated and/or manicured by the homeowner.

- The ordinance exempts registered historical sites, golf course facilities, cemeteries and landscaping for a manufactured cut or fill slope exceeding a gradient of 3:1.

  Should school sites, parks and playing fields be exempted?

- The ordinance states that any plant listed on the "Undesirable Plant Species (Invasive Species)" published by the Los Angeles County Fire Department may not be planted in any zone.

  Should the plants listed on this plant list be permitted within certain ecological zones? Should the list be reformatted so that invasive species are listed by ecological zones?

Low Impact Development (LID)

Low Impact Development is a stormwater management system that aims to protect surface and groundwater quality, maintain the integrity of aquatic living resources and ecosystems, and preserve the physical integrity of receiving streams by controlling rainfall, stormwater and other urban runoff at the source. Key design features include: reducing the amount of stormwater and urban runoff by providing onsite storage measures, maximizing permeable surfaces on a lot, disconnecting impervious surfaces to reduce runoff, and treating runoff by routing it through vegetation.

The draft ordinance, provided by the Department of Public Works, proposes that applicable development maintain stormwater runoff at predevelopment conditions up to and including a 50-year storm event and elimination of pollutants commonly associated with rainwater runoff. A 50-year storm event is a storm that has a two percent chance of occurring during any given year (1/50). Storm rates and frequencies vary throughout the county, as described in the following table:

Location	Los Angeles City College	Dominquez (Lynwood)	Topanga Canyon	Hacienda Heights	Quartz Hill
October 2007-current average (average)	5.76	4.80	7.82	6.20	2.00
Normal seasonal average (expected)	15.12	12.29	24.86	17.22	6.89

The objective to contain up to a 50-year storm event will ensure that LID development will reflect local rainfall and property conditions throughout the county. The Department of Public Works is drafting the "LID Standards Manual" which will incorporate standards, designs and practices for stormwater retention and infiltration. The estimated completion date for the manual is April 2008.

Technical analysis, including drainage, hydromodification rates, and water quality, will be completed by the Department of Public Works. The Department of Public Works will charge a cost-recovery fee for LID review.

The Department of Public Works currently regulates stormwater management and water efficient landscaping through two existing ordinances: Chapter 12.80 – Stormwater and Runoff Pollution Control of Title 12 – Environmental Protection, and Chapter 71- Water Efficient-Landscaping of Title 26 – Building Code. Although the Subdivision and Zoning Ordinances will reference LID requirements (**Attachment 4)**, Planning recommends the ordinance be placed within Title 12, as the submittals will be made to Public Works and Public Works will review and approve the plans. (**Attachment 5**)

Fees and Processing Time – Review by Regional Planning

Discretionary Projects – Review of green building and drought-tolerant landscape standards will not add any fees or processing time on discretionary projects. These

standards will be added to the many standards and requirements that need to be reviewed for the projects.

Non-Discretionary Projects – Review of green building and drought-tolerant landscape standards on non-discretionary projects will add to the fees and processing time of the project. The building standards will be depicted on the site plan for a plot plan/director's review with an accompanying checklist. Planners at the Land Use Coordinating Center estimate it will take 1½ times to review the project. (example – a project that currently takes three hours would take 4½ hours). Likewise, the fees should be adjusted to compensate for the additional time. The current site plan review fee is $695; the fee should be adjusted to $1043.

If the landscaping details are provided as a cut sheet of ordinance requirements attached to the site plan, as opposed to a landscape plan, no additional time or fee would be required.

If DRP hires an additional planner whose primary job is to review these site plans no additional fee should be required.

SARB_016783

GREEN BUILDING PROGRAM **ATTACHMENT 9**
STAFF REPORT TO REGIONAL PLANNING COMMISSION
PUBLIC MEETING RECAP

PUBLIC MEETINGS

In response to the Board's motion for public outreach, and given the limited time period for the project, Regional Planning organized public meetings on December 5, 6, and 10, 2007, which were held in Room 150, 320 W. Temple Avenue, Los Angeles. Approximately 700 invitations to the public meetings were sent to homeowner groups, developers, architects, environmental agencies, consultants and green building consultants, and County Departments. DRP also presented to the Land Development Advisory Committee hosted by Public Works on December 11, 2007.

Regional Planning and representatives from Public Works hosted the public meetings. DRP distributed folders that included fact sheets about the three draft ordinances, links, timeline, benefits, contacts, a copy of the powerpoint presentation that was presented, and a survey. (**Attachment 10**) The information presented to the public was the extended version of the applicability chart that included four residential classifications.

The numbers of attendees at the public hearings are as follows:

Environmental Consultants	3
Town Council	1
Realtor	1
Developers	3
Consultants	10
Architects	4
County Employees	17
Other	5
Total	**44**

Common questions from the attendees included:

Is there a possibility that Building Inspectors or other county staff might become raters to determine compliance with third-party guidelines?
Rating for the purpose of achieving certification may only be done by an accredited third-party rater. A county employee cannot be a third-party rater. However, building department and planning staff will be trained to understand the elements of the systems.

Why is the county phasing in requirements, instead of just requiring them immediately?
Staff believes that there needs to be a period of education, understanding and familiarity with the third-party rating systems for county staff and the developers, builders, code users and the public.

Why does the mandatory requirement for third-party certification for subdivisions begin earlier than the requirements for smaller residential development projects?
The county understands the ecological impact of building and maintaining a residence. This impact is significantly increased when more than one residence is developed, or numerous, even hundreds of homes are constructed as part of a planned development. Staff believes that this type of development needs to be addressed sooner than 2010.

What does requiring a "checklist" mean, as written in Table 1?
This is part of the educational component for phasing in requirements. It entails requiring applicants to review and complete the third-party green building standards and checklists (i.e. LEED for nonresidential new construction or GRP for residences) to identify what green building measures they are already incorporating, identify elements that are relatively easy to incorporate, and beginning to understand what other types of measures they can incorporate into future projects.

How will the county ensure the least amount of inference with projects that are currently in the works (vested tentative map and final map approved), but may not reach completion until after these standards are mandated?
The vesting of tentative maps primarily ensures the developer that any changes made throughout the project will not affect the development of the subdivision; however, it does not protect the builders from modifications in building codes. Builders will need to comply with the building code, subdivision and zoning ordinance that are in effect when the building permit is pulled for the project.

What is the county able to provide for incentives? Suggestions from the audience included expedited permits, density bonuses, fee reductions, grants, tax rebates and reduced pricing on green items or recommended plant materials.
While the Department of Regional Planning cannot provide many of these incentives, we can provide training and technical assistance. The Department will also be looking into establishing a marketing/publicity program and green awards, which will give notoriety to the developers and builders.

Do green buildings cost more to build and maintain than conventionally designed buildings?
Designing and construction a green building does not necessarily cost any more than a conventionally designed building. Significant cost increases are often found where cutting edge technology is being used. For LEED certified buildings, the "green premium" is typically as follows: LEED Certified 0 – 2%, LEED Silver 2 – 3%, LEED Gold 3 – 5%. Additional upfront costs are dropping as builders become more familiar with new techniques and products become more readily available.

Does the county allow the use of greywater?
Yes, Los Angeles County does allow the use of Greywater Systems. The construction, installation, alteration and repair of Greywater Systems requires a plumbing permit and must comply with all the provisions of Appendix G-A of the Los Angeles County Plumbing Code.

Regarding the drought-tolerant landscaping: will there be different requirements for geographic zones within the county? What types of plant species will be allowed? How will these standards differ in fuel modification areas?
The county is preparing a list of drought-tolerant and native plants, categorized into seven different climatic regions of the county, arranged by growth habit and flower color. This list will also include less water-dependent turf species to be used where turf is necessary. Although the fuel modification plan review and approval will still be done by the Fire Department, our planting list will note if the plants are regulated by the Fire Department.

How is County working with the Regional Water Quality Control Board (RWQCB) to avoid conflicting requirements and ensure consistency?
Implementation of the ordinance shall be achieved through the County's "Standard Urban Storm Water Mitigation Plan for Los Angeles County and Cities in Los Angeles County". This document has been approved by the California RWQCB.

Do LID practices vary geographically? Do they differ for urban and rural projects? How will these differences be addressed in the ordinance?
LID practices vary based on a number of factors - location, property size, topography, and soil permeability. The draft ordinance will require that the post development runoff match predevelopment run-off up to a 50-year storm event and developers will have a variety of standards and technologies available in order to meet this requirement.

The surveys collected at the end of the public meetings relayed the following:

Q1: Overall how would you rate the current status of the Green Building Program?
Very Good 15% Good 31% Acceptable 46% Poor 8% Very Poor 0%

Q2: Please indicate how satisfied you are with the following factors of the Green Building Program:

Green Building Thresholds
Very Satisfied 7% Satisfied 33% Neither 33% Dissatisfied 13% Very Dissatisfied 0%

Compliance Timeline
Very Satisfied 0% Satisfied 56% Neither 13% Dissatisfied 31% Very Dissatisfied 0%

Landscape Requirements
Very Satisfied 13% Satisfied 55% Neither 19% Dissatisfied 13% Very Dissatisfied 0%

LID Requirements
Very Satisfied 7% Satisfied 57% Neither 29% Dissatisfied 7% Very Dissatisfied 0%

Outreach
Very Satisfied 15% Satisfied 55% Neither 15% Dissatisfied 15% Very Dissatisfied 0%

Q3: Shall the drought-tolerant and native landscape ordinance apply to:

	YES	*NO*
Cemeteries	100%	

Golf Courses	100%	
Public Parks	100%	
Historical Sites	87%	13%
Single-Family Residences	87%	13%
Subdivisions- less than five units	73%	27%
Subdivisions- five or more units	100%	
Multi-Family	100%	
All Nonresidential Projects	100%	

Q4: Indicate how important the following factors are for inclusion in the landscape or low impact development ordinance.

	Important	*Neither*	*Unimportant*
Water-conserving plants 75% of total	100%		
Grouping of plants based on hydrozones	79%	21%	
Limited use of turf in residential – 75%	94%	6%	
Limited use of turf in nonresidential – 40%	100%		
Low use water retention turf	80%	20%	
Use of 2 – 3" mulch	50%	50%	
Use of decorative rock or paving	*50%*	*43%*	*7%*
Low gallon irrigation systems	*100%*		
Irrigation systems based on hydrozones	*71%*	*29%*	
Irrigation systems based on slope factors	*100%*		
Use of soil moisture sensors	*62%*	*38%*	
Use of impervious surfaces and materials	*100%*		

Q5: Shall low impact development standards apply to:

	YES	*NO*
Subdivisions – less than five units	87%	13%
Subdivisions – five or more units	100%	
Multi-family	100%	
Single-family residences	88%	13%
All residential projects	100%	
All nonresidential projects	100%	

Los Angeles County Department of Regional Planning

Green Building Program

Green Building Standards

- A Green Building is a building that is sited, designed, constructed and operated to enhance the well-being of occupants, and to minimize negative impacts on the community and natural environment.

  Key design features include:
  - Energy efficiency
  - Water efficiency
  - Waste reduction
  - Indoor air quality
  - Sustainable building materials

- The county already
  - Incorporates green concepts into the revisions of the General Plan and Zoning Ordinance.
  - Encourages clustered development within proposed subdivisions.
  - Requires recycling of 50% of construction material and demolition debris for various building projects.

- To date we have
  - Reviewed established third-party green building systems (i.e. LEED, GreenPoint Rated, Green Builder, etc.).
  - Surveyed various jurisdictions regarding their implementation of green building initiatives.
  - Presented findings to the Board of Supervisors.

Drought-Tolerant and Native Landscaping

- Drought-Tolerant and Native Landscaping programs combine various landscaping techniques to create areas that are more resilient during periods of drought and better equipped to the local climate. Some of the techniques used to meet these goals are:
  - The use of native and other climactically suitable plants;
  - The creation of "hydrozones", which group plants with similar watering, lighting and other maintenance needs;
  - Setting minimum allowable areas of high-water use plants, such as turf;
  - Landscape practices, such as mulching; and
  - Maximizing available onsite water sources, including stormwater and urban runoff.

- The County is currently:
  - Requiring the use of native, drought tolerant landscaping and fire-resistant construction in Very High Fire Hazard Severity Zones; and
  - Requiring the design, installation and maintenance of water-efficient systems for landscaped areas in excess of 2,500 square feet for various projects.

- To date, County staff has:
  - Surveyed the drought-tolerant landscape policies and ordinances of various jurisdictions;
  - Compiled a list of drought-tolerant plants native to the County and organized by the different climactic regions of Los Angeles County. The plant list is organized to be user-friendly and easily accessible; and
  - The plant list is further being reviewed by Regional Planning and the Fire Department to identify undesirable plants due to characteristics that make them highly flammable and/or invasive.

Low Impact Development

- Low Impact Development (LID) is a storm water management system that aims to protect surface and groundwater quality, maintain the integrity of aquatic living resources and ecosystems, and preserve the physical integrity of receiving streams by controlling rainfall, storm water and other urban runoff at the source.

  Key design features include:

  - Reducing the amount of stormwater and urban runoff by providing onsite storage measures;
  - Maximizing permeable surfaces on a lot;
  - Disconnecting impervious surfaces to reduce runoff; and
  - Treating runoff by routing it through vegetation.

- The County already:
  - Requires a minimum 70% open space on lots within non-urban hillside management areas of the County;
  - Mandates erosion and sediment control measures;
  - Calls for the preparation, enforcement, and inspection of all local and state Storm Water Pollution Prevention Plans;
  - Requires planting of on-site trees within proposed subdivisions;
  - Requires commercial parking lots to have a minimum 2% landscaped area; and
  - Requires construction and post-construction phase stormwater Best Management Practices.

- To date, County staff has:
  - Reviewed innovative LID design standards as developed by other jurisdictions;
  - Studied the effects these requirements may have on Los Angeles County;
  - Worked with the Department of Public Works to develop menu-based standards; and
  - Presented recommendations to the Board of Supervisors.

CONTACT US

Ordinance Studies
Department of Regional Planning
320 W. Temple Street 13th Floor
Los Angeles, CA 90012
(213) 974-6432
zoup@planning.lacounty.gov

Building and Safety
Department of Public Works
900 S. Fremont Avenue
Alhambra, CA 91803
(626) 458-6365

Watershed Management Division
Department of Public Works
900 So. Fremont Ave.
Alhambra, CA 91803
(626)458-4313

BENEFITS

Environmental benefits:

- Enhance and protect ecosystems and biodiversity
- Improve air and water quality
- Reduce solid waste
- Conserve natural resources

Economic benefits:

- Reduce operating costs
- Enhance asset value and profits
- Improve employee productivity and satisfaction
- Optimize life-cycle economic performance

Health and community benefits:

- Improve air, thermal and acoustic environments
- Enhance occupant comfort and health
- Minimize strain on local infrastructure
- Contribute to overall quality of life

TIMELINE

- Complete ordinance amendments, cost analysis and staff report by early January, 2008
- First draft ordinances to be presented at a Regional Planning Commission public hearing on January 23, 2008
- If necessary, revise ordinances and bring back to RPC in Spring of 2008
- Board of Supervisors public hearing in early to mid-2008

LINKS

- Leadership in Energy and Environmental Design
  United States Green Building Council
  www.usgbc.org

- GreenPoint Rated Program
  Build It Green
  www.builditgreen.org

- California Green Builder
  The Building Industry Institute
  www.cagreenbuilder.org

- Metropolitan Water District
  Bewaterwise.com
  http://bewaterwise.com/

- American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center, the United States Botanic Garden
  The Sustainable Sites Initiative
  http://www.sustainablesites.org/

County of Los Angeles Department of Regional Planning

GREEN BUILDING PROGRAM SATISFACTION SURVEY

Please tick the boxes that most closely match your personal opinions

Q1 **Overall how would you rate the current status of the Green Building Program?**

Very good ☐ *Good* ☐ *Acceptable* ☐ *Poor* ☐ *Very Poor* ☐

Additional Comments_____

_____

_____

_____

Q2 **Please indicate how satisfied you are with the following factors of the Green Building Program:**

	Very Satisfied	*Satisfied*	*Neither Satisfied nor Dissatisfied*	*Dissatisfied*	*Very Dissatisfied*
Green Building Thresholds	☐	☐	☐	☐	☐
Compliance Timeline	☐	☐	☐	☐	☐
Landscape Requirements	☐	☐	☐	☐	☐
LID Requirements	☐	☐	☐	☐	☐
Outreach	☐	☐	☐	☐	☐

Additional Comments_____

_____

_____

_____

Q3 **Shall the drought-tolerant and native landscape ordinance apply to:**

	Yes	*No*
All nonresidential projects	☐	☐
Multi-family residential projects of five or more units	☐	☐
Subdivisions of five or more units	☐	☐
Subdivisions of five or less units	☐	☐
Single-family residences	☐	☐
Registered historical sites	☐	☐
Public parks	☐	☐
Golf courses	☐	☐
Cemeteries	☐	☐

Additional Comments_____

_____

_____

_____

Survey continued on back

Q4 Indicate how important the following factors are for inclusion in the landscape or LID ordinance:

	Important	*Neither Important nor Unimportant*	*Unimportant*
Use of water conserving plants in 75% or more of total landscape area	☐	☐	☐
Grouping of plants based on hydrozones	☐	☐	☐
Limited use of turf: residential 75% of required area	☐	☐	☐
Limited use of turf: nonresidential 40% of required area	☐	☐	☐
Use low water retention turf (i.e. Marathon, hybrid fescue)	☐	☐	☐
Use of mulch two to three inches	☐	☐	☐
Use of decorative rock or paving	☐	☐	☐
Low gallonage irrigation systems	☐	☐	☐
Irrigation system designed by hydrozones	☐	☐	☐
Irrigation system sensitive to slope factors	☐	☐	☐
Use of soil moisture sensors	☐	☐	☐
Use of impervious surfaces and materials	☐	☐	☐

AdditionalComments_____

_____

Q5 Shall Low Impact Development standards apply to:

	Yes	*No*
All nonresidential projects	☐	☐
All residential projects	☐	☐
Single-family residences	☐	☐
Multi-family residential projects of five or more units	☐	☐
Subdivisions of five or more units	☐	☐
Subdivisions of five or less units	☐	☐

Additional Comments_____

_____

Q6 Indicate what type of standards you would like to see incorporated in to the Low Impact Development ordinance:

	Yes	*No*
Uniform System (regardless of use or size)	☐	☐
Tiered System based on use type	☐	☐
Tiered System based on use size	☐	☐
Other (explain below)	☐	☐

Additional Comments_____

_____

Name_____Occupation_____

Address or e-mail_____

Do you wish to be further involved with the Green Building Program? *Yes* ☐ *No* ☐

Thank you for taking the time to complete this form.

Department of Regional Planning 320 W. Temple St, Los Angeles, CA 90012 213-974-6432 fax 213-626-0434

THE DEPARTMENT OF REGIONAL PLANNING
COUNTY OF LOS ANGELES

NOTICE OF PUBLIC HEARING

PROJECT NUMBERS R2007-02984, R2007-02985, R2007-02988
CASE NUMBERS RADV200700023, RADV200700024, RADV200700025

Proposed amendments to the Los Angeles County Code, Title 21 (Subdivisions) and Title 22 (Planning and Zoning), to establish new case processing procedures and development standards for low impact development, drought-tolerant and native landscaping and green buildings.

NOTICE IS HEREBY GIVEN that a public hearing will be held before the Regional Planning Commission to consider the above amendments on **Wednesday, January 23, 2008** at 9:00 a.m. in Room 150, Hall of Records, 320 West Temple Street, Los Angeles, California 90012. Interested persons will be given an opportunity to testify. Room 150 will open at 8:50. The Categorical Exemption associated with these amendments will also be considered.

This project has been determined to be categorically exempt from the environmental reporting requirements of the California Environmental Quality Act (CEQA), Class 8 (Actions by regulatory agencies for protection of the environment).

Case materials are available for review between 7:30 a.m. and 6:00 p.m., Monday through Thursday **(closed on Fridays)** in the offices of the Department of Regional Planning, Hall of Records, Room 1355, 320 West Temple Street, Los Angeles, California 90012. Selected materials are also on the Regional Planning website at:
http://planning.lacounty.gov/spgreenbuildingprogram.htm and beginning Monday, January 14, 2008 at all county libraries.

If you are unable to attend the public hearing but wish to submit written comments, you may send them to Karen Simmons, Department of Regional Planning at ZOUP@planning.lacounty.gov or at the above mailing address. For further information, please call Monday through Thursday at (213) 974-6432 between the hours of 7:30 a.m. and 6:00 p.m. The Department is closed on Fridays.

Éste es Aviso Oficial que la Comisión de Planificación Regional del Condado de Los Angeles va celebrar una audiencia pública el día miércoles 23 de enero, 2008, empezando a las 9:00 a.m., en la Sala 150 del edifico "Hall of Records", ubicado en 320 W. Temple St., Los Angeles, CA 90012, con respecto a la siguiente propuesta:

Se propone una enmienda de ordenanza al Títulos 21 y 22 del Código del Condado de Los Angeles con respecto a los nuevos procedimientos para las entablaciones de desarrollos de bajos impactos, edificios "verdes" y las plantas resistentes a la sequía . Si no entiende éste aviso o si necesita más información, por favor llame al (213) 974-6432.

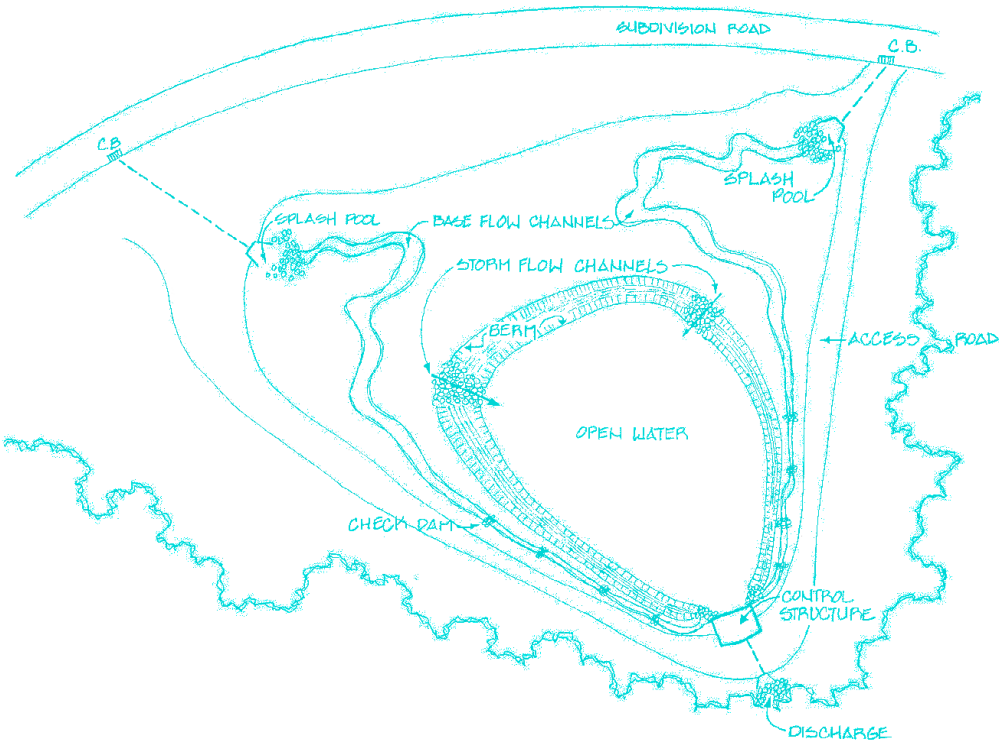
"ADA ACCOMMODATIONS: If you require reasonable accommodations or auxiliary aids and services such as material in alternate format or a sign language interpreter, please contact the ADA (Americans with Disabilities Act) Coordinator at (213) 974-6488 (Voice) or (213) 617-2292 (TDD), with at least three business days notice".

United States
Environmental Protection
Agency

Office of Water (4303)
Washington, DC 20460

EPA-821-R-99-012
August 1999

Preliminary Data Summary of Urban Storm Water Best Management Practices



SARB_016798

Acknowledgments

This report was prepared by Eric Strassler, Project Manager, Jesse Pritts, Civil Engineer, and Kristen Strellec, Economist, of the Engineering and Analysis Division, Office of Science and Technology. Assistance was provided by Parsons Engineering Science, Inc., Limno-Tech, Inc. and the Center for Watershed Protection under EPA Contract No. 68-C6-0001. EPA reviewers were Eugene Bromley, Rod Frederick, John Kosco, Marjorie Pitts, Marvin Rubin, Steven Sweeney and Kathy Zirbser. EPA thanks its external reviewers for this report:

George Aponte Clarke, Natural Resources Defense Council
Edward U. Graham, P.E., and John Galli, Metropolitan Washington Council of Governments
Jonathan E. Jones, P.E., Wright Water Engineers, Inc.
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SARB_016799

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1.0 Summary

The significance of storm water runoff in affecting water quality in the United States has become an increasing concern in recent years, as further improvements are made in controlling other point sources such as municipal sewage and industrial waste. EPA conducted a broad analysis of storm water runoff characteristics in its *Nationwide Urban Runoff Program* between 1979 and 1983. During the 1980's the Agency made several attempts to promulgate regulatory controls for storm water runoff under the statutory framework of the 1972 Clean Water Act. Following enactment of the Water Quality Act of 1987, EPA began development of a more comprehensive regulatory program. During the course of these actions, the use of best management practices (BMPs) in addressing runoff problems was frequently identified, however it was known that additional research on the performance of BMPs was also needed.

EPA's Engineering and Analysis Division conducted a study on storm water best management practices during 1997 and 1998 as part of its series of preliminary studies in the effluent guidelines program. This report summarizes existing information and data regarding the effectiveness of BMPs to control and reduce pollutants in urban storm water. The report provides a synopsis of what is currently known about the expected costs and environmental benefits of BMPs, and identifies information gaps as well.

Detailed information about BMP design is beyond the scope of this report. Readers are encouraged to consult the wide range of storm water BMP design manuals available from states and localities and other organizations for detailed design guidelines. Information regarding BMP performance and selection is also provided in other EPA documents, such as *Guidance Specifying Management Measure for Sources of Nonpoint Source Pollution in Coastal Water* (US EPA, 1993a); *Urban Runoff Pollution Prevention and Control Planning* (US EPA, 1993c); and *Municipal Wastewater Management Fact Sheets: Storm Water Best Management Practices* (US EPA, 1996e). In addition, readers are encouraged to consult the ASCE/WEF Manuals of Practice, *Design and Construction of Urban Stormwater Management Systems* (ASCE/WEF, 1992) and *Urban Runoff Quality Management* (ASCE/WEF, 1998) for a more thorough discussion of storm water management design.

Summary of Findings

1. Waterways and receiving waters near urban and suburban areas are often adversely affected by urban storm water runoff. Impacts may be manifested in terms of:

- alterations in hydraulic characteristics of streams receiving runoff such as higher peak flow rates, increased frequency and duration of bankfull and sub-bankfull flows, increased occurrences of downstream flooding, and reduced baseflow levels

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- changes in receiving stream morphology such as increased rates of sediment transport and deposition, increased shoreline erosion, stream channel widening, and increased stream bed scouring

- aquatic habitat impacts leading to changes in fish and macroinvertebrate populations and loss of sensitive species

- public health and recreation impacts such as increased risk of illness due to contact with contaminated water bodies, contamination of drinking water supplies, beach closures, restrictions on fishing, and shellfish bed closures.

2. A wide variety of BMPs, both structural and non-structural, are available to address urban storm water runoff and discharges.

- For various reasons (such as cost, suitability to site, etc.) some of these BMP types are widely used, some infrequently; some are relatively new designs that are not widely in use.

- Many BMPs are used primarily for water quantity control (i.e. to prevent flooding), although they may provide ancillary water quality benefits.

- Some BMP types have been analyzed for performance in terms of site-specific pollutant removal, although not extensively enough to allow for generalizations.

- The pollutant removal performance of some BMP types is essentially undocumented.

- Some BMP types, particularly non-structural and those that do not have discrete inflow or outflow points, are difficult to monitor.

- There is no widely-accepted definition of "efficiency" or "pollutant removal" for storm water BMPs.

- The role of chemical pollutant monitoring vs. receiving stream biological monitoring in evaluating BMP performance is not well documented.

3. Only a few cost studies have been conducted for storm water BMPs.

- Due to the limited cost data, a lack of clear definitions of performance, and limited "performance" data, it is difficult at this time to develop cost-effectiveness comparisons for various BMP types.

4. The benefits of individual BMPs are site-specific and depend on a number of factors including:

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- the number, intensity and duration of wet weather events;
- the pollutant removal efficiency of the BMP;
- the water quality and physical conditions of the receiving waters;
- the current and potential use of the receiving waters; and
- the existence of nearby "substitute" sites of unimpaired waters.

Because these factors will vary substantially from site to site, data are not available with which to develop estimates of benefits for individual BMP types.

5. A number of researchers are continuing to work on BMP performance monitoring, and there are several attempts underway to develop comparison frameworks through the construction of comprehensive databases on BMP design characteristics and performance.

Organization of Report

This report is divided into six chapters. Chapter 1 presents a summary of the major findings of the report. Chapter 2 presents a general introduction of the purposes and goals of this evaluation. Chapter 3 summarizes existing regulations and permits developed by EPA to address urban storm water discharges, including regulations under the National Pollutant Discharge Elimination System (NPDES) and the Coastal Zone Act Reauthorization Amendments (CZARA). Chapter 4 presents an assessment of the environmental problems attributable to urban storm water discharges and Chapter 5 identifies the best management practices that can be used to control the quantity and improve the quality of storm water prior to discharge. Chapter 6 identifies the costs and benefits of storm water BMPs.

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2.0 Introduction and Scope

2.1 Effluent Guidelines Program and Consent Decree Requirements

Effluent guidelines are national standards for categories of dischargers to surface waters. The program was established in 1972 under Title III of the Clean Water Act (CWA). Since that time EPA has developed effluent guideline regulations for over 50 categories, primarily industrial dischargers. In these regulations the Agency typically establishes numeric "end-of-pipe" effluent limitations for specific chemical pollutants and/or indicator parameters (e.g. BOD, oil and grease). For some categories, EPA has also issued narrative requirements for best management practices (BMPs) to address control of storm water runoff, plant maintenance schedules and training of plant personnel. The effluent limitations are generally based on the performance of available or demonstrated control and treatment technologies. Resulting effluent limitations are commonly referred to as "technology-based" standards. The regulations are implemented in National Pollutant Discharge Elimination System (NPDES) permits, which are issued by EPA and State agencies under the authority of CWA Section 402.

The Water Quality Act of 1987 added section 304(m) to the CWA. This provision requires EPA to publish a biennial Effluent Guidelines Plan and develop additional regulations. EPA's effluent guidelines program is currently subject to a consent decree ("Decree") in *Natural Resources Defense Council et al v. Browner* (D.D.C. 89-2980, January 31, 1992, as amended). The Decree requires the Agency to propose effluent guideline regulations and take final action for 20 point source categories, according to a specified schedule. Additionally, the Decree requires that the Agency conduct 11 preliminary studies to assist in selecting categories for regulation development.

The 1987 amendments also added section 402(p) to the CWA, which requires development of a national program for regulation of storm water discharges. This is discussed further in Chapter 3 of this report.

In 1996, the Natural Resources Defense Council (NRDC) recommended that EPA develop effluent guidelines for categories of storm water dischargers, to supplement the existing NPDES permit regulations covering storm water discharges. Because municipal storm water discharges present a range of complex phenomena that have not been extensively documented in the professional literature, and because there is a lack of generally accepted methods for evaluating storm water management practices, EPA determined that conducting a preliminary study would be appropriate to satisfy one of the study obligations under the Decree. This preliminary study is intended to assist decision making on initiating regulatory development projects.

2.2 Types of Discharges Addressed

This study is focused on BMPs designed to prevent, control or treat storm water discharges, and the nature and measurement of storm water discharges. Storm water discharges may flow directly into surface waters, into municipal separate storm sewer systems ("MS4s"), and/or infiltrate into groundwater. The emphasis on BMPs is intended to support the national NPDES storm water program. Some aspects of the BMPs described herein may also be relevant for other types of wet weather pollution problems, such as combined sewer overflows (CSOs).

Storm water BMPs may be organized into two major groups with multiple subgroups:

- *Structural* BMPs include:
  - infiltration systems such as infiltration basins and porous pavement
  - detention systems such as basins and underground vaults
  - retention systems such as wet ponds
  - constructed wetland systems
  - filtration systems such as media filters and bioretention systems
  - vegetated systems such as grass filter strips and vegetated swales
  - minimizing directly-connected impervious surfaces
  - miscellaneous and vendor-supplied systems such as oil/water separators and hydrodynamic devices

- *Non-Structural* BMPs include:
  - automotive product and household hazardous material disposal
  - commercial and retail space good housekeeping
  - industrial good housekeeping
  - modified use of fertilizers, pesticides and herbicides
  - lawn debris management
  - animal waste disposal
  - maintenance practices such as catch basin cleaning, street and parking lot sweeping, road and ditch maintenance
  - illicit discharge detection and elimination
  - educational and outreach programs
  - storm drain inlet stenciling
  - low-impact development and land use planning.

The impacts of storm water discharges are described in Chapter 4. Various BMP designs for addressing storm water discharges are described in Chapter 5, and the costs and economic impacts of BMP are described in Chapter 6.

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2.3 Data Sources and Data Collection Techniques

ASCE National Stormwater BMP Database

Since 1995, EPA and the American Society of Civil Engineers (ASCE) have operated under a cooperative agreement to develop a database of storm water BMP design and performance. The initial version of this database provides pollutant removal data and other performance measures on approximately 75 BMPs based on published studies and reports. These studies and reports were carefully selected from a comprehensive screening of virtually all available published literature on BMP performance, amounting to about 800 bibliographic references.

A significant objective of the database is to provide a design tool for local storm water designers and planners. The database has the capacity to report extensive detail about the design of BMPs, along with descriptive information about the adjacent watershed, hydrology and other geographic data.

As of early 1999, the initial version of the database is being tested, and a public release will be available in mid-1999. EPA and ASCE are continuing to develop the database and are encouraging organizations that have conducted BMP monitoring to submit their findings to the ASCE Database Clearinghouse for entry into the database. As new data are gathered, periodic updates will be made available to the public through use of the Internet.

Center for Watershed Protection National Pollutant Removal Performance Database

In 1997, the Center for Watershed Protection developed a database for the Chesapeake Research Consortium titled, "National Pollutant Removal Performance Database for Stormwater BMPs" (Brown and Schueler, 1997a). This database focuses on the pollutant removal efficiency of commonly used and innovative urban BMPs for storm water control. The database is derived from 123 research studies developed between 1977 and 1996.

All of the studies in the database utilized data collected with automated sampling equipment and had documented methods to compute pollutant removal efficiencies. More than three-quarters of the studies were based on four or more storm samples, while the remaining studies were either based on fewer than four storms or the sample size was not stated.

Literature Cited

- EPA reports including the Nationwide Urban Runoff Program (NURP), National Water Quality Inventory, Coastal Nonpoint Pollution Program Guidance, NPDES Rules, guidance documents and fact sheets.

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- Other Federal agency publications from U.S. Geological Survey and U.S. Department of Agriculture.
- Professional journals and manuals of practice such as those from ASCE and the Water Environment Federation
- Publications of research organizations such as the Center for Watershed Protection, Terrene Institute, Metropolitan Washington Council of Governments and the Watershed Management Institute
- State and local government BMP design manuals.

BMP Performance Data Developed for this Preliminary Study

EPA conducted field performance evaluations at three structural BMP sites during 1998. While these evaluations contribute to the literature on BMP performance, EPA also intended that the field testing would serve as an experimental framework for refining evaluation methodology. Three sites in the Washington, D.C. area were monitored: a constructed wetland, a peat-sand filter, and a regional wet pond. Data summaries for these monitoring activities appear in Chapter 5. Additional findings will be provided in a supplement to this report.

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3.0 Existing Storm Water Regulations and Permits

Congress added Section 402(p) to the Clean Water Act in 1987 to require implementation of a comprehensive approach for addressing storm water discharges in two phases. Section 402(p)(4) required EPA to develop permit application regulations under the National Pollutant Discharge Elimination System (NPDES), submission of NPDES permit applications, issuance of NPDES permits, and compliance with NPDES permit conditions. Section 402(p)(6) requires EPA to designate storm water discharges to be regulated (within the statutory definitions provided in section 402(p)(2)) and establish a comprehensive regulatory program, which may include performance standards, guidelines, guidance, and management practices and treatment requirements.

3.1 Phase I NPDES

EPA promulgated the first phase of NPDES storm water permit application regulations ("Phase I") on November 16, 1990 (US EPA, 1990). The provisions addressing MS4s cover those systems serving a population of 100,000 or more. This includes 173 cities, 47 counties and additional systems designated by EPA or states based on such system's interrelationship with or proximity to the aforementioned systems, such as state highway departments. A total of 260 permits, covering approximately 880 operators (local governments, state highway departments, etc.) have been identified as subject to Phase I permit application requirements. As of late 1998, approximately 228 such permits have been issued in final form.

The CWA requires that MS4 permits effectively prohibit non-storm water discharges into the storm sewers as well as reduce the discharge of pollutants to the maximum extent practicable (including management practices, control techniques and system, design and engineering methods, and other provisions appropriate for the control of such pollutants).

Phase I MS4 permittees were required to submit an application that included source identification information, precipitation data, existing data on the volume and quality of storm water discharges, a list of receiving water bodies and existing information on impacts on receiving waters, a field screening analysis for illicit connections and illegal dumping, and other information.

Following this submission, MS4 permittees were to gather and provide additional information including:

- discharge characterization data based on quantitative data from 5 to 10 representative locations in approved sampling plans; estimates of the annual pollutant load and event mean concentration of system discharges for selected conventional pollutants and heavy metals; a proposed schedule to provide estimates of seasonal pollutant loads; and the mean concentration for certain detected constituents in a representative storm event;

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- a proposed management program including descriptions of: structural and source control measures that are to be implemented to reduce pollutants in runoff from commercial and residential areas; a program to detect and remove illicit discharges; and a program to control pollutants in construction site runoff.

The Phase I rule also covers storm water discharges "associated with industrial activity." This includes facilities covered by effluent guidelines and other designated classes of industrial and commercial facilities, such as hazardous waste treatment, storage, or disposal; landfills; recycling; vehicle maintenance and equipment cleaning; sewage sludge handling; construction activity (sites with 5 or more acres of disturbed land); and facilities where materials are exposed to storm water. Permittees must prepare a storm water pollution prevention plan which describes pollution sources, measures and controls.

EPA and the states used several permit mechanisms for the many facilities receiving NPDES permits for the first time. EPA issued "baseline" general permits to cover a wide range of facilities with basic requirements, with the intent that more specific requirements would follow in subsequent permit cycles. Industry-specific or "group" permits were issued based on applications submitted by business associations, and other sites were issued individual permits.

The management and pollution prevention plans prepared by MS4s and industrial permittees vary in their level of detail and specificity regarding design and implementation of best management practices (BMPs). EPA and some states have issued guidance on preparation of these plans (US EPA, 1992d; US EPA, 1992e). The Agency has not conducted a nationwide review of these plans.

3.2 Phase II NPDES

EPA proposed the NPDES storm water regulations for the second phase of storm water discharge control (“Phase II”) on January 9, 1998 (US EPA, 1998c). EPA is required to promulgate the Phase II rule in 1999 under a separate consent decree.

The proposal designates two classes of facilities for automatic coverage on a nationwide basis under the NPDES program, (1) small municipal separate storm sewer systems located in urbanized areas (about 3,500 municipalities would be included in the program); and (2) construction activities (pollutants include sediments and erosion from these sites) that disturb equal to or greater than one and less than five acres of land (about 110,000 sites per year will be included in the program). Those facilities designated above would need to apply for NPDES storm water permits by 2002. EPA is anticipating that most permittees would be covered under general permits.

EPA is also proposing to conditionally exclude from the NPDES storm water program Phase I facilities that have "no exposure" of industrial activities, such as industrial products,

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processes, or raw materials, to storm water, thereby reducing application of the program to many industrial activities currently covered by the program that have no industrial storm water discharges.

Some facilities that EPA is proposing to cover under the Phase II rule are currently subject to state and/or local storm water management requirements.

3.3 Coastal Zone Act Requirements

Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 provides that States with approved coastal zone management programs must develop and submit coastal nonpoint pollution control programs to EPA and the National Oceanic and Atmospheric Administration (NOAA) for approval. Failure to submit an approvable program would result in a reduction of federal grants to such states under both the Coastal Zone Management Act and section 319 of the CWA.

State coastal nonpoint pollution control programs under CZARA are to include enforceable policies and mechanisms that ensure implementation of the management measures throughout the coastal management area. Section 6217(g)(5) defines management measures as "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives." The amendments provide for a technology-based approach based on technical and economic achievability under the rationale that neither States nor EPA have the money, time, or other resources to create and expeditiously implement a program that depends on establishing cause and effect linkages between particular land use activities and specific water quality problems. If this technology-based approach fails to achieve and maintain applicable water quality standards and to protect designated uses, sec. 6217(b)(3) requires additional management measures.

EPA issued *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* under sec. 6217(g) in January 1993 (US EPA, 1993a). The guidance identifies management measures for five major categories of nonpoint source pollution: agriculture; forestry; urban; marinas and recreational boating; and hydromodification. The management measures reflect the greatest degree of pollutant reduction that is economically achievable for each of the listed sources. These management measures provide reference standards for the states to use in developing or refining their coastal nonpoint programs. In general, the management measures were written to describe systems designed to reduce the generation of pollutants. A few management measures, however, contain quantitative standards that specify pollutant loading reductions. For example, the new development management measure, which is applicable to storm water runoff associated with construction in urban areas,

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requires (1) that by design or performance the average annual total suspended solid loadings be reduced by 80 percent and (2) to the extent practicable, that the pre-development peak runoff rate and average volume be maintained. The management measures approach was adopted to provide state officials with flexibility in selecting strategies and management systems and practices that are appropriate for regional or local conditions, provided that equivalent or higher levels of pollutant control are achieved.

Storm water discharges regulated under the existing NPDES program, such as discharges from municipal separate storm sewers serving a population of 100,000 or more and from construction activities that disturb 5 or more acres, do not need to be addressed in Coastal Nonpoint Pollution Control programs. However, potential new sources, such as urban development adjacent to or surrounding municipal systems serving a population of 100,000 or more, smaller urbanized areas, and construction sites that disturb less than 5 acres, that are identified in management measures under section 6217 guidance need to be addressed in Coastal Nonpoint Pollution Control Programs until such discharges are issued an NPDES permit. EPA and NOAA have worked and continue to work together in their activities to ensure that authorities between NPDES and CZARA do not overlap.

EPA and NOAA published *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance* (US EPA, 1993d), which addresses such issues as the basis and process for EPA/NOAA approval of State Coastal Nonpoint Pollution Control programs, how EPA and NOAA expect state programs to implement management measures in conformity with EPA guidance, and procedures for reviewing and modifying state coastal boundaries to meet program requirements. The document clarifies that states generally must implement management measures for each source category identified in the EPA guidance developed under section 6217(g). The document also sets quantitative performance standards for some measures. Coastal Nonpoint Pollution Control programs are not required to address sources that are clearly regulated under the NPDES program as point source discharges. Specifically, such programs would not need to address small municipal separate storm sewer systems and construction sites covered under NPDES storm water permits (both general and individual). The guidance also clarifies that regulatory and non-regulatory mechanisms may be used to meet the requirement for enforceable policies and mechanisms, provided that non-regulatory approaches are backed by enforceable state authority ensuring that the management measures will be implemented. Backup authority may include sunset provisions for incentive programs. For example, a state may provide additional incentives if too few owners or operators participate in a tax incentive program or develop mandatory requirements to achieve the necessary implementation of management measures.

3.4 Regional, State and Local Programs

In addition to the existing Federal storm water management programs, there are a variety of State, local and regional storm water management programs in existence. Many of these

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programs pre-date the Federal programs and may include BMP design or performance standards, site plan review and inspection programs, and technical assistance. A review of these programs is outside the scope of this report.

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4.0 Environmental Assessment

Waterways and receiving waters near urban and suburban areas are often adversely affected by urban storm water runoff. The degree and type of impact varies from location to location, but it is often significant relative to other sources of pollution and environmental degradation. Urban storm water runoff affects water quality, water quantity, habitat and biological resources, public health, and the aesthetic appearance of urban waterways. As reported in the National Water Quality Inventory 1996 Report to Congress (US EPA, 1998d), urban runoff was the leading source of pollutants causing water quality impairment related to human activities in ocean shoreline waters and the second leading cause in estuaries across the nation. Urban runoff was also a significant source of impairment in rivers and lakes. The percent of total impairment attributed to urban runoff is substantial. This impairment constitutes approximately 5,000 square miles of estuaries, 1.4 million acres of lakes, and 30,000 miles of rivers. Seven states also reported in the Inventory that urban runoff contributes to wetland degradation.

Adverse impacts on receiving waters associated with storm water discharges have been discussed by EPA (1995b) in terms of three general classes. These are:

- Short-term changes in water quality during and after storm events including temporary increases in the concentration of one or more pollutants, toxics or bacteria levels.

- Long-term water quality impacts caused by the cumulative effects associated with repeated storm water discharges from a number of sources.

- Physical impacts due to erosion, scour, and deposition associated with increased frequency and volume of runoff that alters aquatic habitat.

As described in the Terrene Institute's *Fundamentals of Urban Runoff Management* (Horner et al, 1994), pollutants associated with urban runoff potentially harmful to receiving waters fall into the categories listed below:

- Solids
- Oxygen-demanding substances
- Nitrogen and phosphorus
- Pathogens
- Petroleum hydrocarbons
- Metals
- Synthetic organics.

These pollutants degrade water quality in receiving waters near urban areas, and often contribute to the impairment of use and exceedences of criteria included in State water quality standards. The quantity of these pollutants per unit area delivered to receiving waters tends to increase with the degree of development in urban areas.

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While water quality impacts are often unobserved by the general public, other storm water impacts are more visible. Stream channel erosion and channel bank scour provide direct evidence of water quantity impacts caused by urban storm water. Urban runoff increases directly with imperviousness and the degree of watershed development. As urban areas grow, urban streams are forced to accommodate larger volumes of storm water runoff that recur on a more frequent basis. This leads to stream channel instability. The change in watershed hydrology associated with urban development also causes channel widening and scour, and the introduction of larger amounts of sediment to urban streams. Visible impacts include eroded and exposed stream banks, fallen trees, sedimentation, and recognizably turbid conditions. The increased frequency of flooding in urban areas also poses a threat to public safety and property.

Both water quality and water quantity impacts associated with urban storm water combine to impact aquatic and riparian habitat in urban streams. Higher levels of pollutants, increased flow velocities and erosion, alteration of riparian corridors, and sedimentation associated with storm water runoff negatively impact the integrity of aquatic ecosystems. These impacts include the degradation and loss of aquatic habitat, and reduction in the numbers and diversity of fish and macroinvertebrates.

Public health impacts are for the most part related to bacteria and disease causing organisms carried by urban storm water runoff into waters used for water supplies, fishing and recreation. Water supplies can potentially be contaminated by urban runoff, posing a public health threat. Bathers and others coming in contact with contaminated water at beaches and other recreational sites can become seriously ill. Beach closures caused by urban runoff have a negative impact on the quality of life, and can impede economic development as well. Similarly, the bacterial contamination of shellfish beds poses a public health threat to consumers, and shellfish bed closures negatively impact the fishing industry and local economies.

Aesthetic impacts in the form of debris and litter floating in urban waterways and concentrated on stream banks and beaches are quite visible to the general public. Storm water is a major source of floatables that include paper and plastic bags and packaging materials, bottles, cans, and wood. The presence of floatables and other debris in receiving waters during and following storm events reduces visual attractiveness of the waters and detracts from their recreational value. Nuisance algal conditions including surface scum and odor problems can also be attributed to urban storm water in many instances.

Based on available information and data, the following general statements can be made about urban storm water impacts.

- Impacts to water quality in terms of water column chemistry tend to be transient and elusive, particularly in rivers.
- Impacts to habitat and aquatic life are generally more profound, and are easier to see and quantify than changes in water column chemistry.

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- Impacts are typically complex because urban storm water is often one of several sources including municipal discharges and diffuse runoff from agricultural and rural areas that affect urban waterways.
- Impacts are often interrelated and cumulative. For example, both degraded water quality and increased water quantity join to impact habitat and biological resources.

The following sections describe the sources of urban storm water runoff, the pollutants contained in urban runoff and the impacts attributable to urban storm water discharges. Examples supported by field observation and data have been used extensively to show storm water impacts. The impacts described include water quality impacts, water quantity impacts, public health impacts, habitat impacts, and aesthetic impacts.

4.1 Overview of Storm Water Discharges

Storm water runoff from urbanized areas is generated from a number of sources including residential areas, commercial and industrial areas, roads, highways and bridges. Essentially, any surface which does not have the capability to pond and infiltrate water will produce runoff during storm events. When a land area is altered from a natural forested ecosystem to an urbanized land use consisting of rooftops, streets and parking lots, the hydrology of the system is significantly altered. Water which was previously ponded on the forest floor, infiltrated into the soil and converted to groundwater, utilized by plants and evaporated or transpired into the atmosphere is now converted directly into surface runoff. An important measure of the degree of urbanization in a watershed is the level of impervious surfaces. As the level of imperviousness increases in a watershed, more rainfall is converted to runoff. Figure 4-1 illustrates this transformation.

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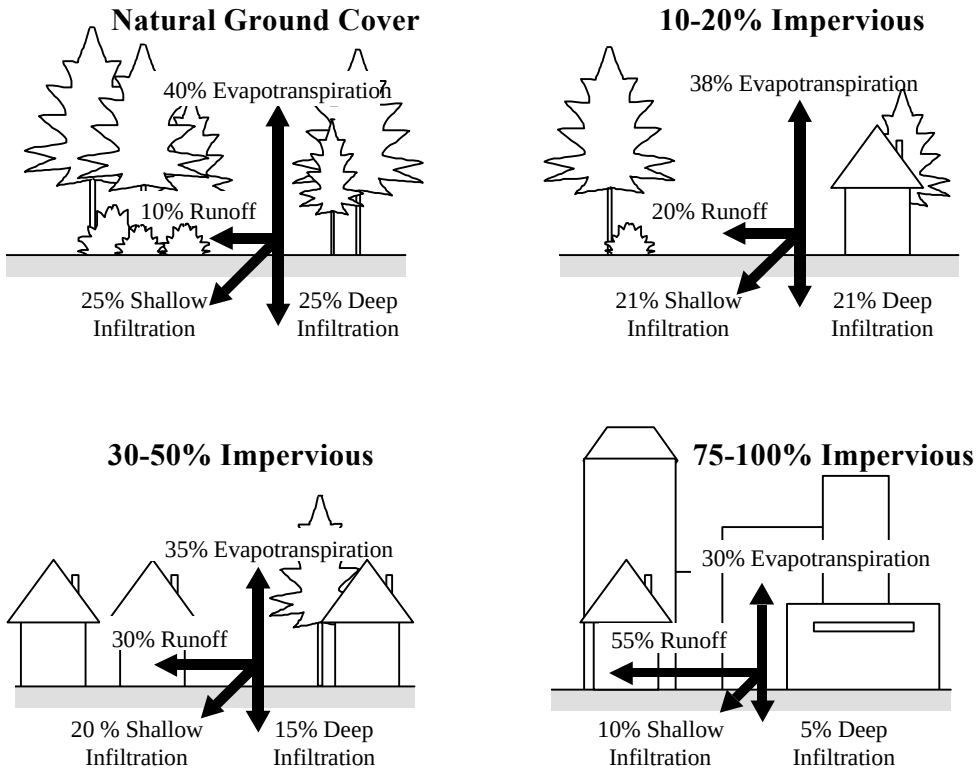
Figure 4-1. Effects of Imperviousness on Runoff and Infiltration



Source: Adapted from Arnold and Gibbons, 1996

The traditional means of managing storm water runoff in urban areas has been to construct a vast curb-and-gutter, catch basin, and storm drain network to transport this runoff volume quickly and efficiently away from the urbanized area and discharge the water to receiving streams. Two types of sewer systems are used to convey storm water runoff: separate storm sewers and combined sewers.

- *Separate storm sewer systems* convey only storm water runoff. Water conveyed in separate storm sewers is frequently discharged directly to receiving streams without receiving any intentional form of treatment. (In a municipality with a separate storm sewer system, sanitary sewer flows are conveyed in a distinct sanitary sewer system to municipal wastewater treatment plants.)

- In a *combined sewer system*, storm water runoff is combined with sanitary sewer flows for conveyance. Flows from combined sewers are treated by municipal wastewater

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treatment plants prior to discharge to receiving streams. During large rainfall events however, the volume of water conveyed in combined sewers can exceed the storage and treatment capacity of the wastewater treatment system. As a result, discharges of untreated storm water and sanitary wastewater directly to receiving streams can frequently occur in these systems. These types of discharges are known as combined sewer overflows (CSOs).

Historically, as urbanization occurred and storm drainage infrastructure systems were developed in this country, the primary concern was to limit nuisance and potentially damaging flooding due to the large volumes of storm water runoff that are generated. Little, if any, thought was given to the environmental impacts of such practices. As a result, streams that receive storm water runoff frequently cannot convey the large volumes of water generated during runoff events without significant degradation of the receiving stream. In addition to the problems associated with excess water volume, the levels of toxic or otherwise harmful pollutants in storm water runoff and CSOs can cause significant water quality problems in receiving streams.

In addition to point sources such as municipal separate storm sewers and combined sewer overflows, storm water runoff can enter receiving streams as a non-point source. Storm water runoff from a variety of sources such as parking lots, highways, open land, rangeland, residential areas and commercial areas can enter waterways directly as sheet flow or as a series of diffuse, discrete flows. Due to the diffuse nature of many storm water discharges, it is difficult to quantify the range of pollutant loadings to receiving streams that are attributable to storm water discharges. It is much easier, however, to measure the increased stream flows during rainfall events that occur in urbanized areas and to document impacts to streams that receive storm water runoff.

Awareness of the damaging effects storm water runoff is causing to the water quality and aquatic life of receiving streams is a relatively recent development. Storm water management traditionally was, and still is in many cases, a flood control rather than a quality control program. Local governments intending to improve the quality of their runoff-impacted streams are incorporating best management practices (BMPs) into their drainage programs. BMPs which reduce the volume of runoff discharged to receiving streams, such as minimizing directly connected impervious surfaces, providing on-site storage and infiltration and implementing stream buffers and restoring riparian cover along urban streams can help to prevent further degradation and even result in improvements of streams which receive storm water discharges. However, in many existing urbanized areas, the cost of infrastructure changes necessary to retrofit existing storm water drainage systems with structural BMPs--to provide for storm water quality as well as quantity control--can be prohibitively expensive. In these cases, non-structural BMPs can be implemented to reduce pollutant sources and to reduce the transfer of urban pollutants to runoff, before more expensive, structural controls are instituted.

The climate of a region can have a significant impact on the quantity and quality of storm water runoff. Factors such as the length of the antecedent dry periods between storms, the

average rainfall intensity, the storm duration and the amount of snowmelt present can have significant impacts on the characteristics of runoff from an area. In areas where there is a significant amount of atmospheric deposition of particulates, storm water runoff can contain high concentrations of suspended solids, metals and nutrients. Areas that have infrequent rainfall such as the southwest U.S. can have runoff with significant concentrations of pollutants, especially from “hot spots” such as roads, parking lots and industrial areas. These areas, which typically have high-intensity, short-duration rainfall events, can generate significant loadings of suspended solids in storm water runoff. Many specific geographic factors can influence the nature and constituents contained in storm water runoff. Factors such as the soil types, slopes, land use patterns and the amount of imperviousness of a watershed can greatly affect the quality and quantity of runoff that is produced from an area.

4.2 Pollutants in Urban Storm Water

Storm water runoff from urban areas can contain significant concentrations of harmful pollutants that can contribute to adverse water quality impacts in receiving streams. Effects can include such things as beach closures, shellfish bed closures, limits on fishing and limits on recreational contact in waters that receive storm water discharges. Contaminants enter storm water from a variety of sources in the urban landscape.

Urban storm water runoff has been the subject of intensive research since the inception of the Water Quality Act of 1965. There have been numerous studies conducted to characterize the nature of urban storm water runoff and the performance of storm water BMPs. Data sources include the "208 Studies," the area-wide waste treatment management plans conducted by states under section 208 of the 1972 CWA; EPA's Nationwide Urban Runoff Program (NURP); the U.S. Geological Survey (USGS) Urban Stormwater Database; and the Federal Highway Administration (FHWA) study of storm water runoff loadings from highways. In addition to these federal sources, there is a great deal of information in the technical literature, as well as data collected by states, counties and municipalities. A recent data source is storm water monitoring data collected by municipalities regulated by the Phase I NPDES storm water regulations. As part of the Phase I permit application, regulated municipalities were required to collect data from five representative sites during a minimum of three storm events.

The most comprehensive study of urban runoff was NURP, conducted by EPA between 1978 and 1983. NURP was conducted in order to examine the characteristics of urban runoff and similarities or differences between urban land uses, the extent to which urban runoff is a significant contributor to water quality problems nationwide, and the performance characteristics and effectiveness of management practices to control pollution loads from urban runoff (US EPA, 1983). Sampling was conducted for 28 NURP projects which included 81 specific sites and more than 2,300 separate storm events. NURP focused on the following ten constituents:

- Total Suspended Solids (TSS)

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- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Phosphorus (TP)
- Soluble Phosphorus (SP)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate + Nitrite (N)
- Total Copper (Cu)
- Total Lead (Pb)
- Total Zinc (Zn).

NURP examined both the soluble and the particulate fraction of pollutants, since the water quality impacts can depend greatly on the form that the contaminant is present. NURP also examined coliform bacteria and priority pollutants at a subset of sites. Median event mean concentrations (EMCs) for the ten general NURP pollutants for various urban land use categories are presented in Table 4-1.

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Table 4-1. Median Event Mean Concentrations for Urban Land Uses

Pollutant	Units	Residential		Mixed		Commercial		Open/ Non-Urban	
		Median	COV	Median	COV	Median	COV	Median	COV
BOD	mg/l	10	0.41	7.8	0.52	9.3	0.31	--	--
COD	mg/l	73	0.55	65	0.58	57	0.39	40	0.78
TSS	mg/l	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	µg/l	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper	µg/l	33	0.99	27	1.32	29	0.81	--	--
Total Zinc	µg/l	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen	µg/l	1900	0.73	1288	0.50	1179	0.43	965	1.00
Nitrate + Nitrite	µg/l	736	0.83	558	0.67	572	0.48	543	0.91
Total Phosphorus	µg/l	383	0.69	263	0.75	201	0.67	121	1.66
Soluble Phosphorus	µg/l	143	0.46	56	0.75	80	0.71	26	2.11

COV: Coefficient of variation
Source: Nationwide Urban Runoff Program (US EPA 1983)

Results from NURP indicate that there is not a significant difference in pollutant concentrations in runoff from different urban land use categories. There is a significant difference, however, in pollutant concentrations in runoff from urban sources than that produced from non-urban areas.

The pollutants that are found in urban storm water runoff originate from a variety of sources. The major sources include contaminants from residential and commercial areas, industrial activities, construction, streets and parking lots, and atmospheric deposition. Contaminants commonly found in storm water runoff and their likely sources are summarized in Table 4-2.

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Table 4-2. Sources of Contaminants in Urban Storm Water Runoff

Contaminant	Contaminant Sources
Sediment and Floatables	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/ Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

The concentrations of pollutants found in urban runoff are directly related to degree of development within the watershed. This trend is shown in Table 4-3, a compilation of typical pollutant loadings from different urban land uses.

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Table 4-3. Typical Pollutant Loadings from Runoff by Urban Land Use (lbs/acre-yr)

Land Use	TSS	TP	TKN	NH_3-N	NO_2+NO_3-N	BOD	COD	Pb	Zn	Cu
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4
Parking Lot	400	0.7	5.1	2	2.9	47	270	0.8	0.8	0.04
HDR	420	1	4.2	0.8	2	27	170	0.8	0.7	0.03
MDR	190	0.5	2.5	0.5	1.4	13	72	0.2	0.2	0.14
LDR	10	0.04	0.03	0.02	0.1	NA	NA	0.01	0.04	0.01
Freeway	880	0.9	7.9	1.5	4.2	NA	NA	4.5	2.1	0.37
Industrial	860	1.3	3.8	0.2	1.3	NA	NA	2.4	7.3	0.5
Park	3	0.03	1.5	NA	0.3	NA	2	0	NA	NA
Construction	6000	80	NA	NA	NA	NA	NA	NA	NA	NA

HDR: High Density Residential, MDR: Medium Density Residential, LDR: Low Density Residential
NA: Not available; insufficient data to characterize loadings
Source: Horner et al, 1994

As indicated in Table 4-3, urban storm water runoff can contain significant concentrations of solids, nutrients, organics and metals. A comparison of the concentration of water quality parameters in urban runoff with the concentrations in domestic wastewater is shown in Table 4-4.

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Table 4-4. Comparison of Water Quality Parameters in Urban Runoff with Domestic Wastewater (mg/l)

Constituent	Urban Runoff		Domestic Wastewater		
	Separate Sewers		Before Treatment		After Secondary
	Range	Typical	Range	Typical	Typical
COD	200-275	75	250-1,000	500	80
TSS	20-2,890	150	100-350	200	20
Total P	0.02-4.30	0.36	4-15	8	2
Total N	0.4-20.0	2	20-85	40	30
Lead	0.01-1.20	0.18	0.02-0.94	0.10	0.05
Copper	0.01-0.40	0.05	0.03-1.19	0.22	0.03
Zinc	0.01-2.90	0.02	0.02-7.68	0.28	0.08
Fecal Coliform per 100 ml	400-50,000		10^6-10^8		200

Source: Bastian, 1997

As indicated in Table 4-4, the concentrations of select water quality parameters in urban runoff is comparable to that found in untreated domestic wastewater. When untreated urban runoff is discharged directly to receiving streams, the loadings of pollutants can be much higher than the loadings attributable to treated domestic wastewater.

The following paragraphs summarize the major pollutants which are commonly found in urban storm water runoff.

4.2.1 Solids, Sediment and Floatables

Solids are one of the most common contaminants found in urban storm water. Solids originate from many sources including the erosion of pervious surfaces and dust, litter and other particles deposited on impervious surfaces from human activities and the atmosphere. Stream bank erosion and erosion at construction sites are also major sources of solids. Solids contribute to many water quality, habitat and aesthetic problems in urban waterways. Elevated levels of solids increase turbidity, reduce the penetration of light at depth within the water column, and limit the growth of desirable aquatic plants. Solids that settle out as bottom deposits contribute to sedimentation and can alter and eventually destroy habitat for fish and bottom-dwelling organisms

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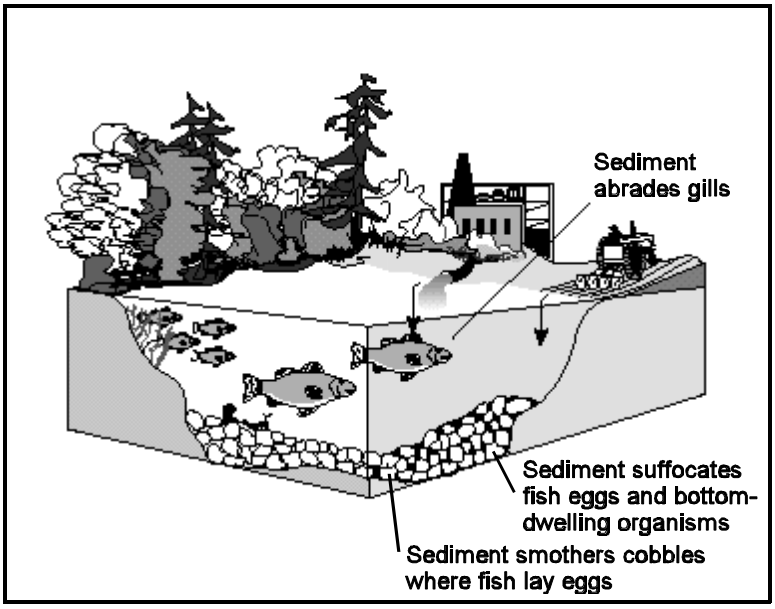
(see Figure 4-2). Solids also provide a medium for the accumulation, transport and storage of other pollutants including nutrients and metals. Sediment bound pollutants often have a long history of interaction with the water column through cycles of deposition, re-suspension, and re-deposition. Impaired navigation due to sedimentation represents another impact affecting recreation and commerce. The relative contribution of TSS in urban storm water from different land uses is presented in Table 4-3. As shown in Table 4-4, the typical concentration of TSS in urban runoff is substantially higher than that in treated wastewater (Bastian, 1997). Construction produces the highest loading of TSS over other urban land use categories evaluated.

Figure 4-2. Effects of Siltation on Rivers and Streams



Source: US EPA, 1998d.

4.2.2 Oxygen-Demanding Substances and Dissolved Oxygen

The oxygen-demanding substances found in urban storm water can be measured by Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Organic Carbon (TOC). Maintaining appropriate levels of dissolved oxygen in receiving waters is one of the most important considerations for the protection of fish and aquatic life. The amount of dissolved oxygen in urban runoff is typically 5.0 mg/l or greater, and it rarely poses a direct threat to in-stream conditions. As shown in Table 4-4, the level of COD associated with urban runoff is comparable to treated wastewater. The direct impact of urban storm water runoff on dissolved oxygen conditions in receiving waters is not thought to be substantial. However, the secondary impacts on the dissolved oxygen balance in receiving waters due to nutrient enrichment, eutrophication, and resulting sediment oxygen demand may be important.

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4.2.3 Nitrogen and Phosphorus

Nitrogen and phosphorus are the principal nutrients of concern in urban storm water. The major sources of nutrients in urban storm water are urban landscape runoff (fertilizers, detergents, plant debris), atmospheric deposition, and improperly functioning septic systems (Terrene Institute, 1996). Animal waste can also be an important source. There are a number of parameters used to measure the various forms of nitrogen and phosphorus found in runoff. Ammonia (NH_3) nitrogen is the nitrogen form that is usually the most readily toxic to aquatic life. Nitrate (NO_3) and nitrite (NO_2) are the inorganic fractions of nitrogen. Very little nitrite is usually found in storm water. Total Kjeldahl nitrogen (TKN) measures the organic and ammonia nitrogen forms. By subtraction, the organic fraction can be determined. Total phosphorus measures the total amount of phosphorus in both the organic and inorganic forms. Ortho-phosphate measures phosphorus that is most immediately biologically available. Most of the soluble phosphorus in storm water is usually present in the ortho-phosphate form.

The degree to which nitrogen and phosphorus are present in a river, lake or estuary can determine the trophic status and amount of algal biomass produced. Excess nutrients tend to increase primary biological productivity. The major impact associated with nutrient over-enrichment is excessive growth of algae that leads to nuisance algal blooms and eutrophic conditions. A secondary impact is the residual negative effect of decomposing algae in the form of sediment oxygen demand that depletes dissolved oxygen concentrations, particularly in bottom waters. The NURP study reported that nutrient levels in urban runoff appear not to be high in comparison with other possible discharges. However, more recent studies and programs have recognized that the amount of nitrogen and phosphorus present in urban storm water can be substantial, and becomes increasingly important as other point sources of nutrients are brought under control. Walker (1987) reported that "cause-effect relationships linking urban development to lake and reservoir eutrophication are well established," and that "urban watersheds typically export 5 to 20 times as much phosphorus per unit per year, as compared to undeveloped watersheds in a given region." The nutrient loadings from different urban and suburban land uses are presented in Table 4-3. As shown in Table 4-4, the total phosphorus and total nitrogen concentrations in urban runoff are substantially less than treated wastewater concentrations, but storm water volumes can be greater during wet weather events.

4.2.4 Pathogens

Pathogens are disease-producing organisms that present a potential public health threat when they are present in contact waters. Since storm water runoff typically does not come into contact with domestic wastewaters, and direct exposure to runoff is usually limited, there is generally little threat of pathogens in storm water runoff causing a public health risk. However, where runoff is discharged to recreational waters such as beaches and lakes, or where runoff comes into contact with shellfish beds, there is a potential public health risk associated with pathogen contamination.

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There are a number of indicator organisms that have been used to evaluate the presence of harmful pathogens in storm water runoff. Several strains of bacteria are present naturally in the soil and can be transported by runoff. In addition, BMPs with standing water can be breeding grounds for naturally occurring bacteria. Therefore, interpretation of bacteriological sampling results can be difficult. Nevertheless, indicator organisms can provide useful insight into the public health risk associated with runoff. Fecal coliform has been widely used as an indicator for the presence of harmful pathogens in domestic wastewaters, and therefore studies characterizing storm water runoff have frequently used this indicator as well. Other bacterial indicators that have been used to evaluate the presence of harmful pathogens in storm water runoff include *Escherichia coli, streptococci* and *enterococci*. The presence of enteric viruses has also been evaluated in storm water runoff, as well as protozoans such as *Giardia lamblia* and *cryptosporidium*.

Fecal coliform concentrations in urban runoff were evaluated by NURP at 17 sites for 156 storm events. NURP reported that coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in many surface waters, even those providing high degrees of dilution. Concentrations of fecal coliform found by NURP exhibited a large degree of variability, and did not indicate any distinctions based on land use. Data from different sites did show a dramatic seasonal effect on coliform concentrations. Coliform counts in urban runoff during warmer periods of the year were found to be approximately 20 times greater that those found during colder periods. Based on this data, NURP concluded that coliform sources unrelated to those traditionally associated with human health risk may be significant.

The Terrene Institute (1996) reported that the primary sources of pathogens in urban storm water drains are animal wastes (including pets and birds), failing septic systems, illicit sewage connections, and boats and marinas. Field et al (1993) reported pathogens levels from storm water runoff and urban streams as shown in Table 4-5. Pathogens enumerated included bacteria (total and fecal coliform, fecal streptococci, enterococci, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Salmonella*) and enteroviruses (poliovirus, Coxsackie virus, and Echovirus).

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Table 4-5. Densities of Selected Pathogens and Indicator Microorganisms in Storm Water in Baltimore, Maryland Area

Geometric Mean Densities								
Sampling Station	Entero-virus	*Salmon sp.*	*Pseudomon. aeruginosa*	*Staph. aureus*	Total Coliform	Fecal Coliform	Fecal Strep.	*Enterococci*
	PFU/ 10 L	MPN/ 10 L	MPN/ 10 L	MPN/ 100 mL	MPN/ 100 mL (10^4)	MPN/ 100 mL (10^3)	No./ 100 mL (10^4)	No./100 mL (10^4)
Bush St.	6.9	30	2000	120	38	83	56	12
Northwood	170	5.7	590	12	3.8	6.9	5	2.1

PFU: Plaque-forming units
MPN: Most Probable Number
Source: Field et al, 1993

As shown earlier in Table 4-4, typical fecal coliform concentrations for separate urban storm sewers varied widely, ranging between 400-50,000 mpn/100 ml. An example of fecal coliform concentrations measured in sheet flow associated with different impervious surfaces is presented in Table 4-6. The broad range in concentrations illustrates the highly variable nature of fecal coliform concentrations in storm water.

Table 4-6. Fecal Coliform Concentrations Collected in Sheetflow from Urban Land Uses

Land Use	**Median (MPN/100 ml)**	**Range (MPN/100 ml)**
Unpaved driveways and storage areas	26	0.02-300
Roof runoff	1.6	0.56-2.6
Sidewalks	55	19-90
Paved parking and driveways	2.8	0.03-66
Paved roads	19	1.8-430

MPN: Most Probable Number
Source: Field et al, 1993.

4.2.5 Petroleum Hydrocarbons

Petroleum hydrocarbons include oil and grease; the "BTEX" compounds: benzene, toluene, ethyl benzene, and xylene; and a variety of polynuclear aromatic hydrocarbons (PAHs). Sources of petroleum hydrocarbons include parking lots and roadways, leaking storage tanks,

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auto emissions, and improper disposal of waste oil. Petroleum hydrocarbons are typically concentrated along transportation corridors.

Petroleum hydrocarbons are known for their acute toxicity at low concentrations (Schueler, 1987). A study by Shepp (1996) measured the petroleum hydrocarbon concentrations in urban runoff from a variety of impervious areas in the District of Columbia and suburban Maryland. The amount of car traffic affects the concentration of hydrocarbons in runoff, with median concentrations ranging from 0.7 to 6.6 mg/l. Concentrations at these levels exceed the maximum concentrations recommended for the protection of drinking water supplies and fisheries protection. As pointed out by Shepp, the maximum concentration of petroleum hydrocarbons for protection of fisheries is 0.01 to 0.1 mg/l.

4.2.6 Metals

The primary sources of metals in urban storm water are industry and automobiles. Atmospheric deposition (both wet and dry) can make a substantial contribution in some parts of the country. A major finding of the NURP study is as follows:

> Heavy metals (especially copper, lead and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff. End-of-pipe concentrations exceed EPA ambient water quality criteria and drinking water standards in many instances. Some of the metals are present often enough and in high enough concentrations to be potential threats to beneficial uses.

Metals in urban storm water have the potential to impact water supply and cause acute or chronic toxic impacts for aquatic life. Typical pollutant loading rates and urban runoff concentrations for lead, zinc and copper are presented in Tables 4-3 and 4-4. The frequency with which metals were detected as priority pollutants in the NURP study is presented in Table 4-7.

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Table 4-7. Most Frequently Detected Priority Pollutants in Nationwide Urban Runoff Program Samples (1978-83)

Inorganics	Organics
Detected in 75% or more	
94% Lead 94% Zinc 91% Copper	None
Detected in 50-74%	
58% Chromium 52% Arsenic	None
Detected in 20-49%	
48% Cadmium 43% Nickel 23% Cyanides	22% Bis(2-ethylhexyl)phthalate 20% α-Hexachloro-cyclohexane
Detected in 10-19%	
13% Antimony 12% Beryllium 11% Selenium	19% α-Endosulfan 19% Pentachlorophenol* 17% Chlordane* 15% Lindane* 15% Pyrene** 14% Phenol 12% Phenanthrene** 11% Dichloromethane 10% 4-Nitrophenol 10% Chrysene** 10% Fluoranthene**

* Chlorinated hydrocarbon
** Polynuclear aromatic hydrocarbon
Source: US EPA, 1983

A major study of the quality of Wisconsin storm water (Bannerman et al, 1996) found that the probability of event mean concentrations for some metals (particularly copper and zinc) exceeding Wisconsin water quality criteria for cold water fish communities was high (Table 4-8). A study in Coyote Creek, California reported lead and zinc levels from urban runoff of 100 to 500 times the concentration in the ambient water column (Pitt, 1995).

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Table 4-8. Probability of Event Mean Concentration of Constituents in Wisconsin Storm Water Exceeding Wisconsin Surface Water and Ground Water Quality Standards: Metals

Constituent	Probability of exceeding acute toxicity criteria for cold water fish communities (percent)	
	Storm Sewers	Streams
Cadmium, total recoverable	11	0
Copper, total recoverable	87	9
Lead, total recoverable	18	0
Silver, total recoverable	20	-
Zinc, total recoverable	91	7

Source: Bannerman et al, 1996.

4.2.7 Synthetic Organic Compounds

Synthetic organic compounds include a variety of manufactured compounds covering pesticides, solvents and household and industrial chemicals. The frequency that synthetic inorganics were detected as priority pollutants in the NURP study is presented in Table 4-7. In general, organic contaminants were found in less than 20 percent of samples. Nevertheless, synthetic organics do represent a threat. Even low concentrations of some synthetic organics over a long period of time have the potential to pose a severe health risks to humans and aquatic life though direct ingestion or bioaccumulation in the food chain. There is also some evidence that pesticides are found in higher concentrations in urban areas than agricultural areas (US EPA, 1995b). Further, Bannerman et al found that the probability for storm water and urban stream samples to exceed human cancer criteria for public water supply, and toxicity criteria for coldwater fish communities equaled or approached 100 percent for 10 compounds (Table 4-9).

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Table 4-9. Probability of Event Mean Concentration of Constituents in Wisconsin Storm Water Exceeding Wisconsin Surface Water and Ground Water Quality Standards: Synthetic Organic Compounds

Constituent (Human cancer criteria for public water supply/ coldwater fish communities)	**Probability of exceedance (percent)**	
	Storm Sewers	**Streams**
Benzo[a]anthracene	98	100
Benzo[a]pyrene	99	100
Benzo[b]fluoranthene	100	100
Benzo[ghi]perylene	99	100
Benzo[k]fluoranthene	99	99
Chrysene	100	100
Indeno pyrene	100	99
Phenanthrene	100	99
Pyrene	100	100
DDT	98	100

Source: Bannerman et al, 1996

4.2.8 Temperature

Water temperature is an important measure of water quality. As described by Malina (1996), "the temperature of water affects some of the important physical properties and characteristics of water, such as… specific conductivity and conductance, salinity, and the solubility of dissolved gases (e.g., oxygen and carbon dioxide)." Specifically, water holds less oxygen as it becomes warmer, resulting in less oxygen being available for respiration by aquatic organisms. Furthermore, elevated temperatures increase the metabolism, respiration, and oxygen demand of fish and other aquatic life, approximately doubling the respiration for a 10°C (18°F) temperature rise; hence the demand for oxygen is increased under conditions where supply is lowered (California SWRCB, 1963).

Certain species of fish, such as salmon and trout, are particularly sensitive and require relatively low water temperatures. Even lower temperatures are required for spawning and egg

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hatching (US EPA, 1976). If the temperature of a stream reach is raised by 5 to 10°C (9 to 18°F), it is probable that such cold-water game fish will avoid this reach and that they will be replaced by "rougher," more tolerant fish (California SWRCB, 1963). Thus, even without direct mortality, the character of the fish life will change. Sudden changes in temperature directly stress the aquatic ecosystem. The states have adopted varying criteria to protect fisheries from such stresses. Typically, states limit in-stream temperature rises above natural ambient temperatures to 2.8°C (5°F). Allowable temperature rises in streams that support cold water fisheries may be lower, with some states adopting values as low as 1°C (1.8°F) and 0.6°C (1°F) (US EPA, 1988).

The temperature of urban waters is often affected directly by urban runoff. Urban runoff can be heated as it flows over rooftops, parking lots and roadways. When it reaches urban waterways it can cause a temporary fluctuation in the in-stream water temperature. Other factors that tend to increase summer water temperature in urban waters include the removal of vegetation from stream banks, reduced ground water baseflow, and discharges from storm water facilities with elevated water temperature. Frequent fluctuations in stream temperature stress the aquatic ecosystem, and make it difficult for temperature-sensitive species to survive.

Galli (1990a) undertook a major study of thermal impacts associated with urbanization and storm water management in Maryland. Temperature observations were taken at stream stations representing different levels of development, with impervious cover ranging from 1 percent to 60 percent. Results were compared with Maryland Class III standards for natural trout waters (68 °F) and Class IV standards for recreational trout waters (75 °F). As shown in Figure 4-3, streams in developed watersheds (Lower Whiteoak and Tanglewood Stations) have significantly higher spring and summer temperatures than streams in less developed watersheds. Galli also found that "imperviousness together with local meteorological conditions had the largest influence on urban stream temperatures." As shown in Figure 4-4, the rate of increase in baseflow water temperature in this study was determined to be 0.14 °F for each one percent increase in watershed imperviousness.

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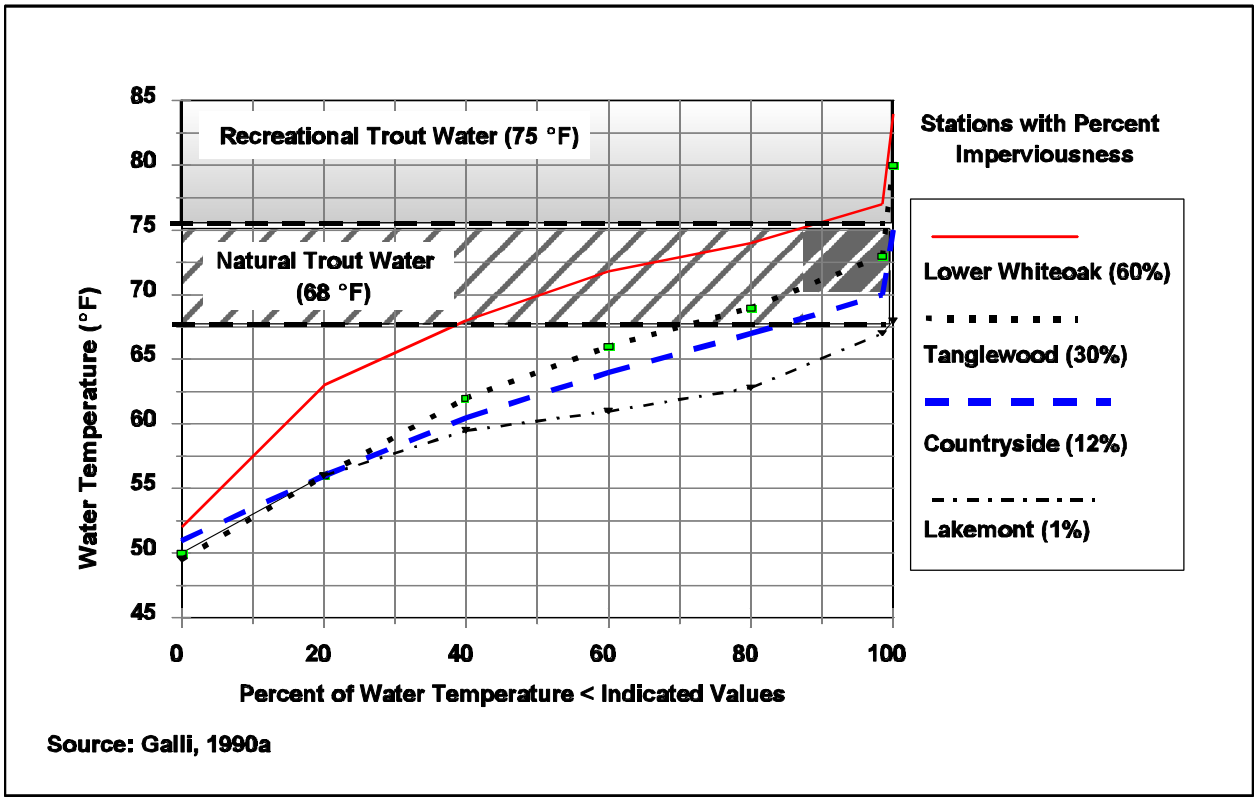
Figure 4-3. Relationship Between Increasing Imperviousness and Urban Stream Temperature



Source: Galli, 1990a

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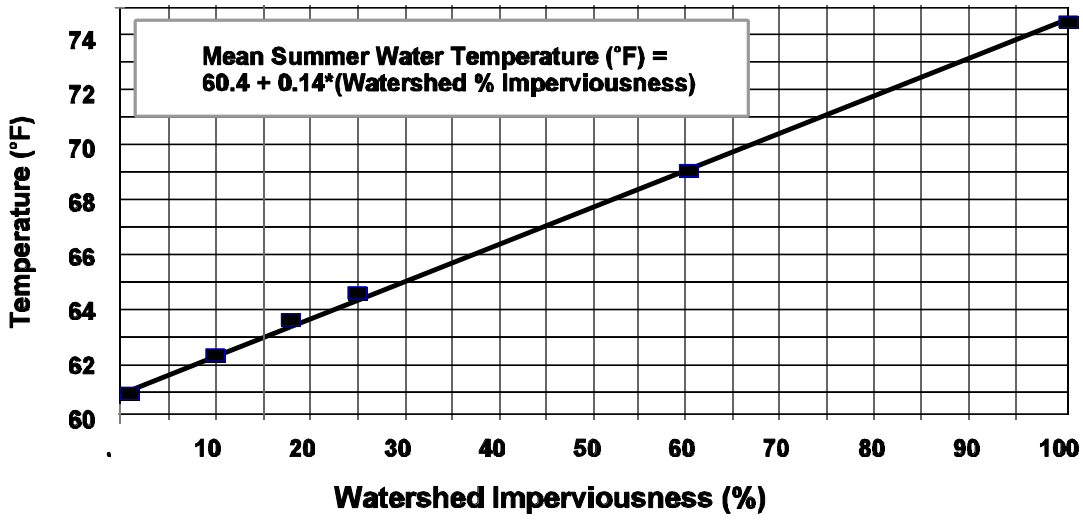
Figure 4-4. Relationship Between Watershed Imperviousness and Baseflow Water Temperature



Source: Galli, 1990a

4.2.9 pH

As pointed out by Novotny and Olem (1994), "most aquatic biota are sensitive to pH variations," and "fish kills and reduction and change of other species result when the pH is altered outside their tolerance limits." Most pH impacts in urban waters are caused by runoff of rainwater with low pH levels (acid precipitation). In fact, urban areas tend to have more acidic rainfall than less developed areas. Some buffering of low pH rainwater occurs during contact with buildings, parking lots, roads and collection systems, and during overland flow. This is often very site specific. The alkalinity and thus the capacity of receiving waters to neutralize acidic storm water can also be important, and again is very site specific. Examples of pH impacts on fish populations are difficult to identify due to the cumulative, overlapping impacts from other factors. However, it is thought that the acidification problem in both the United States and Canada grows in magnitude when "episodic acidification" (brief periods of low pH levels from snow melt or heavy downpours) is taken into account (US EPA, 1992a). The spring snow melt can coincide with fish spawning periods.

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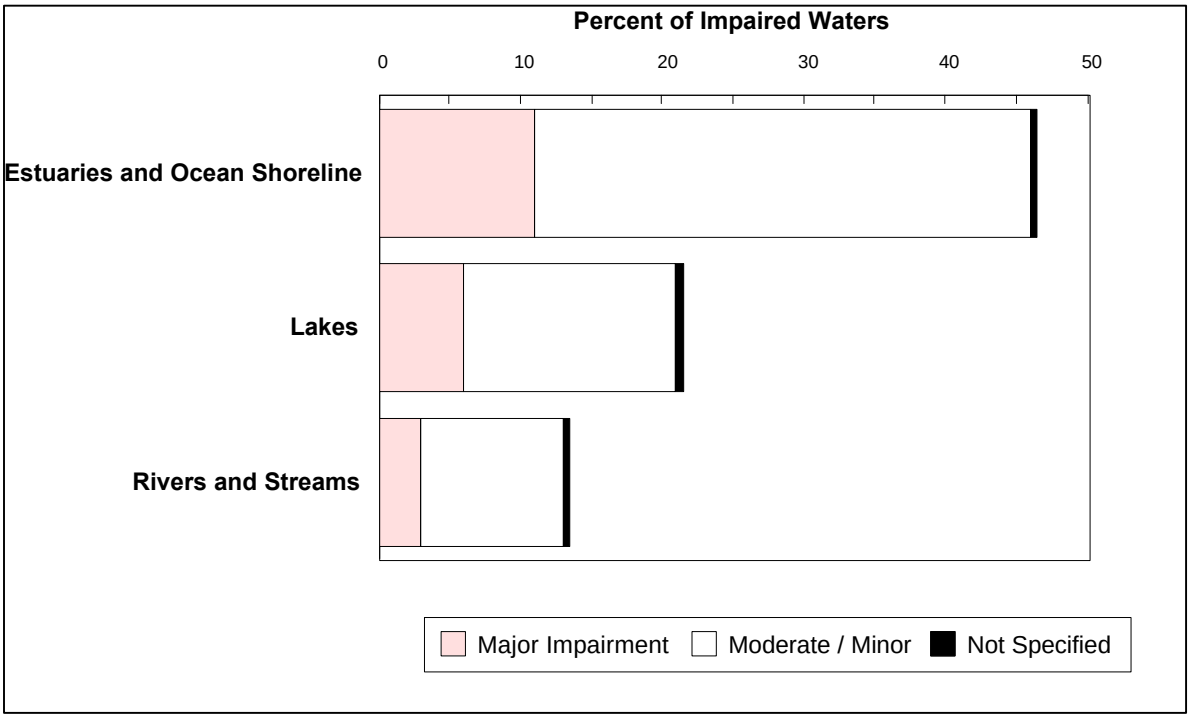
4.3 Reported Impacts of Urban Storm Water

Urban runoff, which includes runoff from impervious surfaces such as streets, parking lots, buildings, lawns and other paved areas is one of the leading causes of water quality impairment in the United States. Based on the 1996 state Water Quality Inventory reports, siltation (sediment discharged from urban runoff, as well as construction sites, agriculture, mining and forests) is the leading cause of impaired water quality in rivers and streams. In the portion of the inventory identifying sources, urban runoff was listed as the leading source of pollutants causing water quality impairment related to human activities in ocean shoreline waters and the second leading cause in estuaries across the nation. Urban runoff was also a significant source of impairment in rivers and lakes. Urban runoff accounts for 47 percent of impaired miles of surveyed ocean shoreline, 46 percent of the impaired square miles of surveyed estuaries, 22 percent of the impaired acres of surveyed lakes and 14 percent of the impaired miles of surveyed rivers. Figure 4-5 illustrates the level of impairment attributable to urban storm water runoff based on states' Water Quality Inventory assessment reports.

Figure 4-5. Proportions of Impaired Water Bodies Attributed to Urban Runoff



Source: EPA, 1998d.

4.3.1 Flow Impacts

The volume and flow rate of storm water discharges can have significant impacts on receiving streams. In many cases, the impacts on receiving streams due to high storm water flow

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rates or volumes can be more significant than those attributable to the contaminants found in storm water discharges. While studies linking increased storm water flows due to urbanization to stream degradation are generally lacking in quantitative data, there are a number of studies that support this hypothesis. EPA summarized studies which contain documented evidence of impacts on steams due to urbanization (US EPA, 1997a). Impacts of urbanization and increased storm water discharges to receiving streams documented in this evaluation include:

- Increase in the number of bankfull events and increased peak flow rates
- Sedimentation and increased sediment transport
- Frequent flooding
- Stream bed scouring and habitat degradation
- Shoreline erosion and stream bank widening
- Decreased baseflow
- Loss of fish populations and loss of sensitive aquatic species
- Aesthetic degradation
- Changes in stream morphology
- Increased temperatures.

The amount of runoff generated within a watershed increases steadily with development. The presence of impervious areas such as roofs, parking lots and highways limits the volume of rain water infiltrated into the soil, and increases the amount of runoff generated. Urbanized areas also tend to have reduced storage capacities for runoff because of regrading, paving, and the removal of vegetative cover. Decreases in infiltration and evapotranspiration and an increase in runoff are the result of urbanization, with runoff volume linked to the percent of impervious area. The relationship between runoff coefficient and percent impervious area is illustrated in Figure 4-6.

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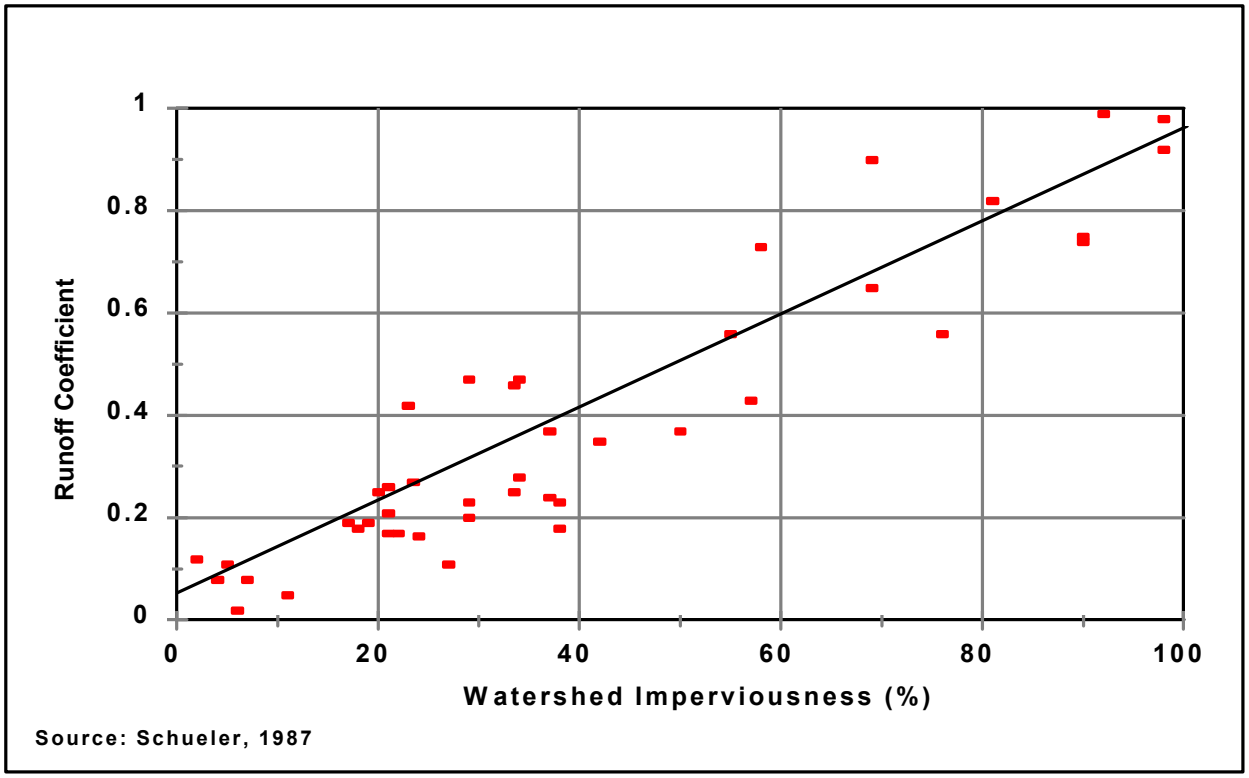
Figure 4-6. Relationship of Watershed Imperviousness to Runoff Coefficient Levels



As shown in Table 4-10, the physical impacts to streams associated with increased imperviousness are substantial (US EPA, 1997a).

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Table 4-10. Impacts from Increases in Impervious Surfaces

Increased Imperviousness Leads to:	Resulting Impacts				
	Flooding	Habitat loss	Erosion	Channel Widening	Stream bed Alteration
Increased Volume	✔	✔	✔	✔	✔
Increased Peak Flow	✔	✔	✔	✔	✔
Increased Peak Duration	✔	✔	✔	✔	✔
Increased Stream Temp.		✔			
Decreased Base Flow		✔			
Changes in Sediment Loading	✔	✔	✔	✔	✔

Source: EPA, 1997

The Delaware Department of Natural Resources and Environmental Control also identified a list of impacts on physical stream habitat attributed to urban storm water (DE DNREC, 1997). This list is as follows:

- Accelerated bank erosion
- Accelerated bank undercutting
- Increased siltation (burial of stable habitats)
- Elimination of meanders (channelization)
- Channel widening
- Reduced depth
- Reduced baseflow
- Loss of shade
- Increased temperature.

Specific impacts in the areas of flooding, stream bank erosion, and ground water recharge are described in the following subsections.

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Flooding

Urbanization increases the frequency and severity of flooding due to increased runoff. Because of the decreased availability of pervious, permeable surfaces, and the related decrease in storage capacity, smaller more frequently occurring storms can create flooding problems. Hydrographs in urban streams peak higher and faster than streams in undeveloped areas. A comparison of estimated runoff volume and peak discharge for developed and undeveloped areas is presented in Table 4-11. As shown, both runoff volume and peak discharge are substantially increased under developed conditions.

Table 4-11. Comparison of Estimated Runoff Volume and Peak Discharge for Developed and Undeveloped Areas

Storm Frequency (years)	Undeveloped Conditions (Woods in good condition)		Developed Conditions (Half-Acre Residential)	
	Estimated Runoff (in)	Estimated Peak Discharge (cfs)	Estimated Runoff (in)	Estimated Peak Discharge (cfs)
2	0.14	1.00	0.60	11.6
10	0.52	5.60	1.33	27.4
100	1.40	19.7	2.64	58.6

Source: Horner et al, 1994

The effects of urbanization on stream shape and the flood plain are illustrated in Figure 4-7. Increased peak discharge raises the flood plain level, flooding areas which were previously not at risk.

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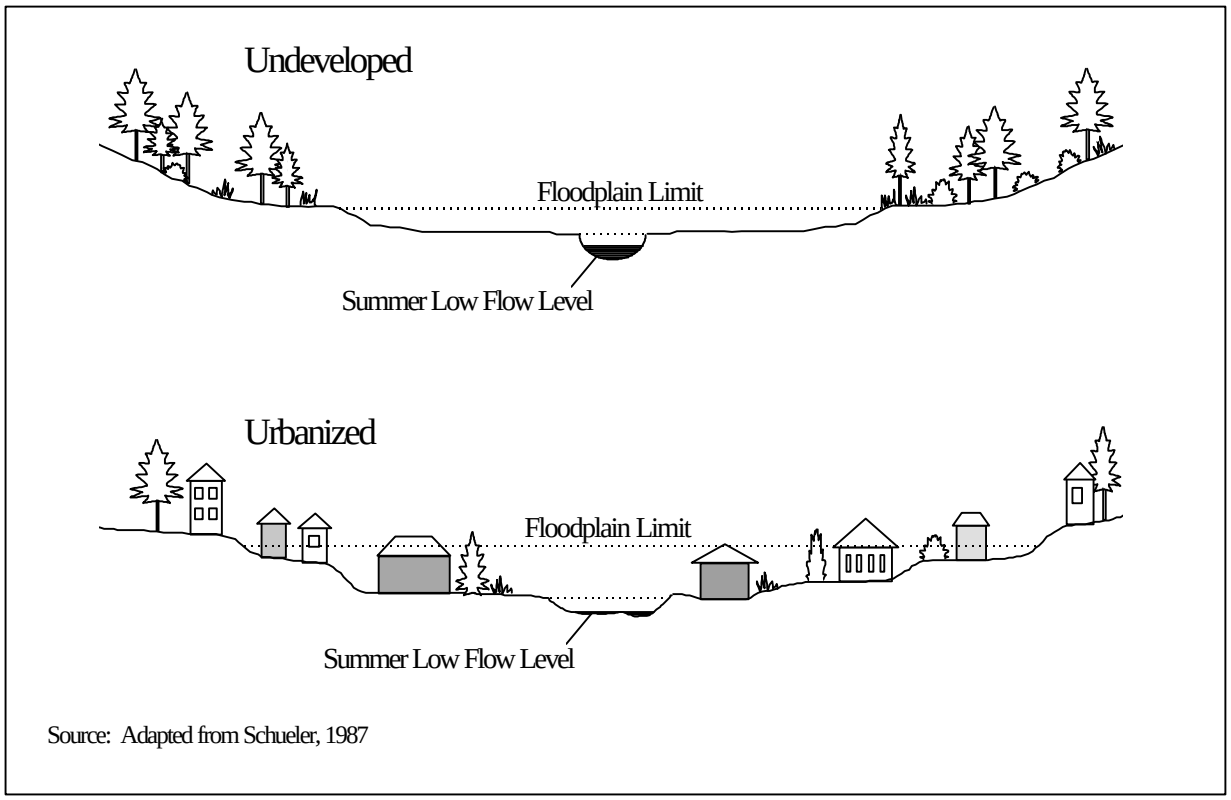
Figure 4-7. Effect of Urbanization on Stream Slope and Flooding



A comparison of hydrographs from an urbanized stream (Lincoln Creek) and a non-urbanized stream (Jackson Creek) in Wisconsin are presented in Figure 4-8 (Masterson and Bannerman, 1994). As illustrated, the hydrograph for the urbanized stream exhibits a much higher peak flow rate that would correspond to a higher flood level.

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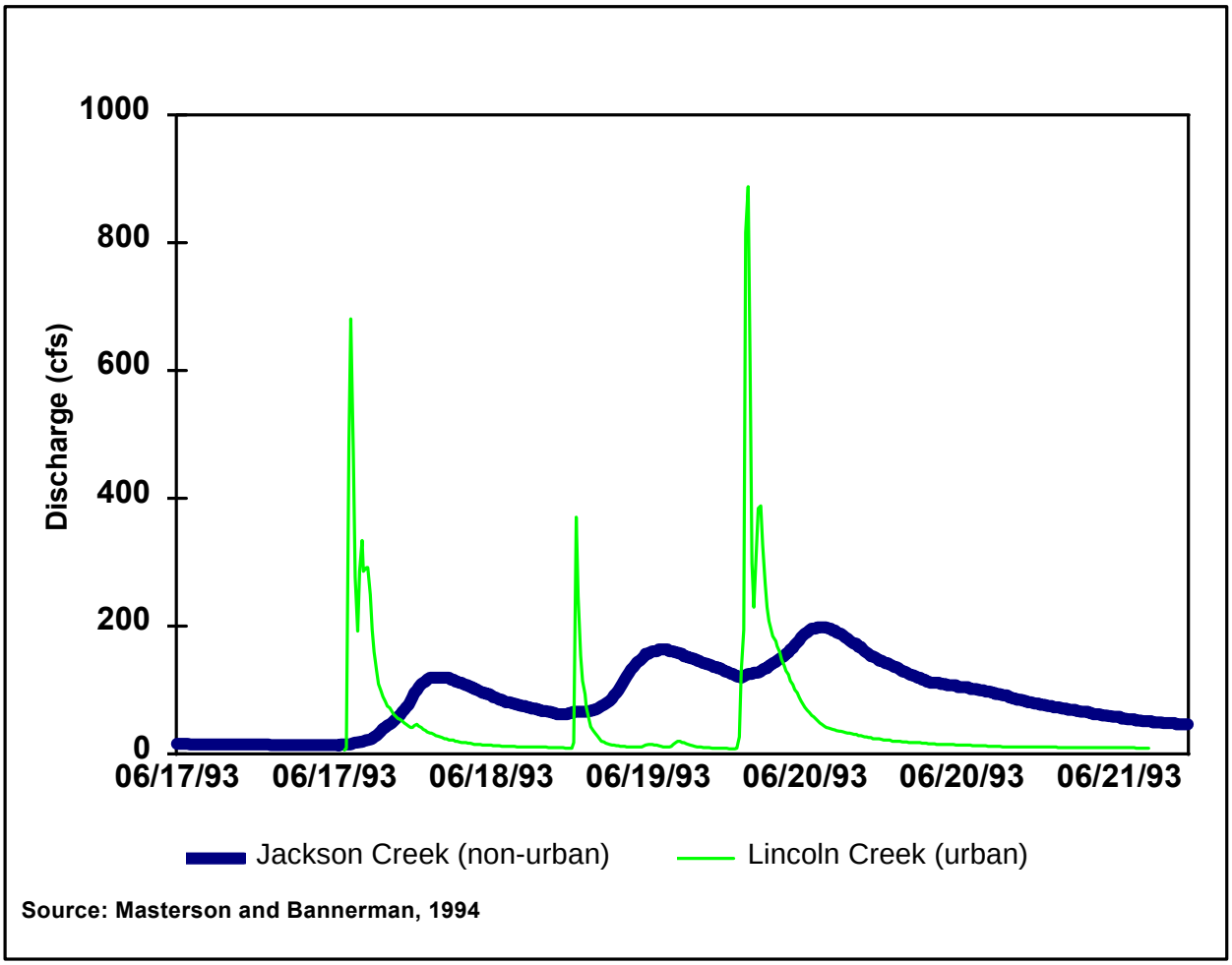
Figure 4-8. Hydrographs for Urban and Non-Urban Streams



Source: Masterson and Bannerman, 1994

Stream Bank Erosion

Stream bank erosion is a natural phenomenon and source of both sediment and nutrients. However, urbanization can greatly accelerate the process of stream bank erosion. As the amount of impervious area increases, a greater volume of storm water is discharged directly to receiving waters, often at a much higher velocity. The increased volume and velocity of the runoff can overwhelm the natural carrying capacity of the stream network. In addition, streams in urbanized areas can experience an increase in bankfull flows. Since bankfull flows are highly erosive, substantial alterations in stream channel morphology can result.

Excessive bank erosion occurs as streams become wider and straighter to accommodate greater flows and an excess number of erosion-causing events. Signs of stream bank erosion attributable to increased storm water include undercut and fallen stream banks, felled bushes and

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trees along the banks, and exposed sewer and utility pipes. Sediments from eroding banks (and upland construction) are deposited in areas where the water slows, causing buildup, destruction of benthic habitat, and a decreased stream capacity for flood waters. This ultimately results in a greater potential for further erosion.

Krug and Goddard (1986) documented these phenomena in their study of Pheasant Branch, a developing watershed of 24.5 square miles near Middleton, Wisconsin. Local population grew markedly between 1970 to 1980, from 8,246 to 11,851, and is projected to reach 18,000 by the year 2000. Problems of stream channel erosion and suspended sediment developed in Pheasant Branch as a result of this growth. The increased erosion and sediment loadings have decreased the mean stream bed elevation by almost 2 feet, and increased the mean channel width by nearly 35 percent.

Table 4-12 shows the modeled percent increase at three sites for the volume of the 2-year flood, bankfull width, and bankfull depth under two development scenarios. These are the projected development levels in the year 2000 (projected urbanization), and complete urbanization of the watershed. The projected results are shown relative to pre-development conditions.

Table 4-12. Percent Increase of Two-Year Flood, Bankfull Width, and Bankfull Depth from Pre-Development Conditions to Urbanized Conditions (Based on Modeling Results)

Site	Projected Urbanization			Complete Urbanization		
	2-year	Width	Depth	2-year	Width	Depth
	(Percent Increase from Pre-urbanization)			(Percent Increase from Pre-urbanization)		
Site 1	99	40	30	140	60	40
Site 2	324	110	80	361	110	80
Site 3	32	10	10	224	80	60

Source: EPA, 1997a

An example of the impact of urbanization on increased sediment loadings in several small streams in Wisconsin before, during and after development is illustrated in Figure 4-9 (Krug and Goddard, 1986). Sediment loads are greatest during construction, but remain elevated after construction relative to pre-development conditions.

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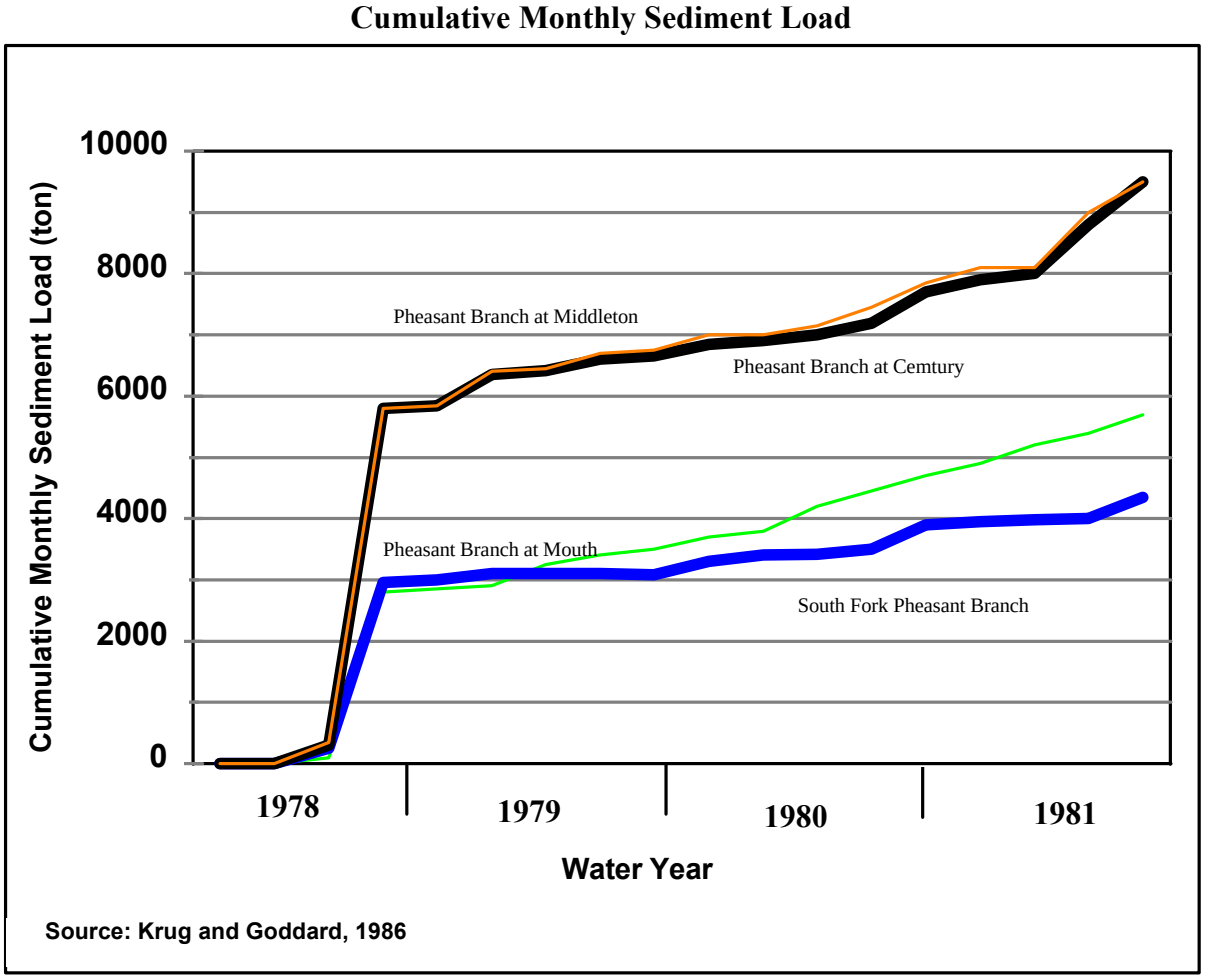
Figure 4-9. Sediment Loadings on Small Streams in Wisconsin



Ground Water Recharge

Urbanization can have a major impact on ground water recharge. As shown earlier in Figure 4-1, both shallow and deep infiltration decrease as watersheds undergo development and urbanization. Ground water recharge is reduced along with a lowering of the water table. This change in watershed hydrology alters the baseflow contribution to stream flow, and it is most pronounced during dry periods. Ferguson (1990) points out that "base flows are of critical environmental and economic concern for several reasons. Base flows must be capable of absorbing pollution from sewage treatment plants and non-point sources, supporting aquatic life dependent on stream flow, and replenishing water-supply reservoirs for municipal use in the seasons when [water] levels tend to be lowest and water demands highest."

Base flows on Long Island, New York were substantially impacted by the construction of storm water conveyance systems during the period of rapid development between the 1940s and

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1970s. As illustrated in Table 4-13, a steady decline in the average percent of baseflow was observed for streams in urbanized sewered areas relative to streams in un-sewered or rural areas (US EPA, 1997a).

Table 4-13. Average Percent Base Flow of Selected Streams on Long Island by Area

Years	Urbanized Sewered Area (% Flow from Base Flow)		Urbanized Un-sewered Area (% Flow from Base Flow)		Rural Un-sewered Area (% Flow from Base Flow)	
	Stream 1	Stream 2	Stream 1	Stream 2	Stream 1	Stream 2
1948-1953	(No data)	86	84	94	96	95
1953-1964	63	69	89	89	95	97
1964-1970	17	22	83	84	96	97

Source: US EPA, 1997a

4.3.2 Habitat Impacts

Natural ecosystems are a complex arrangement of interactions between the land, water, plants, and animals. The relationship between storm water discharge and the biological integrity of urban streams is illustrated in Figure 4-10 (Masterson and Bannerman, 1994). As shown, habitat is impacted by changes in both water quality and quantity, and the volume and quality of sediment. As reported by Schueler (1987), "no single factor is responsible for the progressive degradation of urban stream ecosystems. Rather, it is probably the cumulative impacts of many individual factors such as sedimentation, scouring, increased flooding, lower summer flows, higher water temperatures, and pollution."

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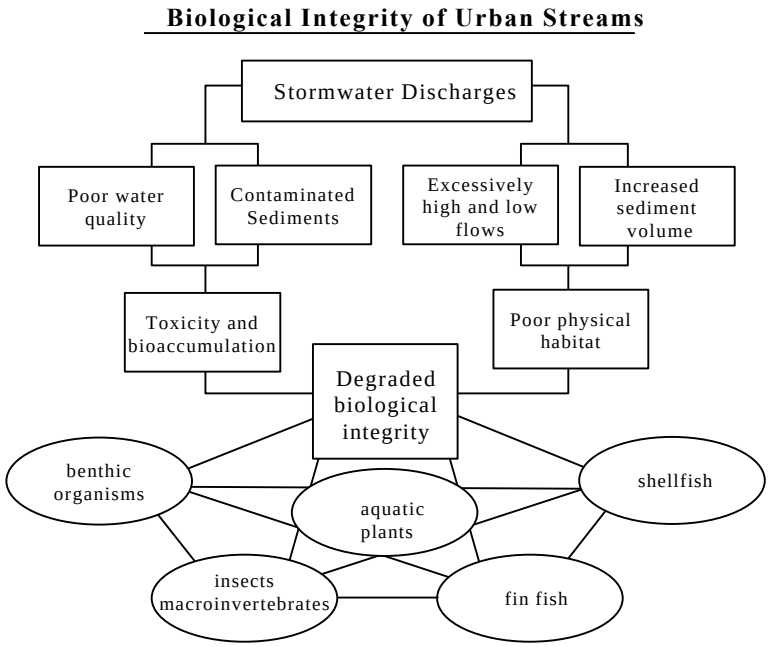
Figure 4-10. Relationship Between Urban Storm Water and Aquatic Ecosystems



Source: Adapted from Masterson and Bannerman, 1994

Schueler and Claytor (1995) also suggest a direct relationship between watershed imperviousness and stream health (Figure 4-11), and found that stream health impacts tend to begin in watersheds with only 10-20 percent imperviousness (the ten percent threshold). As shown, sensitive streams can exist relatively unaffected by urban storm water with good levels of stream quality where impervious cover is less than 10 percent although some sensitive streams have been observed to experience water quality impacts at as low as 5 percent imperviousness. Impacted streams are threatened and exhibit physical habitat changes (erosion and channel widening) and decreasing water quality where impervious cover is in the range of 10 to 25 percent. Streams in watersheds where the impervious cover exceeds 25 percent are typically degraded, have a low level of stream quality, and do not support a rich aquatic community.

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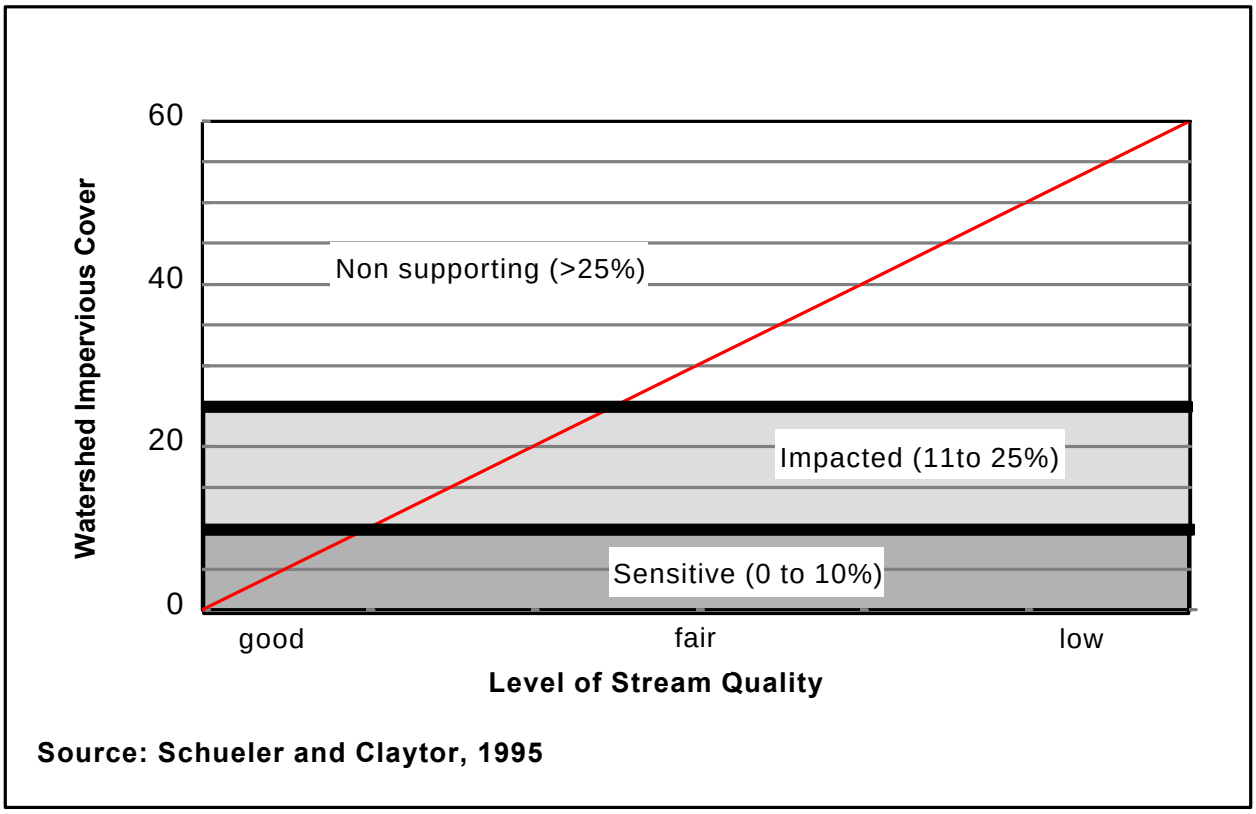
Figure 4-11. Relationship Between Impervious Cover and Stream Quality



Source: Schueler and Claytor, 1995

A summary of water quality impacts on habitat is presented in Table 4-14. The alteration of species distribution is the major impact, with pollutant tolerant and less sensitive species replacing native species in storm water impacted receiving waters.

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Table 4-14. Water Quality Parameters Affecting Habitat

Water Quality Parameter	Habitat Effect
Bacteria	Contamination
Heavy metals	Alteration of species distribution
Toxic organics	Alteration of species distribution
Nutrients	Eutrophication, algal blooms
Sediment	Decreased spawning areas
BOD	Reduced dissolved oxygen levels
Temperature	Reduced dissolved oxygen levels
pH	Alteration of species distribution

Figure 4-12 illustrates that the pH tolerance of various forms of aquatic life varies substantially (US EPA, 1992b). The tolerance of aquatic life to changes in temperature, turbidity and toxic substances is also very important. Contaminants like heavy metals, pesticides, and hydrocarbons can alter the species distribution in receiving waters. Acute and chronic toxicity impacts may also occur. The relative toxicity of storm water samples from a variety of loading source areas is presented in Table 4-15. Some of the identified chronic toxicity effects are decreased growth and respiration rates (US EPA, 1996a). Toxic loads can reduce the hatching and survival rates of aquatic organisms, cause gross effects such as lesions or fin erosion in fish, and can eventually destroy the entire population of some sensitive species (Novotny and Olem, 1994). Hydrocarbons can be especially detrimental to benthic organisms because they can become bound to urban runoff sediments (Schueler, 1987).

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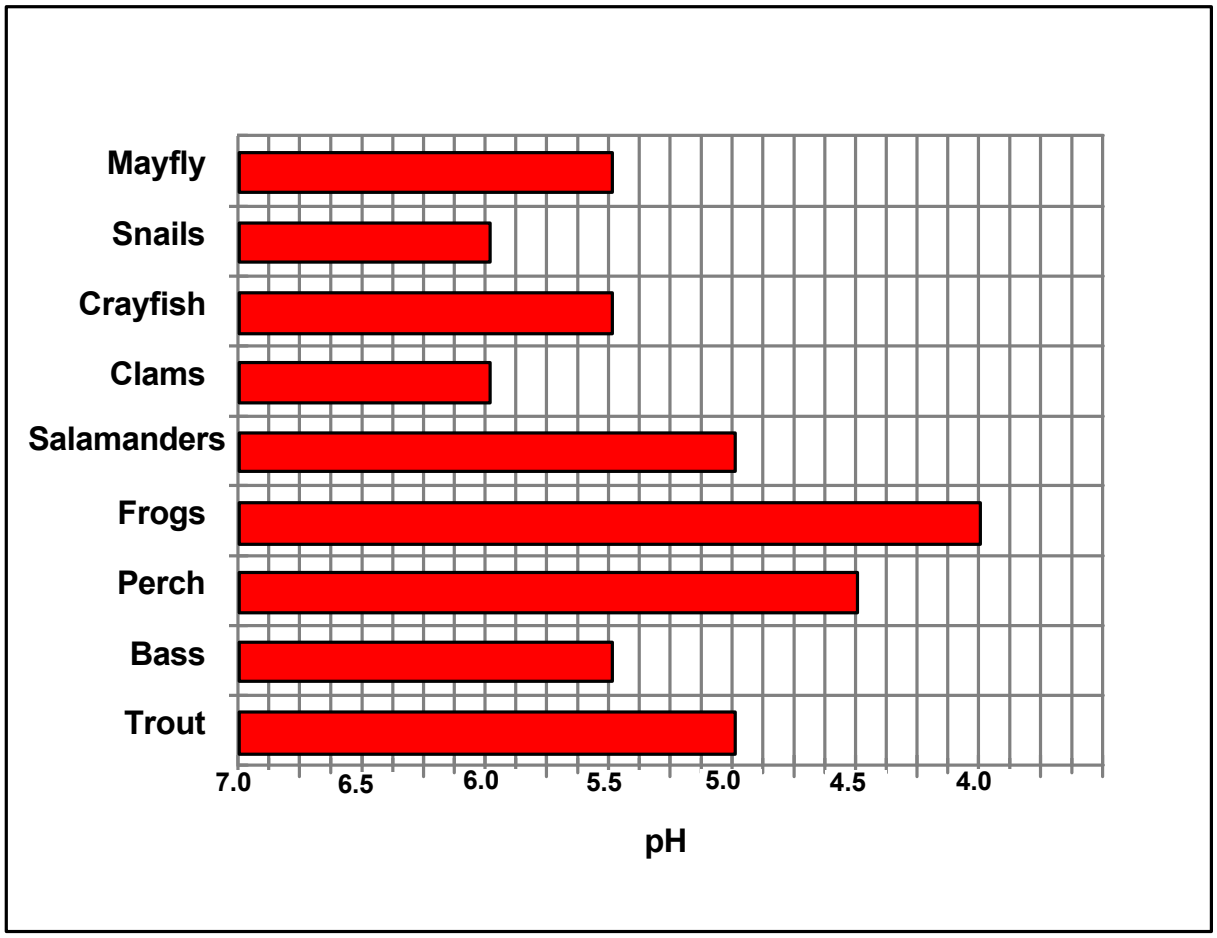
Figure 4-12. Low pH Tolerance by Different Species



Source: EPA, 1992b

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Table 4-15. Relative Toxicities of Samples Using Microtox® Measurement Method

Local Source Areas	Highly Toxic (%)	Moderately Toxic (%)	Not Toxic (%)
Roofs	8	58	33
Parking areas	19	31	50
Storage areas	25	50	25
Streets	0	67	33
Loading docks	0	67	33
Vehicle service areas	0	40	60
Landscaped areas	17	17	66
Urban creeks	0	11	89
Detention ponds	8	8	84
All source areas	9	32	59

Note: Microtox® results are primarily for comparison purposes.
Source: Pitt et al, 1995.

The physical impacts to streams due to urbanization and changes in watershed hydrology also cause many habitat changes. As illustrated in the comparison of healthy and eroding stream banks in Figure 4-13, loss of depth, sediment deposition, loss of shoreline vegetation, and higher temperatures combine to impact habitat.

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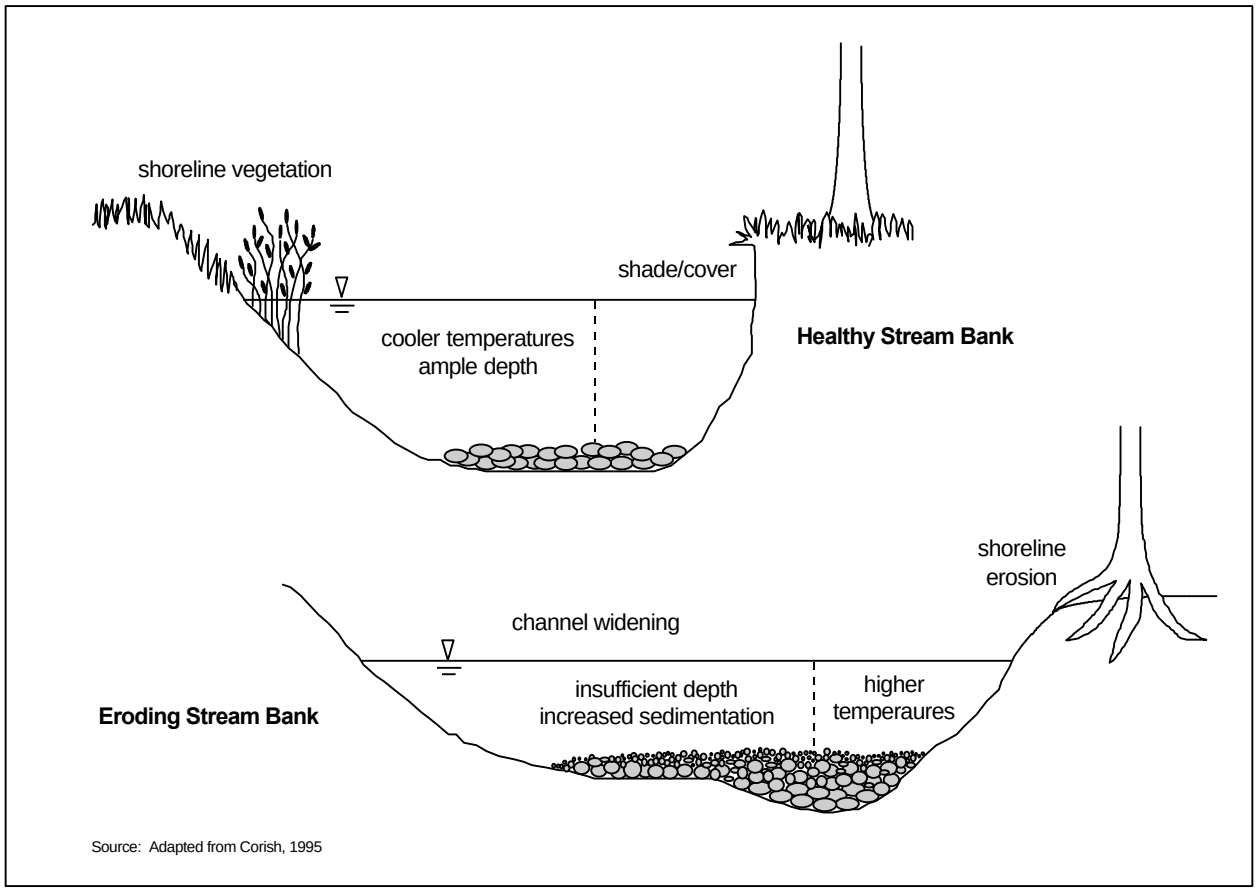
Figure 4-13. Comparison of a Healthy Stream Bank and an Eroding Bank



Schueler (1987) states that sediment pollution in the form of increased suspended solids can cause the following harmful impacts to aquatic life:

- Increased turbidity
- Decreased light penetration
- Reduced prey capture for sight feeding predators
- Clogging of gills/filters of fish and aquatic invertebrates
- Reduced spawning and juvenile fish survival.

Sediment is also a carrier of metals and other pollutants, and a source of bioaccumulating pollutants for bottom feeding organisms. The rate of bioaccumulation is widely variable based upon site specific conditions including species, concentration, pH, temperature, and other factors. Barron (1995) reports that the bioaccumulation of organic contaminants results primarily from direct exposure to water and sediment rather than through the food chain.

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Macroinvertebrate Impacts

The biological integrity of receiving waters impacted by urban storm water is typically reduced from more pristine, undeveloped circumstances. Impacts include a reduction in total numbers and diversity of macroinvertebrates, and the emergence of more pollutant-tolerant species. In a study in Delaware, it was found that approximately 70 percent of the macroinvertebrate community in streams in undeveloped, forested watersheds consisted of pollution sensitive mayflies, stoneflies and caddisflies, as compared with 20 percent in urbanized watersheds (Maxted and Shaver, 1997). As shown in Table 4-16, the relative abundance of pollution tolerant organisms increased with urbanization, including worms, midges and beetles.

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Table 4-16. Delaware Insect Population Abundance by Degree of Urbanization

Population Description				Relative Abundance by Degree of Urbanization (%)		
Class/ Order	**Genus species**	**Common Name**	**PT**	**None**	**Low**	**High**
Insecta/Trichoptera	Diplectrona modesta	caddisfly	0	14	2	1
Insecta/Ephemeroptera	Ephemerella spp.	mayfly	1	12	1	0
Insecta/Plecoptera	Allocapnia spp.	stonefly	3	10	18	3
Insecta/Ephemeroptera	Eurylophella spp.	mayfly	1	8	1	2
Insecta/Coleoptera	Anchytarsus bicolor	beetle	4	6	3	0
Insecta/Ephemeroptera	Stenonema spp.	mayfly	4	5	3	1
Insecta/Coleoptera	Optiservus spp.	beetle	4	4	2	8
Insecta/Coleoptera	Oulimnius latiusculus	beetle	2	4	3	5
Insecta/Trichoptera	Cheumatopsyche spp.	caddisfly	5	1	10	8
Insecta/Trichoptera	Hydropsyche betteni	caddisfly	6	1	4	5
Insecta/Diptera	Simulium vittatum	blackfly	7	0	8	1
Insecta/Diptera	Parametriocnemus spp.	midge	5	0	0	4
Oligochaeta	unidentified (Tubificidae)	worm	10	0	0	4

Note: rare organisms (fewer than 4 per 100 organisms) not included. Relative abundance (%) and pollution tolerance (PT) of macroinvertebrate species commonly found in Piedmont streams of Delaware for three levels of urbanization; none (0-2% impervious cover), low (6-13%), and high (15-50%); PT range from 0 (low tolerance) to 10 (high tolerance).
Source: Maxted and Shaver, 1997.

A study by Kohlepp and Hellenthal (1992) quantified the effects of sediment deposits on macroinvertebrates in Juday Creek, a tributary to the St. Joseph River in Indiana. The study included data before and after upstream channel maintenance operations introduced a large amount of sediment to the creek, similar to increased sediment yield from urban areas. A dramatic change in the species distribution of macroinvertebrates in the river was observed, and this was attributed to the changing sediment load and increased sedimentation. As shown in Figure 4-14, "the result was a shift from a community dominated by filter-feeders in both numbers and production rate in 1981-82, to a community in 1989-90 in which less desirable collector-gatherers and shredders increased in importance in terms of relative contribution to both numbers and production."

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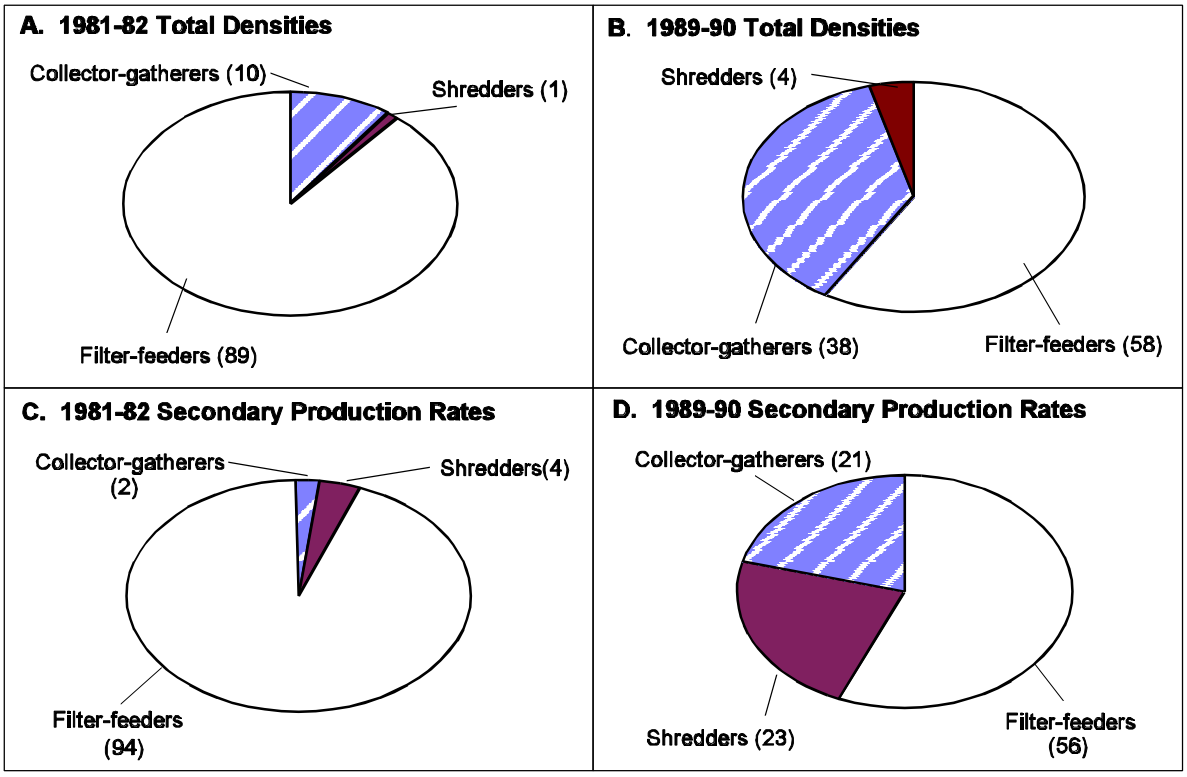
Figure 4-14. Effects of Sediment Deposits on Macroinvertebrates in Juday Creek, Indiana Proportion by Functional Feeding Group (percent)



Source: Kohlepp and Hellenthal, 1992

Fish Impacts

The health of an ecosystem is often measured by the abundance and variety of fish species present, and the presence of native species. A case study in California compared fish populations in urbanized and non-urbanized sections of Coyote Creek (Pitt, 1995). The relative abundance of different fish species in the different reaches is presented in Table 4-17. As shown, the native fish are generally replaced by introduced fish in the urbanized section.

Table 4-17. Relative Abundance of Native and Introduced Fish in Urbanized and Non-Urbanized Areas in Coyote Creek, California

Species	Relative Abundance (%)	
	Non-urbanized Reach	Urbanized Reach
Native Fish		
Hitch	34.8	4.8
Threespine stickleback	27.3	0.8
Sacramento sucker	12.6	0.1
Introduced Fish		
Mosquitofish	5.6	66.9
Fathead Minnow	0.6	20.6
Threadfin shad	-	2.4

Source: Pitt, 1995

An illustration of the abundance of fish eggs and larvae associated with different levels of urban land use in New York is presented in Figure 4-15 (Limburg and Schmidt, 1990). This graph supports the "10 percent rule" reported by Schueler and Claytor (1995): stream impacts tend to begin in watersheds with only 10 to 20 percent imperviousness.

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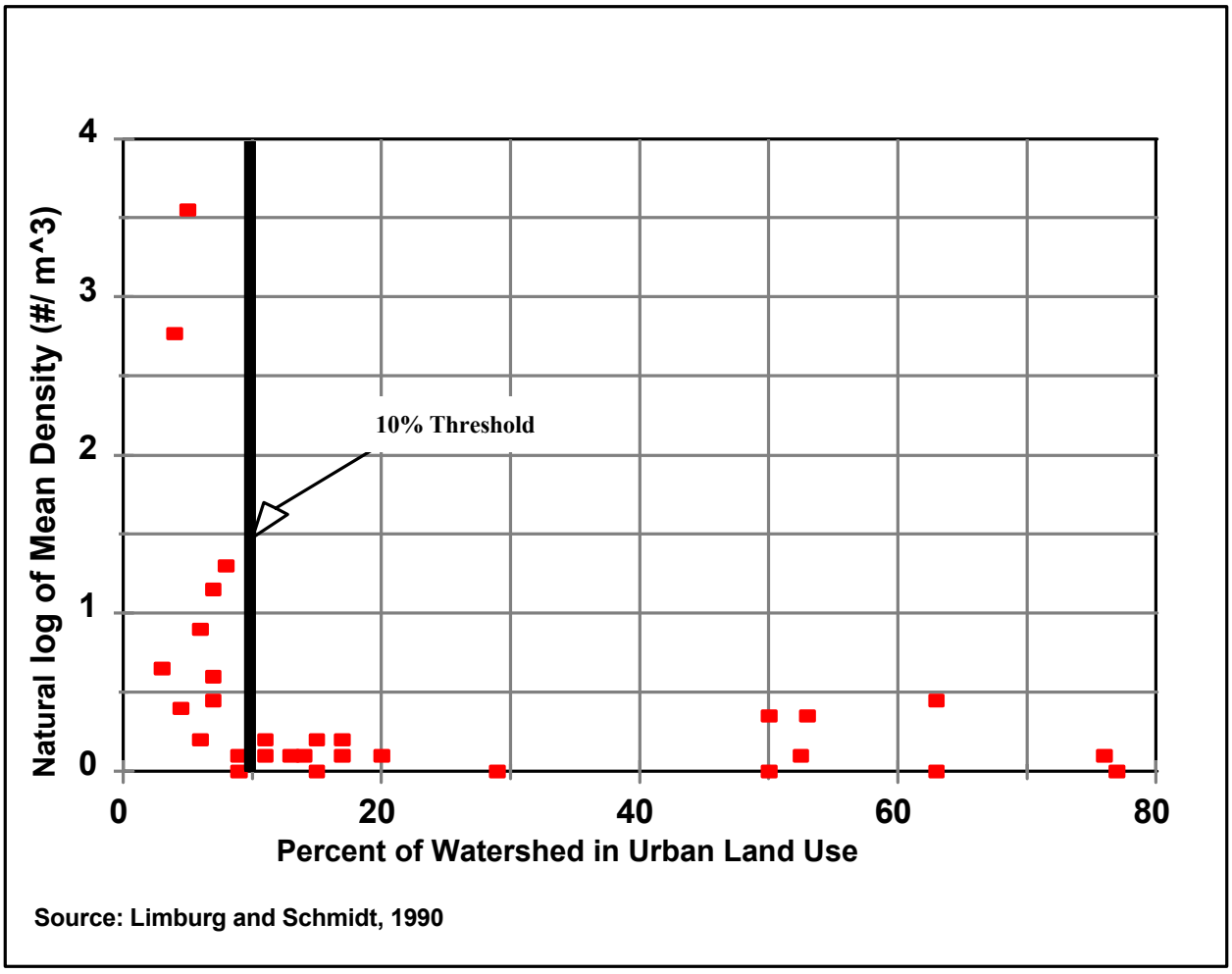
Figure 4-15. Average Densities of Fish Eggs and Larvae in New York



The change in the resident fish community due to urbanization in Tuckahoe Creek in Virginia was quantified by Weaver and Garman (1994). With urbanization increasing the percent of urban land from 7 percent to 28 percent between 1958 and 1990, a dramatic change in the fish assemblage was observed. As shown in Table 4-18, the total number of fish observed dropped sharply along with the total number of species present and the number of common species present.

SARB_016859

Table 4-18. Effects of Urbanization on the Fish Community of Tuckahoe Creek, Virginia (Composite of 6 Sites)

Indicator	Fish Assemblage Year	
	1958	1990
% Urban (by land area)	7	28
total abundance	2,056	412
# species - total	31	23
# species - common*	21	6
% bluegill/shiner	28	67

* more than 10 individuals
Source: Weaver and Garman, 1994

4.3.3 Public Health Impacts

Public health impacts associated with urban storm water occur when humans ingest or come in contact with pathogens. While these impacts are not widely reported, they do occur, and some impacts have been documented. Examples related to swimming and contact recreation impacts and shellfish impacts are presented.

Contact Recreation Impacts

Beach closures are a common occurrence in many communities throughout the United States. Beach closures are primarily due to high levels of bacteria in water samples. The presence of medical waste and other dangerous floatable substances on beaches can also cause beach closures to occur. Storm water runoff can be responsible for both bacteria and floatables. Elevated levels of bacteria and viruses represent the most common threat to public health. Diarrhea and infection of the ear, eye, nose, or throat are possible.

A study of epidemiological impacts associated with swimming in the vicinity of storm water outfalls in Santa Monica Bay in California was conducted in 1995 (SMBRP, 1996). The study focused on health effects, and not on possible sources of contamination to the storm drain

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system, such as illicit sewage connections and infiltration.[1] While the effects observed may be atypical of properly constructed and maintained storm drain outfalls, the findings indicate the potential health risks associated with pathogens. Major findings of this study are as follows:

- There is an increased risk of illness associated with swimming near flowing storm drain outlets in Santa Monica Bay.
- There is an increased risk of illness associated with swimming in areas with high densities of bacterial indicators.
- The total coliform to fecal coliform ratio was found to be one of the better indicators for predicting health risks.
- Illnesses were reported more often on days when the samples were positive for enteric viruses.
- High densities of bacterial indicators were measured on a significant number of survey days, particularly in front of drains.

People who swim in areas adjacent to flowing storm drains were found to be 50 percent more likely to get sick than people who swam in other areas. The sicknesses included fever, nausea, gastroenteritis, and flu-like symptoms such as nasal congestion, sore throat, fever, or coughing. As illustrated in Figure 4-16, swimmers who swam directly in front of storm drains were much more likely to become ill than those who swam away from the storm drains at distances of 100 to 400 meters. A comparative health outcome in terms of relative risk for swimming in front of the storm drain vs. swimming 400 meters away is presented in Table 4-19.

[1] Pilot studies conducted in the Bay prior to 1995 noted that some outfalls had regular dry weather discharges; this is a common indicator of storm drain contamination (SMBRP, 1990; SMBRP, 1992).

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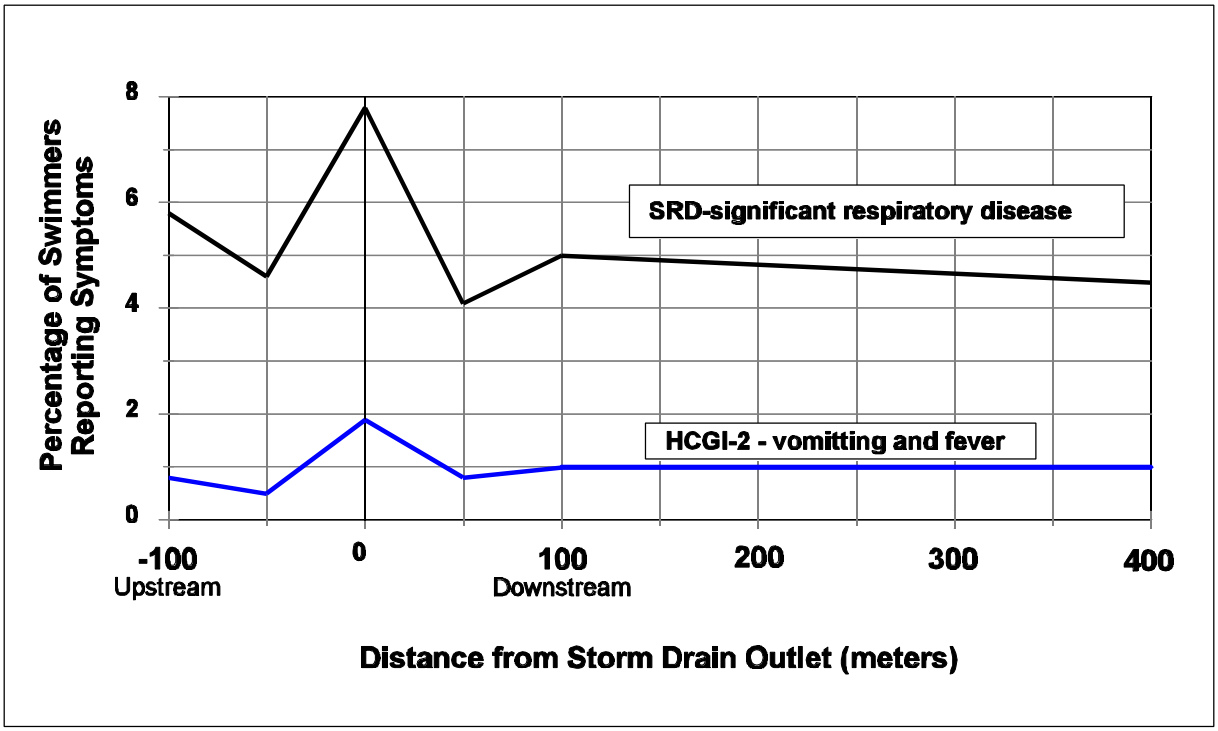
Figure 4-16. Health Effects Observed Relative to Distance from Santa Monica Bay Storm Drains



Source: Santa Monica Bay Restoration Project, 1996

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Table 4-19. Comparative Health Outcomes for Swimming in Front of Drains in Santa Monica Bay

Health Outcome	Relative Risk for Swimming in Front of Drains*	Estimated No. Of Excess Cases per 10,000 Persons
Fever	57%	259
Chills	58%	138
Ear Discharge	127%	88
Vomiting	61%	115
Coughing with phlegm	59%	175
Any of the above symptoms	44%	373
HCGI-2	111%	95
SRD	66%	303
HCGI-2 or SRD	53%	314

* Compared to swimming 400 meters or more away from drains
Source: Santa Monica Bay Restoration Project, 1996

Seafood Hazard

The consumption of contaminated seafood, particularly shellfish, is a major public health problem. Shellfish are susceptible to bioaccumulating bacteria and viruses because they are filter feeders. In waters polluted by urban runoff, bacteria and viruses can be concentrated in the shellfish to much higher levels than those found in the surrounding waters. This becomes a public health concern because many potentially harmful bacteria and viruses can be ingested when people eat contaminated shellfish. As shown in Figure 4-17, the largest proportion of shellfish harvesting restrictions are caused by urban runoff (US EPA, 1995a).

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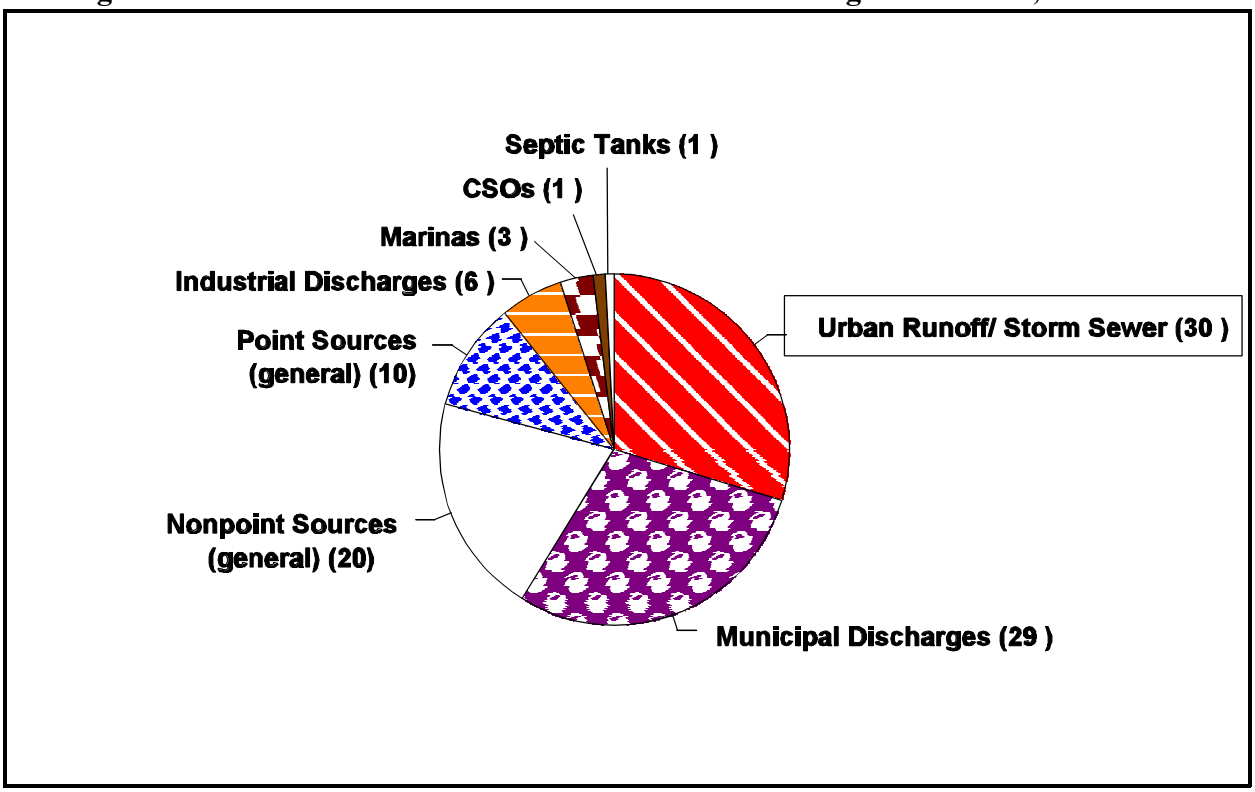
Figure 4-17. Sources Associated with Shellfish Harvesting Restrictions, in Percent



Source: US EPA, 1995a

Fish can also be contaminated for a number of reasons. Recent fish sampling surveys in regions of the U.S. have shown widespread mercury contamination in streams, wetlands, reservoirs, and lakes. Based on 1997 data, 33 states have issued fish consumption advisories because of mercury contamination (US EPA, 1998a). Mercury is an urban/industrial pollutant that is released into the air and ends up in urban runoff by atmospheric deposition (Krabbenhoft and Rickert, 1995). The effects of fish contamination go beyond health issues, and hurt the recreational fishing industry as a whole.

4.3.4 Aesthetic Impacts

The aesthetic impacts associated with urban storm water are often difficult to quantify. However, aesthetic impacts are often very visible to the general public. EPA reports that "people have a strong emotional attachment to water, arising from its aesthetic qualities--tranquillity, coolness, and beauty" (US EPA, 1995c). The presence of floatables within urban waters and deposited along the banks of waterways represents a common aesthetic impact in most urban settings. Floatable wastes originate from street litter and improper solid waste disposal practices. The average total street debris loading rate in New York City was quantified at approximately 156 pounds per curb-mile per day, with a range from 3 to 2,700 pounds (HydroQual, 1995).

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Aesthetic impacts from the eutrophication of urban waterways is caused in part by nutrients delivered in urban storm water. As reported by Schueler (1987), aesthetic impacts and nuisance conditions associated with eutrophication can include:

- Surface algal scum
- Water discoloration
- Strong odors
- Release of toxins.

The visual damage to urban streams from accelerated rates of storm water runoff also contribute to aesthetic impacts. These include eroded stream banks, fallen trees, and sedimentation. In summary, aesthetic impacts are often very visible in public areas where shoreline recreation occurs. Aesthetic impacts are therefore the storm water impacts most familiar to the general public.

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5.0 Description and Performance of Storm Water Best Management Practices

A storm water best management practice (BMP) is a technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner. BMPs can be either engineered and constructed systems ("structural BMPs") that improve the quality and/or control the quantity of runoff such as detention ponds and constructed wetlands, or institutional, education or pollution prevention practices designed to limit the generation of storm water runoff or reduce the amounts of pollutants contained in the runoff ("non-structural BMPs"). No single BMP can address all storm water problems. Each type has certain limitations based on drainage area served, available land space, cost, pollutant removal efficiency, as well as a variety of site-specific factors such as soil types, slopes, depth of groundwater table, etc. Careful consideration of these factors is necessary in order to select the appropriate BMP or group of BMPs for a particular location.

5.1 Goals of Storm Water Best Management Practices

Storm water BMPs can be designed to meet a variety of goals, depending on the needs of the practitioner. In existing urbanized areas, BMPs can be implemented to address a range of water quantity and water quality considerations. For new urban development, BMPs should be designed and implemented so that the post-development peak discharge rate, volume and pollutant loadings to receiving waters are the same as pre-development values. In order to meet these goals, BMPs can be implemented to address three main factors: flow control, pollutant removal and pollutant source reductions.

5.1.1 Flow Control

Flow control involves managing both the volume and intensity of storm water discharges to receiving waters. Urbanization significantly alters the hydrology of a watershed. Increasing development leads to higher amounts of impervious surfaces. As a result, the response of an urbanized watershed to precipitation is significantly different from the response of a natural watershed. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff volumes. Factors that influence the amount of runoff produced include precipitation depth, infiltrative capacity of soils, soil moisture, antecedent rainfall, cover type, the amount of impervious surfaces and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow and roughness of flow surfaces. Peak discharges are based on the relationship of these parameters, and on the total drainage area of the watershed, the time distribution of rainfall, and the effects of any natural or manmade storage (USDA/NRCS, 1986).

High flow rates of storm water discharges can cause a number of impacts to receiving streams (see section 4.3), and may also increase the pollutant concentrations in storm water runoff. High velocity runoff can detach and transport significant amounts of suspended solids and

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associated pollutants such as nutrients and metals from the urban landscape. In addition, high flow rates in drainage channels and receiving waters can erode stream banks and channels, further increasing suspended solids concentrations in waters that receive storm water discharges. In order to reduce the pollutant concentrations in runoff and receiving water impacts associated with high storm water flow rates, BMPs that provide flow attenuation are frequently implemented.

In areas undergoing new development or redevelopment, the most effective method of controlling impacts from storm water discharges is to limit the amount of rainfall that is converted to runoff. By utilizing site design techniques that incorporate on-site storage and infiltration and reduce the amounts of directly connected impervious surfaces, the amount of runoff generated from a site can be significantly reduced. This can reduce the necessity for traditional structural BMPs to manage runoff from newly developed areas. There are a number of practices that can be used to promote on-site storage and infiltration and to limit the amount of impervious surfaces that are generated. However, the use of on-site infiltration can be limited in certain areas due to factors such as slope, depth to the water table, and geologic conditions.

- *Site design features* such as providing rain barrels, dry wells or infiltration trenches to capture rooftop and driveway runoff, maintaining open space, preserving stream buffers and riparian corridors, using porous pavement systems for parking lots and driveways, and using grassed filter strips and vegetated swales in place of traditional curb-and-gutter type drainage systems can greatly reduce the amount of storm water generated from a site and the associated impacts.

- *Street construction features* such as placing sidewalks on only one side of the street, limiting street widths, reducing frontage requirements and eliminating or reducing the radius of cul-de-sacs also have the potential to significantly reduce the amount of impervious surfaces and therefore the amount of rainfall that is converted to runoff.

- *Construction practices* such as minimizing disturbance of soils and avoiding compaction of lawns and greenways with construction equipment can help to maintain the infiltrative capacity of soils.

There are several guides that contain useful information regarding development practices that can limit the impacts associated with storm water runoff (Delaware DNREC, 1997; US EPA, 1996b; Center for Watershed Protection, 1998).

In areas that are already developed, flow control can be more complicated. Since a drainage infrastructure already exists, retrofitting these systems to provide flow control can be prohibitively expensive. Regional storm water management systems can be used to manage runoff in these areas, but space considerations and high capital costs can limit their usefulness. Depending on site-specific constraints, however, there are a number of practices that can be incorporated on-site to reduce runoff volumes from these areas. Down spouts can be disconnected from the storm drain system and this rainfall can instead be collected and stored on a

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property in rain barrels to be used for watering lawns and landscaping during inter-event periods. Infiltration and retention practices such as bioretention areas and infiltration trenches can be constructed to capture runoff from rooftops, lawns and driveways and reduce the volume of runoff discharged to storm sewers. Curb-and-gutter systems can be replaced with grassed swales or wetland channels to provide temporary ponding of runoff. Storm water from commercial areas and golf courses can be collected and stored in ponds and subsequently be used for irrigation. Storm water reuse can help to maintain a more natural, pre-development hydrologic balance in the watershed (Livingston et al, 1998). Parking lots can also be used as short-term storage areas for ponded storm water, and bioretention facilities placed around the perimeter of parking lots can be used to infiltrate this water volume.

Where the generation of runoff cannot be avoided, end-of-pipe structural BMPs may be implemented to decrease the impacts of storm water discharges to receiving streams. However, BMPs are limited in their ability to control impacts, and frequently cause secondary impacts such as increased temperatures of discharges to receiving streams. BMPs that can be designed to provide significant flow attenuation include grassed swales, vegetated filter strips, detention and retention basins, wetland basins, and wetland channels and swales. These BMPs can also provide the added benefit of removing pollutants such as suspended solids and associated nutrients and metals from storm water runoff.

The environmental aspects of storm water quantity control must be carefully balanced against the hazard and nuisance effects of flooding. Large or intense storm events or rapid snowmelt can produce significant quantities of runoff from urban areas with high levels of imperviousness. This runoff must be rapidly transported from urbanized areas in order to prevent loss of life and property due to flooding of streets, residences and businesses. This is frequently accomplished by replacing natural drainage paths in the watershed with paved gutters, storm sewers or other artificial means of drainage. These drainage systems can convey runoff at a faster rate than natural drainage paths, allowing rapid transport of runoff away from areas where flooding is likely to occur. However, as large quantities of runoff are conveyed rapidly from the urban landscape and discharged to receiving streams, downstream areas can flood. Following urbanization, large volumes of runoff can be produced from even small storm events due to the high amounts of impervious surfaces. As a result, flooding of streams that receive runoff can occur much more frequently following urbanization due to this excessive amount of runoff production. Therefore, design of storm water drainage systems must always balance flood protection with ecological concerns.

In highly urbanized and densely populated cities, little opportunity exists for retrofitting storm drainage systems with BMPs to provide water quantity control due to flooding considerations. The large area of impervious surfaces in heavily urbanized areas produce large quantities of runoff. Rapid conveyance by the storm drain system is frequently the only option that exists in order to prevent flooding of yards, streets and basements. In these areas, the most appropriate BMPs are those that limit the generation of pollutants or remove pollutants from the urban landscape. With this principle in mind, a unique opportunity exists in newly developing

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areas or in more sparsely populated suburban areas to use BMPs that control runoff at the point of generation, instead of trying to manage it at the point of discharge to the receiving stream. When rainfall is managed as a *resource* instead of as a waste stream requiring treatment, future problems with quantity control may be avoidable. When rainfall is managed at the site level by promoting the concepts of conservation design, and by providing on-site storage, infiltration and usage of rainfall for irrigation of the urban landscape, the need for traditional curb-and-gutter storm drainage system can be reduced. As a result, the need for constructing and maintaining capital-, land- and maintenance-intensive regional BMPs to manage large flows from developed watersheds may be reduced. Nuisance flooding of downstream areas can also be limited by reducing the overall volume of water draining from a watershed. Limiting the discharge of large volumes of storm water to urban streams can help to prevent the degradation of these streams to the point of being non-supporting of a designated use.

5.1.2 Pollutant Removal

Urbanized areas export large quantities of pollutants during storm events. The high population of pollutant sources in urbanized areas contribute large quantities of pollutants that accumulate on streets, rooftops and other surfaces. During rainfall or snowmelt, these pollutants are mobilized and transported from the streets and rooftops into the storm drain system, where they are conveyed and ultimately discharged to waterways. In order to reduce the impacts to receiving waters from the high concentrations of pollutants contained in the runoff, BMPs can be implemented to remove these pollutants.

Properly-designed, constructed and maintained structural BMPs can effectively remove a wide range of pollutants from urban runoff. Pollutant removal in storm water BMPs can be accomplished through a number of physical and biochemical processes. The efficiency of a given BMP in removing pollutants is dependent upon a number of site-specific variables, including the size, type and design of the BMP; the soil types and characteristics; the geology and topography of the site; the intensity and duration of the rainfall; the length of antecedent dry periods; climatological factors such as temperature, solar radiation, and wind; the size and characteristics of the contributing watershed; and the properties and characteristics of the various pollutants.

Pollutant removal in urban storm water BMPs can occur through the following mechanisms:

Sedimentation

Sedimentation is the removal of suspended particulates from the water column by gravitational settling. The settling of discrete particles is dependent upon the particle velocity, the fluid density, the fluid viscosity, and the particle diameter and shape. Sedimentation can be a major mechanism of pollutant removal in BMPs such as ponds and constructed wetlands. Sedimentation can remove a variety of pollutants from storm water runoff. Pollutants such as metals, hydrocarbons, nutrients and oxygen demanding substances can become adsorbed or attached to particulate matter, particularly clay soils. Removal of these particulates by

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sedimentation can therefore result in the removal of a large portion of these associated pollutants. The main factor governing the efficiency of a BMP at removing suspended matter by sedimentation is the time available for particles to undergo settling. Fine particulates such as clay and silt can require detention times of days or even weeks to settle out of suspension. Therefore, it is important to evaluate the settling characteristics of the particulates in runoff before BMP design in order to determine the detention time necessary for adequate settling to occur. The overall efficiency of a BMP in removing particulates by settling is also dependent upon the initial concentration of suspended solids in the runoff. In general, runoff with higher initial concentrations of suspended solids will have a greater removal efficiency. In addition, some particles, such as fine clays, will not settle out of suspension without the aid of a coagulant. As a result there is usually a minimum practical limit of approximately 10 mg/l of TSS, below which additional TSS removal can not be expected to occur (UDFCD, 1992).

Flotation

Flotation is the separation of particulates with a specific gravity less than that of water. Trash such as paper, styrofoam "peanuts" used for packaging, and other low-density materials can be removed from storm water by the mechanism of flotation. If the inlet area of the BMP is designed to allow for the accumulation of floatable materials, then these accumulated materials can periodically be manually removed from the BMP. Significant amounts of floatables can be removed from storm water in properly designed BMPs in this manner. In addition, oils and hydrocarbons will frequently rise to the surface in storm water BMPs. If the BMP is designed with an area for these materials to accumulate, then significant removals of these pollutants can occur. Many modular or drop-in filtration systems incorporate an oil and grease or hydrocarbon trap with a submerged outlet pipe that allows these contaminants to accumulate and to be periodically removed.

Filtration

Filtration is the removal of particulates from water by passing the water through a porous media. Media commonly used in storm water BMPs include soil, sand, gravel, peat, compost, and various combinations such as peat/sand, soil/sand and sand/gravel. Filtration is a complex process dependent on a number of variables. These include the particle shape and size, the size of the voids in the filter media, and the velocity at which the fluid moves through the media. Filtration can be used to remove solids and attached pollutants such as metals and nutrients. Organic filtration media such as peat or leaf compost can also be effective at removing soluble nutrients from urban runoff.

Infiltration

Infiltration is the most effective means of controlling storm water runoff since it reduces the volume of runoff that is discharged to receiving waters and the associated water quality and quantity impacts that runoff can cause. Infiltration is also an important mechanism for pollutant control. As runoff infiltrates into the ground, particulates and attached contaminants such as metals and nutrients are removed by filtration, and dissolved constituents can be removed by adsorption. However, infiltration is not appropriate in all areas.

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Adsorption

Adsorption, while not a common mechanism used in storm water BMPs, can occur in infiltration systems where the underlying soils contain appreciable amounts of clay. Dissolved metals that are contained in storm water runoff can be bound to the clay particles as storm water runoff percolates through clay soils in infiltration systems.

Biological Uptake

Biological uptake of nutrients is an important mechanism of nutrient control in storm water BMPs. Urban runoff typically contains significant concentrations of nutrients. Ponds and wetlands can be useful for removing these nutrients through biological uptake. This occurs as aquatic plants, algae, microorganisms and phytoplankton utilize these nutrients for growth. Periodic harvesting of vegetation in BMPs allows for permanent removal of these nutrients. If plants are not harvested, however, nutrients can be re-released to the water column from plant tissue after the plants die.

Biological Conversion

Organic contaminants can be broken down by the action of aquatic microorganisms in storm water BMPs. Bacteria present in BMPs can degrade complex and/or toxic organic compounds into less harmful compounds that can reduce the toxicity of runoff to aquatic biota.

Degradation

BMPs such as ponds and wetlands can provide the conditions necessary for the degradation of certain organic compounds, including certain pesticides and herbicides. Open pool BMPs can provide the necessary conditions for volatilization, hydrolysis and photolysis of a variety of organic compounds to take place.

5.1.3 Pollutant Source Reductions

Source reduction is an effective non-structural way of controlling the amounts of pollutants entering storm water runoff. A wide range of pollutants are washed off of impervious surfaces during runoff events. Removing these contaminants from the urban landscape prior to precipitation can effectively limit the amounts of pollutants contained in the storm water runoff. Source reduction can be accomplished by a number of different processes including: limiting applications of fertilizers, pesticides and herbicides; periodic street sweeping to remove trash, litter and particulates from streets; collection and disposal of lawn debris; periodic cleaning of catch basins; elimination of improper dumping of used oil, antifreeze, household cleaners, paint, etc. into storm drains; and identification and elimination of illicit cross-connections between sanitary sewers and storm sewers.

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5.2 Types of Storm Water Best Management Practices

There are a variety of storm water BMPs available for managing urban runoff. Regardless of the type, storm water BMPs are most effective when implemented as part of a comprehensive storm water management program that includes proper selection, design, construction, inspection and maintenance. Storm water BMPs can be grouped into two broad categories: structural and non-structural. *Structural* BMPs are used to treat the storm water at either the point of generation or the point of discharge to either the storm sewer system or to receiving waters. *Non-structural* BMPs include a range of pollution prevention, education, institutional, management and development practices designed to limit the conversion of rainfall to runoff and to prevent pollutants from entering runoff at the source of runoff generation. The descriptions in this section provide summary information on a variety of commonly used structural and nonstructural storm water BMPs. Information provided includes a general description of the technology or practice, important components and factors to incorporate into BMP design and planning, and the positive and negative aspects of the technology or practice. In addition, maintenance considerations for structural BMPs are discussed. Quantitative performance data for BMPs are not included in this section. These data are included in section 5.5, "Effectiveness of BMPs in Managing Urban Runoff."

5.2.1 Structural BMPs

There are a wide variety of structural BMPs in use for storm water management. Structural BMPs include engineered and constructed systems that are designed to provide for water quantity and/or water quality control of storm water runoff. Structural BMPs can be grouped into several general categories. However, the distinction between BMP types and the terminology used to group structural BMPs is an area that needs standardization. In particular, the terms "retention" and "detention" are sometimes used interchangeably, although they do have distinct meanings. Storm water detention is usually defined as providing temporary storage of a runoff volume for subsequent release (WEF/ASCE, 1992). Examples include detention basins, underground vaults, tanks or pipes, and deep tunnels, as well as temporary detention in parking lots, roof tops, depressed grassy areas, etc. Retention is generally defined as providing storage of storm water runoff without subsequent surface discharge (WEF/ASCE, 1992). With the strict interpretation of this definition, retention practices would be limited to those practices that either infiltrate or evaporate runoff, such as infiltration trenches, wells or basins. However, retention is also commonly used to describe practices that retain a runoff volume (and hence have a permanent pool) until it is displaced in part or in total by the runoff event from the next storm. Examples include retention ponds, tanks, tunnels, and underground vaults or pipes, and wetland basins. For purposes of this document, and in being consistent with the definitions and terminology used in the ASCE National Stormwater BMP Database, structural BMPs have been grouped and defined as follows:

- Infiltration systems capture a volume of runoff and infiltrates it into the ground.

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- Detention systems capture a volume of runoff and temporarily retain that volume for subsequent release. Detention systems to not retain a significant permanent pool of water between runoff events.

- Retention systems capture a volume of runoff and retain that volume until it is displaced in part or in total by the next runoff event. Retention systems therefore maintain a significant permanent pool volume of water between runoff events.

- Constructed wetland systems are similar to retention and detention systems, except that a major portion of the BMP water surface area (in pond systems) or bottom (in meadow-type systems) contains wetland vegetation. This group also includes wetland channels.

- Filtration systems use some combination of a granular filtration media such as sand, soil, organic material, carbon or a membrane to remove constituents found in runoff.

- Vegetated systems (biofilters) such as swales and filter strips are designed to convey and treat either shallow flow (swales) or sheetflow (filter strips) runoff

- Minimizing directly connected impervious surfaces describes a variety of practices that can be used to reduce the amount of surface area directly connected to the storm drainage system by minimizing or eliminating traditional curb and gutter. This is considered by some to be a non-structural practice, but is has been included under the structural heading in this report due to the need to design and construct alternative conveyance and treatment options.

- Miscellaneous and vendor-supplied systems include a variety of proprietary and miscellaneous systems that do not fit under any of the above categories. These include catch basin inserts, hydrodynamic devices, and filtration devices.

5.2.1.1 Infiltration Systems

Infiltration systems include infiltration basins, porous pavement systems, and infiltration trenches or wells. An infiltration BMP is designed to capture a volume of storm water runoff, retain it and infiltrate that volume into the ground. Infiltration of storm water has a number of advantages and disadvantages. The advantages of infiltration include both water quantity control and water quality control. Water quantity control can occur by taking surface runoff and infiltrating this water into the underlying soil. This reduces the volume of water that is discharged to receiving streams, thereby reducing some of the potential impacts caused by an excess flow as well as increased pollutant concentrations in the receiving stream. Infiltration systems can be designed to capture a volume of storm water and infiltrate this water into the ground over a period of several hours or even days, thereby maximizing the infiltrative capacity of the BMP. Infiltration can have many secondary benefits such as increasing recharge of underlying aquifers

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and increasing baseflow levels of nearby streams. Infiltration BMPs can also provide water quality treatment. Pollutant removal can occur as water percolates through the various soil layers. As the water moves through the soil, particles can be filtered out. In addition, microorganisms in the soil can degrade organic pollutants that are contained in the infiltrated storm water.

Although infiltration of storm water has many benefits, it also has some drawbacks. First, infiltration may not be appropriate in areas where groundwater is a primary source of drinking water due to the potential for contaminant migration. This is especially true if the runoff is from a commercial or industrial area where the potential for contamination by organics or metals is present. Also, the performance of infiltration BMPs is limited in areas with poorly permeable soils. In addition, infiltration BMPs can experience reduced infiltrative capacity and even clogging due to excessive sediment accumulation. Frequent maintenance may be required to restore the infiltrative capacity of the system. Care must also be taken during construction to limit compaction of the soil layers underlying the BMP. Excessive compaction due to construction equipment may cause a reduced infiltrative capacity of the system. Plus, excessive sediment generation during construction and site grading/stabilization may cause premature clogging of the system. Infiltration systems should not be placed into service until disturbed areas in the drainage have been stabilized by dense vegetation or grasses.

Infiltration Basins

Infiltration basins are designed to capture a storm water runoff volume, hold this volume and infiltrate it into the ground over a period of days. Infiltration basins are almost always placed off-line, and are designed to only intercept a certain volume of runoff. Any excess volume will be bypassed. The basin may or may not be lined with plants. Vegetated infiltration systems help to prevent migration of pollutants and the roots of the vegetation can increase the permeability of the soils, thereby increasing the efficiency of the basin. Infiltration basins are typically not designed to retain a permanent pool volume. Their main purpose is to simply transform a surface water flow into a ground water flow and to remove pollutants through mechanisms such as filtration, adsorption and biological conversion as the water percolates through the underlying soil. Infiltration basins should be designed to drain within 72 hours in order to prevent mosquito breeding and potential odor problems due to standing water and to ensure that the basin is ready to receive runoff from the next storm (US EPA, 1993a). In addition to removing pollutants, infiltration basins are useful to help restore or maintain pre-development hydrology in a watershed. Infiltration can increase the water table, increase baseflow and reduce the frequency of bankfull flooding events. A diagram of a typical infiltration basin is shown below.

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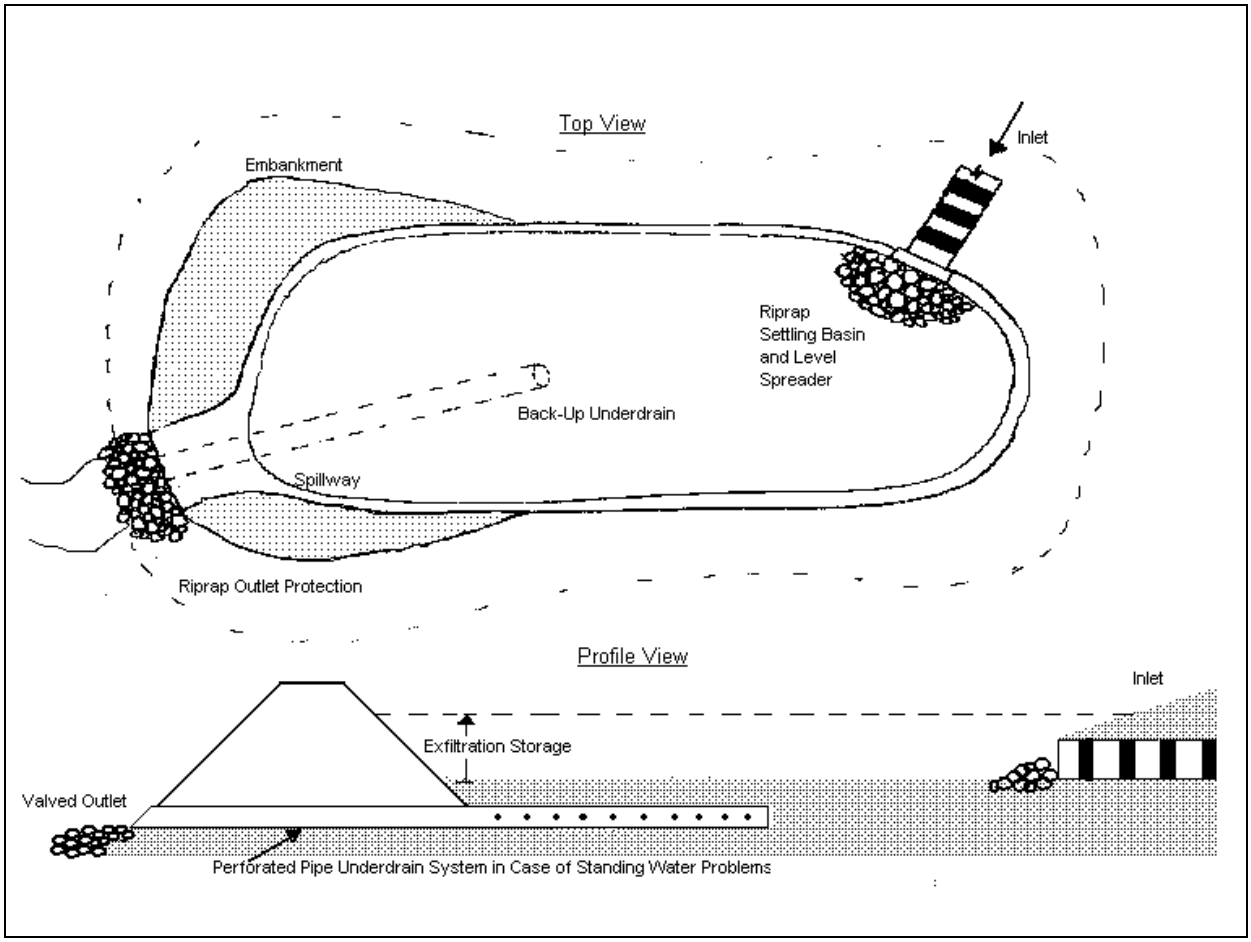
Figure 5-1. Infiltration Basin



Source: Adapted from Schueler et al, 1992

Porous Pavement Systems

Porous pavement is an infiltration system where storm water runoff is infiltrated into the ground through a permeable layer of pavement or other stabilized permeable surface. These systems can include porous asphalt, porous concrete, modular perforated concrete block, cobble pavers with porous joints or gaps or reinforced/stabilized turf (Urbonas and Strecker, 1996). Permeable pavement can be used in parking lots, roads and other paved areas and can greatly reduce the amount of runoff and associated pollutants leaving the area. Porous pavement systems are suitable for a limited number of applications. Typically, porous pavement can only be used in areas that are not exposed to high volumes of traffic or heavy equipment. They are particularly useful for driveways and streets and in residential areas, and in parking areas in commercial areas. Porous pavement is not effective in areas that receive runoff with high amounts of sediment due to the tendency of the pores to clog. Porous pavements require maintenance including periodic vacuuming or jet-washing to remove sediment from the pores. Paved areas should be clearly marked to indicate that a porous pavement system is in use and to prevent frequent use by

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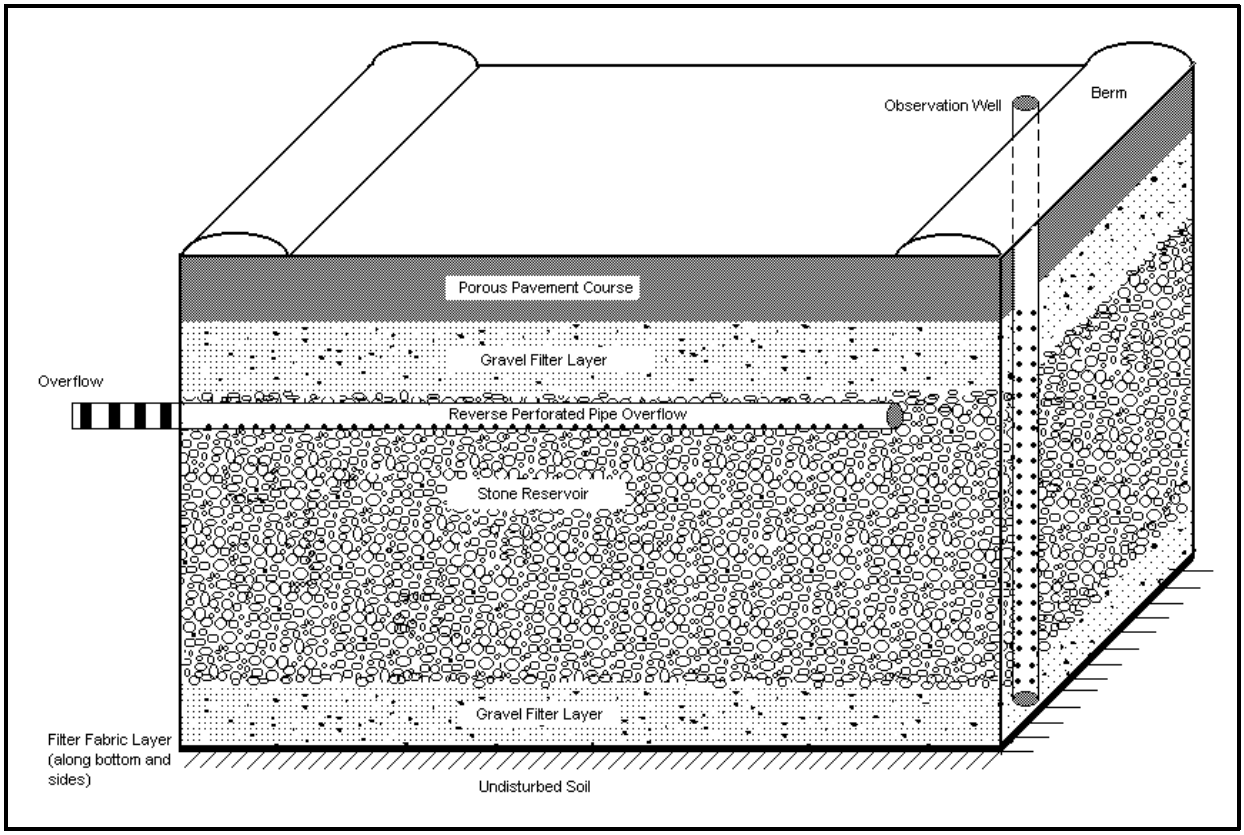
equipment, to prevent excess traffic volume, to limit the use of de-icing chemicals and sand, and to prevent resurfacing with non-porous pavement.

The performance of porous asphalt has been historically very poor in the mid-Atlantic region. However, many of these failures can be attributed to lack of proper erosion and sediment controls during construction or lack of contractor experience with installation of porous pavement systems. Porous concrete systems in use in Florida have performed very well (Florida Concrete and Products Assn., 1993). When properly designed and maintained, porous pavement systems can be an effective means of managing urban storm water runoff. Porous pavement systems are particularly useful for overflow parking areas that are not used on a daily basis. A diagram of a porous asphalt pavement system is shown below.

Figure 5-2. Porous Pavement System



Source: Adapted from Schueler, 1987.

Infiltration Trenches and Wells

An infiltration trench or well is a gravel-filled trench or well designed to infiltrate storm water into the ground. A volume of storm water runoff is diverted into the trench or well where it infiltrates into the surrounding soil. Typically infiltration trenches and wells can only capture a small amount of runoff and therefore may be designed to capture the first flush of a runoff event. For this reason, they are frequently used in combination with another BMP such as a detention

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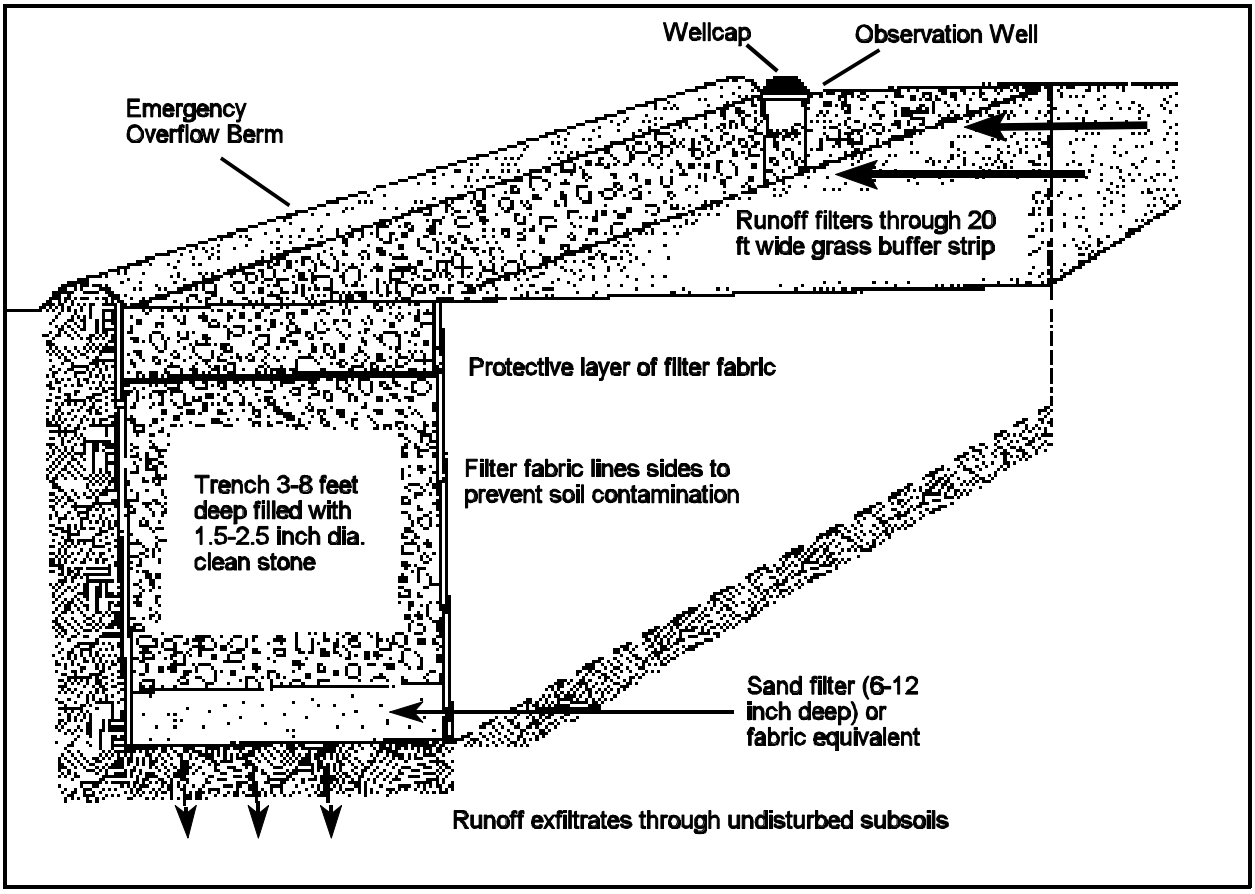
basin to control peak hydraulic flows. Infiltration trenches and wells can be used to remove suspended solids, particulates, bacteria, organics and soluble metals and nutrients through the mechanisms of filtration, absorption and microbial decomposition. They are also useful to provide groundwater recharge and to increase base flow levels in nearby streams. As with all infiltration practices, the possibility for groundwater contamination exists and must be considered where groundwater is a source of drinking water. A diagram of an infiltration trench is shown below.

Figure 5-3. Infiltration Trench



Source: Schueler et al, 1992.

5.2.1.2 Detention Systems

Detention systems are BMPs that are designed to intercept a volume of storm water runoff and temporarily impound the water for gradual release to the receiving stream or storm sewer system. Detention systems are designed to completely empty out between runoff events, and therefore provide mainly water quantity control as opposed to water quality control. Detention basins can provide limited settling of particulate matter, but a large portion of this material can be

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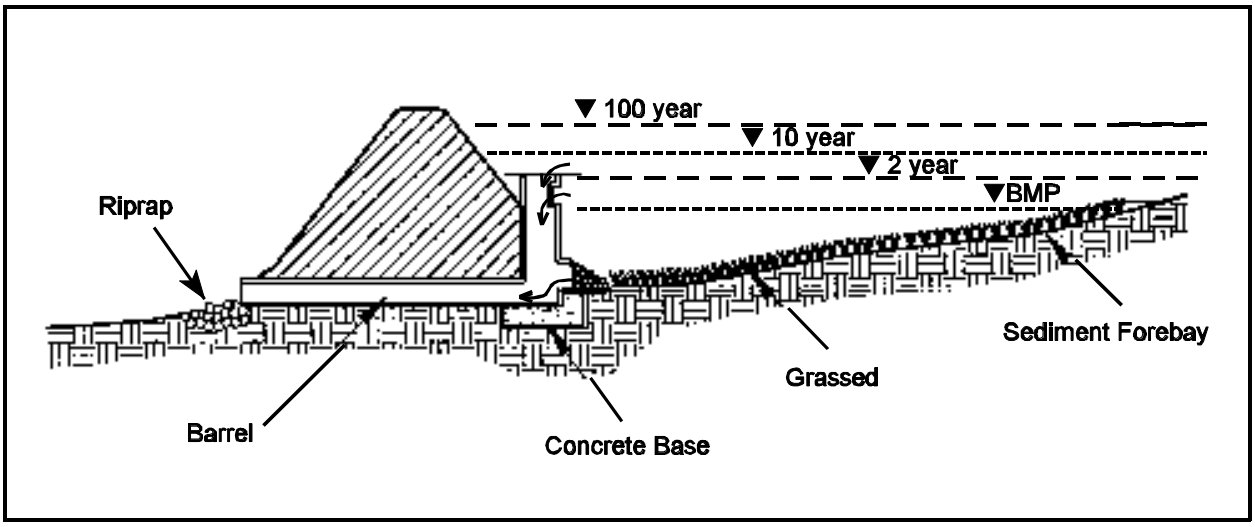
re-suspended by subsequent runoff events. Detention facilities should be considered mainly as practices used to reduce the peak discharge of storm water to receiving streams to limit downstream flooding and to provide some degree of channel protection. There are several types of detention facilities used to manage storm water runoff, including detention basins and underground vaults, pipes and tanks.

Detention Basins

Detention basins are designed to intercept a volume of storm water, temporarily impound the water and release it shortly after the storm event. The main purpose of a detention basin is quantity control by reducing the peak flow rate of storm water discharges. They are designed to not retain a permanent pool volume between runoff events. and most basins are designed to empty in a time period of less than 24 hours. The treatment efficiency of detention basins is usually limited to removal of suspended solids and associated contaminants due to gravity settling. The efficiency can be increased by incorporating a forebay or pre-settling chamber for the accumulation of coarse sediment, facilitating periodic cleaning in order to prevent washout by subsequent runoff events. Detention basins can limit downstream scour and loss of aquatic habitat by reducing the peak flow rate and energy of storm water discharges to the receiving stream, but their removal of pollutant of potential water quality concern can be limited. A diagram of a typical detention basin is shown below.

Figure 5-4. Detention Basin



Source: NVPDC, 1992.

Underground Vaults, Pipes and Tanks

Underground detention facilities, such as vaults, pipes and tanks, are designed to provide temporary storage of storm water runoff. Significant water quality improvements should not be expected in underground detention facilities. They should mainly be used for providing storage to limit downstream effects due to high peak flow rates. Like detention basins, underground

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detention systems are designed to empty out between runoff events so that storage capacity is available for subsequent runoff events. In addition, studies are being conducted to evaluate the usefulness of in-system detention (storing runoff temporarily in the storm drainage system through the use of valves, gates, orifices, etc.), although these evaluations are in the preliminary stages and are only useful in certain cases (Lake Barcroft Watershed Improvement District, 1998). This is a potential alternative for retrofitting existing storm drains in the upper portions of the drainage system to delay the peak discharge rate and provide a limited amount of additional temporary storage volume. However, a careful analysis of the storm drainage system is necessary in order to prevent flooding in the upper reaches of the drainage area.

5.2.1.3 Retention Systems

Retention systems include wet ponds and other retention systems such as underground pipes or tanks. Retention systems are designed to capture a volume of runoff and retain that volume until it is displaced in part or in total by the next runoff event. Retention systems can provide both water quantity and quality control. The volume available for storage, termed the water quality volume, is provided above the permanent pool level of the system. The main pollutant removal mechanisms in retention systems is sedimentation. By retaining a permanent pool of water, retention systems can benefit from the added biological and biochemical pollutant removal mechanisms provided by aquatic plants and microorganisms, mimicking a natural pond or lake ecosystem. Also, sediments that accumulate in the pond are less likely to be re-suspended and washed out due to the presence of a permanent pool of water. In addition to sedimentation, other pollutant removal mechanisms in retention systems include filtration of suspended solids by vegetation, infiltration, biological uptake of nutrients by aquatic plants and algae, volatilization of organic compounds, uptake of metals by plant tissue, and biological conversion of organic compounds.

Retention Ponds

Retention ponds (also known as wet ponds) are designed to intercept a volume of storm water runoff and to provide storage and treatment of this runoff volume. Water in the pond above the permanent pool level is displaced in part or completely by the runoff volume from subsequent runoff events. Retention ponds, when properly designed and maintained, can be extremely effective BMPs, providing both water quality improvements and quantity control, as well as providing aesthetic value and aquatic and terrestrial habitat for a variety of plants and animals.

Pollutant removal in retention ponds can occur through a number of mechanisms. The main mechanism is the removal of suspended solids and associated pollutants through gravity settling. Aquatic plants and microorganisms can also provide uptake of nutrients and degradation of organic contaminants. Retention basins that incorporate an aquatic bench around the perimeter of the basin that is lined with aquatic vegetation can have an added pollutant removal efficiency. This littoral zone can aid in pollutant removal efficiency by incorporating mechanisms found in wetland systems. These mechanisms include removal of sediment by filtration by aquatic plants,

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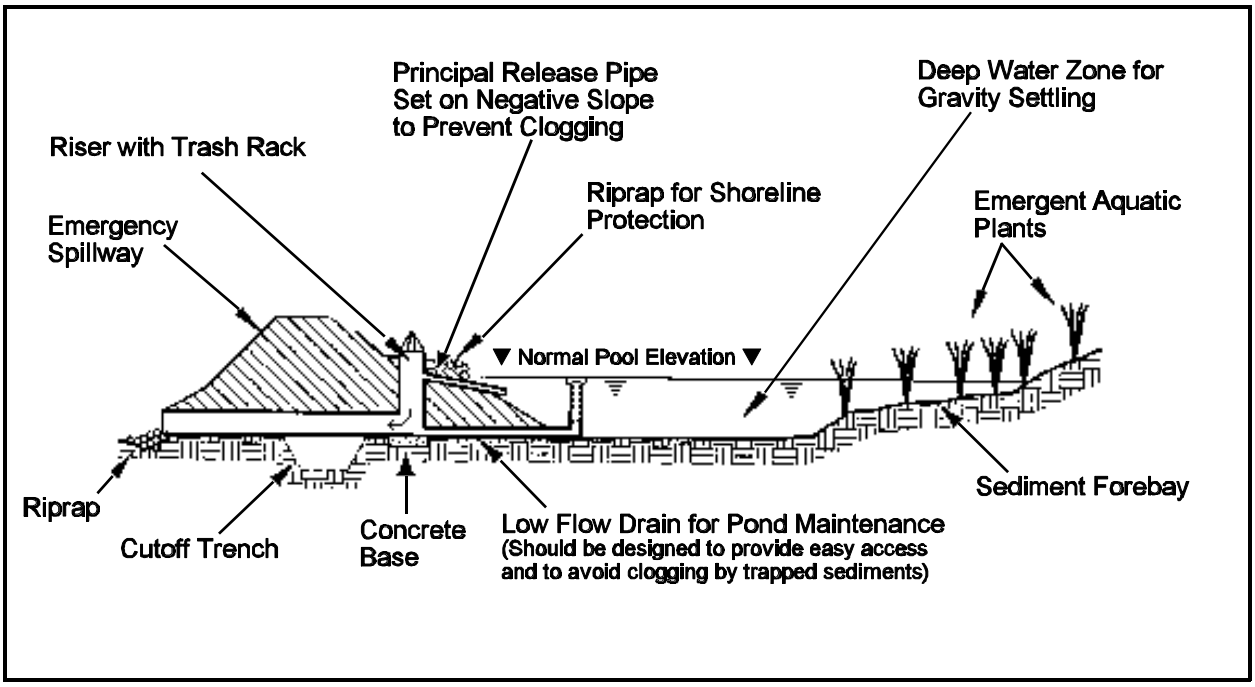
removal of metals and nutrients through biological uptake by aquatic vegetation and degradation of organic contaminants. If the bottom of the pond is not lined, then infiltration can occur aiding in the maintenance of local groundwater supplies. A diagram of a typical wet pond is shown below.

Figure 5-5. Retention Pond



Source: NVPDC, 1992.

Retention Tanks, Tunnels, Vaults and Pipes

Retention systems other than ponds include surface tanks and underground vaults, pipes and tunnels. These systems are not as prevalent as typical wet ponds, and therefore little information is contained in the literature about their design, applicability and usefulness.

5.2.1.4 Constructed Wetland Systems

Constructed wetland systems incorporate the natural functions of wetlands to aid in pollutant removal from storm water. Constructed wetlands can also provide for quantity control of storm water by providing a significant volume of ponded water above the permanent pool elevation. Constructed wetland systems have limits to their application. A water balance must be performed to determine the availability of water to sustain the aquatic vegetation between runoff events and during dry periods. In addition, a sediment forebay or some other pretreatment provision should be incorporated into the wetland system design to allow for the removal of coarse sediments that can degrade the performance of the system. Also, construction sediment should be prevented from entering constructed wetlands, as the resulting sediment loading can

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severely degrade the performance of the system. Constructed wetlands are particularly appropriate where groundwater levels are close to the surface because groundwater can supply the water necessary to sustain the wetland system.

Storm water runoff should not be intentionally routed to natural wetlands without pretreatment due to the potentially damaging effects runoff can have on natural wetland systems. In addition, natural wetlands that receive storm water runoff should be evaluated to determine if the runoff is causing degradation of the wetland, and if so measures should be taken to protect the wetland from further degradation and to repair any damage that has been done. In addition, local permitting authorities should be consulted prior to designing and maintaining constructed wetland systems in order to determine if any local regulations apply to their use or maintenance.

Wetland Basins and Wetland Channels

Wetland basins and channels are any of a number of systems that incorporate mechanisms of natural wetland systems for water quality improvement and quantity control. A wetland channel is designed to develop dense wetland vegetation and to convey runoff very slowly (Urbonas and Strecker, 1996). Generally, this rate is less that 2 feet-per-second at the 2-year peak flow. Wetland basins may be designed with or without an open water (permanent pool) component. Wetland basins with open water are similar to retention ponds, except that a significant portion (usually 50 percent or more) of the permanent pool volume is covered by emergent wetland vegetation. Wetland basins without open water are inundated with water during runoff events, but do not maintain a significant permanent pool. Wetland basins of this type, also known as a wetland meadow, support a variety of wetland plants adapted to saturated soil conditions and tolerant of periodic inundation by runoff.

Pollutant removal in wetlands can occur through a number of mechanisms including sedimentation, filtration, volatilization, adsorption, absorption, microbial decomposition and plant uptake. In addition, wetlands can provide for significant water storage during runoff events, thus supplying water quantity control as well. A diagram of a typical storm water wetland system is included below.

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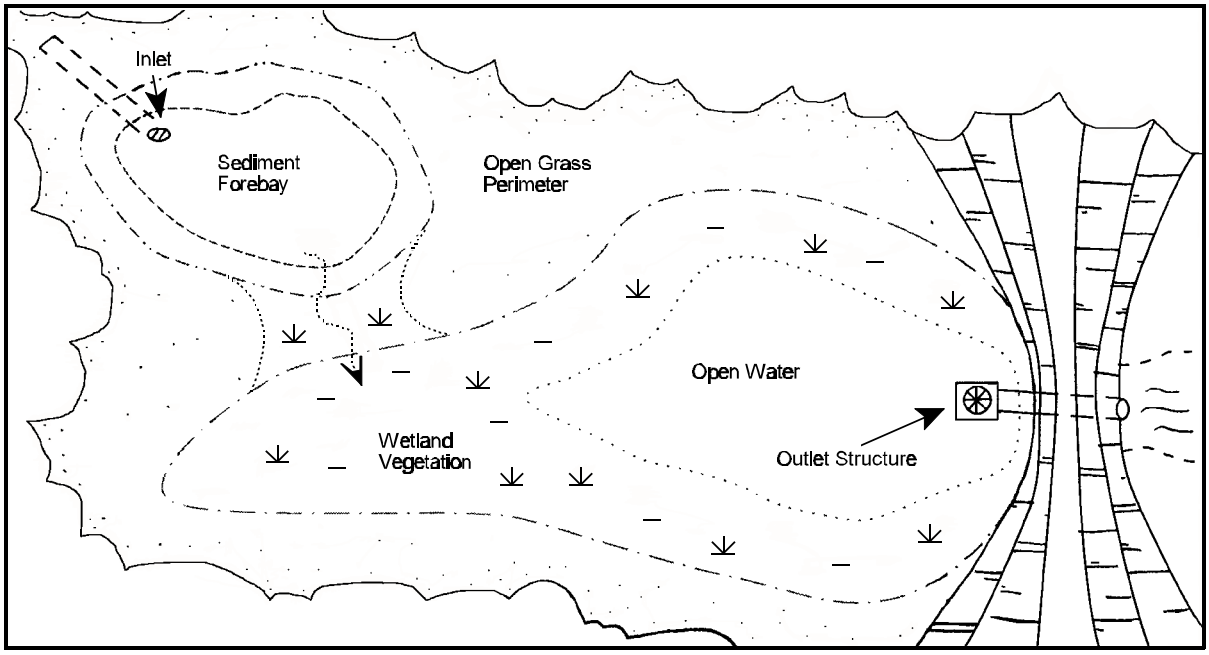
Figure 5-6. Constructed Wetland System



5.2.1.5 Filtration Systems

A filtration system is a device that uses a media such as sand, gravel, peat or compost to remove a fraction of the constituents found in storm water. There are a wide variety of filter types in use. There are also a variety of proprietary designs that use specialized filter media made from materials such as leaf compost. Filters are primarily a water quality control device designed to remove particulate pollutants. Quantity control can be included by providing additional storage volume in a pond or basin, by providing vertical storage volume above the filter bed, or by allowing water to temporarily pond in parking lots or other areas before being discharged to the filter. Media filters are commonly used to treat runoff from small sites such as parking lots and small developments, in areas with high pollution potential such as industrial areas, or in highly urbanized areas where land availability or costs preclude the use of other BMP types. Filters should be placed off-line (i.e., a portion of the runoff volume, called the water quality volume, is diverted to the BMP, while any flows in excess of this volume are bypassed) and are sometimes designed to intercept and treat only the first half inch or inch of runoff and bypass larger storm water flows. A benefit of using filters in highly urbanized areas is that the filter can be placed under parking lots or in building basements, limiting or eliminating costly land requirements. However, placing filters “out of sight” may have implications for continued maintenance and performance. Media filters should use a forebay or pre-settling chamber to remove a portion of the settleable solids prior to filtration. This helps to extend the life of the filter run and prevent clogging of the filter media by removing a portion of the coarse sediment. Also, care must be

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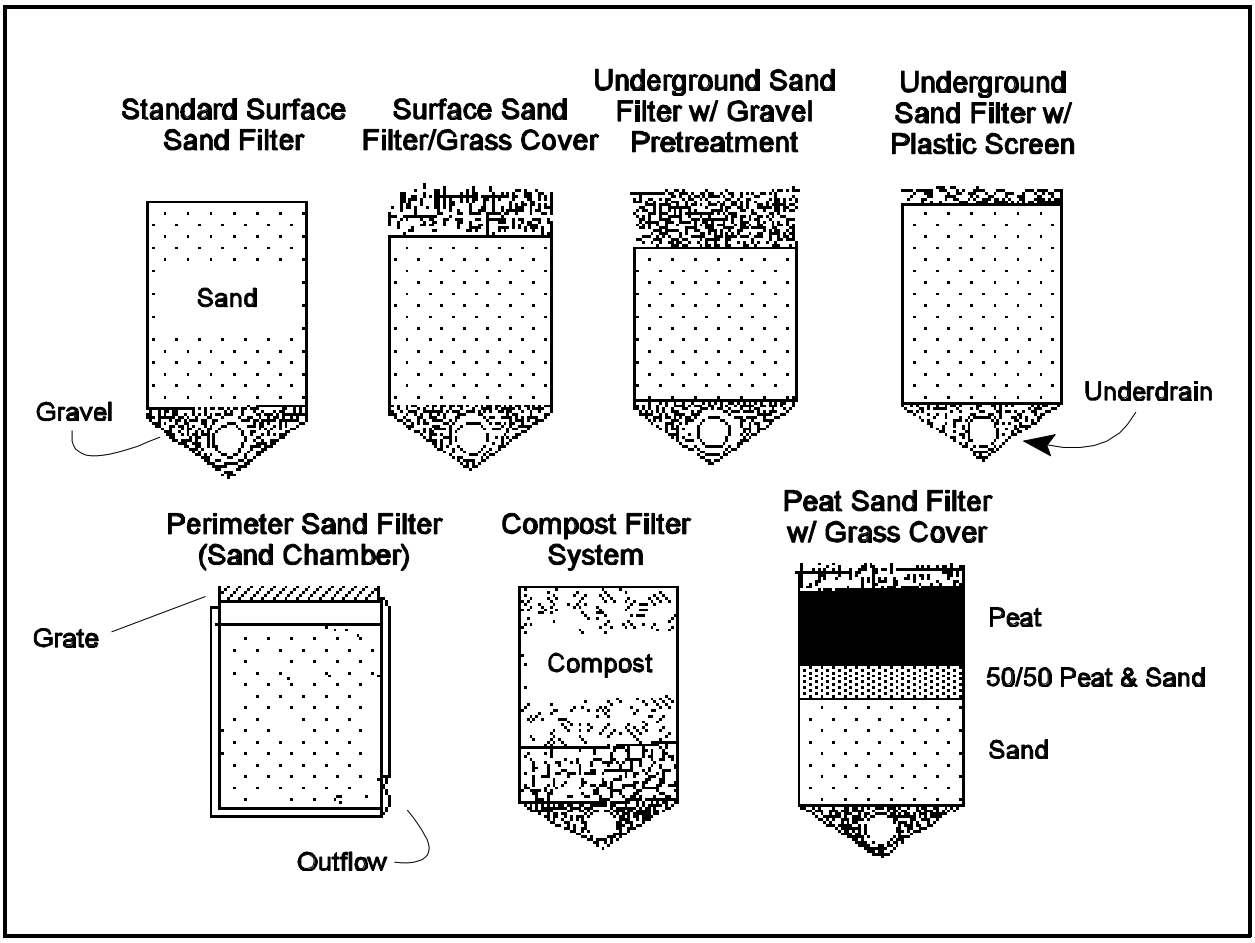
taken to prevent construction site sediments and debris such as fines washed off of newly paved areas from entering the filter, as these can cause premature clogging of the filter.

Filter types in common use include surface sand filters such as the "Austin" sand filter and underground vault filters such as the "D.C." sand filter and the "Delaware" sand filter. There are a number of variations of these basic designs in common use. In addition, there are a number of proprietary filtering systems in use. There are also a number of variations in the types of filtration media that are in use in media filters. Designs may incorporate features such as a layer of filter cloth or a plastic screen, a gravel layer, a peat layer, a compost layer, a layer of peat or a peat/sand mixture. Typical variations in filtration media are shown below.

Figure 5-7. Filter Media



Source: Claytor and Schueler, 1996

Surface Sand Filter

The surface sand filter was developed in Florida in 1981 for sites that could not infiltrate runoff or were too small for effective use of detention systems. The city of Austin, Texas took the development of filter technology further in the mid-1980's. The surface sand filter system

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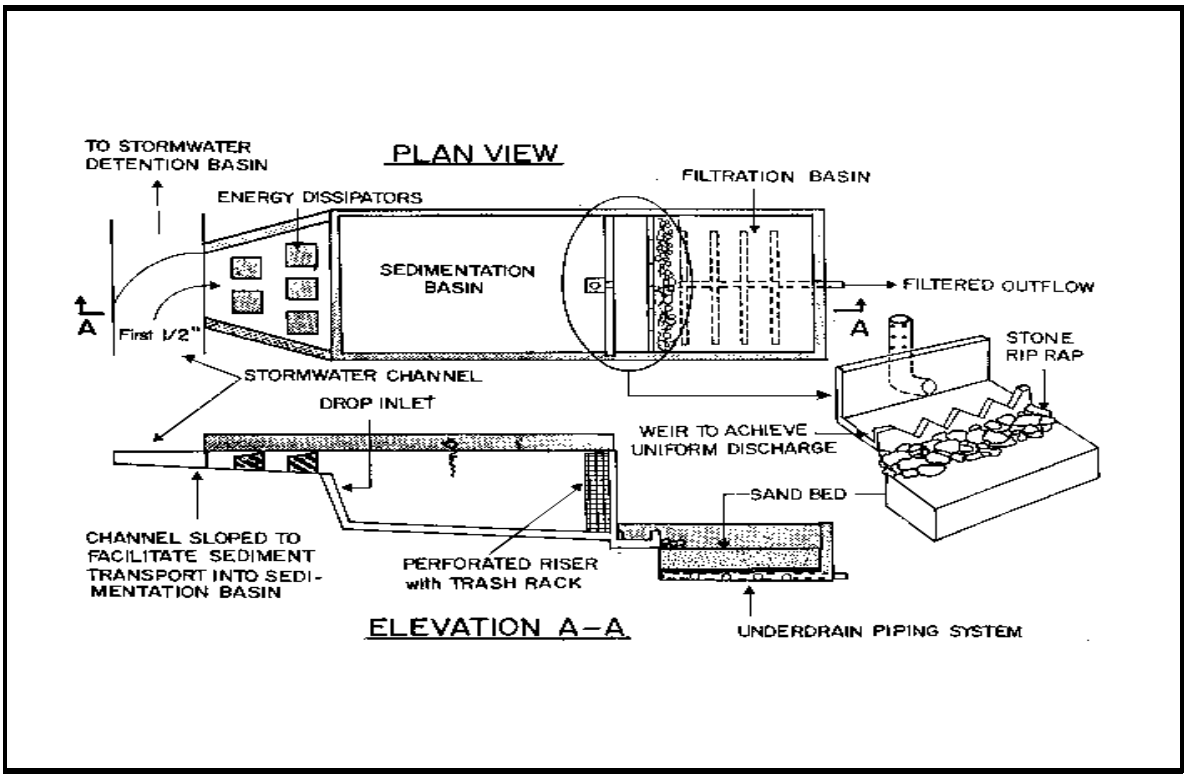
usually incorporates two basins. Runoff first enters a sedimentation basin where coarse particles are removed by gravity settling. This sedimentation basin can be either wet or dry. Water then flows over a weir or through a riser into the filter basin. The filter bed consists of sand with a gravel and perforated pipe under-drain system to capture the treated water. The surface of the filter bed may be planted with grass. Additional storage volume is provided above the filter bed to increase the volume of water that can be temporarily ponded in the system prior to filtration. This two-basin configuration can help to limit premature clogging of the filter bed due to excessive sediment loading. There are several design variations of the simple surface sand filter. Austin uses two variations, termed the partial and the full sedimentation-filtration systems. A diagram of the Austin surface sand filter is shown in Figure 5-8.

Figure 5-8. Austin Full Sedimentation-Filtration System



Source: Bell, 1998

Underground Vault Sand Filter

The underground vault sand filter was developed by the District of Columbia in the late 1980's. This filter design incorporates three chambers. The first chamber and the throat of the second chamber contain a permanent pool of water and functions as a sedimentation chamber and an oil and grease and floatables trap, as well as provides for temporary runoff storage. A submerged opening or inverted elbow near the bottom of the dividing wall connects the two chambers. This submerged opening provides a water seal that prevents the transfer of oil and

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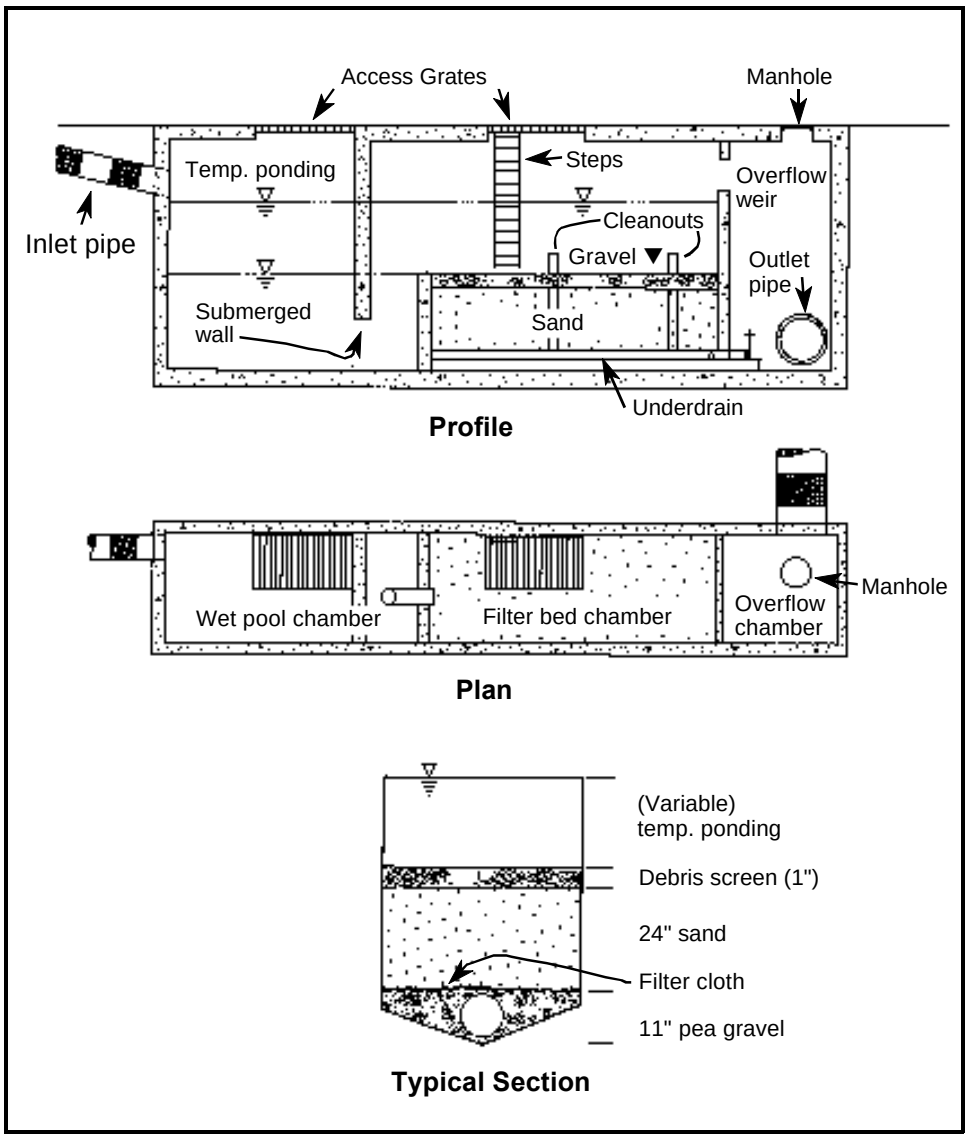
floatables to the second chamber which contains the filter bed. During a storm event, water flows through the opening into the second chamber and onto the filter bed. Additional runoff storage volume is provided above the filter bed. Filtered water is collected by a gravel and perforated pipe under-drain system and flows into the third chamber, which contains a clearwell and a connection to the storm drain system. Overflow protection can be provided by placing the filter off-line, or by providing a weir at the top of the wall connecting the filter chamber with the clearwell chamber to serve as an overflow. A schematic of the "D.C. Sand Filter" is shown below.

Figure 5-9. Underground Vault Sand Filter



Source: Claytor and Schueler, 1996.

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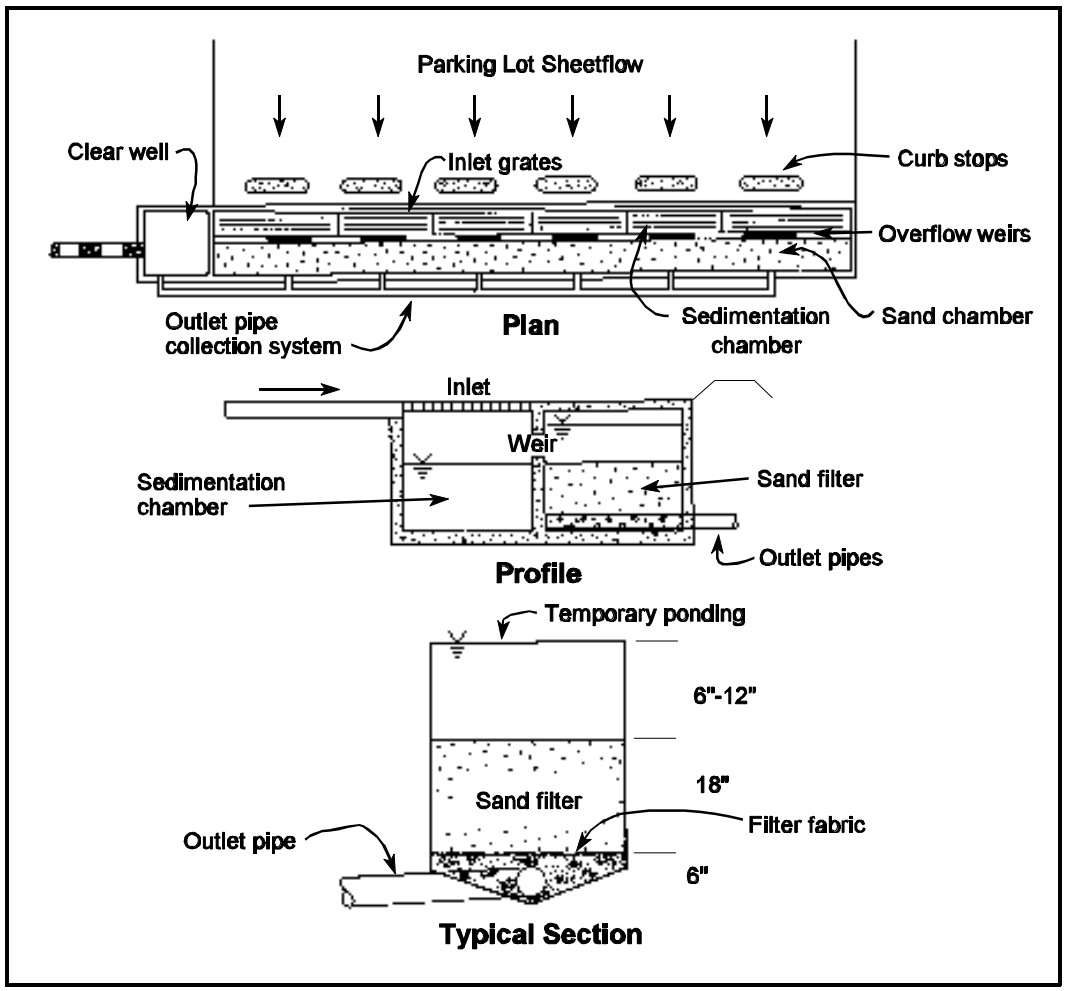
Another underground vault sand filter, also termed a "perimeter" sand filter because it is particularly suited for use around the perimeter of parking lots, was developed in Delaware by Shaver and Baldwin and is known as the "Delaware Sand Filter." This system contains two chambers and a clearwell. Storm water runoff enters the first chamber, which serves as a sedimentation chamber. Water then flows over a series of weirs and into the second chamber which contains the filter media. Additional storage volume is provided by water temporarily ponding in both chambers. Filtered water is collected by a series of gravel and perforated pipe under-drains, and flows into a clearwell that contains a connection to the storm drain system. A schematic of the Delaware Sand Filter is shown below.

Figure 5-10. Delaware Sand Filter



Source: Shaver and Baldwin, 1991

In addition to the three basic filtering systems (D.C., Austin, and Delaware), there are a number of variations in use. The city of Alexandria, Virginia has developed a compound storm water filtering system (Bell, 1998). This design incorporates an anoxic filtration zone in a

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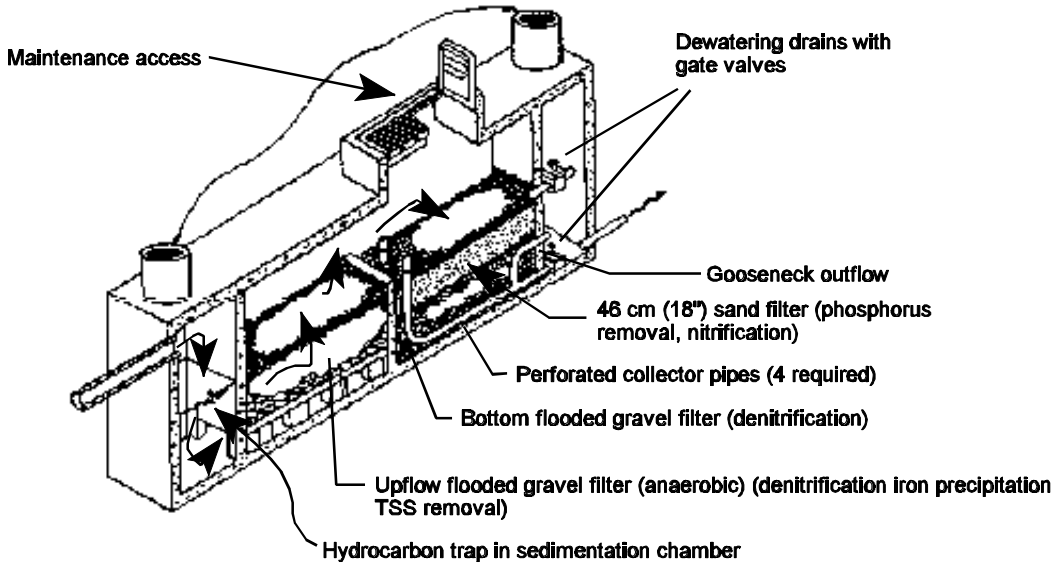
permanently flooded gravel layer in the filter. This anoxic zone aids in nitrogen removal by anoxic denitrification. Another configuration uses an upflow anaerobic filter upstream of the sand filter to enhance phosphorus removal by precipitating more iron on the sand filter. A diagram of the Alexandria Compound Filtration System is shown below.

Figure 5-11. Alexandria Compound Filter



Source: Bell, 1998.

Filters that use an organic filtration media, such as peat or leaf compost, are useful in areas where additional nutrient or metal control is desirable due to the adsorptive capacity, its ion-exchange capability, and is ability to serve as a medium for the growth of a variety of microorganisms. However, peat must be carefully selected (fibric and/or hemic peat should be used, not sapric) and one must question the environmental consequences of destroying peat bogs to obtain filtration media when other technologies are available.

There are a number of references available that contain information on the design and selection of filtering systems for storm water treatment (Urbonas, 1999; Bell, 1998; Claytor and Schueler, 1996; Galli, 1990b; MDE, 1998; NVPDC, 1996a).

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Biofiltration/Bioretention Systems

Bioretention systems are designed to mimic the functions of a natural forest ecosystem for treating storm water runoff. Bioretention systems are a variation of a surface sand filter, where the sand filtration media is replaced with a planted soil bed. Storm water flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Pollutants are removed by a number of processes including adsorption, filtration, volatilization, ion exchange and decomposition (Prince George's County, MD, 1993). Treated water is allowed to infiltrate into the surrounding soil, or is collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters. When water is allowed to infiltrate into the surrounding soil, bioretention systems can be an excellent source of groundwater recharge. A diagram of a typical bioretention area is shown below.

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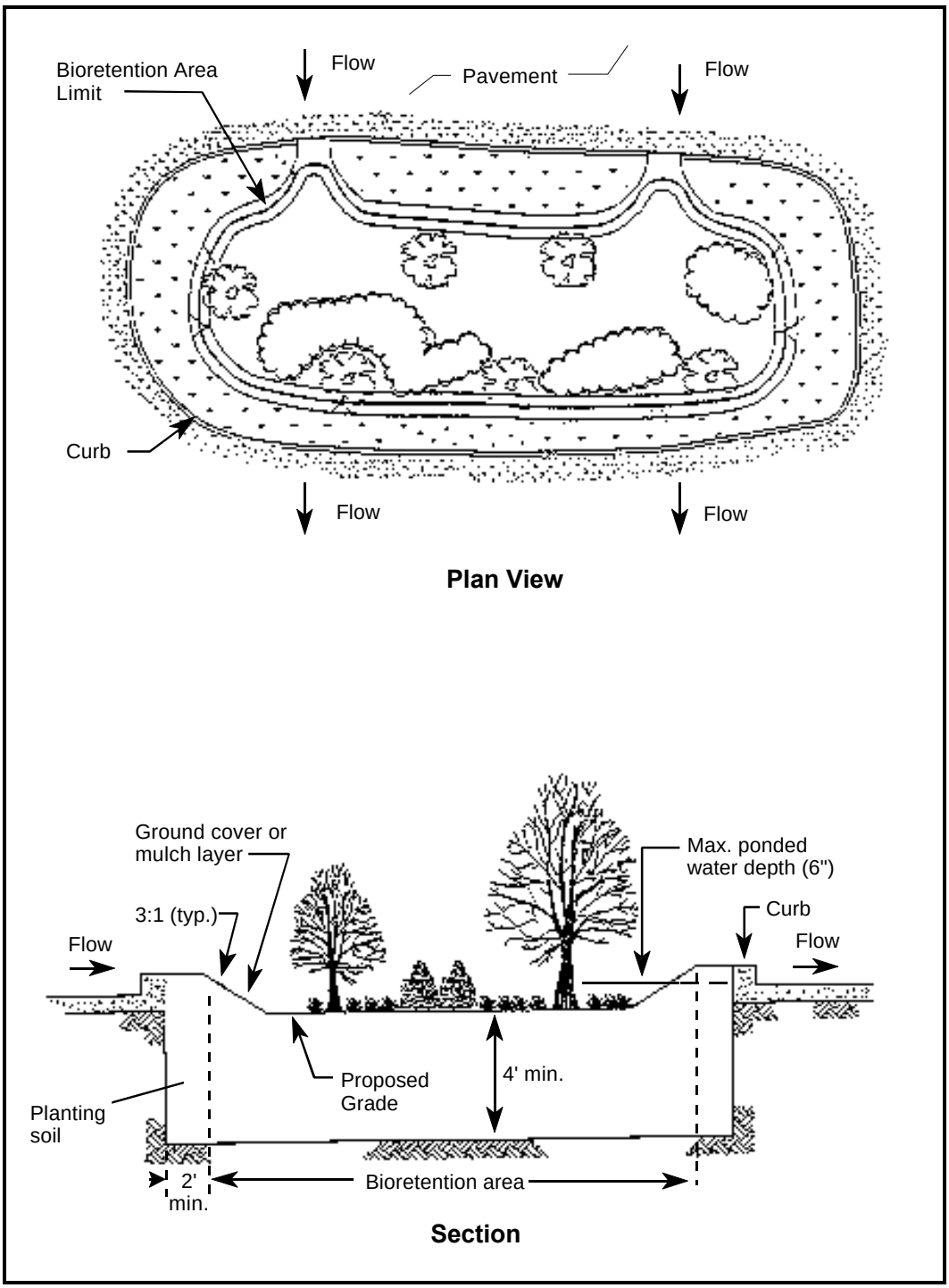
Figure 5-12. Bioretention System
Traffic Island



Source: Prince George's County, 1993.

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The components of a bioretention system include:

- *Grass Buffer Strips* - runoff enters the bioretention area as sheet flow through the grass buffer strips. The buffers reduce the velocity of the runoff and filter particulates from the runoff.

- *Ponding Area* - The ponding area provides for surface storage of storm water runoff before it filters through the soil bed. The ponding area also allows for evaporation of ponded water as well as allows for settling of sediment in the runoff.

- *Organic Mulch Layer* - The organic mulch layer has several functions. It protects the soil bed from erosion, retains moisture in the plant root zone, provides a medium for biological growth and decomposition of organic matter, and provides some filtration of pollutants.

- *Planting Soil Bed* - The planting soil bed provides water and nutrients to support plant life in the bioretention system. Storm water filters though the planting soil bed where pollutants are removed by the mechanisms of filtration, plant uptake, adsorption and biological degradation.

- *Sand Bed* - the sand bed underlies the planting soil bed and allows water to drain from the planting soil bed through the sand bed and into the surrounding soil. The sand bed also provides additional filtration and allows for aeration of the planting soil bed.

- *Plants* - Plants are an important component of a bioretention system. Plants remove water though evapotranspiration and remove pollutants and nutrient through uptake. The plant species selected are designed to replicate a forested ecosystem and to survive stresses such as frequent periods of inundation during runoff events and drying during inter-event periods.

In addition to providing for treatment of storm water, bioretention facilities, when properly maintained, can be aesthetically pleasing. Bioretention facilities can be placed in areas such as parking lot islands, in landscaped areas around buildings, the perimeter of parking lots, and in other open spaces. Since local regulations frequently require site plans to incorporate a certain percentage of open landscaped area, additional land requirements for bioretention facilities are often not required. The layout of bioretention facilities can be very flexible, and the selection of plant species can provide for a wide variety of landscape designs. However, it is important that a landscape architect with proper experience in designing bioretention areas be consulted prior to construction to insure that the plants selected can tolerate the growing conditions present in bioretention facilities. Bioretention facilities can be adapted easily for use on individual residential lots. Prince George's County, MD has developed the concept of "rain gardens" which are small bioretention systems for use in single or multi-lot residential areas. They provide an easily maintainable, aesthetically pleasing, and effective means of controlling runoff from residential

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areas. By disconnecting down spouts and placing a series of bioretention areas throughout a residential area, the volume of storm water runoff produced and requiring subsequent management can be significantly reduced.

Additional design information on bioretention facilities can be found in *Design Manual for Use of Bioretention in Stormwater Management* (Prince George's County, 1993) and in *Design of Stormwater Filtering Systems* (Claytor and Schueler, 1996).

5.2.1.6 Vegetated Systems (Biofilters)

Vegetated systems such as grass filter strips and vegetated swales are used for conveying and treating storm water flows. These BMPs are commonly referred to as *biofilters*, since the grasses and vegetation "filter" the storm water as it flows. Open channel vegetated systems are alternatives to traditional curb-and-gutter and storm sewer conveyance systems. By conveying storm water runoff in vegetated systems, some degree of treatment, storage and infiltration can be provided prior to discharge to the storm sewer system. This can help to reduce the overall volume of storm water runoff that is generated from a particular drainage area.

Grass Filter Strips

Grass filter strips are densely vegetated, uniformly graded areas that intercept sheet runoff from impervious surfaces such as parking lots, highways and rooftops. Grass filter strips are frequently planted with turf grass, however alternatives that adopt any natural vegetated form such as meadows or small forest may be used. Grass filter strips can either accept sheet flow directly from impervious surfaces, or concentrated flow can be distributed along the width of the strip using a gravel trench or other level spreader. Grass filter strips are designed to trap sediments, to partially infiltrate this runoff and to reduce the velocity of the runoff. Grass filter strips are frequently used as a "pretreatment" system prior to storm water being treated by BMPs such as filters or bioretention systems. Grass filter strips can also be used in combination with riparian buffers in treating sheet flows and in stabilizing drainage channel banks and stream banks. In semi-arid climates, grass filter strips may need to be irrigated to maintain a dense stand of vegetation and to prevent export of unstabilized soil. A diagram of a grass filter strip is shown below.

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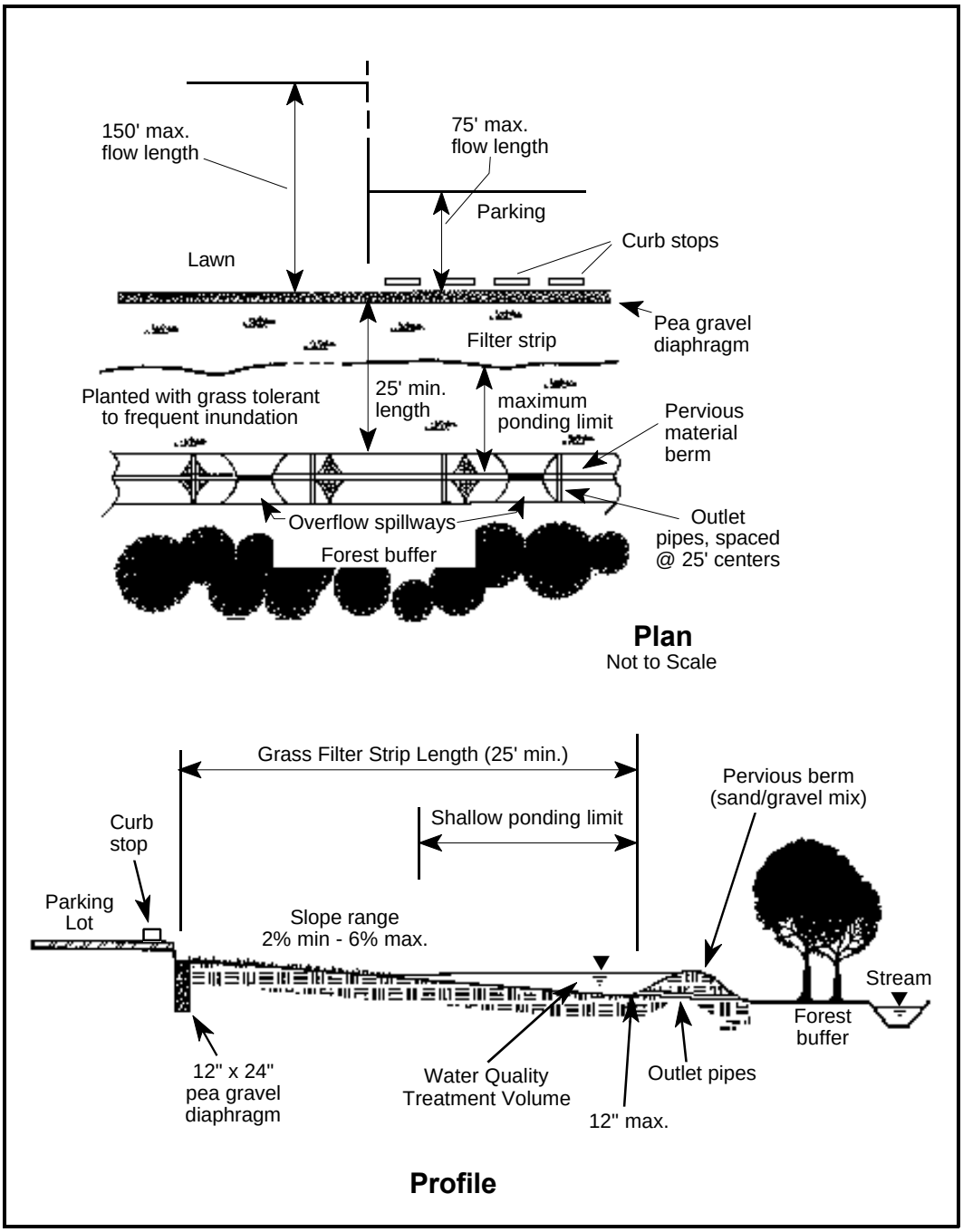
Figure 5-13. Grass Filter Strip



Source: Claytor and Schueler, 1996.

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Vegetated Swales

Vegetated swales are broad, shallow channels with a dense stand of vegetation covering the side slopes and channel bottom. Vegetated swales are designed to slowly convey storm water runoff, and in the process trap pollutants, promote infiltration and reduce flow velocities. Vegetated swales can be either wet or dry. Dry swales are used in areas where standing water is not desired, such as in residential areas. Wet swales can be used where standing water does not create a nuisance problem and where the groundwater level is close enough to the surface to maintain the permanent pool in inter-event periods. Wet swales provide the added benefit of being able to include a range of wetland vegetation to aid in pollutant removal.

5.2.1.7 Minimizing Directly-Connected Impervious Surfaces

Minimizing directly-connected impervious surface areas involves a variety of practices designed to limit the amount of storm water runoff that is directly connected to the storm drainage system. Runoff is instead directed to landscaped areas, grass buffer strips, and grassed swales to reduce the velocity of runoff, reduce runoff volumes, attenuate peak flows, and encourage filtration and infiltration of runoff (UDFCD, 1992). By incorporating these principles into site designs, the size and number of conventional BMPs such as ponds and constructed wetland systems can be significantly reduced.

Minimizing directly connected impervious surfaces incorporates both non-structural and structural control measures. Discussions in this section address the structural measures that can be incorporated into existing urbanized or newly developed areas to minimize the amount of runoff discharged to the storm drain system. Additional discussion on non-structural practices that can be used to minimize runoff generation in new developments is included in Section 5.2.3 "Low Impact Development Practices."

The Denver *Urban Storm Drainage Criteria Manual* (UDFCD, 1992) identifies the following three levels of minimizing directly connected impervious areas:

- *Level 1*: Runoff generated from impervious surfaces such as rooftops, driveways and parking lots is directed to flow over vegetated areas before flowing to a storm sewer system. This increases the travel time of runoff and promotes the removal of suspended solids by sedimentation and filtration.
- *Level 2*: Street curb-and-gutter systems are replaced by grassed swales and pervious street shoulders. Conveyance systems and storm sewer inlets are still used to collect runoff at downstream intersections and crossings.
- *Level 3*: In addition to incorporating Levels 1 and 2, swales are oversized and driveway and street crossing culverts are configured to use the grassed swales as detention basins having the capacity to capture runoff volume for a design storm (2-, 5-, 10- or 100-year runoff).

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Practices that reduce the amount of directly connected impervious surfaces can easily be incorporated into site design plans during the planning stages of development projects. Using these practices can result in significant development cost savings due to the decreased need for drainage infrastructure and large end-of-pipe structural BMPs such as ponds and constructed wetlands. These practices can also limit secondary impacts from structural BMPs, such as temperature increases from retention ponds. Minimizing directly connected impervious areas can also be applied to existing urbanized areas through retrofit. Practices that can be used in retrofit instances include disconnecting rooftop downspouts from the storm drain system, use of on-site retention and infiltration to limit the amount of runoff leaving the site and replacing traditional curb-and-gutter systems with grassed swales and wetland channels. Additional discussion on practices that minimize runoff generation is included in Section 5.2.3.

5.2.1.8 Miscellaneous and Vendor-Supplied Systems

There are a wide variety of miscellaneous and proprietary devices that are used for urban storm water management. Many of these systems are "drop-in" systems, and incorporate some combination of filtration media, hydrodynamic sediment removal, oil and grease removal, or screening to remove pollutants from storm water. A few of the systems available include:

- BaySaver
- CDS Technologies
- Hydrasep®
- Storm*ceptor*®
- StormFilter™
- StormTreat™ System
- Vortechs™.

A thorough evaluation of vendor-supplied systems was not conducted in this report. Readers are encouraged to contact the product vendors to obtain information regarding these systems.

One of the main problems facing the use of proprietary devices is the lack of peer-reviewed performance data for these systems. Several vendor-supplied storm water treatment systems are being evaluated through EPA's Environmental Technology Verification (ETV) program. With financial assistance from the ETV program, the Civil Engineering Research Foundation (CERF) established the Environmental Technology Evaluation Center, commonly known as "EvTEC, " in 1998. EvTEC is a private sector program designed to utilize networks of experts, testing facilities and stakeholders to evaluate technologies dealing with a variety of environmental problems. One of the EvTEC projects is a collaborative effort with the Washington Department of Transportation (WSDOT) to verify the performance of innovative storm water BMPs under field operating conditions. These evaluations, which are scheduled to begin in 1999, are expected to provide comparable, peer-reviewed data on the performance of these systems (CERF, 1998).

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5.2.2 Non-Structural BMPs

Non-structural BMPs include institutional and pollution-prevention type practices designed to prevent pollutants from entering storm water runoff or reduce the volume of storm water requiring management. Non-structural BMPs can be very effective in controlling pollution generation at the source, which in turn can reduce or eliminate the need for costly end-of-pipe treatment by structural BMPs. Non-structural BMPs discussed in this report include education and source controls, recycling and maintenance practices.

5.2.2.1 Education, Recycling and Source Controls

Public education can be an effective means of reducing the amounts of non-point source pollutants entering receiving streams. The public is often unaware that the combined effects of their actions can cause significant non-point source pollution problems. Proper education on day-to-day activities such as recycling of used automotive fluids, household chemical and fertilizer use, animal waste control and other activities can significantly reduce non-point source pollutant loadings to urban streams. The main components of a public education program include:

Automotive Product Disposal

Discharge of automotive fluids such as motor oil and antifreeze to the land or storm drains can cause significant water quality problems. "Do-it-yourself" automobile mechanics often incorrectly assume that materials that are dumped into storm drains will receive treatment at a wastewater treatment plant prior to discharge. Education on appropriate recycling and disposal techniques for these materials can help to reduce pollutant loadings to streams. Education programs should identify the location of community automotive products recycling centers. In addition to impacts associated with dumping used oil and antifreeze, potential runoff pollutant sources from home automobile maintenance activities include dirt, cleaners, oils and solvents from car washing, leaking fluids such as brake and transmission fluid and gasoline spills. To reduce impacts from these activities, the following practices should be used:

- all spills or leaks should be cleaned up using a dry absorbent such as cat litter or commercially available absorbents and disposed of appropriately;
- car washing should be done away from storm drains using biodegradable cleaners, or at a commercial carwash;
- all used fluids should be recycled or disposed of appropriately;
- all fluid leaks should be repaired as soon as possible to reduce loss to the environment.

Commercial and Retail Space Good Housekeeping

Commercial and retail areas can contribute significant pollutant loadings to runoff. The biggest contributor of pollutant is usually impervious surfaces used for vehicle parking, storage and maintenance areas, which can contribute sediment, metals and hydrocarbons. Other sources include raw material and finished product storage areas, pesticides and fertilizers from grounds maintenance, and rooftop runoff. Good housekeeping practices include using porous pavement or

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modular paving systems for vehicle parking lots; limiting exposure of materials and equipment to rainfall; spill cleanup, using dry cleanup techniques instead of wet techniques; and limiting direct runoff of rooftops to storm drains.

General Community Outreach

A main problem associated with identifying and controlling nonpoint source pollution is that the public is generally unaware of the sources and control measures for urban nonpoint source pollutants. Information dissemination is a critical need of most local storm water programs. Information that explains the sources of nonpoint source pollution, control measures available and the steps homeowners and commercial owners can do to reduce impacts of their activities can help to increase the public awareness of the need to control nonpoint source pollution. A few of the techniques available for providing educational materials to the public include television, radio and newspaper announcements, distribution of flyers, community newsletters, workshops and seminars, conducting teacher training programs at schools, and supporting citizen-based watershed stewardship groups and volunteer monitoring programs.

Industrial Good Housekeeping

Industrial areas can contribute significant loadings of toxic pollutants to storm water runoff. Therefore, educational programs that inform industrial site owners and operators about pollution prevention and source control programs to reduce nonpoint source pollutant can significantly reduce the amounts of pollutants discharged from industrial areas. Pollution prevention practices include minimizing or eliminating exposure of materials and products to rainfall by storing inside or under cover, spill cleanup, minimizing pesticide/herbicide and fertilizer use, and minimizing discharges of equipment wash water to storm drains.

Storm Drain Inlet Stenciling

Since storm drains frequently discharge runoff directly to water bodies without receiving any type of treatment, storm drain stenciling programs that educate residents not to dump materials into storm drains or onto sidewalks, streets, parking lots and gutters can be effective at reducing nonpoint source pollution associated with illegal dumping. Residents are frequently unaware that materials dumped down storm drains may be discharged to a local water body. Therefore, stenciling the inlets can be a simple yet effective means of alerting residents of this fact. The Northern Virginia *Nonstructural Urban BMP Handbook* (NVPDC, 1996b) contains a useful discussion on developing a storm drain stenciling program.

Pesticide/Herbicide Use

Due to their high aquatic toxicity, pesticides and herbicides can be a significant source of water quality impairment in urban streams. Pesticide usage in the United States was estimated at more than 1.2 billion pounds of active ingredients in 1995 (US EPA, 1997b). Of this total, agricultural usage constituted 939 million pounds (77 percent), commercial, industrial and government usage accounted for 150 million pounds (13 percent) and home and garden usage accounted for 133 million pounds (11 percent). A significant portion of these applications find their way into storm water runoff and ultimately into receiving streams through spray drift,

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transport by soils, solubilization by runoff, and by spillage, dumping and improper disposal of containers and residuals. Education on the proper methods of application, application rates and alternatives to pesticides can help to reduce the amount of pesticides that are carried by urban runoff. Alternatives to pesticides, such as in integrated pest management program and pesticide alternatives such as insecticidal soap or natural bacteria, can also reduce the need for pesticides.

Fertilizer Use

A significant amount of nutrients in urban runoff results from misapplication of fertilizer to the urban landscape. Residential lawn and garden maintenance and maintenance of landscape and turfgrass at golf courses, schools and commercial areas uses significant amounts of fertilizers containing nitrogen and phosphorus. Since most fertilizers are water soluble, over-application or application before rainfall events can allow significant quantities to be carried away by storm water runoff. Education on proper application of fertilizers can help to reduce the quantities of nutrients reaching receiving waters.

Household Hazardous Material Disposal

A variety of hazardous and potentially harmful chemicals and materials are improperly used and disposed of by residential homeowners. Materials such as paints and thinners, cleaning products, wood preservatives, driveway sealants and a variety of other miscellaneous household chemicals can find their way into storm water if improperly used, stored or disposed of. Education on usage and holding an annual or semi-annual community household hazardous waste collection program can help to reduce the amounts of these materials that enter storm water runoff.

Lawn Debris Management

Lawn debris such as grass trimmings and leaves require proper management in order to reduce impacts to urban streams. Grass trimmings and leaves can be carried away by runoff and can find their way into streams where they rapidly decompose and release nutrients. Grass trimmings and leaf litter can be controlled by composting or by community curbside collection programs. Composted yard debris can be an excellent source of mulch for residential landscape and gardens. Use of mulch can greatly reduce the need for inorganic fertilizers, which helps to keep nutrient loadings to streams to a minimum.

Pet Waste Disposal

Pet waste can cause significant loadings of bacteria, nutrients and oxygen demanding substances to urban runoff. Pet waste deposited on yards, sidewalks and streets can be carried by runoff into storm drains. As an example, it is estimated that 11,445 pounds of dog waste are generated in the Four Mile Run watershed in northern Virginia each day.[2] 378 pounds of BOD, 39 pounds of total phosphorus and 189 pounds of total nitrogen are washed off into Four Mile Run and its tributaries annually as a result of this pollution load (NVPDC, 1996b). In many areas,

[2] This estimate was calculated based on the total waste load generated by the dog population in the area, not the waste load deposited on yards, sidewalks and streets.

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regulations exist prohibiting the deposit of pet waste on public property. However, it is often very difficult to enforce these laws. Community education on the impacts associated with pet waste and alternative disposal methods such as flushing and disposal in the trash can help to reduce impacts associated with pest waste. A particularly useful method of controlling pet waste is for communities to provide pet waste receptacles in parks and other public areas for pet owners to deposit droppings from their pets.

Illicit Discharge Detection and Elimination

Illicit discharges to storm sewers can be a significant source of pollutants in urban storm water. A study conducted in Sacramento, California indicated that slightly less than one-half of the water discharged from a municipal separate storm sewer system was not directly attributable to precipitation runoff (US EPA, 1993b). A major source of illicit discharges to storm drain systems are direct connections of sanitary sewer piping to the storm drain system. In addition to direct connections, seepage and sewage from leaking sanitary sewer lines can find their way into storm drains, especially in areas where storm drains run parallel to the sanitary sewer lines. Spills can also be collected by storm drain inlets.

Detection and elimination of illicit connections and discharges can significantly reduce the concentrations of bacteria, nutrients and oxygen demanding substances contained in storm water discharges. Several methods exist for detection and elimination of illicit cross-connections. Useful indicators of the presence of cross connections include dry weather flows in storm sewer lines and biological indicators that indicate the presence of human fecal matter in storm drain outfalls. Once illicit connections are detected, excavation and correction of the illicit connections are necessary. In addition to detection and elimination of existing cross-connections, plans for new development should be carefully reviewed and inspections should be conducted during construction in order to prevent future cross-connections from being placed. Storm drain stenciling programs and a public spill reporting system can help to educate the public on proper procedures for managing spills to prevent discharge to the storm sewer system.

5.2.2.2 Maintenance Practices

Maintenance programs are necessary in order to reduce the pollutant contribution from the urban landscape and to ensure that storm water collection and treatment systems are operating as designed. Major maintenance practices that can be used include:

Catch Basin Cleaning

Catch basins naturally accumulate sediment and debris such as trash and leaf litter. In order to ensure their continued effectiveness, catch basins need to be periodically cleaned. This can be done by manual means, or by using a vacuum truck.

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Street and Parking Lot Sweeping

Urban streets and parking lots can accumulate large amounts of pollutants that can be washed off during storm events. Streets and parking lots comprise a significant portion of the total impervious area within a developed watershed, and a large percentage, if not the entire area, of streets and parking lots are usually directly connected to the storm drain system. In an investigation conducted by Bannerman (Bannerman et al, 1993), data on runoff volumes from streets and parking lots collected during 4 years from two urbanized areas in Wisconsin indicated that 54 percent of the total runoff volume from residential areas was due to direct runoff from streets and parking lots, and that 80 percent of the total runoff volume from commercial areas was due to direct runoff from streets and parking lots. A breakdown of the runoff volumes based on source area is shown in Table 5-1.

Table 5-1. Percent Runoff Volumes Contributed by Source Area in Two Urbanized Areas of Wisconsin

Land Use	**Source Area Percent Runoff Contribution**					
	Feeder Streets	Collector Streets	Arterial Streets	Parking Lots	Total % due to roads and parking lots	Total Other %*
Residential	34	20	--	--	54	46
Commercial	--	10	21	49	80	20

* Other land uses include lawns, driveways, rooftops and sidewalks
Source: Adapted from Bannerman et al, 1993

Furthermore, Bannerman found that runoff from streets and parking lots contributed a significant portion of the total runoff pollutant loading. Table 5-2 summarizes the pollutant load contributions based on land uses, and indicates the total contaminant contribution in the urbanized area attributable to runoff from streets and parking lots.

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Table 5-2. Contaminant Load Percentages in Two Urbanized Areas of Wisconsin

Contaminant	Percent Contribution by Source Area						Total Contaminant Contribution by Streets and Parking Lots
	Residential		*Commercial*		*Industrial*		
	Streets	**Parking Lots**	**Streets**	**Parking Lots**	**Streets**	**Parking Lots**	
Total Solids	76	--	57	31	20	60	**78**
Suspended Solids	80	--	68	27	25	55	**80**
Total Phosphorus	58	--	56	28	19	29	**54**
Dissolved Phosphorus	46	--	50	27	18	11	**39**
Dissolved Copper	73	--	50	39	16	73	**82**
Total Copper	78	--	60	32	22	67	**85**
Total Zinc	80	--	45	32	9	30	**49**
Fecal Coliform	78	--	82	10	10	19	**71**

Source: Adapted from Bannerman et al, 1993

Based on these data, streets and parking lots can contribute significant pollutant loadings to urban runoff. Therefore, sweeping programs that can remove a portion of these materials from streets and parking lots may significantly reduce the pollutant load contributions to urban runoff.

Road and Ditch Maintenance

Road and street surfaces undergo breakdown due to frictional action of traffic, freeze-thaw breakdown, frost heaving, and erosion of road subbase. Failure to correct deteriorating pavement can allow exposure of unstabilized subbase material to erosive forces of water and subsequent increases in suspended solids concentrations. The same process occurs in roadside ditches where high runoff rates cause channelization and erosion. Roadside ditches also accumulate sediment and debris from the road surface, which enters runoff during rainfall events. Maintenance of roads and cleaning and stabilization of ditches can help to reduce pollutant loadings from these sources. In roadside ditches, reducing the length and slope of ditch runs and

reducing the velocity of runoff by using check dams can help to prevent excessive channelization and erosion.

Road Salting and Sanding

Road salting and sanding can contribute large quantities of sediment and salts to runoff. Highway maintenance programs in areas where road icing is a problem frequently apply large quantities of sand, salt, and coal ash to prevent icy road surfaces. Snowmelt can carry a large portion of these materials into the storm drainage system and ultimately to receiving streams. High salt concentrations can have significant impacts on receiving streams. In addition, road salt can contain cyanide, which may cause acute or chronic toxicity to aquatic organisms. Alternative deicing products such as acetates, formates and agricultural residues can be used if impacts due to traditional deicing products are significant.

Sediment and Floatables Removal from BMPs

Sediment and floatables removal is an important component of maintenance for BMPs that are designed for sediment capture. Removal of accumulated sediment is important so that the BMP continues to operate efficiently. Accumulation of excess sediment in pond and constructed wetland systems can lead to reduced storage capacity, short-circuiting and re-suspension of previously settled particles. All of these can lead to decreased efficiency of the BMP. Floatables in BMPs can accumulate and block outlet structures leading to changes in BMP hydraulics. Floatables can cause aesthetic impacts, and floating material such as algal scum and other debris can lead to odor problems. Sediment removal is also needed periodically in filtration systems. Sedimentation chambers require periodic cleanout of sediments and floatables (including accumulated oil) and filter beds will accumulate a sediment layer on the surface that will decrease the filtration rate of the system over time. Periodic removal of this sediment layer and a portion of the filtration media is necessary in order to restore the filtration capacity of the system. Sediments also accumulate in infiltration basins. The accumulation of sediments, particularly sediments from construction activities and improperly stabilized soil, will lead to a rapid reduction of the infiltrative capacity of infiltration basins, trenches and wells.

The frequency of sediment removal in BMP types can vary widely. Some BMPs require sediment removal every two or three years, while others may not need maintenance for more than 20 years. The frequency that sediment must be removed depends greatly on the land use and degree of soil stabilization in the contributing watershed. BMPs that receive runoff from a watershed that has significant construction activities will accumulate sediment at a rate much faster than a watershed with little or no construction activity. In addition, watersheds with dense, well established vegetation will contribute less sediment than sparsely vegetated watersheds. Also, watersheds in arid or semi-arid regions, which frequently are subject to high intensity rainfall and highly erosive storm water flows will produce large quantities of solids requiring frequent removal from BMPs. Table 5-3 summarizes maintenance requirements and frequency for different structural BMP types.

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Vegetation Maintenance

Vegetative BMPs such as constructed wetlands, grassed filter strips, vegetated swales, and bioretention facilities require periodic vegetation maintenance to enhance performance. Grassed filter strips and vegetated swales require a dense stand of vegetation in order to function properly and to prevent export of sediment from unstabilized planting areas. Several seasons of planting and re-seeding of sparsely vegetated areas may be needed in order to reach optimum performance. Constructed wetland systems frequently require re-planting of wetland vegetation in areas where original plantings failed to become established. Once wetland systems are functioning, periodic vegetation harvesting is necessary to remove excess vegetation and stored nutrients. Invasive species also need to be periodically removed to promote growth of beneficial wetland vegetation. Grassed filter strips and vegetated swales require periodic mowing to remove excess vegetation and stored nutrients. Mowing of these systems should not be done too close to the ground, as dense vegetation is needed for optimum performance.

General BMP Maintenance

BMPs require a variety of periodic maintenance activities in order to enhance performance. In addition to sediment removal and vegetation maintenance, periodic maintenance and repair of outlet structures is needed, filtration media need to be periodically replaced, and eroded areas need to be repaired, to name a few. Table 5-3 summarizes general maintenance activities and frequency for a few BMP types. The actual maintenance schedule varies considerably based on site-specific conditions, and the values given should be used only as a general guideline for established residential or commercial areas without significant inputs of construction sediment or other sediment loadings.

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Table 5-3. Recommended BMP Maintenance Schedules

BMP	Activity	Schedule
Retention Pond / Wetland[1]	• Cleaning and removal of debris after major storm events • Harvest excess vegetation • Repair of embankment and side slopes • Repair of control structure	Annual or as needed
	• Removal of accumulated sediment from forebays or sediment storage areas	5-year cycle, or as needed
	• Removal of accumulated sediment from main cells of pond once the original volume has been significantly reduced	20-year cycle (although can vary)
Detention Basin	• Removal of accumulated sediment • Repair of control structure • Repair of embankment and side slopes	Annual or as needed
Infiltration Trench[1]	• Cleaning and removal of debris after major storm events • Mowing[4] and maintenance of upland vegetated areas • Maintenance of inlets and outlets	Annual or as needed
Infiltration Basin[2]	• Cleaning and removal of debris after major storm events • Mowing[4] and maintenance of upland vegetated areas	Annual or as needed
	• Removal of accumulated sediment from forebays or sediment storage areas	3- to 5-year cycle
Sand Filters[3]	• Removal of trash and debris from control openings • Repair of leaks from the sedimentation chamber or deterioration of structural components • Removal of the top few inches of sand and cultivation of the surface when filter bed is clogged (only works for a few cycles) • Clean-out of accumulated sediment from filter bed chamber • Clean out of accumulated sediment from sedimentation chamber	Annual or as needed

1. Modified from Livingston et al (1997)
2. Modified from Livingston et al (1997), based on infiltration trench requirements
3. Modified from Claytor and Schueler (1996)
4. Mowing may be required several times a year, depending on local conditions

Table 5-3. Recommended BMP Maintenance Schedules (continued)

BMP	Activity	Schedule
Bioretention[1]	• Repair of eroded areas • Mulching of void areas • Removal and replacement of all dead and diseased vegetation • Watering of plant material	Bi-Annual or as needed
	• Removal of mulch and application of a new layer	Annual
Grass Swale[2]	• Mowing[4] and litter and debris removal • Stabilization of eroded side slopes and bottom • Nutrient and pesticide use management • De-thatching swale bottom and removal of thatching • Discing or aeration of swale bottom	Annual or as needed
	• Scraping swale bottom, and removal of sediment to restore original cross section and infiltration rate • Seeding or sodding to restore ground cover (use proper erosion and sediment control)	5-year cycle
Filter Strip[3]	• Mowing[4] and litter and debris removal • Nutrient and pesticide use management • Aeration of soil in the filter strip • Repair of eroded or sparse grass areas	Annual or as needed

1. Modified from Prince George's County (1993)
2. Modified from Livingston et al (1997)
3. Modified from Livingston et al (1997) based on grass swale recommendations
4. Mowing may be required several times a year, depending on local conditions

5.2.3 Low-Impact Development Practices

There are a number of low-impact development practices that can be used at the site level. While these practices often do not produce direct removal of pollutants from runoff, they can significantly reduce runoff volumes that are generated, reduce the impacts associated with runoff and reduce the need for conventional structural BMPs. There are a number of practices that are in use, and therefore an exhaustive summary has not been included in this document. However, a few of the more common practices in use are presented briefly in the following sections.

Minimizing Impervious Areas

Minimizing the amount of impervious surfaces that are created in a new development can greatly reduce the volume of storm water runoff that is generated. There are many opportunities that exist for reducing impervious surfaces, including:

- limiting the number, length and radius of cul-de-sacs;

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- using porous pavement or modular block pavers in parking areas and low-traffic areas;
- reducing the width of streets;
- placing sidewalks on only one side of the street;
- reducing frontage requirements to lessen paved surface areas.

Although the above practices can reduce the amounts of impervious surfaces that are created, there will still be a great deal of impervious surfaces that must be included into a site plan such as rooftops, streets, driveways and lawns. To limit the impacts associated with runoff from these surfaces, it is important to limit the amount of areas that are directly connected to the storm drainage system. This can be accomplished by providing on-site retention and infiltration to collect rooftop and driveway runoff, and through the use of BMPs such as grassed swales, vegetated filter strips and wetland channels in place of traditional curb-and-gutter systems.

Directed Growth

Directed growth involves placing controls on land use through mechanisms such as master planning and zoning ordinances. Local governments may utilize these mechanisms in order to protect sensitive areas from development and to target growth to areas that are more suitable for development where it is easier to control the impacts associated with runoff. Directed growth can be a complex process, and must balance a number of factors such as economic considerations, local laws and ordinances, secondary impacts such as increased traffic and population in certain areas, as well as the availability of public utilities such as sewage treatment and drinking water service, and schools, hospitals and fire stations. Nevertheless, with careful planning and consideration, directed growth can help to reduce impacts associated with development of an area.

Sensitive Area Protection

Sensitive area protection is an important component of conservation design. Sensitive areas include the areas adjacent to streams, wetlands and natural drainage channels, cold water fisheries, shellfish beds, swimming beaches, recharge areas, and drinking water supplies. These areas are particularly susceptible to degradation by storm water runoff. Preservation of these areas and incorporation of stream and wetland buffers into site plans can help to preserve the integrity of these areas.

Open Space Preservation

Preservation of open space such as forested areas and meadows can help to reduce the impacts associated with development of an area. Open space preservation helps to reduce the generation of runoff, and can reduce the overall impact that results from development of an area by limiting the amount of impervious areas that are created. Open space allows the preservation of buffers and natural drainage corridors, and retains the natural storm water filtering, retention and infiltration effects of these areas. Open space can also increase the aesthetics of a development, and make the area more desirable to potential home buyers.

Minimizing Soil and Vegetation Disturbance

Soil and vegetation disturbance can significantly increase the amount of runoff that is generated from a site and the concentrations of pollutants that are transported by the runoff. Disturbed soil areas are particularly susceptible to erosion during storm events. Vegetation helps to stabilize soil and prevent detachment and transport by flowing water. By minimizing the area that is disturbed to only areas undergoing active construction (often termed "fingerprinting"), erosion of soil can be minimized. In addition, disturbance of soil and vegetation should be limited to only those areas that are necessary. Disturbing soil by excavation, grading and compaction reduces the infiltrative capacity of the soil, creating additional runoff that must be managed. Maintaining naturally vegetated areas minimizes the amount of increased runoff that is produced.

5.3 BMP Selection

BMP selection is a complex process. There are a number of competing factors that need to be addressed when selecting the appropriate BMP or suite of BMPs for an area. It should be stressed that BMPs should be incorporated into a comprehensive stormwater management program. Without proper BMP selection, design, construction and maintenance, BMPs will not be effective in managing urban runoff. BMP selection can be tailored to address the various sources of runoff produced from urbanized areas. For example, a particular suite of BMPs may be developed for use on construction sites and new land development, where opportunities exist for incorporating BMPs that are focused on runoff prevention, reducing impervious surfaces and maintaining natural drainage patterns. In established urban communities, a different suite of BMPs may be more appropriate due to space constraints. In these areas, BMPs may be selected to focus on pollution prevention practices along with retrofit of the established storm drain system with regional BMPs. *Site suitability* for selecting a particular BMP strategy is key to successful performance. Most BMPs have limitations for their applicability, and therefore cannot be applied nationwide. A few considerations to incorporate into BMP selection are:

- drainage area;
- land uses;
- average rainfall frequency, duration and intensity;
- runoff volumes and flow rates;
- soil types;
- site slopes;
- geology/topography;
- availability of land;
- future development/land use in watershed;
- depth to groundwater table;
- availability of supplemental water to support vegetative BMPs;
- susceptibility to freezing;
- safety and community acceptance;
- maintenance accessability;
- periodic and long-term maintenance/rehabilitation needs.

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In addition to site-specific applicability requirements, factors such as BMP cost, local regulations or requirements, aesthetics, the experience of a developer or contractor with a particular design, and competing receiving water considerations such as temperature and nutrient levels should be addressed. The combination of these factors make selection of appropriate BMPs a difficult task, and one that should be done only by an experienced storm water practitioner. This is especially true in established urban areas, where knowledge of local factors that affect design and performance is needed. BMP use in arid and semi-arid climates also presents unique challenges. The availability of water to support vegetative and open pool BMPs such as retention ponds and wetland systems is of primary concern in these areas. Without adequate water sources, these systems may not function properly and may become public nuisances. A designer with adequate experience in designing BMPs for arid climates should be consulted in these instances. In addition to arid climates, BMP use in areas where freezing conditions can be encountered presents design problems. In cold climates, design modifications may be needed to adjust for freezing and spring snowmelt (Caraco and Claytor, 1997). Given the variety of local considerations that exist, developing a matrix of BMP applicability is outside of the scope of this report. There are several references that readers should consult to obtain additional information on BMP selection, including *Fundamentals of Urban Runoff Management* (Horner et al, 1994), *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs* (Schueler, 1987), *A Watershed Approach to Urban Runoff: Handbook for Decisionmakers* (Terrene Institute, 1996), *Urban Targeting and BMP Selection* (Terrene Institute, 1990), *Guidance Specifying Management Measures for Sources on Nonpoint Source Pollution in Coastal Waters* (US EPA, 1993a), *Handbook Urban Runoff Pollution Prevention and Control Planning* (US EPA, 1993c), *Municipal Wastewater Management Fact Sheets: Storm Water Best Management Practices* (US EPA, 1996e), *Design and Construction of Urban Stormwater Management Systems* (WEF and ASCE, 1992), and *Urban Runoff Quality Management* (WEF and ASCE, 1998).

5.4 Monitoring BMP Effectiveness

Monitoring the effectiveness of BMPs can be done in a number of ways. Since urban runoff frequently contains pollutants that can contribute to water quality impacts to receiving streams, the ability of a BMP to remove pollutants from runoff is often of concern. The typical method for measurement of the pollutant removal efficiency of a BMP system is to collect and analyze *water quality samples*. This can be accomplished by measuring the concentration of a target parameter or group of parameters in an inflow sample or set of samples and comparing these values to samples collected from the outflow of the BMP. The reduction in concentrations or loading across the BMP can be termed the pollutant removal efficiency.

In addition to monitoring the pollutant removal efficiency of BMPs, it is important to *monitor the hydraulic performance* of the BMP. A major problem associated with urban runoff is the total volume and flow rate of water that is discharged to the storm sewer system or the receiving stream. To evaluate the effectiveness of BMPs in reducing these impacts, hydraulic parameters such as the reduction in peak discharge rate, reduction in total volume discharged, and

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the time effects of discharges are frequently measured. To do this, measurement of flow rates and water volumes into and out of the system are conducted by using flow monitoring equipment.

Since the ultimate goal of BMPs is to protect or improve the quality of receiving streams, another method of evaluating the effectiveness of BMPs is to *evaluate the quality of waters receiving runoff*. Measures of water quality such as pollutant levels, pH, dissolved oxygen and other parameters can give an indication as to the effectiveness of a given BMP or group of BMPs. Evaluation of the contaminant levels present in sediments of receiving waters is also an important measure of BMP effectiveness. In addition, measures of aquatic habitat and stream channel morphology can give an indication as to the effectiveness of BMPs in controlling impacts or improving channel or habitat quality. Another measure to evaluate the effectiveness of BMPs is to measure the organisms that live in the receiving stream. Biological indicators such as macroinvertebrate counts, fish counts, and aquatic plant surveys can indicate the overall health of the receiving stream and indicate, over time, the effectiveness of BMPs. A potential problem with in-stream indicators is that it is sometimes difficult to isolate the impacts or improvements attributable to one particular variable. Since there are potentially a number of different factors that can influence a stream such as the amount of riparian cover, the existence of point source discharges, seepage from on-site disposal systems, as well as urban runoff, in can be very difficult to isolate impacts or improvements attributable to one particular stressor. Therefore, many years of data, collected both before and after a BMP implementation, may be needed to indicate a change. In spite of these shortcomings, in-stream monitoring and evaluation of the cumulative effects in a watershed as a result of BMP implementation is a very important measure of BMP effectiveness.

5.4.1 Water Quality Monitoring of BMPs

BMP monitoring can be conducted for a number of reasons, and the type of monitoring conducted and the instrumentation or equipment used can vary greatly depending upon the parameters of interest. BMP monitoring and data analysis is a complex process, and therefore a thorough explanation of all of the available monitoring practices and procedures is not included here. An important point to emphasize with respect to BMP monitoring is that consistent data reporting is needed in order to compare data between studies. Consistent reporting of BMP design parameters and watershed parameters as well as consistent monitoring methods and data analysis protocols is key to conducting data comparisons. It is recommended that individuals conducting BMP monitoring use the data reporting protocols developed by the American Society of Civil Engineers (ASCE) for the National Stormwater BMP Database (Urbonas and Strecker, 1996). These protocols are included with the database software, and are also available from the ASCE website.[3]

The following discussion includes a description of the most common methods used to evaluate BMP performance. Readers are encouraged to consult various monitoring manuals that

[3] The website address is http://www.asce.org/peta/tech/nsbd01.html

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are available and papers that are contained in the literature for more detailed information on BMP monitoring and data analysis. Recommended references include *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (US EPA, 1997c), *NPDES Storm Water Sampling Guidance Document* (US EPA, 1992c), and *Stormwater NPDES Related Monitoring Needs* (Torno, 1995).

BMPs are frequently evaluated by collecting inflow and outflow samples and comparing concentrations of pollutants. Samples can be collected in a number of different ways. The most common way is by collecting flow- or time-weighted composite samples from inflow and outflow points and measuring the concentrations of a targeted group of parameters in these samples. Composite samples can be collected by using automatic samplers, or by collecting a series of discrete samples and manually compositing. Composite samples are useful for determining an overall average or "event mean" concentration for a particular sampling point, and are commonly used to evaluate BMP performance. However, composite samples cannot be used to evaluate any trends in pollutant concentrations over time or varying flow rates. In order to conduct these types of evaluations, it is necessary to collect a series of discrete grab samples either by an automatic sampler or by collecting grabs manually. By collecting a series of discrete time-weighted or flow-weighted samples, a "pollutograph" of concentration versus time or flow rate can be prepared, which can give insight into the performance of the BMP under various hydraulic loadings. Sample results can then be combined mathematically to determine representative event mean concentrations. Manual grab samples are also used for collecting samples that are not amenable to collection by automated equipment, such as microbiological samples, samples for oil and grease evaluation, and samples for volatile organic compounds analysis.

BMP monitoring frequently incorporates measurements of water flow rates and volumes into and out of the system. Flow rates are frequently determined by using a combination of a primary control device (weir, flume or orifice) that is calibrated to discharge water according to a known relationship based on the depth of the water flowing over or through the device, along with a secondary control device (bubbler, pressure transducer, float, etc.) that is used to measure the depth of water flowing through or over the primary control device. A digital recorder is frequently used to record the depth of water measured by the secondary control device and to calculate the flow rate through the primary control device based on a pre-determined relationship between water depth and flow rate. The digital recorder can be used to log this flow data for subsequent retrieval and analysis, and can activate automated sampling equipment to collect samples at pre-determined flow rates or times. By using a configuration such as this, flow-weighted samples or discrete samples can be collected automatically, reducing or eliminating the need for personnel to be on-site during an event.

In addition to measuring surface runoff contributions to BMPs, measurement of the contribution of groundwater and subsurface flow may be necessary for BMPs that have a significant groundwater contribution. Constructed wetland systems that are close to or at groundwater level are a good example of BMPs where measurement of groundwater flows may be necessary.

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BMP monitoring programs also frequently incorporate measurements of rainfall depths, intensities and duration by using a rain gauge. Additional meteorological monitoring equipment can measure parameters such as air temperature, solar radiation, humidity, atmospheric pressure and wind speed and direction, which can aid in interpreting BMP performance data. Other instruments such as continuous pH, dissolved oxygen, and conductivity meters are also frequently incorporated into BMP monitoring programs in order to measure parameters of interest.

BMP monitoring programs can also include measurements of the atmospheric deposition rates of pollutants by using wet deposition and dry deposition sampling equipment. Atmospheric deposition can contribute significant loadings of pollutants to storm water BMPs, especially to BMPs that have a large surface area such as ponds or constructed wetlands.

Analysis of data collected from BMP monitoring programs can be conducted in a number of ways. Some of the most common methods used to measure effectiveness are measures of pollutant removal efficiency based on event mean concentrations (EMC). An event mean concentration can be determined directly from a flow-weighted composite sample. Estimations of pollutant removal efficiency in use include the efficiency ratio, the summation of loads, and the regression of loads. These methods are defined as follows (from Martin and Smoot, 1986 and reported by Strecker, 1995):

- The efficiency ratio (ER) is defined in terms of the average event mean concentration of pollutants from inflows and outflows:

$$ER = 1 - \frac{Average\ outlet\ EMC}{Average\ inlet\ EMC}$$

- The summation of loads method is based on the loads of pollutants removed during monitored storms:

$$SOL = 1 - \frac{\sum of\ outlet\ loads}{\sum of\ inlet\ loads}$$

- The regression of loads method defines the efficiency ratio as the slope of a simple linear regression of inlet loads and outlet loads of pollutants. The equation is:

$$Loads\ in = \$ \cdot Loads\ out$$

where β equals the slope of the regression line, with the intercept constrained at zero.

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The above are only a few of the methods available for computing BMP pollutant removal efficiency. The selection of method can have a large impact on the reported removal efficiency. As a result, reported removal efficiency is not always comparable between studies due to differences in the way that pollutant removal was calculated. Additional work is needed in this area in order to standardize BMP data analysis and reporting.

5.4.2 Receiving Stream Assessments

Receiving stream assessments are an important means of determining the effectiveness of BMPs. The health of the biological community and the quality of the habitat present in the stream can be strong indicators of the effectiveness of BMPs. There are a number of biological indicators that can be used to evaluate streams, and a discussion of these methods is not within the scope of this document. Readers are encouraged to consult available documents for additional information on this subject, and for recommendations on developing biological criteria programs. Recommended readings include *Biological Criteria Technical Guidance for Streams and Small Rivers* (US EPA, 1996c) and *Restoring Life in Running Waters: Better Biological Monitoring* (Karr and Chu, 1998).

Physical habitat and fish and macroinvertebrate diversity indices have been identified as suitable indicators to assess the effectiveness of storm water controls (Center for Watershed Protection, 1996). EPA's *Rapid Bioassessment Protocols for Use in Streams and Rivers* (US EPA, 1997f) can be used to survey biological communities. In addition, many local and state environmental protection agencies have developed monitoring protocols for streams within their geographic area. Readers are encouraged to contact county and state environmental agencies to obtain more information regarding stream assessments. In addition to surveys of biological communities, measures of stream habitat are also useful for determining the effectiveness of BMPs. Some available methods for assessing habitat include:

- Physical habitat assessment component of EPA's Rapid Bioassessment Protocols;
- The Rapid Stream Assessment Technique (RSAT);
- The Ohio EPA's Qualitative Habitat Evaluation Index (QHEI);
- The Rosgen Stream Classification.

EPA used several receiving stream assessment methods in its 1998 field work at one BMP site. Findings from these assessments will appear in a supplement to this report.

5.5 Effectiveness of BMPs in Managing Urban Runoff

There has been a great deal of storm water and BMP monitoring data collected by a number of organizations. However, most of these data have focused on characterization of pollutants in runoff, and not on the effectiveness of various control measures. Several nation-wide monitoring programs have been conducted to characterize pollutants in urban storm water

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runoff and to evaluate the performance of storm water BMPs. The major federal monitoring programs that have been conducted are listed in Table 5-4.

Table 5-4. Sources of Storm Water Runoff and BMP Monitoring Data

Data Source	Year	Type of Monitoring Conducted
"208 Studies" under FWPCA Amendments of 1972	late 1970's	Limited storm water quality data
Nationwide Urban Runoff Program (NURP)	1978-83	Storm water quality data collected at 81 outfalls at 28 cities for a total of 2,300 storm events as well as some BMP data
Federal Highway Administration (FHWA)	1970's - 80's	Storm water runoff loadings from highways at 31 sites in 11 states
USGS Urban Storm Studies*	1970's - 90's	Rainfall, runoff and water-quality data for areas throughout the United States
Phase I NPDES Municipalities (260 permittees)	1990's	Storm water and BMP monitoring data for 5 representative sites during a minimum of 3 storm events

* USGS prepared a database that includes rainfall, runoff and water-quality data for 717 storms from 99 stations in 22 metropolitan areas throughout the United States, including much of the data collected during the NURP program, in the mid-1980's (Driver et al, 1985)

The USGS has been collecting urban rainfall and runoff data for several decades. In the 1970's and early 1980's, monitoring programs were conducted to collect water quality data in addition to rainfall and runoff data in order to characterize the pollutants present in storm water runoff and to evaluate the impacts attributable to wet weather discharges. The major programs included the Nationwide Urban Runoff Program (NURP) conducted by EPA and USGS and the FHWA evaluation of runoff from highways. Data from these evaluations indicated that urban storm water runoff was contributing significant levels of pollutants to the nations waters, and that control of urban runoff was warranted. However, these investigations also indicated that there was insufficient data available to quantify the degree of impacts attributable to urban runoff and to evaluate the effectiveness of various runoff control practices.

In addition to the major federal investigations, some data has been published in the professional literature. A number of bibliographies have been prepared that include storm water BMP-related literature. These include the ASCE Urban BMP Effectiveness Bibliography, and the National Highway Runoff Water-Quality Data and Methodology Synthesis Bibliography compiled by USGS and FHWA. The Center for Watershed Protection (CWP) has prepared a database containing BMP performance data for 123 structural BMPs (Brown and Schueler, 1997a). The

FHWA and ASCE are currently developing databases of published highway and urban BMP effectiveness data. In addition to data in the published literature, a large amount of data has been collected by various cities and municipalities as part of the storm water permitting program under the Phase I NPDES program for storm water discharges. To date, EPA has not undertaken a concerted effort to collect and evaluate this data. In addition to published data sources, a number of states, counties and cities have collected a significant amount of monitoring data for their own use. The extent of this data is not currently known, but several county and city storm water programs have collected a great deal of potentially useful BMP monitoring data. An effort to collect and evaluate these data may provide more useful information on the effectiveness of various control measures.

The effectiveness of BMPs can be measured in various ways. Non-structural BMPs deal mainly with pollution prevention and limiting the amounts of pollutants that are carried away by runoff. Their effectiveness is best measured in terms of the degree of change in people's habits following implementation of the management program or by the degree of reduction of various pollutant sources. It is oftentimes very difficult to measure the success of non-structural BMPs in terms of pollution reduction and receiving stream improvements. Structural BMPs can be measured in terms in the reductions of pollutants discharged from the system and by the degree of attenuation of storm water flow rates and volumes discharged to the environment. Various physical, chemical and biological evaluation methods exist for determining the pollutant removal efficiency of structural BMPs. The following sections summarize existing data on the pollutant removal efficiency of a variety of BMPs.

5.5.1 Controlling Pollution Generation

The literature on the effectiveness of BMPs in controlling the generation of pollutants is not very extensive. Pollution prevention type BMPs such as street sweeping, public education and outreach, collection of lawn debris, etc., are conceptually very effective means of controlling the generation of pollutants that can enter storm water runoff. However, it is often very difficult to develop a representative means of monitoring or evaluating their effectiveness. Additional work in this area is needed in order to measure the effectiveness of these controls. Effectiveness data and information for pollution prevention BMPs that has been identified is presented in the following sections.

Education and Outreach

Evaluating the performance of education and outreach programs is difficult. There is little quantitative data in the literature that measures the effectiveness of these programs in improving water quality. Information exists on how educational programs have been implemented and what their success rate has been as far as changing the habits of a select group of people, but data linking implementation with improvements in water quality are scarce. Nevertheless, educational programs are a valuable component of a comprehensive storm water management program. Surrogate measures of the effectiveness of education and outreach programs include:

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- numbers of flyers distributed per given time period;
- number of radio or television broadcasts;
- number of public workshops held per year;
- the percentage of storm drains that have been stenciled;
- the number of volunteer monitoring and stewardship groups that have been formed.

A literature review by ASCE (Strecker and Quigley, 1998) did not identify any published studies that contained quantitative information evaluating the effectiveness of Education and Outreach BMPs in improving water quality.

Recycling and Source Controls

Evaluating the effectiveness of recycling and source control programs can be measured in terms of the quantities of materials that are being recycled, but it is often difficult to determine water quality improvements as a result of these programs. Measures of effectiveness include:

- surveys that evaluate how many residents have changed habits such as picking up pet waste and composting lawn debris;
- volumes of materials such as used oil and antifreeze that are recycled;
- the volume and types of materials collected during community household hazardous waste collection days;
- the number of illicit cross connections that have been detected and eliminated;
- the total curb miles of streets that are swept annually and the quantity of materials removed; and
- reductions in pesticide and fertilizer usage.

Monitoring of storm water quality to evaluate the effectiveness of source control programs is possible, however very few studies have been conducted. The difficulty stems from isolating the impacts of a particular source control program on the overall water quality draining from the watershed. The ASCE bibliography identified one study that potentially contains quantitative information about the effectiveness of recycling automotive products as a BMP (Horner et al, 1985). Additional data are needed in this area in order to evaluate the effectiveness of recycling and source controls.

Maintenance Practices

Maintenance practices are a necessary part of any municipal storm water program. In addition to maintenance of storm water management infrastructure and BMP maintenance, a range of municipal maintenance activities impact the quality of storm water runoff. As with other non-structural control practices, data evaluating the effectiveness of maintenance practices at reducing the impacts associated with storm water discharges are scarce.

Studies conducted during the NURP project indicated that street sweeping was generally not an effective BMP. This is mainly due to the fact that street sweepers remove only the coarse particles on streets, and are not generally effective at removing the fine particles. It is the "fines"

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that frequently contain the highest fractions of pollutants, especially metals. In fact, the NURP study report from Winston-Salem reported that street sweeping could actually increase the concentrations of select pollutants by removing the surface "armoring" of coarse particles, which during normal runoff events inhibit the removal of fine surface loads (Noel et al, 1987). Likewise, NURP studies conducted in Long Island, New York, Champaign, Illinois and Bellevue, Washington found little or no benefit of street sweeping programs. A study in Durham, New Hampshire, which evaluated the effectiveness of pavement vacuum cleaning, indicated that this technology was effective at removing BOD and fecal streptococci bacteria. It was thought that these contaminants were mainly associated with the coarser sediments, which this technology was able to effectively remove. Although the NURP data indicated that street sweeping was not an effective BMP for improving water quality, the usefulness of street sweeping programs cannot be discounted. Improvements in sweeper technology have occurred since the NURP studies were conducted, and today's sweepers may be more efficient at removing fine particulates. Regardless, sweeping programs can remove a significant amount of dirt and debris from streets and parking lots. However, obtaining data linking sweeping programs to water quality improvements may be difficult due to the variety of pollutant sources present in urban areas.

Data on other maintenance practices are likewise scarce. Practices such as catch basin cleaning, street pavement repair, and ditch maintenance are all necessary components of a storm water management program. However, data that indicate their effectiveness may be difficult to obtain due to the lack of appropriate evaluation methodologies and the difficulty associated with isolating water quality improvements attributable to these practices. The ASCE bibliography identified two NURP studies that included evaluating the effectiveness of catch basin cleaning as a storm water BMP (Lake Hills and Surrey Downs, Bellevue, Washington).

5.5.2 Controlling Pollution Discharges

There has been a great deal of published data documenting the efficiency of BMPs in removing pollutants from storm water. Much of this data provides useful insights into the performance of various types of storm water BMPs. For the purposes of this study, *efficiency* has been used to describe the ability of the management practice to remove pollutants from runoff. *Effectiveness* refers to the actual improvements in water quality, habitat or other parameters as a result of implementing the management practice. Most of the data contained in the literature reports efficiency of a BMP. Little of the available data can be used to evaluate actual effectiveness.

Brown and Schueler (1997a) documented the pollutant removal efficiency of commonly used and innovative urban storm water BMPs. The number of monitoring reports of various BMP categories included in this study are summarized in Table 5-5.

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Table 5-5. Monitoring Studies for BMP Categories

BMP Type	Number of Studies
Detention Basins	8
Retention Basins	35
Wetland Systems	36
Filtration Systems	15
Swales and Filter Strips	20
Other	4

Evaluation of the existing BMP monitoring data gives an indication of the information gaps that exist in BMP monitoring studies that have been performed to date. Commonly used BMPs that are seldom monitored include infiltration trenches, infiltration basins, bioretention practices and filter strips. The reason for the limited number of monitoring studies for these practices is due to the difficulty involved in collecting inflow and outflow samples to calculate pollutant removals. Bioretention practices and filter strips frequently accept runoff as sheet flow, which must be concentrated in order to collect a representative sample. Infiltration practices and bioretention practices can discharge water through a large surface area into surrounding soil layers, and therefore collection of a representative "outflow" sample is problematic. There are also a number of innovative and infrequently used BMPs that are seldom monitored. These include sand filters, vegetated filter strips, filters with organic media, wetland channels and swales.

In addition to a general lack of monitoring data for certain types of BMPs, there is also a lack of performance data for all BMP types for certain parameters. While BMP monitoring studies typically monitor for parameters such as total phosphorus, total lead, and total suspended solids, there is little monitoring data available for parameters such as bacteria, dissolved metals and hydrocarbons. Table 5-6 summarizes the frequency with which selected parameters have been monitored in BMP performance studies (Brown and Schueler, 1997a).

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Table 5-6. Extent of Monitoring for Selected Pollutants in BMP Performance Studies

Parameter	Percent Monitored
Total Phosphorus	94
Total Lead	94
Total Suspended Solids	92
Total Nitrogen	70
Soluble Nitrogen	70
Total Zinc	67
Soluble Phosphorus	60
Organic Carbon	55
Total Copper	42
Bacteria	19
Total Cadmium	15
Total Dissolved Solids	13
Dissolved Metals	10
Hydrocarbons	9

Review of the existing BMP monitoring data gives an indication of the pollutant removal efficiency of various BMPs. Several efforts have been conducted to attempt to evaluate the range of pollutant removals that can be expected to occur in various BMP designs. Evaluation of these data can give an indication of the range of pollutant removals expected, however arriving at a fixed numerical "percent removal" for each BMP type or category is a difficult task. The main problem associated with comparing BMP performance data is the variety of techniques that are used to compute performance, as well as the variation in the ways that samples are collected and in the parameters that are measured in the samples. Performance calculations are further complicated by the errors that result from measuring flow rates and volumes of storm water that pass through the BMP. A study conducted by USGS evaluated 23 flow measurement techniques in order to determine potential differences in reported flows. Average percent differences between reported total storm volumes were in many cases greater than 25 percent over a range of storms (Strecker, 1998). With errors of this magnitude, calculation of pollutant loadings and loadings reductions can be complicated significantly.

Efficiency of a BMP can be related to the removal of individual pollutants on both an event basis and on a long-term basis. Frequently, the statistical rigor with which BMP sampling data are analyzed is poor or even nonexistent. Most BMP performance data are reported as event mean concentrations (EMCs). An EMC can either be determined directly from a flow-weighted composite sample, or calculated based on a series of discrete samples. While an EMC may be an appropriate method for determining the reduction in pollutant concentrations for an individual event, an EMC may not give an indication of the long-term performance of the BMP or the performance for runoff events of varying intensity and volume. A more appropriate means of determining the long-term performance of a BMP may be to do a statistical evaluation of inflow

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and outflow loadings over a range of storm event sizes and durations. Samples must also account for the seasonality of performance that results with certain BMP types such as ponds and constructed wetlands. The selection of the method used can have a significant impact on the reported performance. Additional work to standardize BMP monitoring protocols and to standardize calculations for performance is needed in order to make BMP monitoring data comparable from site to site.

BMP performance can vary considerably based on differences in the design criteria and performance standards for which the BMP was designed. Comparing pollutant removal efficiency for similar BMP types with very different performance goals may result in widely disparate efficiency estimations. In addition to differences in performance goals, variations in watershed parameters can cause significant differences in performance among otherwise similar BMPs. In most cases, parameters such as the size of the drainage area, the level of watershed imperviousness, the duration and volume of runoff entering the BMP, and the land use of contributing drainage areas are not easily comparable from study to study. In addition, differences in BMP design parameters such as the ratio of the BMP volume to the contributing drainage area, the retention time in the BMP, the physical dimensions and the construction of the BMP further complicate direct comparisons between BMP monitoring data. Also, a great deal of variability exists in the performance of each BMP due to event and seasonal variations.

Despite these shortcomings, some general ranges of expected BMP efficiency have been compiled from the literature. Documents that summarize BMP efficiency information include the CWP's National Pollutant Removal Performance Database (Brown and Schueler, 1997a), the Terrene Institute's report *The Use of Wetlands for Controlling Stormwater Pollution* (Strecker et al, 1992), as well as a variety of articles and documents contained in the professional and scientific literature. In addition, the ASCE National Storm Water BMP Database is expected to provide BMP monitoring studies in a format that will facilitate evaluation and comparison of BMP performance data. Readers are encouraged to consult the variety of referenced information resources for more detailed BMP performance data than is presented in this report. Table 5-7 presents expected pollutant removal efficiencies for various BMP types (US EPA, 1993c). The values found in this table give an indication of the expected overall pollutant removal efficiency for a properly sited, designed, sized, constructed and maintained BMP. The sections that follow Table 5-7 summarize the actual performance data contained in the literature on pollutant removal efficiencies for selected BMP types.

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Table 5-7. Structural BMP Expected Pollutant Removal Efficiency

BMP Type	Typical Pollutant Removal (percent)				
	Suspended Solids	Nitrogen	Phosphorus	Pathogens	Metals
Dry Detention Basins	30 - 65	15 - 45	15 - 45	< 30	15 - 45
Retention Basins	50 - 80	30 - 65	30 - 65	< 30	50 - 80
Constructed Wetlands	50 - 80	< 30	15 - 45	< 30	50 - 80
Infiltration Basins	50 - 80	50 - 80	50 - 80	65 - 100	50 - 80
Infiltration Trenches/ Dry Wells	50 - 80	50 - 80	15 - 45	65 - 100	50 - 80
Porous Pavement	65 - 100	65 - 100	30 - 65	65 - 100	65 - 100
Grassed Swales	30 - 65	15 - 45	15 - 45	< 30	15 - 45
Vegetated Filter Strips	50 - 80	50 - 80	50 - 80	< 30	30 - 65
Surface Sand Filters	50 - 80	< 30	50 - 80	< 30	50 - 80
Other Media Filters	65 - 100	15 - 45	< 30	< 30	50 - 80

Source: Adapted from US EPA, 1993c.

Infiltration Systems

Infiltration systems can be considered 100 percent effective at removing pollutants in the fraction of water that is infiltrated, since the pollutants found in this volume are not discharged directly to surface waters. Quantifying the removal efficiency of infiltration systems, therefore, can perhaps best be determined by calculating the percent of the average annual runoff volume that is infiltrated, and assuming 100 percent removal of the pollutants found in that runoff volume. Since collecting samples of runoff once it has been infiltrated can be very difficult, little field data exist on the efficiency of infiltration for treatment of storm water. Since infiltrated water does not leave the BMP as a discrete flow, there is no representative way of collecting a true outflow sample. Infiltration systems can be monitored by installing a series of wells around the perimeter of the BMP for collecting samples. However, this can add significant costs to any monitoring effort. Table 5-8 summarizes the available field data on the efficiency of infiltration practices in treating storm water. Reported removal efficiencies are based on the results of three studies that evaluated the performance of infiltration trenches and two studies that evaluated the efficiency of porous pavement systems.

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Table 5-8. Pollutant Removal Efficiency of Infiltration Practices

Parameter	Median or Average Removal Efficiency (percent)	Number of Observations
Total Phosphorus	65	5
Ammonia-Nitrogen	83	3
Nitrate	82	3
Total Nitrogen	83	2
Suspended Solids	89	2
Organic Carbon	82	1
Lead	98	1
Zinc	99	1

Source: Brown and Schueler, 1997a

Conceptually, infiltration should provide significant pollutant removal for a wide variety of storm water pollutants. As water moves through the underlying soil layers, suspended particulates and associated pollutants should be filtered out. In addition, pollutants can be adsorbed by soil particles and microorganisms in the soil can degrade organic pollutants. There is little data available, however, regarding the potential mobility of metals and hydrocarbons that enter groundwater due to infiltration of storm water. This may be a particular problem in areas with extremely high soil permeabilities (such as coastal areas), where pollutants can rapidly enter underlying aquifers with insufficient contact time for breakdown or adsorption of contaminants. Consequently, additional data gathering to target the behavior of these pollutants is warranted.

The success of infiltration systems has been mixed. In same areas, infiltration has been applied successfully, while in others infiltration systems have clogged in a very short time. Many failures can be attributed to contractor inexperience, to compaction of soil by construction equipment and to excess sediment loading during construction activities, and to improper design and siting. In order to apply infiltration successfully, the following guidelines should be applied:

- Permeability of soils must be verified. A percolation rate of 0.5 inches per hour or more, and an soil layer of 4 feet or more is essential (Cahill, 1994).
- Construction site runoff must be kept from entering the recharge bed, and the infiltration system should not be placed into service until all disturbed land that drains to the system has been stabilized by vegetation. Strict erosion and sediment controls during any construction or re-landscaping is a must to prevent clogging of the system.

- A sedimentation basin or chamber placed before the infiltration system to remove a portion of the sediment can help to extend the life of the infiltration system.
- Use of filter fabric between the recharge bed and soil interface (in porous pavement and infiltration trench systems) can prevent the migration of soil into the recharge bed.
- Construction traffic should be directed away from the infiltration bed before and during construction to prevent compaction of underlying soil layers and loss of infiltrative capacity.
- Porous pavement systems should be clearly marked to prevent use by heavy vehicles and resurfacing with non-porous pavement.
- A basin drain should be provided so that the basin can be drained and maintenance performed if the basin becomes clogged.

Readers are encouraged to consult the ASCE/WEF manual of practice (WEF and ASCE, 1992) for additional guidelines on using infiltration systems.

Retention Basins (wet ponds)

Retention basins can be very effective systems for removing pollutants from storm water. Retention basins provide quiescent conditions with long retention times that allow a large fraction of suspended solids and associated pollutants such as metals, nutrients and organics to be removed by sedimentation. In addition, degradation of organic compounds by microorganisms and uptake of nutrients by aquatic vegetation can provide additional water quality benefits. Retention basins have been one of the most widely-monitored storm water BMP types, mainly due to their prevalence and relative ease of monitoring in comparison to other BMP types. In arid regions, artificial or decorative lakes can function as retention basins. However, as with all other BMP types, the available monitoring data are not always comparable from study to study due to variations in procedures, protocols and methods. Although the mechanisms taking place in retention basins are fairly well known, additional data are needed in order to determine what the important design parameters are and to determine what event, seasonal and long-term performance variances exist. Table 5-9 summarizes the pollutant removal efficiency of retention basins systems. Reported removal efficiencies are based on data contained in 35 studies evaluating retention basins.

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Table 5-9. Pollutant Removal Efficiency of Retention Basins

Parameter	Median or Average Removal Efficiency (percent)	Range of Removals (percent)		Number of Observations
		Low	High	
Soluble Phosphorus	34	-12	90	20
Total Phosphorus	46	0	91	44
Ammonia-Nitrogen	23	-107	83	14
Nitrate	23	-85	97	27
Organic Nitrogen	23	2	34	6
Total Nitrogen	30	-12	85	24
Suspended Solids	70	-33	99	43
Bacteria	74	-6	99	10
Organic Carbon	35	-30	90	29
Cadmium	47	-25	54	5
Chromium	49	25	62	5
Copper	55	10	90	18
Lead	67	-97	95	34
Zinc	51	-38	96	32

Source: Brown and Schueler, 1997a

The wide range of variability in reported removal efficiencies of retention systems is due to a number of factors. Watershed variables such as the area draining to the pond, the percent imperviousness and land use of the watershed, the design features of the basin such as surface area and depth of permanent pool, and hydraulic and hydrologic parameters such as rainfall intensity, rainfall volume, length of antecedent dry periods, time of concentration and peak inflow rate can have a large impact on the efficiency of a particular retention system. Studies that contain data on the efficiency of retention systems sometimes report only pollutant removal statistics, but fail to report the relationship to the hydraulics of the system. A thorough evaluation of the hydraulics of the system is needed in order to properly evaluate the efficiency of ponds. This evaluation should also include a measure of the expected suspended solids settling characteristics of the pond influent through a settling velocity column test or particle size distribution analysis, which can shed light on the observed efficiency of the pond in removing

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sediments and associated pollutants. Greb and Bannerman (1997) reported that the influent particle size distribution plays a significant role in the overall solids removal efficiency. Perhaps the greatest parameter influencing pond efficiency is retention time. Studies indicate that residence times on the order of 14 days may be necessary to allow for sufficient removal of sediment and associated pollutants and to meet receiving water standards (Rushton and Dye, 1993). In fact, Florida requires that the permanent pool volume of ponds treating runoff from new land use activities must provide a minimum residence time of 14 days.

While retention systems can be very effective at removing pollutants from storm water, there are some potential problems associated with these systems. During periods of intense runoff, the retention time in the pond can decrease, resulting in decreased efficiency. In addition, previously removed sediments can be re-suspended, resulting in a net export of pollutants from the pond. This is one of the reasons that negative removals are frequently reported for pond systems for parameters such as suspended solids and associated contaminants such as nutrients and metals. Also, changes in water chemistry such as increased or decreased pH, alkalinity and hardness can occur in the pond, which can effect the solubility of metals that are present in pond sediments and the behavior of various nutrient species. This can also affect the chemistry of the receiving waters, since the aquatic toxicity of certain metal species is dependant on hardness. There is also evidence that anaerobic bottom sediments promote more soluble forms of phosphorus and some metals, which can increase their release to the water column (Rushton and Dye, 1993).

Perhaps the greatest problem is the increased temperature of discharges that occur from storm water retention systems. Retention ponds can have a significant surface area, and during summer months elevation of the temperature of water in the pond can occur. When this warm water is displaced during the next runoff event, the elevated temperature can cause detrimental impacts to the receiving waters, including loss of sensitive species and downstream shift of trophic status (Galli, 1988). Ponds can also fail to function properly in the winter time when the surface of the pond freezes. Water entering the pond can flow over the ice surface directly to the outlet structure. This short circuiting can limit the retention time of storm water entering the ponds and reduce the sedimentation efficiency. Outlet structures are also prone to freezing in the winter time, which can cause serious flooding problems. In order to prevent cold-weather problems with wet ponds, several design features can be incorporated in ponds that are used in cold climates. Readers are encouraged to consult the *Stormwater BMP Design Supplement for Cold Climates* published by CWP (Caraco and Claytor, 1997) for additional information regarding BMP designs for cold climates.

Retention systems also present a potential hazard to nearby residents and children, can often become populated with large number of waterfowl, and can be breeding grounds for mosquitoes and odor producers if not designed and maintained properly. Large ponds also can present a danger of downstream flooding and risk of catastrophic loss of life and property in the event of an embankment or outlet structure failure. Several pond failures have occurred that are attributable to piping around outlet structures and eventual failure of embankments due to poor

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installation. Careful adherence to design and construction standards is necessary and inspections during construction should be conducted to ensure that ponds are installed correctly.

In addition to relating performance to measures of pollutant reduction across the BMP, evaluations that measure effluent from BMPs and compares these values to receiving water criteria can provide useful data. One such study was conducted in Florida, and it was determined that effluent from 22 wet detention facilities was in most cases in compliance with class III Florida state water quality standards. The ponds evaluated in this study were permitted by Florida and met the required state design criteria. Parameters analyzed in samples included eight metal species, six nutrient species, turbidity, TSS, temperature, dissolved oxygen, pH and conductivity. The constituents that were in compliance 100 percent of the time included un-ionized ammonia, iron, manganese (class II standard) and nickel. All other analyzed parameters, with the exception of dissolved oxygen, were in compliance greater than 65 percent of the time, with most in compliance greater than 79 percent of the time. Dissolved oxygen was in noncompliance 64 percent of the time (Carr and Kehoe, 1997). The results of this study indicate that evaluation of constituents in BMP effluent and comparison with water quality standards may be an effective measure of BMP effectiveness. In many cases, data of this nature may be more useful than data that indicates percent removal of a targeted group of constituents across the BMP. It is also important to note that the Florida study found that concentrations of constituents (with the exception of dissolved oxygen) in samples collected at these systems did not vary significantly between samples collected immediately before the outflow weir and after the outflow weir. Therefore, sampling before the weir, where more convenient, does not significantly alter sample results. This may be useful where the BMP discharges through an outflow structure where samples are not easily collected (such as in a manhole or other confined space).

In addition to treating runoff, retention systems can be adapted for storm water reuse. Florida is actively seeking reuse of storm water runoff for reuse as irrigation water. Reuse of storm water reduces the volume of water and the amount of pollutants discharged to receiving streams. In addition, reuse of storm water as irrigation water can help to recharge aquifers and restore pre-development hydrologic conditions. Also, significant financial incentives exist for reuse as irrigation in areas where water rates are high. However, the health risks of storm water reuse have not been thoroughly investigated. Additional research in this area is warranted to determine if a risk of exposure to potentially harmful microorganisms or other health risks exist. Livingston et al (1998) presented a discussion of storm water reuse opportunities and discussed design considerations for sizing ponds for reuse. Readers are encouraged to consult this reference for additional information on storm water reuse.

There are a number of design features that can be included in retention system designs to increase their effectiveness, reduce maintenance burdens and reduce impacts to receiving waters. These include:

- A broad, flat aquatic bench around the perimeter of the pond planted with emergent wetland vegetation;

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- A permanent pool volume that provides a long residence time to promote maximum removal of suspended solids;
- An irregular pool shape that increases sinuosity of flow paths;
- A sediment forebay for removal of coarse sediments and ease of maintenance;
- A submerged reversed-slope pipe or other non-clogging low-flow orifice;
- Concrete, rather than corrugated metal risers and outlet structures;
- Preservation of riparian cover along drainage channels to limit temperature increases;
- Maintenance access to forebays and inlet and outlet structures for removal of sediments and repairs.

Prince William Parkway Regional Wet Pond

In 1998 EPA conducted sampling activities at a retention system in Prince William County, Virginia. The Prince William Parkway Wet Pond is a regional wet pond located adjacent to a major county road in Dale City. The pond has a surface area of 4 acres, and has a total volume of approximately 25 acre-feet at the permanent pool level. The pond is approximately 1,000 feet in length, 260 feet wide at its widest point, and was constructed by placing an earthen dam in what appears to previously have been a natural drainage channel. The discharge is to Cow Branch, a tributary of Neabsco Creek. The contributing drainage area to the pond is approximately 310 acres. The land use of the watershed is approximately 20 percent commercial, 30 percent forested, 40 percent open land, 5 percent residential (mostly lots less than 1 acre) and 5 percent from other sources. The pond is designed to control up to the 100-year storm event for the fully developed watershed conditions. There are a total of 5 discrete inflow points to the wet pond. Three of these points were natural drainage channels (identified as P1, P2 and P3), while the 4th and 5th points were concrete channels. Points P1, P2 and P3, which represent a majority of the contributing drainage area, were monitored during the course of the study period. The contributing drainage area and percent imperviousness of these sub-basins are:

Sub-Basin	Area (acres)	Imperviousness (%)
P1	84	41
P2	122	17
P3	107	17

The other two inflow points, which conveyed runoff from a small segment of Prince William Parkway, were not monitored and their contributions of both storm flow and pollutant loadings were considered negligible due to the small drainage area in comparison to the overall watershed area. The outflow of the pond occurs through a pair of 8 by 8-foot concrete box culverts. A concrete V-notch weir is installed at the outflow of the pond. See Figure 5-14.

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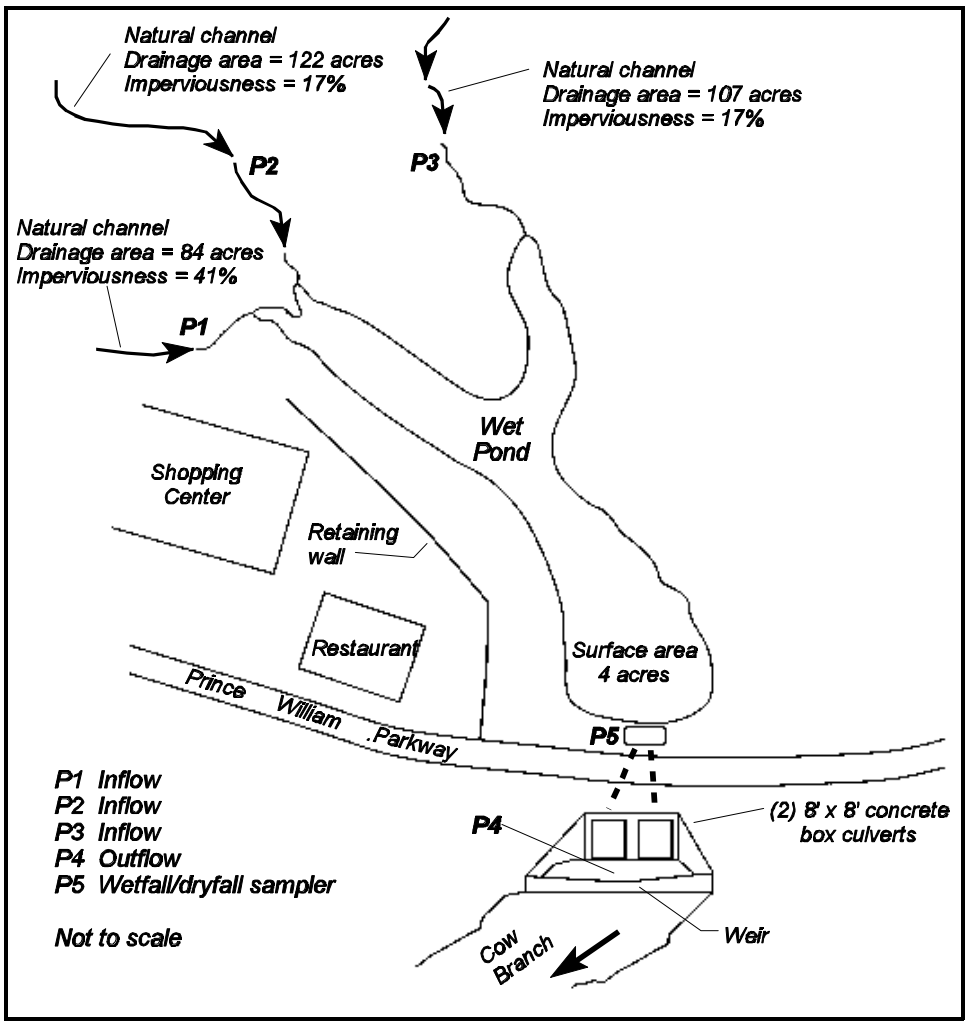
Figure 5-14. Prince William Parkway Regional Wet Pond



During May through October 1998, rainfall and hydrologic data were collected for 14 storm events and water quality samples were collected during 10 storm events at the pond. In addition, samples of atmospheric deposition (dryfall) and precipitation (wetfall) were collected for a number of storms. The following tables summarize a portion of the analytical data collected during the study period and the corresponding flow volume at each of the sampling points. Wetfall volumes were determined by multiplying the total storm rainfall depth by the surface area of the pond. A detailed presentation of the sampling results and an analysis of the sampling data will be included in a supplement to this report.

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Table 5-10. Summary of Prince William Parkway Regional Wet Pond Sampling Data

Sample Location ➤ / Sample Dates and Analytes	P1	P1 (dissolved)	P2	P2 (dissolved)	P3	P3 (dissolved)	P4	P4 (dissolved)	Wetfall	Dryfall
6/01/98										
Total Kjeldahl Nitrogen (mg/l as N)	---	---	---	0.95	---	---	---	1.1	0.67	ND (0.1)
Ammonia (mg/l as N)	---	---	0.97	0.39	---	---	0.39	0.37	0.61	ND (0.1)
Nitrate/Nitrite (mg/l as N)	---	---	0.45	0.52	---	---	0.13	0.18	0.18	ND (0.01)
Biochemical Oxygen Demand (mg/l)	---	---	4	7	---	---	4	3	---	---
Chemical Oxygen Demand (mg/l)	---	---	ND (20)	ND (10)	---	---	ND (10)	ND (10)	---	---
Total Organic Carbon (mg/l)	---	---	7	9.1	---	---	5.4	6.5	2.2	ND (1)
Phosphorus (mg/l)	---	---	0.02	ND (0.01)	---	---	0.02	0.03	ND (0.01)	ND (0.01)
Total Orthophosphate (mg/l)	---	---	ND (0.01)	---	---	---	ND (0.01)	---	---	ND (0.01)
Total Suspended Solids (mg/l)	---	---	266	---	---	---	48	---	---	---
Total Dissolved Solids (mg/l)	---	---	46	---	---	---	65	---	---	---
Volatile Suspended Solids (mg/l)	---	---	26	---	---	---	14	---	---	---
Chloride (mg/l)	---	---	4	---	---	---	13	---	---	---
Alkalinity (mg/L)	---	---	5	---	---	---	26	---	---	---
Hardness (mg/l as CaCO3)	---	---	35	---	---	---	35	---	---	---
Runoff Volume (gallons)	201,800		619,700		152,500		1,071,000		61,000	
6/11/98										
Total Kjeldahl Nitrogen (mg/l as N)	---	---	5.6	1.12	---	---	9.52	9.52	2.24	8.96
Ammonia (mg/l as N)	---	---	ND (1)	ND (1)	---	---	ND (1)	ND (1)	ND (1)	ND (1)
Nitrate/Nitrite (mg/l as N)	---	---	0.53	0.59	---	---	0.13	0.16	0.18	0.42
Biochemical Oxygen Demand (mg/l)	---	---	---	3.65	---	---	6.9	2.8	---	---
Chemical Oxygen Demand (mg/l)	---	---	45.6	26	---	---	27.6	27.2	---	---
Total Organic Carbon (mg/l)	---	---	9.35	7.91	---	---	9.35	6.47	3.58	3.58
Phosphorus (mg/l)	---	---	0.25	0.051	---	---	0.25	0.017	0.044	0.038
Total Orthophosphate (mg/l)	---	---	0.094	---	---	---	0.062	---	ND (0.01)	---
Total Suspended Solids (mg/l)	---	---	14	---	---	---	8	---	---	---
Total Dissolved Solids (mg/l)	---	---	49	---	---	---	62	---	---	---
Volatile Suspended Solids (mg/l)	---	---	3	---	---	---	3	---	---	---
Alkalinity (mg/L)	---	---	13.2	---	---	---	24	---	---	---
Hardness (mg/l as CaCO3)	---	---	18	---	---	---	26	---	---	---
Runoff Volume (gallons)	244,500		849,400		242,200		1,434,000		81,500	

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Sample Location ➤ Sample Dates and Analytes	P1	P1 (dissolved)	P2	P2 (dissolved)	P3	P3 (dissolved)	P4	P4 (dissolved)	Wetfall	Dryfall
6/12/98										
Total Kjeldahl Nitrogen (mg/l as N)	8.96	11.8	8.96	2.8	---	---	1.68	8.4	5.04	---
Ammonia (mg/l as N)	1.12	ND (1)	ND (1)	ND (1)	---	---	ND (1)	ND (1)	1.12	---
Nitrate/Nitrite (mg/l as N)	1	0.88	0.57	0.61	---	---	0.15	0.12	0.66	---
Biochemical Oxygen Demand (mg/l)	4.3		2.5	2	---	---	3.7	40.8	---	---
Chemical Oxygen Demand (mg/l)	36.4	47.2	106	14	---	---	27.2	20.4	---	---
Total Organic Carbon (mg/l)	5.83	10.2	5.83	5.83	---	---	10.2	10.2	4.37	---
Phosphorus (mg/l)	0.1	0.049	0.82	0.08	---	---	0.18	0.04	0.046	---
Total Orthophosphate (mg/l)	0.038	---	0.099	---	---	---	0.099	---	---	---
Total Suspended Solids (mg/l)	18	---	53	---	---	---	9	---	---	---
Total Dissolved Solids (mg/l)	90	---	37	---	---	---	65	---	---	---
Volatile Suspended Solids (mg/l)	6	---	6	---	---	---	6	---	---	---
Alkalinity (mg/L)	13.9	---	9.7	---	---	---	24	---	---	---
Hardness (mg/l as CaCO3)	28	---	20	---	---	---	28	---	---	---
Runoff Volume (gallons)	162,400		237,600		191,700		631,000		36,000	
6/13/98										
Total Kjeldahl Nitrogen (mg/l as N)	---	---	ND (1)	7.84	---	---	1.68	17.4	---	---
Ammonia (mg/l as N)	---	---	ND (1)	1.12	---	---	ND (1)	ND (1)	---	---
Nitrate/Nitrite (mg/l as N)	---	---	0.2	0.25	---	---	0.28	0.29	---	---
Biochemical Oxygen Demand (mg/l)	---	---	5.9	2.5	---	---	3.9	ND (2)	---	---
Chemical Oxygen Demand (mg/l)	---	---	32.8	25.2	---	---	22.8	20.8	---	---
Total Organic Carbon (mg/l)	---	---	4.37	4.37	---	---	5.83	5.83	---	---
Phosphorus (mg/l)	---	---	0.35	---	---	---	0.091	0.17	---	---
Total Orthophosphate (mg/l)	---	---	0.097	---	---	---	ND (0.1)	---	---	---
Total Suspended Solids (mg/l)	---	---	31	---	---	---	8	---	---	---
Total Dissolved Solids (mg/l)	---	---	245	---	---	---	54	---	---	---
Volatile Suspended Solids (mg/l)	---	---	6	---	---	---	4	---	---	---
Alkalinity (mg/L)	---	---	5.2	---	---	---	22	---	---	---
Hardness (mg/l as CaCO3)	---	---	10		---	---	24	---	---	---
Runoff Volume (gallons)	166,700		411,600		136,000		765,000		43,500	

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Sample Location ➤ Sample Dates and Analytes	P1	P1 (dissolved)	P2	P2 (dissolved)	P3	P3 (dissolved)	P4	P4 (dissolved)	Wetfall	Dryfall
6/15/98										
Total Kjeldahl Nitrogen (mg/l as N)	3.92	2.24	8.4	13.4	---	---	21.3	5.6	---	---
Ammonia (mg/l as N)	---	2.8	1.12	9.52	---	---	16.8	6.16	---	---
Nitrate/Nitrite (mg/l as N)	0.23	0.21	0.2	0.35	---	---	0.29	0.31	---	---
Biochemical Oxygen Demand (mg/l)	4.25	3.8	4.05	2.7	---	---	1.8	4	---	---
Chemical Oxygen Demand (mg/l)	18.4	24	22	66.4	---	---	21.6	17.2	---	---
Total Organic Carbon (mg/l)	7.11	19	4.47	9.75	---	---	5.79	20.3	---	---
Phosphorus (mg/l)	0.072	---	0.2	---	---	---	0.069	---	---	---
Total Orthophosphate (mg/l)	0.017	---	ND (0.01)	---	---	---	ND (0.01)	---	---	---
Total Suspended Solids (mg/l)	ND (4)	---	21	---	---	---	ND (4)	---	---	---
Total Dissolved Solids (mg/l)	61	---	58	---	---	---	19	---	---	---
Volatile Suspended Solids (mg/l)	ND (4)	---	5	---	---	---	ND (4)	---	---	---
Alkalinity (mg/L)	10	---	4.2	---	---	---	ND (20)	---	---	---
Hardness (mg/l as CaCO3)	18	---	10	---	---	---	24		---	---
Runoff Volume (gallons)	841,600		1,260,900		719,600		3,097,500		176,000	
6/17/98										
Total Kjeldahl Nitrogen (mg/l as N)	1.05	1.06	---	---	0.55	---	0.75	0.97	---	---
Ammonia (mg/l as N)	0.32	0.26	---	---	ND (0.1)	---	ND (0.1)	ND (0.1)	---	---
Nitrate/Nitrite (mg/l as N)	0.33	0.33	---	---	0.12	---	0.19	0.2	---	---
Biochemical Oxygen Demand (mg/l)	4	4	---	---	---	---	6	4	---	---
Chemical Oxygen Demand (mg/l)	ND (10)	ND (10)	---	---	ND (10)	---	ND (10)	26	---	---
Total Organic Carbon (mg/l)	8.8	9	---	---	7.5	---	8	7.9	---	---
Phosphorus (mg/l)	0.12	---	---	---	0.11	---	0.13	---	---	---
Total Orthophosphate (mg/l)	ND (0.01)	---	---	---	ND (0.01)	---	ND (0.01)	---	---	---
Total Suspended Solids (mg/l)	ND (4)	---	---	---	19	---	8	---	---	---
Total Dissolved Solids (mg/l)	142	---	---	---	121	---	79	---	---	---
Volatile Suspended Solids (mg/l)	ND (4)	---	---	---	ND (4)	---	ND (4)	---	---	---
Alkalinity (mg/L)	26	---	---	---	13	---	10	---	---	---
Hardness (mg/l as $CaCO_3$)	24	---	---	---	---	---	12	---	---	---
Runoff Volume (gallons)	129,400		215,200		162,500		554,500		31,500	

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Sample Location ➤ Sample Dates and Analytes	P1	P1 (dissolved)	P2	P2 (dissolved)	P3	P3 (dissolved)	P4	P4 (dissolved)	Wetfall	Dryfall
6/23/98										
Total Kjeldahl Nitrogen (mg/l as N)	0.22	---	1.44	6.1	1.15	0.3	0.76	0.51	---	---
Ammonia (mg/l as N)	0.12	---	0.2	0.5	0.14	0.13	0.31	ND (0.1)	---	---
Nitrate/Nitrite (mg/l as N)	0.23	---	0.4	0.42	0.15	0.14	0.21	0.17	---	---
Biochemical Oxygen Demand (mg/l)	ND (2)	---	ND (2)	6	ND (2)	23	ND (2)	52	---	---
Chemical Oxygen Demand (mg/l)	ND (10)	---	31	15	34	ND (10)	ND (10)	ND (10)	---	---
Total Organic Carbon (mg/l)	3.1	---	4.4	7.7	4.7	7.4	3.2	3.8	---	---
Phosphorus (mg/l)	0.06	---	0.02	---	ND (0.01)	---	0.04	---	---	---
Total Orthophosphate (mg/l)	0.03	---	ND (0.01)	---	ND (0.01)	---	ND (0.01)	---	---	---
Total Suspended Solids (mg/l)	19	---	33	---	29	---	10	---	---	---
Total Dissolved Solids (mg/l)	47	---	79	---	64	---	69	---	---	---
Volatile Suspended Solids (mg/l)	9	---	16	---	13	---	11	---	---	---
Alkalinity (mg/L)	6	---	13	---	7	---	14	---	---	---
Hardness (mg/l as $CaCO_3$)	8	---	20	---	10	---	19	---	---	---
Runoff Volume (gallons)	1,207,300		1,064,200		756,800		3,499,000		199,000	
6/24/98										
Total Kjeldahl Nitrogen (mg/l as N)	0.73	---	0.71	---	0.7	---	0.53	---	---	---
Ammonia (mg/l as N)	0.22	---	0.22	---	0.16	---	0.55	---	---	---
Nitrate/Nitrite (mg/l as N)	0.4	---	0.61	---	0.27	---	0.32	---	---	---
Biochemical Oxygen Demand (mg/l)	3	---	4	---	3	---	2	---	---	---
Chemical Oxygen Demand (mg/l)	ND (10)	---	ND (10)	---	14	---	ND (10)	---	---	---
Total Organic Carbon (mg/l)	3.8	---	4	---	5.6	---	3.1	---	---	---
Phosphorus (mg/l)	0.05	---	0.1	---	0.05	---	0.12	---	---	---
Total Orthophosphate (mg/l)	ND (0.01)	---	ND (0.01)	---	ND (0.01)	---	ND (0.01)	---	---	---
Total Suspended Solids (mg/l)	ND (4)	---	57	---	54	---	8	---	---	---
Total Dissolved Solids (mg/l)	45	---	48	---	69	---	51	---	---	---
Volatile Suspended Solids (mg/l)	4	---	5	---	6	---	3	---	---	---
Alkalinity (mg/L)	6	---	6	---	12	---	8	---	---	---
Hardness (mg/l as $CaCO_3$)	8	---	11	---	17	---	15	---	---	---
Runoff Volume (gallons)	293,200		682,400		290,400		1,415,000		80,000	

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Sample Location ➤ Sample Dates and Analytes	P1	P1 (dissolved)	P2	P2 (dissolved)	P3	P3 (dissolved)	P4	P4 (dissolved)	Wetfall	Dryfall
7/31/98										
Total Kjeldahl Nitrogen (mg/l as N)	1.3	1	2.7	---	---	---	1.2	---	---	---
Ammonia (mg/l as N)	1	1.1	0.74	---	---	---	0.96	---	1.5	---
Nitrate/Nitrite (mg/l as N)	1.51	1.51	1.81	---	---	---	0.13	---	---	---
Biochemical Oxygen Demand (mg/l)	6	26	27	6	---	---	5	---	---	---
Chemical Oxygen Demand (mg/l)	16	ND (10)	106	---	---	---	ND (10)	---	---	---
Total Organic Carbon (mg/l)	11	11	20	---	---	---	8.1	---	---	---
Phosphorus (mg/l)	0.05	---	0.36	---	---	---	0.09	---	---	---
Total Orthophosphate (mg/l)	0.03	---	ND (0.1)	---	---	---	ND (0.01)	---	ND (0.01)	---
Total Suspended Solids (mg/l)	9	---	51	---	---	---	11	---	---	---
Total Dissolved Solids (mg/l)	92	---	115	---	---	---	90	---	---	---
Volatile Suspended Solids (mg/l)	9	---	16	---	---	---	7	---	---	---
Alkalinity (mg/L)	17	---	15	---	---	---	25	---	---	---
Hardness (mg/l as $CaCO_3$	40	---	52	---	---	---	36	---	---	---
Runoff Volume (gallons)	79,400		436,900		32,000		593,000		33,500	

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Constructed Wetland Systems

Constructed wetlands can be effective BMPs for removing pollutants from urban storm water. The main mechanism of pollutant removal in wetland systems is sedimentation (Strecker et al, 1992). Other pollutant removal mechanisms include filtration by aquatic vegetation and by underlying soil and gravel in systems where subsurface flow is present, biological conversion of organic compounds by microorganisms, uptake of nutrients by aquatic plants and algae, uptake of metals by plant tissue, adsorption of metals by clay soils, and volatilization of hydrocarbons and volatile organics. While the literature contains hundreds of references to constructed wetlands systems, very few quantitative studies have been conducted with sufficient rigor to provide good estimates of performance. Strecker's evaluation of the literature on wetland treatment systems identified only 17 reports that discussed the results of research on a functioning wetland system (of 140 reviewed reports). This indicates that there is a general lack of thorough, scientifically-defensible evaluations on the performance of wetland treatment systems. As a result, there is a wide range of variability in reported efficiency data. Table 5-11 summarizes the pollutant removal efficiency of constructed wetland systems based on Strecker's evaluation of published studies.

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Table 5-11. Pollutant Removal Efficiency of Constructed Wetland Systems

Parameter	Median Removal Efficiency (percent)	Range of Removals (percent)		Number of Observations
		Low	High	
Soluble Phosphorus	23	-30	78	12
Ortho-Phosphate	28	-109	93	7
Total Phosphorus	46	-120	97	37
Ammonia-Nitrogen	33	-86	62	15
Nitrate	46	4	95	18
Organic Nitrogen	7	-36	39	7
Total Nitrogen	24	-20	83	11
Suspended Solids	76	-300	98	26
Bacteria	78	55	97	3
Organic Carbon	28	-31	93	15
Cadmium	69	-80	80	6
Chromium	73	38	98	3
Copper	39	2	84	10
Lead	63	23	94	17
Zinc	54	-74	90	16

Sources: Strecker at al (1992); Organic Carbon, Bacteria and Metals from Brown and Schueler, 1997a

Evaluation of wetland performance is problematic because the basic mechanisms taking place in wetland systems are not well understood. Wetlands are complex ecosystems, and variations in design and watershed factors can have a significant impact on performance. As a result, data collected from various sites are not always comparable.

Due to the limited amount of comparable data that is available on the performance of storm water wetland systems, it is difficult to arrive at any meaningful relationships indicating the important factors in wetland system design. Strecker indicated that perhaps the greatest factor influencing performance of constructed wetlands is the hydrology of the watershed and the inflow hydraulics. Other factors having a major influence on performance are wetland size and volume, the design of the inlet and outlet structures, flow patterns through the system, vegetational

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community structure, seasonal productivity and decay of wetland plants, and changes in evapotranspiration rates. In addition, the presence of subsurface flows can complicate wetland performance evaluations.

Strecker recommends that an important evaluation step in determining wetland performance is to compare runoff volumes with storage volumes and contact surface area of the wetland. However, he was unable to conduct this evaluation due to the lack of consistent reporting of rainfall statistics, watershed imperviousness, land uses, flow volumes, capacity and surface areas for contact. In order to ensure the comparability of future data reporting for wetland systems, it is recommended that a standardized set of monitoring protocols be adopted for all future monitoring efforts.

An important factor in the variation of reported efficiency is the wide range of designs that are used in constructed wetland systems. A few design variations include:

- ponds with an emergent wetland area on the pond perimeter;
- shallow wetlands with subsurface flow;
- wetland channels;
- pond-wetland systems;
- extended detention wetlands.

Although the design of a particular systems is dependent upon a number of site-specific variables, there are some important design factors that should be incorporated in wetland system designs including:

- a pre-settling chamber for removal of heavy sediments and to limit disturbance of the wetland to remove accumulated sediments;
- adjustable level control at the outlet by means of an adjustable weir or orifice;
- design the flow path to limit short circuiting and dead space and to maximize detention time;
- a broad, densely planted aquatic bench;
- selection of planting species to produce a dense stand of vegetation for filtration and nutrient uptake;
- periodic harvesting of excess vegetation to prevent nutrient release and to remove undesirable species.

Crestwood Marsh Constructed Wetland

In 1998 EPA conducted sampling activities at a constructed wetland in Manassas, Virginia. The Crestwood Marsh is located in a residential area and was originally constructed as a dry detention basin, but conditions at the site were such that a wetland system formed on its own. The outlet structure was modified in 1995 to provide an extended detention time of 24 hours within the wetland. As a result of this modification, the system has developed into a shallow emergent marsh and contains a variety of wetland species. The wetland has a surface area of

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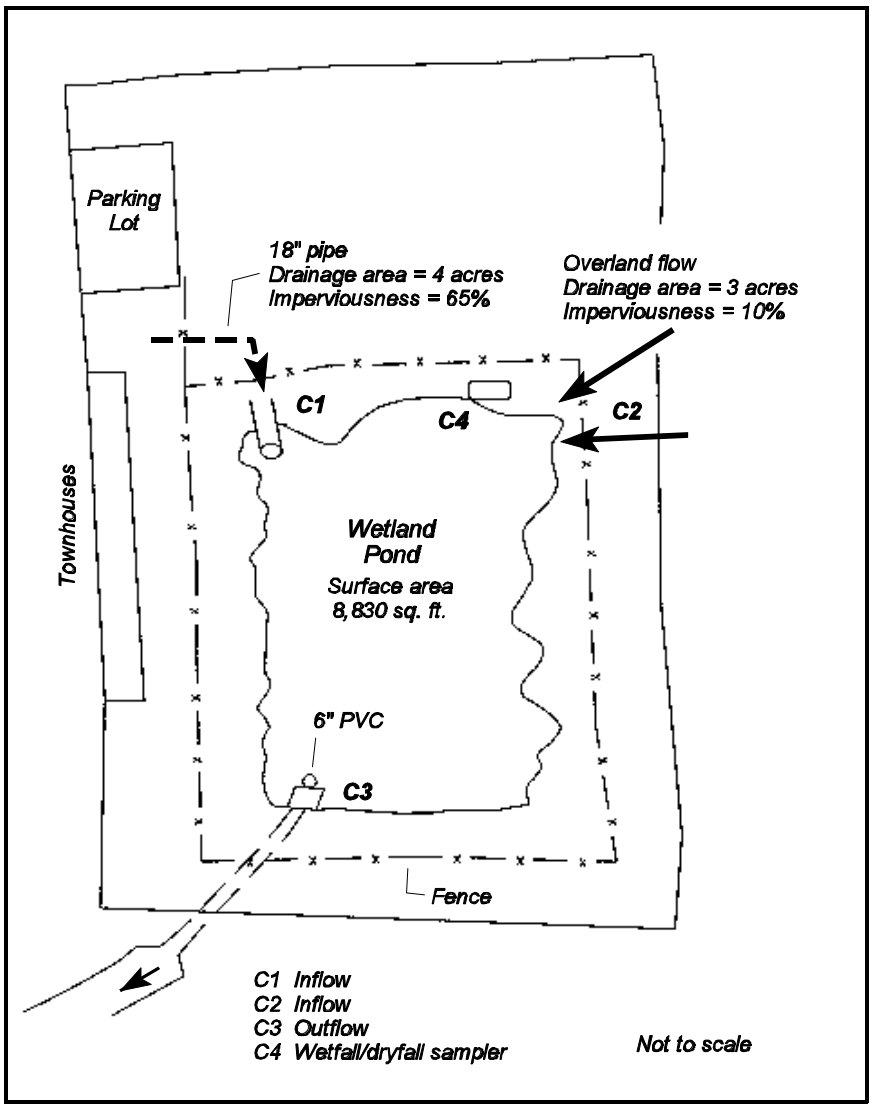
8,830 ft^2. The water quality detention volume of the wetland is 2,524 ft^3, and the flood control volume above the water quality volume is 3,523 ft^3. The area draining to the wetland is a 7-acre townhouse community, with the land area consisting of approximately 60 percent townhouses, 30 percent forested and 10 percent open space. The drainage area is estimated to be approximately 40 percent impervious. The constructed wetland is located at the headwaters of a small unnamed stream that drains to Bull Run, within the Occoquan River Watershed.

Flow enters the wetland at the eastern corner through an 18-inch concrete pipe situated flush with the bottom grade (point C1). From this point, water gradually spreads throughout the wetland and drains to the northern corner of the pond and is discharged through a 6-inch PVC outlet pipe (point C3). There is an additional inlet point located at the southwest corner of the wetland, which consists of overland flow from an adjacent area of forested parkland. EPA concentrated the flow at this point in order to allow estimation of flow rates and volumes, and to allow for collection of water quality samples (point C2). See Figure 5-15.

SARB_016935

Figure 5-15. Crestwood Marsh Constructed Wetland



During the spring and summer of 1998, storm event sampling was conducted during nine events. Sampling consisted of collecting flow-weighted composite samples as well as recording rainfall depth, and runoff flow rates and volumes into and out of the wetland. In addition to water quality monitoring, atmospheric deposition and wetfall deposition samples were collected during the study period. The water quality sampling data collected during the study period are summarized in the tables below. Additional data, as well as a detailed description of the sampling program, wetland design, and an evaluation of the performance of the wetland will be included in a supplement to this report.

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Table 5-12. Summary of Crestwood Marsh Constructed Wetland Sampling Data

Sample Date ➤	06/01/98			06/11/98			06/12/98		
Analytes **Location ➤**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**
Runoff Volume (gal)	7,625	No Flow	1,376	9,439	No Flow	3,237	11,621	No Flow	3,903
Total Suspended Solids (mg/l)	41	--	--	18	--	--	70	--	4
Chemical Oxygen Demand (mg/l)	75	--	--	28.4	--	--	37.2	--	--
Total Organic Carbon (mg/l)	13	--	--	5.02	--	--	5.83	--	--
Total Kjeldahl Nitrogen (mg/l as N)	2	--	--	12.3	--	--	5.04	--	--
Total Inorganic Nitrogen (mg/l as N)	0.67	--	--	0.33	--	--	0.47	--	--
Ammonia (mg/l as N)	0.75	--	--	<1	--	--	1.12	--	--
Total Phosphorus (mg/l)	0.12	--	--	0.084	--	--	0.22	--	--
Ortho-Phosphate (mg/l)	<0.01	--	--	0.032	--	--	0.18	--	0.021
Alkalinity (mg/l as $CaCO_3$)	31	--	--	6.8	--	--	4.8	--	4.3
Hardness (mg/l as $CaCO_3$)	--	--	--	--	--	--	14	--	--
Lead	--	--	--	--	--	--	6.9	--	--
Copper	--	--	--	--	--	--	10.1	--	--
Zinc	--	--	--	--	--	--	64.9	--	--
Nickel	--	--	--	--	--	--	6.6	--	--
Aluminum	--	--	--	--	--	--	2690	--	--
Chromium	--	--	--	--	--	--	4.4	--	--

Sample Date ➤	06/14/98			06/16/98			06/23/98		
Analytes **Location ➤**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**
Runoff Volume (gal)	7,624	No Flow	No Flow	53,457	6,985	57,216	81,327	6,334	139,390
Total Suspended Solids (mg/l)	44	--	--	<4	19	<4	5	34	6
Chemical Oxygen Demand (mg/l)	64	--	--	12.8	45.6	15.2	<10	24	<10
Total Organic Carbon (mg/l)	14.3	--	--	4.47	9.75	5.79	4.1	7.4	3.1
Total Kjeldahl Nitrogen (mg/l as N)	3.36	--	--	2.8	7.28	17.4	0.57	0.44	0.8
Total Inorganic Nitrogen (mg/l as N)	0.4	--	--	0.2	0.15	0.16	0.81	0.27	0.53
Ammonia (mg/l as N)	1.12	--	--	<1	<1	<1	0.37	0.27	0.32
Total Phosphorus (mg/l)	0.17	--	--	0.078	0.2	0.11	0.2	0.24	0.05
Ortho-Phosphate (mg/l)	0.058	--	--	0.05	0.032	0.026	0.12	0.05	0.05
Alkalinity (mg/l as $CaCO_3$)	6.5	--	--	5.2	20	6.7	11	8	<1
Hardness (mg/l as $CaCO_3$)	--	--	--	--	24	44	20	10	<1
Lead	6.6	--	--	<2	<2	<2	--	--	--
Copper	10.3	--	--	<1	<1	<1	--	--	--
Zinc	68.5	--	--	<2	<2	<2	--	--	--

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Analytes / Sample Date ➤ / Location ➤	06/14/98			06/16/98			06/23/98		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Nickel	<1	--	--	2.3	<1	<1	--	--	--
Aluminum	3450	--	--	<54	3420	<54	--	--	--
Chromium	<1	--	--	2	4.7	<1	--	--	--

Analytes / Sample Date ➤ / Location ➤	06/24/98			07/24/98			07/31/98		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Runoff Volume (gal)	11,766	7,604	38,353	20,820	9,645	4,579	11,929	761	No Flow
Total Suspended Solids (mg/l)	37	45	<4	68	--	5	30	--	--
Chemical Oxygen Demand (mg/l)	<10	67	18	32	--	<10	27	--	--
Total Organic Carbon (mg/l)	3.6	17	9.2	7.9	--	10.4	12	--	--
Total Kjeldahl Nitrogen (mg/l as N)	0.52	1.28	0.48	1.14	--	0.9	1	--	--
Total Inorganic Nitrogen (mg/l as N)	0.52	0.11	0.15	0.48	--	0.33	0.67	--	--
Ammonia (mg/l as N)	0.18	0.13	0.15	0.46	--	0.22	0.97	--	--
Total Phosphorus (mg/l)	0.11	0.12	0.02	0.15	--	0.83	0.1	--	--
Ortho-Phosphate (mg/l)	0.03	<0.01	<0.01	0.09	--	0.28	0.03	--	--
Alkalinity (mg/l as $CaCO_3$)	7	17	15	2	--	8	4	--	--
Hardness (mg/l as $CaCO_3$)	6	28	17	15	--	--	21	--	--
Lead	--	--	--	18.2	--	--	16.2	--	--
Copper	--	--	--	10.4	--	--	8	--	--
Zinc	--	--	--	75.2	--	--	86.3	--	--
Nickel	--	--	--	10	--	--	11.1	--	--
Aluminum	--	--	--	2430	--	--	1370	--	--
Chromium	--	--	--	7.7	--	--	4.8	--	--

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Filtration and Bioretention Systems

Filtration systems are seeing increased usage, especially in ultra-urban environments where space constraints prohibit the use of detention, retention and constructed wetland systems. Filtration systems can provide significant water quality improvements, but only a small amount, if any, water quantity control. It should also be stressed that filters must be placed off-line in order to assure continued functioning, and therefore only provide treatment of a volume of water based on a design storm. Any volume in excess of the design storm is bypassed without treatment.

Limited monitoring data are available on the efficiency of storm water filtering systems. This is mainly due to storm water filters being a relatively new technology, as opposed to more conventional BMPs such as wet ponds and constructed wetland systems. As a result, only a few published monitoring studies are available to evaluate the efficiency of various filter designs. The following Table 5-13 summarizes the pollutant removal efficiencies for storm water filtration systems. Removal efficiencies are based on data collected from 13 monitoring studies.

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Table 5-13. Pollutant Removal Efficiency of Storm Water Filtration Systems

Parameter	Median or Average Removal Efficiency (percent)	Range of Removals (percent)		Number of Observations
		Low	High	
Soluble Phosphorus	-31	-37	-25	2
Total Phosphorus	45	-25	80	15
Ammonia-Nitrogen	68	43	94	4
Nitrate	-13	-100	27	13
Organic Nitrogen	28	0	56	2
Total Nitrogen	32	13	71	9
Suspended Solids	81	8	98	15
Bacteria	37	36	83	5
Organic Carbon	57	10	99	11
Cadmium	26	N/A	N/A	1
Chromium	54	47	61	2
Copper	34	22	84	9
Lead	71	-16	89	11
Zinc	69	33	91	15

Source: Brown and Schueler, 1997a

Storm water filtration systems can be highly effective at removing pollutants from storm water runoff. They are particularly effective at removing TSS and total phosphorus, although many filters export inorganic nitrogen due to nitrification of ammonia and organic nitrogen in the filter (Bell, 1998). Bell's study reported that significant phosphorus removals can be attributed to reaction and precipitation with sand that contains iron, calcium and aluminum. Although the limited data that are available on storm water filters indicates that their overall performance is good, additional data are needed to evaluate their efficiency, especially data that can be used to evaluate their long-term hydraulic performance and maintenance requirements. For example, Urbonas et al (1997) found that the hydraulic flow-through rate of a sand filter decreased from 3 feet-per-hour per square foot of filter area to less than 0.05 feet-per-hour after only several storms. This rapid decrease in flow-through rate causes a marked decrease in efficiency, since

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more of the storm flow will be bypassed unless adequate detention storage volume is provided upstream of the filter. Therefore, overall TSS removal rates are significantly lower when this bypass flow is accounted for (for example, Urbonas' evaluation of storms over the 1995 season resulted in only a 15 percent overall TSS removal when bypass flows were taken into account). Due to the potential decrease in efficiency of sand filtration systems, careful consideration of design parameters is needed. Urbonas (1999) presents a thorough discussion of sand filtration design. Readers are urged to consult this reference for information on sand filtration system design.

In order to provide adequate filter functioning, the following basic design and operation guidelines should be followed:

- The filter should be placed off-line;
- A sedimentation chamber or basin should be provided upstream of the filter bed in order to allow for the removal of sediments to extend the length of the filter run between maintenance activities;
- The filter should be sized adequately or else adequate detention facilities should be provided upstream of the filter in order to capture expected storm water flows and to minimize bypasses;
- Care should be taken to limit excessive sediment loadings to the filter during construction or landscaping activities;
- Periodic maintenance to remove accumulated sediments and restore the filter flow-through rate may be necessary in areas with high solids loadings.

As with filtration systems, the available data on the performance of bioretention facilities are limited. Since bioretention facilities incorporate many of the same mechanisms as filtration systems, their performance for removal of parameters such as TSS are expected to be similar. Due to their biological nature, however, bioretention facilities are expected to also provide conditions necessary for uptake of nutrients by vegetation, degradation of organic contaminants by soil microorganisms, and biochemical reactions within the soil matrix and around the root zone of plants. Available data on the efficiency of bioretention facilities (based on laboratory data and one field study) indicates that bioretention can obtain removals on the order of 95-97 percent for metals, 75 percent for total phosphorus, 69 percent for TKN, 79 percent for ammonia, 21 percent for nitrate and 56 percent for total nitrogen (adapted from Bell (1998), average of all reported values).

The following general guidelines should be followed when designing bioretention facilities:

- Water should not be allowed to pond for more than four days in order to prevent mosquito breeding and to prevent adverse effects on plants;
- Plants selected for bioretention should be tolerant to stresses found in urban areas such as pollutants, variable soil moisture, periodic inundation, and high temperatures;

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- Native plant species should be used whenever possible (Prince George's County, 1993), and species diversity should be maintained in order to prevent loss of all plants in the event of disease or infestation.
- Plants should be placed with regard to the elevation and moisture level of the planting bed (i.e., more water-tolerant species should be placed in lower areas where water is likely to pond longer);
- A mulch layer should be installed and maintained in order to prevent erosion of soils and to retain soil moisture;
- Where concentrated runoff enters the bioretention system, reinforcement (such as stone stabilization or synthetic erosion protection materials) may be needed to reduce erosion of the mulch layer and disturbance of the planting bed (Claytor and Schueler, 1996).
- The clay content of soils used in bioretention facilities may need to be limited to prevent clogging of the soil bed (Bell, 1998).

Readers are encouraged to consult *Design Manual for Use of Bioretention in Stormwater Management* (Prince George's County, 1993) and *Design of Stormwater Filtering Systems* (Claytor and Schueler, 1996) for additional information on the bioretention concept.

Hollywood Branch Peat/Sand Filter

In 1998 EPA conducted sampling activities at a peat/sand filter in Montgomery County, Maryland. The Hollywood Branch filter is a surface sand filter with a peat/sand filtration media that was designed based on the Galli paper (1990b). The filter is located in a county park in the Colesville area of Montgomery County and discharges to Hollywood Branch, a first-order stream that discharges into Paint Branch approximately 3,000 feet downstream of the filter. The drainage area covers approximately 140 acres and consists of 73 percent residential, 13 percent industrial and 14 percent other sources. The filter was one of several retrofit projects installed by Montgomery County as part of a watershed restoration effort in the Paint Branch watershed.

The filter is located off-line of the storm drainage system, and is designed to capture the first 0.1 watershed inches of runoff via a flow-splitter located in the storm sewer. This corresponds to a runoff volume of approximately 50,280 ft^3. Any runoff in excess of this amount bypasses the filter and is discharged directly to Hollywood Branch. Runoff from the flow splitter first enters a small stilling basin before being discharged to the filter. The stilling basin functions as a pre-settling chamber to remove coarse sediments in order to prolong the life of the filter. The stilling basin has a volume of 16,940 ft^3 at the permanent pool level, a depth of 3 feet, and length-to-width ratio of approximately 3:1. The edge of the stilling basin is planted with emergent wetland vegetation. Water is discharged from the stilling basin and into the filter through a submerged 18 inch pipe. The filter has dimensions of 265 feet by 63 feet. The filter is designed to pond water to a maximum depth of 2 feet, which corresponds to a volume of 33,880 ft^3. The filter bed is designed to have a minimum infiltration rate of 1.0 inch/hour. The filter bed consists of a 12-inch peat top layer, underlain by a 4-inch sand/peat mix, which is underlain by a 20-inch layer of sand. Water entering the filter is distributed by a series of interconnected 6 inch PVC half-pipes placed along the surface of the filter bed. The filter contains an under-drain system

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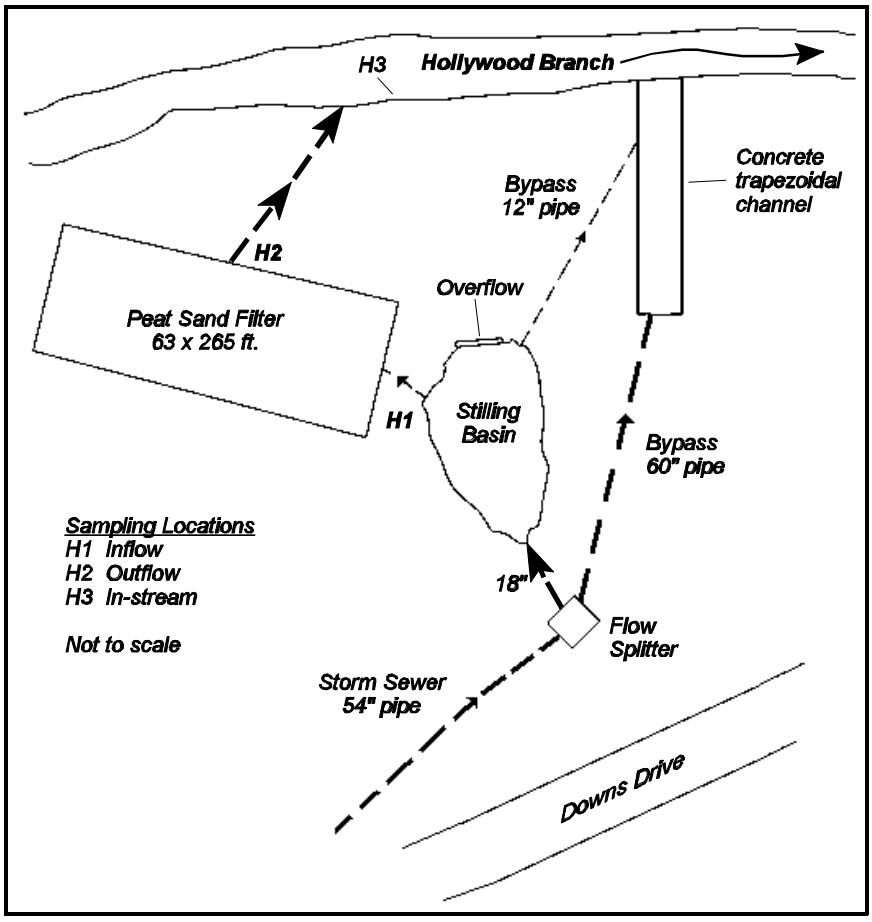
consisting of 6 inch perforated PVC pipes encased in a crushed gravel layer. Filtered water collected in the under-drain system is discharged to Hollywood Branch through a 12-inch concrete pipe. See Figure 5-16.

Figure 5-16. Hollywood Branch Peat/Sand Filter



The monitoring program consisted of recording runoff flow rates and volumes and collecting flow-weighted composite samples from the inflow and outflow of the filter using automatic sampling equipment. A tipping bucket rain gauge was used to record precipitation levels. Flow monitoring and water quality sampling was conducted for five events during the spring and summer of 1998. Baseflow samples were collected from the filter on three occasions. In addition, in-stream sediment samples were collected on one occasion, and bioassessment and physical habitat measurements were also conducted.

The following tables summarize the chemical sampling data collected during this evaluation. Additional information describing the sampling program, additional sampling and

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assessment data (including sediment, bioassessment and physical habitat assessment) and an analysis of the performance of the filter will be included as a supplement to this report.

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Table 5-14. Summary of Hollywood Branch Peat/Sand Filter Storm Event Sampling Data

Analytes / Sample Dates ➤	06/01/98		06/12/98		06/14/98		06/24/98		07/31/98	
	Inflow	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Event Volume (gal)	7,597	No flow	68,436	28,470	308,705	149,184	131,744	75,003	151,395	72,537
Total Suspended Solids (mg/l)	--	--	10	< 4	7	17	12	8	38	31
Chemical Oxygen Demand (mg/l)	16	--	25.2	17.6	24	14.4	< 10	11	30	34
Total Organic Carbon (mg/l)	10.4	--	7.29	4.37	4.37	4.37	5.5	6	14	10.4
Total Kjeldahl Nitrogen (mg/l as N)	2	--	7.28	5.6	2.24	11.2	0.91	0.78	1.8	0.68
Total Inorganic Nitrogen (mg/l as N)	1.11	--	0.77	2.14	0.66	2.07	1	1.86	1.13	2.21
Ammonia (mg/l as N)	0.56	--	< 1	< 1	1.68	14.6	0.28	0.16	0.32	< 0.1
Total Phosphorus (mg/l)	0.14	--	0.094	0.16	0.19	0.14	0.19	0.2	0.18	0.15
Ortho-Phosphate (mg/l)	--	--	0.047	0.27	0.23	0.049	< 0.01	< 0.01	0.1	< 0.01
Lead (µg/l)	2.1	--	13.6	2.4	2.3	3.7	2.7	5.6	3.8	8.9
Copper (µg/l)	6.8	--	8.3	2	4.7	1.3	7	4	6.5	11.3
Zinc (µg/l)	17.1	--	40.1	< 2	< 2	< 2	26.8	22.6	43	41.8
Nickel (µg/l)	2.4	--	2.4	22.3	<1	< 1	1.5	4.7	3.2	7.4
Aluminum (µg/l)	< 54	--	488	1360	899	2010	956	2810	497	3450
Chromium (µg/l)	< 1	--	1.4	6.3	< 1	< 1	< 1	4.8	< 1	7.7

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Table 5-15. Summary of Hollywood Branch Peat/Sand Filter Baseflow Sampling Data

Sample Dates ➤ / Analytes	05/19/98		06/23/98		08/14/98	
	Inflow	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Total Suspended Solids (mg/l)	< 4	< 4	---	< 4	---	< 4
Chemical Oxygen Demand (mg/l)	< 10	< 10	---	< 10	---	< 20
Total Organic Carbon (mg/l)	< 10	< 10	---	3.5	---	6.6
Total Kjeldahl Nitrogen (mg/l as N)	1.66	19.8	---	0.55	---	1.28
Total Inorganic Nitrogen (mg/l as N)	1.79	0.64	---	0.74	---	0.23
Ammonia (mg/l as N)	0.49	< 0.1	---	< 0.1	---	< 1
Total Phosphorus (mg/l)	0.02	< 0.01	---	0.14	---	0.054
Ortho-Phosphate (mg/l)	0.02	0.02	---	< 0.01	---	0.069
Lead (µg/l)	< 2	< 2	---	---	---	< 2
Copper (µg/l)	< 1	< 1	---	---	---	1.2
Zinc (µg/l)	< 2	< 2	---	---	---	30.5
Nickel (µg/l)	2.3	3.1	---	---	---	2.7
Aluminum (µg/l)	59.8	< 54	---	---	---	1590
Chromium (µg/l)	< 1	--	---	---	---	2.3

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Open Channel Vegetated Systems

Open channel vegetated systems are used widely for storm water quality control. However, these systems can be difficult to monitor, especially systems that intercept runoff as sheet flow such as grass filter strips. As a result, data on these types of systems are not as prevalent as other more readily monitored BMP types such as ponds and constructed wetlands. Table 5-16 summarizes the pollutant removal efficiency of open channel vegetated systems. Removal efficiencies are based on data collected from 20 monitoring studies.

Table 5-16. Pollutant Removal Efficiency of Open Channel Vegetated Systems

Parameter	Average or Median Removal Efficiency (percent)	Range of Removals (percent)		Number of Observations
		Low	High	
Soluble Phosphorus	11	-45	72	8
Total Phosphorus	15	-100	99	18
Ammonia-Nitrogen	3	-19	78	4
Nitrate	11	-100	99	13
Organic Nitrogen	39	11	86	3
Total Nitrogen	11	-100	99	10
Suspended Solids	66	-100	99	18
Bacteria	-25	-100	0	5
Organic Carbon	23	-100	99	11
Cadmium	49	20	80	6
Chromium	47	14	88	5
Copper	41	-35	89	15
Lead	50	-100	99	19
Zinc	49	-100	99	19

Source: Brown and Schueler, 1997a

Evaluation of available data does not provide a good indication as to the actual performance of these systems. The above data indicate that a wide range in pollutant removal efficiency is reported in the literature for open channel vegetated systems. Since there are a variety of system designs lumped into the above summary, arriving at efficiency estimates for a

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particular system type given available data is difficult. In general, these types of BMPs should be effective at removing suspended solids and associated pollutants from runoff by sedimentation and by filtration by vegetation, and are certainly effective at slowing the velocity of storm water runoff and for providing detention of runoff if check dams or other structures are incorporated to provide ponding of runoff. However, dense vegetation must be maintained in order to assure proper functioning. In addition, negative removals are frequently reported for sediment and nutrients. If open channel vegetated systems are not properly maintained, significant export of sediments and associated pollutants such as metals and nutrients can occur from eroded soil. In addition, standing water in these systems can be a significant source of bacteria and can provide the conditions necessary for mosquito breeding. Additional data gathering is needed in order to support these assumptions and to quantify the efficiency of these systems.

Open channel vegetated systems can be used as pretreatment devices for other BMPs, or can be used in a "treatment train" approach. For example, grass filter strips are commonly used to accept sheet flow from parking lots in order to pre-treat runoff prior to being treated by a bioretention facility or a filter. Vegetated swales can be used to convey runoff to BMPs such as ponds or constructed wetlands, providing pretreatment of the runoff volume. When used in combination with other BMPs, the overall quality of the treated runoff can be improved and the total runoff volume can be reduced due to infiltration that occurs in the open channel vegetated systems.

Miscellaneous and Vendor-Supplied Systems

Little data exist in the published literature on the efficiency of vendor-supplied systems. Data is frequently available from the vendors, and as more of these systems are installed it is expected that more data will become available. An evaluation of the efficiency of these systems has not been included in this report. The EvTEC program (see section 5.2.1.8) and other evaluation programs should provide useful information that indicates the efficiency of these systems in removing pollutants from runoff.

5.5.3 Controlling Flow Impacts

The removal of pollutants from storm water runoff is an important function of storm water BMPs. However, in many cases receiving water problems are not due to the pollutants contained in storm water, but rather can be attributed to the large flow rates that result in receiving streams that receive storm water discharges. Therefore, in some cases, controlling the volume and flow rate of storm water discharges is as important, if not more important, than removing pollutants prior to discharge. Site-specific parameters will dictate the importance of flow control in preventing degradation of receiving waters.

Evaluating the effectiveness of BMPs in controlling flow impacts is not an easy task. Site-specific variations such as slope, soil types, ground cover, and watershed-imperviousness can greatly impact the hydraulic response of a watershed to rainfall. In addition, receiving water

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parameters greatly influence the degree of flow control that is necessary in order to prevent degradation. As a result, little information is contained in the literature describing the performance of BMPs at controlling impacts in receiving streams due to excessive storm water flows. The literature that does exist, however, indicates a direct correlation between urbanization and receiving stream degradation. It is not difficult to infer, therefore, that storm water flow is a major contributor to receiving stream degradation, and that control of storm water flow rates and volumes is warranted in order to restore degraded receiving waters and to prevent degradation of receiving waters in newly developing areas. Additional information on the hydrological benefits of BMPs is presented in section 6.3.2 of this report.

Important measures of the effectiveness of BMPs at controlling storm water flows include:

- reductions in peak flow rate across the BMP;
- total storage volume provided in the BMP;
- infiltrative capacity of the BMP;
- retention time in the BMP;
- relationship of post-development hydrologic conditions to pre-development hydrology;
- retention volume necessary for receiving stream channel protection.

Local conditions will dictate the BMP design parameters that are necessary to reduce impacts due to flow. For example, the state of Maryland has developed unified BMP sizing criteria that is designed to provide adequate control of pollutants, limit degradation of streams, provide adequate groundwater recharge, and protect downstream areas from flooding. Additional work is needed in other areas of the country to evaluate the effectiveness criteria necessary to limit flow impacts and to provide adequate BMP sizing standards.

Flow control can be accomplished by using both structural and non-structural practices. Structural BMPs that can provide flow control include retention basins, detention basins, constructed wetlands, infiltration practices, grassed swales and minimizing directly connected impervious surface areas. Filters and bioretention facilities can also be adapted to provide some degree of quantity control if they are used in conjunction with detention basins or other means of providing detention of storm water prior to treatment, such as providing temporary ponding in overflow parking areas. Non-structural BMPs and land-use practices that can help to reduce the volume of storm water runoff discharged to receiving streams should also be considered a vital component of storm water management. Practices that can reduce the impact of storm water runoff due to excessive flows include land use regulations such as zoning, natural area and stream buffer preservation, limits on impervious surfaces, and cluster development. Practices that limit the generation of storm water can be very effective in preventing degradation of streams, and can limit the need for structural storm water controls. Information on development practices aimed at reducing impacts due to site development practices can be found in *Conservation Design for Stormwater Management* (Delaware DNREC, 1997) and in *Green Development* (US EPA, 1996b).

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5.6 Conclusions

There are a wide variety of BMPs available to manage storm water runoff. The efficiency of various BMP types has been documented to some degree, but there is still a great need for focused research in certain areas, particularly for newer and innovative structural BMP types, as well as non-structural BMPs. However, due to the complexity involved in isolating the reaction of a complex and highly variable system such as a watershed to one isolated input, evaluations of non-structural BMPs are ambitious tasks. Still, where storm water management is largely driven by the availability of scarce funding, data that indicate the cost-effectiveness of various control strategies are badly needed.

Ultimately, receiving stream morphology, habitat and biological communities may turn out the be the driving factors indicating the success of BMPs at controlling impacts due to storm water flows and the pollutants that they contain. In order for such measures to work, however, it is necessary to isolate the response of a receiving stream system to the implementation of BMPs. Frequently, there are too many variables in a watershed and too many other potential sources of degradation to isolate the improvements (or even to indicate potential negative impacts) of a particular BMP or group of BMPs. For example, Maxted and Shaver (1997) did not observe a significant difference in macroinvertebrate communities between 8 sites with storm water retention ponds and 33 sites with no storm water controls. In addition, the BMPs did not prevent the almost complete loss of sensitive aquatic species. Whether or not these impacts were caused by storm water flows, pollutants or other non-storm water sources was not indicated, and the data to be able to answer these questions may not be forthcoming in the foreseeable future. Therefore, until data are available to indicate that specific BMPs can prevent impacts and prevent degradation of receiving streams in urbanized areas, one should not assume that structural, "end-of-pipe" BMPs are the only answer to the storm water problem.

Available data seem to indicate that urbanization and traditional urban development at almost any level can cause degradation of streams, and that BMPs may be able to mitigate these impacts to a certain level. Accordingly, storm water management should start at the point of runoff generation, and incorporate site planning principles that prevent or minimize the generation of runoff, prevent development in floodplains, preserve natural drainage systems, and avoid disturbing sensitive areas such as wetlands and riparian areas. Where runoff generation cannot be avoided, then properly sited, designed, constructed and operated BMPs can be implemented to attempt to reduce the impacts associated with this runoff. There are data available on the effectiveness of BMPs in reducing pollutant loads, but these data are not comprehensive enough to either characterize the performance of all BMPs in use or to determine if they are actually controlling impacts to receiving waters. Additional data gathering is necessary, but the monitoring and data analysis protocols necessary to do so have not been fully developed. Standardization of monitoring protocols for data transferability is a vital component of successful data evaluation, and is an area that should be actively pursued in the near future.

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6.0 Costs and Benefits of Storm Water BMPs

Storm water best management practices (BMPs) are the primary tool to improve the quality of urban streams and meet the requirements of NPDES permits. They include both the structural and non-structural options reviewed in Section 5.2 of this report. Some BMPs can represent a significant cost to communities, but these costs should be weighed against the various benefits they provide. This chapter will focus on reviewing available data on the costs and potential benefits of both structural and non-structural BMPs designed to improve the quality of urban and urbanizing streams, and the larger water bodies to which they drain.

As described in previous chapters, storm water runoff can contribute loadings of nutrients, metals, oil and grease, and litter that result in impairment of local water bodies. The extent to which these impairments are eliminated by BMPs will depend on a number of factors, including the number, intensity, and duration of wet weather events; BMP construction and maintenance activities; and the site-specific water quality and physical conditions. Because these factors will vary substantially from site to site, data and information are not available with which to develop dollar estimates of costs and benefits for individual types of BMPs. However, EPA's national estimates of costs and benefits associated with implementation of the NPDES Phase II rule are discussed in Section 6.4.

6.1 Structural BMP Costs

The term structural BMPs, often referred to as "Treatment BMPs," refers to physical structures designed to remove pollutants from storm water runoff, reduce downstream erosion, provide flood control and promote groundwater recharge. In contrast with non-structural BMPs, structural measures include some engineering design and construction.

Structural BMPs evaluated in this report include:

- Retention Basins
- Detention Basins
- Constructed Wetlands
- Infiltration Practices
- Filters
- Bioretention
- Biofilters (swales and filter strips).

The two infiltration systems focused on in this report are infiltration trenches and infiltration basins. Although bioretention can serve as a filtering system or infiltration practice, it is discussed separately because it has separate cost data and design criteria. In this report, wet swales are assumed to have the same cost as biofilters, because there are little cost data available on this practice. Additional information about these structural BMPs, including descriptions, applicability and performance data can be found in Chapter 5 of this report. Other BMPs include

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experimental and proprietary products, as well as some conventional structures such as water quality inlets. They are not included in this analysis because sufficient data are not available to support either the performance or the cost of these practices.

6.1.1 Base Capital Costs

The base capital costs refer primarily to the cost of constructing the BMP. This may include the cost of erosion and sediment control during construction. The costs of design, geotechnical testing, legal fees, land costs, and other unexpected or additional costs are not included in this estimate. The cost of constructing any BMP is variable and depends largely on site conditions and drainage area. For example, if a BMP is constructed in very rocky soils, the increased excavation costs may substantially increase the cost of construction. Also, land acquisition costs vary greatly from site to site.[4] In addition, designs vary slightly among BMP types. A wet pond may be designed with or without various levels of landscaping, for example. The data in Table 6-1 represent typical unit costs (dollars per cubic foot of treated water volume) from various studies, and should be considered planning level. In the case of retention and detention basins, ranges are used to reflect the economies of scale involved in designing these BMPs.

[4] Land cost is the largest variable influencing overall BMP cost.

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Table 6-1. Typical Base Capital Construction Costs for BMPs

BMP Type	Typical Cost* ($/cf)	Notes	Source
Retention and Detention Basins	0.50-1.00	Cost range reflects economies of scale in designing this BMP. The lowest unit cost represents approx. 150,000 cubic feet of storage, while the highest is approx. 15,000 cubic feet. Typically, dry detention basins are the least expensive design options among retention and detention practices.	Adapted from Brown and Schueler (1997b)
Constructed Wetland	0.60-1.25	Although little data are available to assess the cost of wetlands, it is assumed that they are approx. 25% more expensive (because of plant selection and sediment forebay requirements) than retention basins..	Adapted from Brown and Schueler (1997b)
Infiltration Trench	4.00	Represents typical costs for a 100-foot long trench.	Adapted from SWRPC (1991)
Infiltration Basin	1.30	Represents typical costs for a 0.25-acre infiltration basin.	Adapted from SWRPC (1991)
Sand Filter	3.00-6.00	The range in costs for sand filter construction is largely due to the different sand filter designs. Of the three most common options available, perimeter sand filters are moderate cost whereas surface sand filters and underground sand filters are the most expensive.	Adapted from Brown and Schueler (1997b)
Bioretention	5.30	Bioretention is relatively constant in cost, because it is usually designed as a constant fraction of the total drainage area.	Adapted from Brown and Schueler (1997b)
Grass Swale	0.50	Based on cost per square foot, and assuming 6 inches of storage in the filter.	Adapted from SWRPC (1991)
Filter Strip	0.00-1.30	Based on cost per square foot, and assuming 6 inches of storage in the filter strip. The lowest cost assumes that the buffer uses existing vegetation, and the highest cost assumes that sod was used to establish the filter strip.	Adapted from SWRPC (1991)

* Base year for all cost data: 1997

In some ways there is no such value as the “average” construction cost for some BMPs, because many BMPs can be designed for widely varying drainage areas. However, there is some

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value in assessing the cost of a typical application of each BMP. The data in Table 6-2 reflect base capital costs for typical applications of each category of BMP. It is important to note that, since many BMPs have economies of scale, it is not practical to extrapolate these values to larger or smaller drainage areas in many cases.

Table 6-2. Base Costs of Typical Applications of Storm Water BMPs[1]

BMP Type	Typical Cost ($/BMP)	Application	Data Source
Retention Basin	$100,000	50-Acre Residential Site (Impervious Cover = 35%)	Adapted from Brown and Schueler (1997b)
Wetland	$125,000	50-Acre Residential Site (Impervious Cover = 35%)	Adapted from Brown and Schueler (1997b)
Infiltration Trench	$45,000	5-Acre Commercial Site (Impervious Cover = 65%)	Adapted from SWRPC (1991)
Infiltration Basin	$15,000	5-Acre Commercial Site (Impervious Cover = 65%)	Adapted from SWRPC (1991)
Sand Filter	$35,000-$70,000[2,3]	5-Acre Commercial Site (Impervious Cover = 65%)	Adapted from Brown and Schueler (1997b)
Bioretention	$60,000	5-Acre Commercial Site (Impervious Cover = 65%)	Adapted from Brown and Schueler (1997b)
Grass Swale	$3,500	5-Acre Residential Site (Impervious Cover = 35%)	Adapted from SWRPC (1991)
Filter Strip	$0-$9,000[3]	5-Acre Residential Site (Impervious Cover = 35%)	Adapted from SWRPC (1991)

1. Base costs do not include land costs.
2. Total capital costs can typically be determined by increasing these costs by approximately 30%.
3. A range is given to account for design variations.

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Although various manuals report construction cost estimates for storm water ponds, EPA has identified only three studies that have systematically evaluated the construction costs associated with structural BMPs since 1985. The three studies used slightly different estimation procedures. Two of these studies were conducted in the Washington, DC region and used a similar methodology (Wiegand et al, 1986; Brown and Schueler, 1997b). In both studies, the costs were determined based on engineering estimates of construction costs from actual BMPs throughout the region. In the third study, conducted in Southeastern Wisconsin, costs were determined using standardized cost data for different elements of the BMP, and assumptions of BMP design (SWRPC, 1991).

Any costs reported in the literature need to be adjusted for inflation and regional differences. All costs reported in this report assume a 3 percent annual inflation rate. In addition, studies are adjusted to the "twenty cities average" construction cost index, to adjust for regional biases, based on a methodology followed by the American Public Works Association (APWA, 1992). Using EPA's rainfall zones (see Figure 6-1), a cost adjustment factor is assigned to each zone (Table 6-3). For example, rainfall region 1 has a factor of 1.12. Thus, all studies in the Northeastern United States are divided by 1.12 in order to adjust for this bias.

Table 6-3. Regional Cost Adjustment Factors

Rainfall Zone	1	2	3	4	5	6	7	8	9
Adjustment Factor	1.12	0.90	0.67	0.92	0.67	1.24	1.04	1.04	0.76

Source: Modified from APWA, 1992

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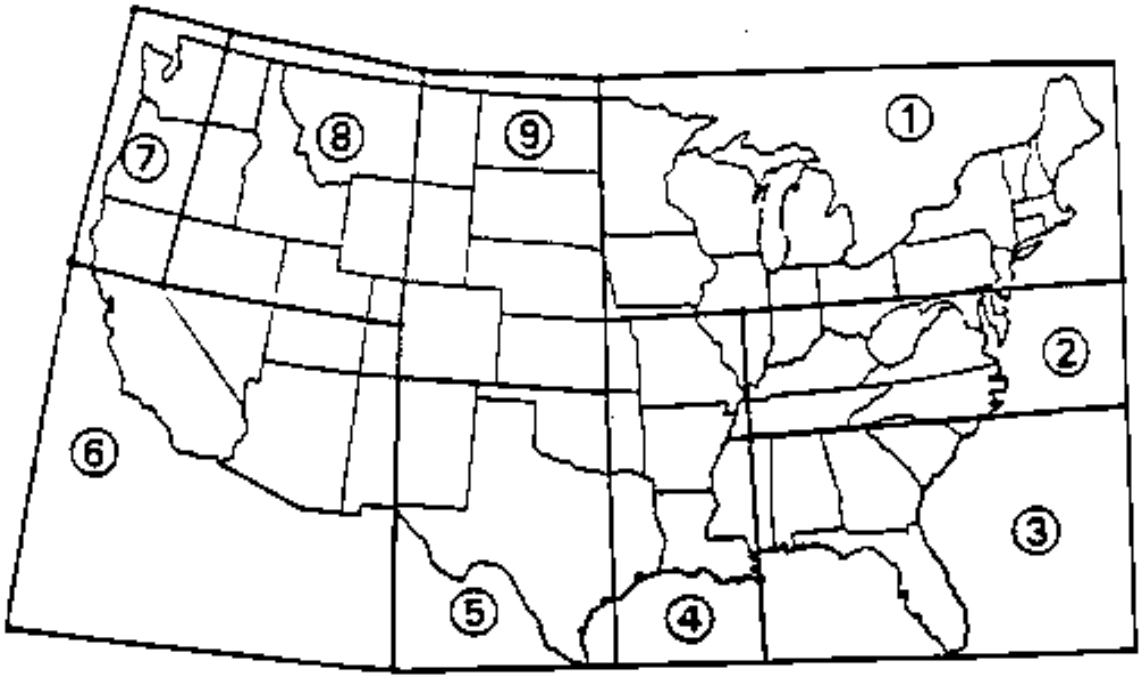
Figure 6-1. Rainfall Zones of the United States



Not shown: Alaska (Zone 7); Hawaii (Zone 7); Northern Mariana Islands (Zone 7); Guam (Zone 7); American Samoa (Zone 7); Trust Territory of the Pacific Islands (Zone 7); Puerto Rico (Zone 3) Virgin Islands (Zone 3).
Source: NPDES Phase I regulations, 40 CFR Part 122, Appendix E (US EPA, 1990)

6.1.1.1 Retention/Detention Basins and Constructed Wetlands

The total volume of the basin is generally a strong predictor of cost (Table 6-4). There are some economies of scale associated with constructing these systems, as evidenced by the slope of the volume equations derived. This is largely because of the costs of inlet and outlet design, and mobilization of heavy equipment that are relatively similar regardless of basin size.

Erosion and sediment control represents only about 5 percent of the construction cost of basins and wetlands (Brown and Schueler, 1997b). Thus, the construction cost estimates presented in Table 6-2 are comparable. The cost of building storm water retention and detention systems has increased since 1986 (Figure 6-2), even after adjusting for inflation. Part of the reason for this increase is thought to be attributable to the improved design of these systems to enhance water quality driven by a more complex regulatory and review environment (Brown and Schueler, 1997b). The cost estimations made by SWRPC (1991) were generally a mid-range between the earlier and more recent studies.

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Table 6-4. Base Capital Costs for Storm Water Ponds and Wetlands

BMP Type	Cost Equation or Estimate	Costs Included		Source
		Construc-tion	E&S Control	
Retention Basins and Wetlands	$7.75V^{0.75}$	✔	✔	Wiegand et al, 1986
	$18.5V^{0.70}$	✔		Brown and Schueler, 1997b
Detention Basins	$7.47V^{0.78}$	✔	✔	Brown and Schueler, 1997b
Retention Basins	1.06V: 0.25 acre retention basin (23,300 cubic feet)	✔		SWRPC, 1991
	0.43V: 1.0 acre retention basin (148,000 cubic feet)			
	0.33V: 3.0 acre retention basin (547,000 cubic feet)			
	0.31V: 5.0 acre retention basin (952,000 cubic feet)			

Notes
V refers to the total basin volume in cubic feet
Costs presented from SWRPC (1991) are "moderate" costs reported in that study.

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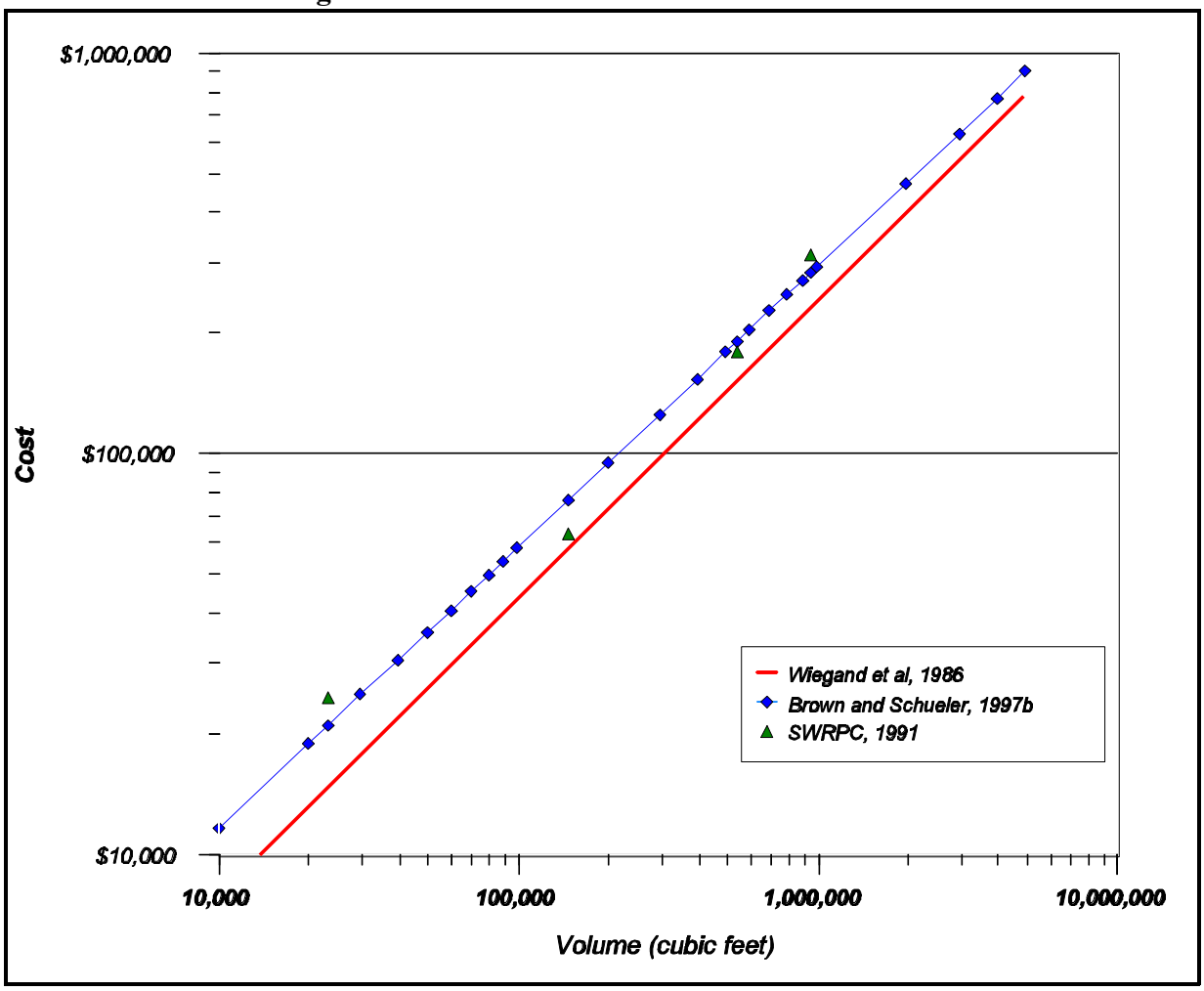
Figure 6-2. Retention Basin Construction Cost



6.1.1.2 Infiltration Practices

Costs for infiltration BMPs are highly variable from site to site, depending on soils and other geotechnical information. Perhaps because of this variability, cost estimates for infiltration trenches have been widely different (Table 6-5; Figure 6-3). Brown and Schueler (1997b) concluded that the Wiegand (1986) equation underestimated cost, partially because of the lack of pretreatment in earlier designs, although they were unable to develop a consistent equation due to a small sample size.

It is difficult to estimate the cost of infiltration basins, mainly due to a lack of recent cost data. The costs estimates for SWRPC are dramatically higher than those estimated by Schueler, 1987 (Figure 6-4). This is largely because the SWRPC document assumes that 50 percent

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additional volume is excavated for the spillway, while Schueler uses a retention basin cost equation.

Table 6-5. Base Capital Costs for Infiltration Practices

BMP Type	Cost Equation or Estimate[4]	Costs Included		Source
		Construc-tion	E&S Control	
Infiltration Trenches[1]	$33.7V^{0.63}$	✔		Wiegand et al, 1986
	2V to 4V; average of 2.5V	✔		Brown and Schueler, 1997b
	\$4,400: 3-foot deep, 4-foot wide, 100-foot long trench	✔		SWRPC, 1991
	\$10,400: 6-foot deep, 10-foot wide, 100-foot long trench			
	3.9V+2,900: 3-foot deep, 100-foot long trench	✔		Modified from SWRPC, 1991
Infiltration Basins[2]	$13.2V^{0.69}$	✔	✔	Schueler, 1987; Modified from Wiegand et al, 1986
	1.3V: 0.25-acre infiltration basin (15,000 cubic feet)	✔		SWRPC, 1991
	0.8V: 1.0-acre infiltration basin (76,300 cubic feet)			
Porous Pavement[3]	50,000A	✔		SWRPC, 1991
	80,000A	✔		Schueler, 1987

1. V for infiltration trenches refers to the treatment volume (cubic feet) within the trench, assuming a porosity of 32%.
2. V for infiltration basins refers to the total basin volume (cubic feet).
3. A is the surface area in acres of porous pavement.
4. Costs presented from SWRPC (1991) are "moderate" costs reported in that study.

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Figure 6-3. Infiltration Trench Cost

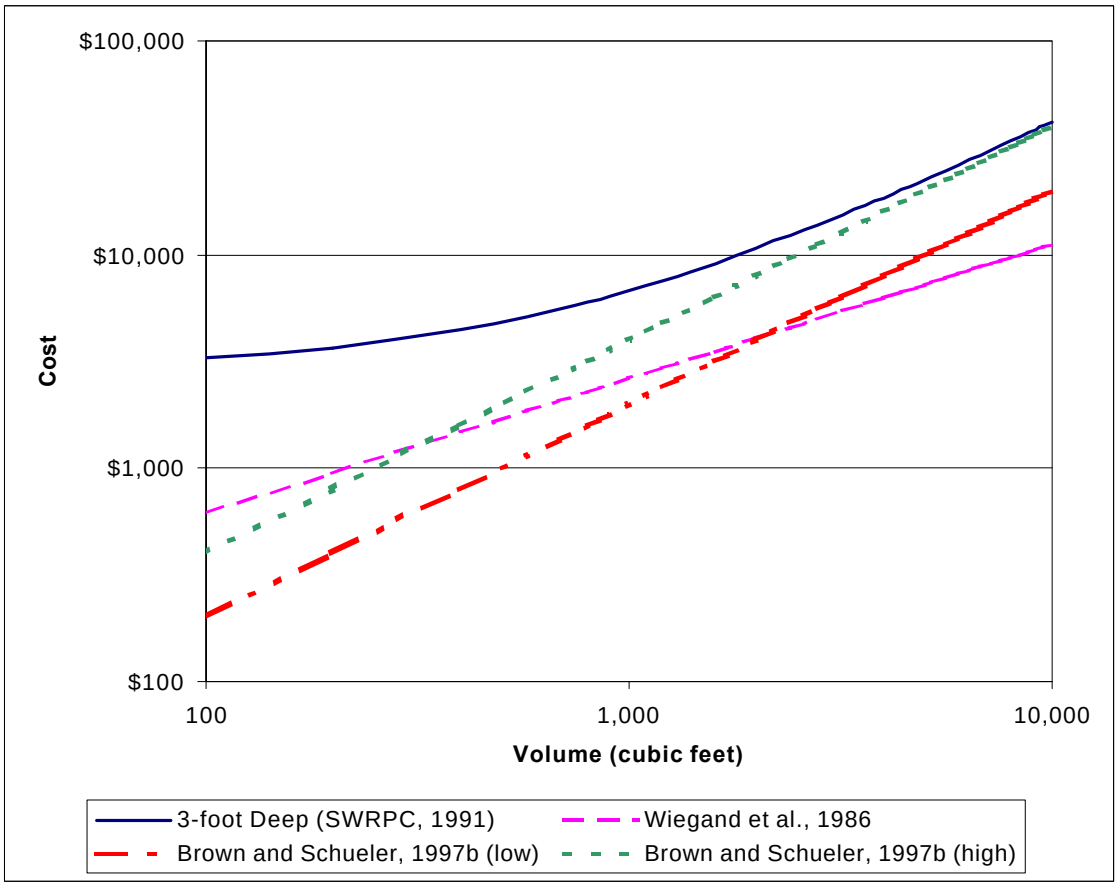

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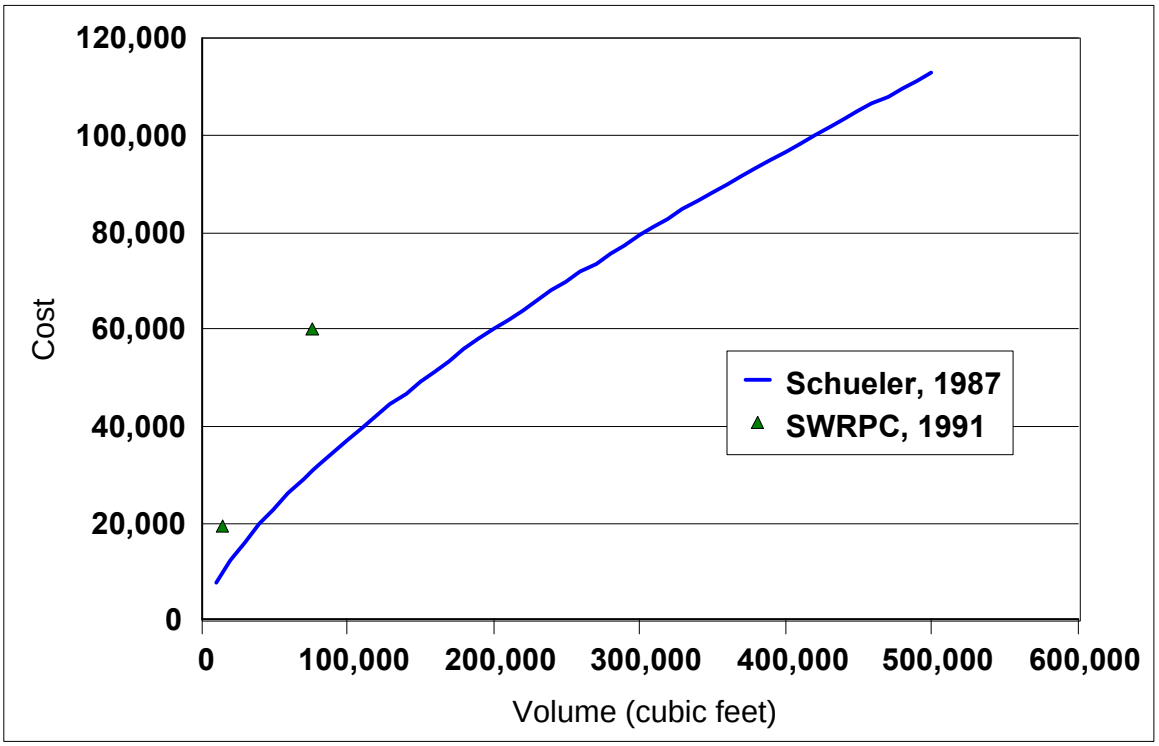
Figure 6-4. Infiltration Basin Construction Cost



6.1.1.3 Sand Filters

Since sand filters have not been used as long as other BMPs, less information is available on their cost than on most BMPs. In addition, the costs of sand filters vary significantly due to the wide range of design criteria for sand filters (Table 6-6). Brown and Schueler (1997b) were unable to derive a valid relationship between sand filter cost and water quality volume, with costs ranging between $2 and $6 per cubic foot of water quality volume, with a mean cost of $2.50 per cubic foot. The water quality volume includes the pore space in the sand filter, plus additional storage in the pretreatment basin.

Because of the lack of cost data, no equation referencing the economies of scale has been developed. However, it appears that economies of scale do exist. For example, data from Austin indicates that the cost per acre decreased by over 80 percent for a design of a 20-acre drainage area, when compared with a 1-acre drainage area. (Schueler, 1994a).

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Table 6-6. Construction Costs for Various Sand Filters

Region (Design)	Cost/Impervious Acre
Delaware	$10,000
Alexandria, VA (Delaware)	$23,500
Austin, TX (< 2 acres)	$16,000
Austin, TX (> 5 acres)	$3,400
Washington, DC (underground)	$14,000
Denver, CO	$30,000-$50,000

Source: Schueler, 1994a

6.1.1.4 Bioretention

Little information is available on the costs of bioretention because it is a relatively new practice. Brown and Schueler (1997b) found consistent construction costs of approximately $5.30 per cubic foot of water quality volume for the construction cost. The water quality volume includes 9 inches above the surface area of the bioretention structure.

6.1.1.5 Vegetative BMPs

The two major types of vegetative BMPs include filter strips and grassed swales (also called “biofilters”). The costs for these BMPs vary, and largely depend on the method used to establish vegetation (Table 6-7).

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Table 6-7. Base Capital Costs of Vegetative BMPs

BMP Type	Cost Equation or Estimate[1]	Costs Included		Source
		Construc-tion	E&S Control	
Filter Strips	Existing Vegetation: 0	✔		SWRPC, 1991
	Seed: $13,800/acre			
	Sod: $29,000/acre			
Grassed Channels	25¢ per square foot	✔		SWRPC, 1991

1. Costs presented from SWRPC (1991) are "moderate" costs reported in that study.

6.1.2 Design, Contingency and Permitting Costs

Most BMP cost studies assess only part of the cost of constructing a BMP, usually excluding permitting fees, engineering design and contingency or unexpected costs. In general, these costs are expressed as a fraction of the construction cost (Table 6-8). These costs are generally only estimates, based on the experience of designers.

Table 6-8. Design, Contingency and Permitting Costs

Additional Costs Estimate (Fraction of base construction costs)	Source	Comments
25%	Wiegand et al, 1986	Includes design, contingencies and permitting fees
32%	Brown and Schueler, 1997b	Includes design, contingencies, permitting process and erosion and sediment control

6.1.3 Land Costs

The cost of land is extremely variable both regionally and by surrounding land use. For example, many suburban jurisdictions require open space allocations within the developed site, reducing the effective cost of land for BMPs to zero (Schueler, 1987). On the other hand, the cost of land may far outweigh construction and design costs in ultra-urban settings. For this

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reason, some underground BMPs that are relatively expensive to construct may be attractive in this "ultra-urban" setting if sub-surface conditions are suitable (Lundgren, 1996). The land consumed per treatment volume depends largely on how much of the BMP's treatment is underground, and varies considerably (Table 6-9).

Table 6-9. Relative Land Consumption of Storm Water BMPs

BMP Type	Land consumption (% of Impervious Area)
Retention Basin	2-3%
Constructed Wetland	3-5%
Infiltration Trench	2-3%
Infiltration Basin	2-3%
Porous Pavement	0%
Sand Filters	0%-3%
Bioretention	5%
Swales	10%-20%
Filter Strips	100%

Note: Represents the amount of land needed as a percent of the impervious area that drains to the practice to achieve effective treatment.
Source: Claytor and Schueler, 1996

6.1.4 Operation and Maintenance Costs

Maintenance can be broken down into two primary categories: aesthetic/nuisance maintenance and functional maintenance. Functional maintenance is important for performance and safety reasons, while aesthetic maintenance is important primarily for public acceptance of BMPs, and because it may also reduce needed functional maintenance. Aesthetic maintenance is obviously more important for BMPs that are very visible, such as ponds and biofiltration facilities.

In most studies, operation and maintenance (O&M) costs have been estimated as a percentage of base construction costs (Table 6-10). While some BMPs require infrequent, costly

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maintenance, others need more frequent but less costly maintenance.[5] Accordingly, selection of appropriate structural BMPs must factor in maintenance cost (and a responsible party to carry out maintenance) to ensure the necessary long-term performance. Typical maintenance activities are included in Table 5-3.

Table 6-10. Annual Maintenance Costs

BMP	Annual Maintenance Cost (% of Construction Cost)	Source(s)
Retention Basins and Constructed Wetlands	3%-6%	Wiegand et al, 1986 Schueler, 1987 SWRPC, 1991
Detention Basins[1]	<1%	Livingston et al, 1997; Brown and Schueler, 1997b
Constructed Wetlands[1]	2%	Livingston et al, 1997; Brown and Schueler, 1997b
Infiltration Trench	5%-20%	Schueler, 1987 SWRPC, 1991
Infiltration Basin[1]	1%-3%	Livingston et al, 1997; SWRPC, 1991
	5%-10%	Wiegand et al, 1986; Schueler, 1987; SWRPC, 1991
Sand Filters[1]	11%-13%	Livingston et al, 1997; Brown and Schueler, 1997b
Swales	5%-7%	SWRPC, 1991
Bioretention	5%-7%	(Assumes the same as swales)
Filter strips	$320/acre (maintained)	SWRPC, 1991

1. Livingston et al (1997) reported maintenance costs from the maintenance budgets of several cities, and percentages were derived from costs in other studies

[5] Maintenance costs can also vary significantly based on a variety of site- and region-specific parameters, therefore the maintenance costs presented in Table 6-10 should be considered only as general guidelines.

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6.1.5 Long-Term BMP Costs: Two Scenarios

In order to compare various BMP options, costs were calculated for a 5-acre commercial site and a 38-acre residential site.[6] Construction costs were evaluated using the following steps:

1. *Calculate the water quality volume* (WQ_v).[7]
Using a water quality volume based on a 1-inch storm, the volume is equal to:

$$WQ_v = (.05 + .9I) A/12$$

where: WQ_v = Water Quality Volume (Acre-Feet)
I = Impervious Fraction in the Watershed
A = Watershed Area (Acres)

2. *Calculate the detention storage volume.*
Total detention storage was determined using standard peak flow methods (USDA/NRCS, 1986). Detention storage was calculated for a 5-inch storm.

3. *Calculate total volume.*
Many BMPs do not require any detention storage, but for BMPs that do provide flood storage, the total volume is the sum of the water quality and detention volumes calculated in steps 1 and 2.

4. *Determine the construction cost.*
The construction cost for each BMP is determined based on equations described in Section 6.1.1.

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[6] Although these evaluations are useful for comparing potential costs of various structural BMPs, they should not be applied for use in all areas of the country. In addition, the BMPs, selected in these examples and the sizing criteria that the costs were based on should not be considered as recommendations for actual BMP selection and design. They are presented solely for illustrative purposes.

[7] "Water quality volume" refers to the volume of water that the BMP is designed to treat. For example, a BMP may be designed to capture the first inch of runoff from the drainage area. Any volume of rainfall over the first inch would bypass the BMP. Therefore water quality volume for this BMP would be one watershed inch.

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6.1.5.1 5-Acre Commercial Development

The following data were used as the basis for the 5-acre commercial development.

Table 6-11. Data for the Commercial Site Scenario

Area (A)	5 acres
Impervious Cover (I)	65%
Water Quality Volume $P \cdot Rv \cdot A/12$ P = 1" of rainfall Rv = 0.5 + 0.9 (I) A = Drainage Area	0.26 ac-ft
Total Detention Storage (using TR-55 model)	0.74 ac-ft
Total Storage	1.00 ac-ft

These data were then used to compare various BMP options (Table 6-12). Grassed swales and filter strips were not included in this analysis because, although they do improve water quality, they are typically used only in combination with other BMPs in a new development area. Again, it is important to note that the cost of land is not included in this calculation. Although retention basins are the least expensive option on an annual basis, the cost of land may drive designs to less space-consumptive BMPs, such as sand filters or bioretention systems.

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Table 6-12. BMP Costs for a Five Acre Commercial Development

BMP Type	Construction Cost Equation	Construction Cost	Typical Design, Contingency & Other Capital Costs (30% of Construction Costs)	Annual Maintenance Costs (% of Construction, $)	Notes	Sources
Retention Basin	$18.5V_t^{0.70}$	$32,700	$9,810	5%; $1,640	Much of the cost associated with this BMP is the extra storage to provide flood control and channel protection. Ponds are very reliable.	a, b, c, d, e
Infiltration Trench	$3.9WQ_v$ +2,900	$47,100	$14,100	12%; $5,650	Although infiltration trenches are designed to last a long time, they need to be inspected and rebuilt if they become clogged.	c, d, e
Infiltration Basin	$1.3WQ_v$	$14,700	$4,410	8%; $1,180	Infiltration basins require careful siting and design to perform effectively..	b, c, d, e
Sand Filter	$4WQ_v$	$45,200	$13,600	12%; $5,420	Sand filters require frequent maintenance in order to function long-term.	a, e, f
Bioretention	$5.30WQ_v$	$60,000	$18,000	6%; $3,600	Bioretention is a relatively new BMP. Little is known about its long-term performance.	a, d

1. WQv = Water Quality Volume, cu. ft. 2. V_t = Total Volume, cu. ft.
3. Sand filter volume was estimated at 4WQv, which is slightly high, to account for the relatively small drainage area.

a. Brown and Schueler, 1997b b. Wiegand et al, 1986 c. Schueler, 1987 d. SWRPC, 1991 e. US EPA, 1993a f. Livingston et al, 1997

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6.1.5.2 38-Acre Residential Development

The following data were used as the basis for the 38-acre residential development.

Table 6-13. Data for the Residential Site Scenario

Area (A)	38 acres
Impervious Cover (I)	36%
Water Quality Volume	1.1 ac-ft
Total Detention Storage (using TR-55 model)	2.8 ac-ft
Total Storage	3.9 ac-ft

The same analysis conducted for the commercial site was repeated for the larger site (Table 6-14). Bioretention and infiltration systems were not included in this analysis, because these BMPs are best applied on smaller sites. The costs of swales and filter strips were also not included, although they could be effectively used in combination with retention systems to provide pretreatment.

6.1.6 Adjusting Costs Regionally

The cost data in these examples can be adjusted to specific zones of the country using the regional cost adjustment factors in Table 6-3. For example, if costs for Rainfall Zone 1 were needed, the data in Tables 6-12 or 6-14 would be multiplied by 1.12.

In addition, design variations in different regions of the country may cause prices to be changed. For example, wetland and wet ponds may be restricted in arid regions of the country. Furthermore, while retention basins are used in semi-arid regions, they usually incorporate design variations to improve their performance (Saunders and Gilroy, 1997). In cold regions, BMPs may need to be adapted to account for snowmelt treatment, deep freezes and road salt application (Oberts, 1994; Caraco and Claytor, 1997), which will cause additional changes in BMP costs.

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Table 6-14. BMP Costs for a Thirty-Eight Acre Residential Development

BMP Type	Construction Cost Equation	Construction Cost	Design, Contingency and other Capital Costs (30% of Construction)	Annual Maintenance Costs (% of Construction; $)	Notes	Sources
Retention Basin	$18.5V_t^{0.70}$	$84,800	$25,400	5%; $4,240	Pond systems are relatively easy to apply to large sites.	a, b, c, d, e
Sand Filter	$2WQ_v$	$95,800	$28,700	12%; $11,500	Although the sand filter is used in this example, some evidence suggests that sand filters may be subject to clogging if used on a site that drains a relatively pervious drainage area such as this one.	a, e, f

1. WQv = Water Quality Volume, cu. ft. 2. Vt = Total Volume, cu. ft.
3. Sand filter volume was estimated at 2V, which is slightly low, to account for the relatively large drainage area

a. Brown and Schueler, 1997b b. Wiegand et al, 1986 c. Schueler, 1987 d. SWRPC, 1991 e. US EPA, 1993a f. Livingston et al, 1997

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6.2 Non-Structural BMP Costs

Non-structural BMPs are management measures that prevent degradation of water resources by preventing pollution at the source, rather than treating polluted runoff. Non-structural practices include a variety of site-specific and regional practices, including: street sweeping, illicit connection identification and elimination, public education and outreach, land use modifications to minimize the amount of impervious surface area, waste collection and proper materials storage. While non-structural practices play an invaluable role in protecting surface waters, their costs are generally not as easily quantified as for structural BMPs. This is primarily because there are no "design standards" for these practices. For example, the cost of a public education program may vary due to staff size. However, it is possible to identify costs associated with specific components of these programs based on past experience.

6.2.1 Street Sweeping

The costs of street sweeping include the capital costs of purchasing the equipment, plus the maintenance and operational costs to operate the sweepers, as well as costs of disposing the materials that are removed. Both equipment and operating costs vary depending on the type of sweeper selected. There are several different options for sweepers, but the two basic choices are mechanical sweepers versus vacuum-assisted sweepers. Mechanical sweepers use brushes to remove particles from streets. Vacuum-assisted dry sweepers, on the other hand, use a specialized brush and vacuum system in order to remove finer particles. While the equipment costs of mechanical sweepers are significantly higher, the total operation and maintenance costs of vacuum sweepers can be lower (Table 6-15).

Table 6-15. Street Sweeper Cost Data

Sweeper Type	Life (Years)	Purchase Price ($)	Operation and Maintenance Costs ($/curb mile)	Sources
Mechanical	5	75,000	30	Finley, 1996; SWRPC, 1991
Vacuum-assisted	8	150,000	15	Satterfield, 1996; SWRPC, 1991

Using these data, the cost of operating street sweepers per curb mile were developed, assuming various sweeping frequencies (Table 6-16). The following assumptions were made to conduct this analysis:

- One sweeper serves 8,160 curb miles during a year (SWRPC, 1991).

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- The annual interest rate is 8 percent.

Table 6-16. Annualized Sweeper Costs ($/curb mile/year)

Sweeper Type	Sweeping Frequency					
	Weekly	Bi-weekly	Monthly	Four times per year	Twice per year	Annual
Mechanical	1,680	840	388	129	65	32
Vacuum-Assisted	946	473	218	73	36	18

Modified from Finley, 1996; SWRPC, 1991; and Satterfield, 1996

6.2.2 Illicit Connection Identification and Elimination

One source of pollutants is direct connections or infiltration to the storm drain system of wastewaters other than storm water, such as industrial wastes. These pollutants are then discharged through the storm drain system directly to streams without receiving treatment. These illicit connections can be identified using visual inspection during dry weather or through the use of smoke or dye tests. Using visual inspection techniques, illicit connections can be identified for between $1,250 and $1,750 per square mile (Center for Watershed Protection, 1996).

6.2.3 Public Education and Outreach

Public education programs encompass many other more specific programs, such as fertilizer and pesticide management, public involvement in stream restoration and monitoring projects, storm drain stenciling, and overall awareness of aquatic resources. All public education programs seek to reduce pollutant loads by changing people's behavior. They also make the public aware of and gain support for programs in place to protect water resources. Most municipalities have at least some educational component as a part of their program. A recent survey found that 30 of the 32 municipal storm water programs surveyed (94 percent) incorporate an education element and 11 programs (34 percent) mandated this element in law or regulation (Livingston et al, 1997).

The City of Seattle, with a population of approximately 535,000, has a relatively aggressive education program, including classroom and field involvement programs. The 1997 budget for some aspects of the program is included in Table 6-17. Although this does not necessarily reflect typical effort or expenditures, it does provide information on some educational expenditures. These data represent only a portion of the entire annual budget.

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Table 6-17. Public Education Costs in Seattle, Washington

Item	Description	1997 Budget
Supplies for Volunteers	Covers supplies for the Stewardship Through Environmental Partnership Program	$17,500
Communications	Communications strategy highlighting a newly formed program within the city	$18,000
Environmental Education	Transportation costs from schools to field visits (105 schools with four trips each)	$46,500
Education Services / Field Trips	Fees for student visits to various sites	$55,000
Teacher Training	Covers the cost of training classroom teachers for the environmental education program	$3,400
Equipment	Equipment for classroom education, including displays, handouts, etc.	$38,800
Water Interpretive Specialist: Staff	Staff to provide public information at two creeks	$79,300
Water Interpretive Specialist: Equipment	Materials and equipment to support interpretive specialist program	$12,100
Youth Conservation Corps	Supports clean-up activities in creeks	$210,900

Source: Washington DOE, 1997

Some unit costs for educational program components (based on two different programs) are included in Table 6-18.

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Table 6-18. Unit Program Costs for Public Education Programs

Item	Cost	Source
Public Attitude Survey	$1,250-$1,750 per 1,000 households	Center for Watershed Protection, 1996
Flyers	10-25¢/ flyer	Ferguson et al, 1997
Soil Test Kit*	$10	Ferguson et al, 1997
Paint	25-30¢/SD Stencil	Ferguson et al, 1997
Safety Vests for Volunteers	$2	Ferguson et al, 1997

* Includes cost of testing, but not sampling.

Although public education has the intended benefit of raising public awareness, and therefore creating support of environmental programs, it is difficult to quantify actual pollutant reductions associated with education efforts. Public attitudes can be used as a gauge of how these programs perform, however. In Prince George's County, Maryland a public survey was used in combination with modeling to estimate pollutant load reductions associated with public education (Smith et al, 1994; Claytor, 1996; Figure 6-5). An initial study was conducted to estimate pollution from field application of fertilizers, and use of detergents, oil and antifreeze. Pollutant reductions were then completed assuming that 70 percent of the population complied with recommendations of the public education program. A follow-up survey was used to assess the effectiveness of the program. Although insufficient data were available to support a second model run, a follow-up survey indicated that educational programs influenced many citizen behaviors, such as recycling. They were unsuccessful, however, at changing the rate at which citizens apply lawn fertilizers.

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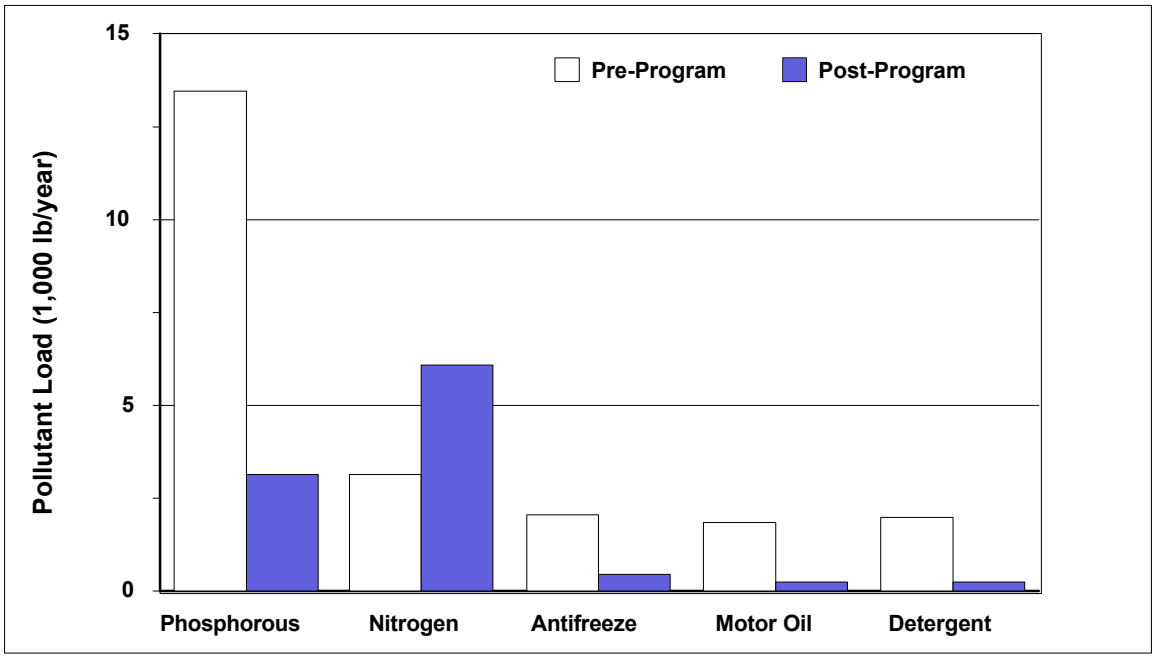
Figure 6-5. Changes in Pollutant Load Associated with a Public Education Program Based on a Public Survey



Source: Claytor, 1996

6.2.4 Land Use Modifications

One of the most effective tools to reduce the impacts of urbanization on water resources is to modify the way growth and development occurs across the landscape. At the jurisdictional or regional level, growth can be managed to minimize the outward extension of development. Jurisdictions can direct growth away from environmentally sensitive areas using such techniques as open space preservation, re-zoning or the transfer of development rights. At the site level, the nature of development can be modified to reduce the impacts of impervious cover at individual development projects through techniques such as reduced street widths, clustered housing, smaller parking lots, and incorporation of vegetative BMPs into site design. While there are legal fees associated with changing both local and regional zoning codes, data suggest that concentrating development and minimizing impervious cover at the site level can actually reduce construction costs to both developers and local governments.

By concentrating development near urban areas, the capital costs of development can be lowered substantially due to existing infrastructure and other public services. With conventional development patterns, the cost of servicing residential developments exceeds the tax revenues from these developments by approximately 15 percent (Pelley, 1997). By encouraging growth to occur in a compact region, rather than over a large area, these capital costs can be reduced substantially (Table 6-19).

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Table 6-19. Comparison of Capital Costs of Municipal Infrastructure for a Single Dwelling Unit

Development Pattern	Capital Costs[1] (1987 Dollars)
Compact Growth[2]	$18,000
Low-Density Growth (3 units/acre)	$35,000
Low-Density Growth, 10 Miles from Existing Development[3]	$48,000

Notes
1. Costs include streets (full curb and gutter), central sewers and water supply, storm drainage and school construction.
2. Assumes housing mix of 30% single family units and townhouses; 70% apartments.
3. Assumes housing is located 10 miles from major concentration of employment, drinking water plant and sewage treatment plant.

Source: Frank, 1989

Savings can also be realized at the site level by reducing the costs of clearing and grading, paving and drainage infrastructure. A recent study compared conventional development plans with alternative options designed to reduce the impacts of development on the quality of water resources. The cost savings realized through these alternative options are summarized in Table 6-20. In all site designs, the road width was reduced from 28 feet to 20 feet, lot sizes were reduced or reconfigured to consume less open space, and on-site storm water treatment was provided.

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Table 6-20. Impervious Cover Reduction and Cost Savings of Conservation Development

Location	Techniques Used	Impervious Cover Reduction	Cost Savings
Sussex County, DE	1. Reduced street widths 2. Smaller lots 3. Cluster development	38%	52%
New Castle County, DE	4.Houses clustered into attached units around courtyards	6%	63%
Kent County, DE	5. Reduced road and driveway widths 6. Minimum disturbance boundary	24%	39%

Source: Delaware DNREC, 1997

6.2.5 Oil and Hazardous Waste Collection

Providing a central location for the disposal of oil or hazardous wastes protects water quality by offering citizens an alternative to disposing of these materials in the storm drain. Disposal costs vary considerably depending on the size of the program, and what types of wastes are collected. One study estimated the capital costs at approximately $30,000, with about $12,000 maintenance for a used oil collection recycling program in a typical MS4 (US EPA, 1998b). This estimate was based on data from the Galveston Bay National Estuary Program. Data from the City of Livonia, Michigan indicates that the cost of hazardous waste disposal averages about $12 per gallon (Ferguson et al, 1997).

6.2.6 Proper Storage of Materials

Proper storage of materials can prevent accidental spills or runoff into the storm drain. The design of storage structures varies depending on the needs of the facility. There are also training costs associated with the proper storage of materials. Typical cost estimates, based on standard construction data, are $6 to $11 per square foot for pre-engineered buildings and $3.40 to $5 per square foot for a 6-inch thick concrete slab (Ferguson et al, 1997).

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6.3 Benefits of Storm Water BMPs

Although it is possible to estimate the economic benefits of water quality improvement (US EPA, 1983a), it is difficult to create a "balance sheet" of economic costs and benefits for individual BMPs. Ideally, benefits analysis would specify and quantify a chain of events: pollutant loading reductions achieved by the BMP; the physical-chemical properties of receiving streams and consequent linkages to biologic/ecologic responses in the aquatic environment; and human responses and values associated with these changes. However, the necessary data to conduct such an analysis does not currently exist. Instead, the benefits can be outlined in terms of: 1) effectiveness at reducing pollutant loads; 2) direct water quality impacts; and 3) economic benefits or costs.

6.3.1 Storm Water Pollutant Reduction

A primary function of storm water BMPs is to prevent pollutants from reaching streams and rivers. While all BMPs achieve this function to some extent, there is considerable variability between different types of BMPs. The extent of benefits from non-structural BMPs may be more speculative, partly because their ability to influence human behavior is difficult to predict.

A detailed discussion of pollution removal efficiencies for individual structural BMPs is provided in Section 5.5 of this report, so only non-structural BMPs will be reviewed in this section. Unlike structural BMPs, it is generally not possible to associate specific pollutant removal rates with non-structural BMPs, with the exception of street sweeping (Satterfield, 1996). However, some non-structural BMPs are targeted at specific pollutants. Table 6-21 outlines non-structural BMPs believed by designers to be the most effective for removing specific types of pollutants.

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Table 6-21. Non-Structural BMPs Suited to Controlling Various Pollutants

Pollutant	Appropriate BMPs	
Solids	Street Sweeping	Land Use Modifications
Oxygen-Demanding Substances	Street Sweeping Education: Storm Drain Stenciling Land Use Modifications	Education: Pet Scoop Ordinance Illicit Connections Eliminated
Nitrogen and Phosphorus	Street Sweeping Education: Pet Scoop Ordinance Land Use Modifications Proper Materials Handling	Illicit Connections Eliminated Education: Lawn Care Materials Storage and Recycling
Pathogens	Illicit Connections Eliminated Land Use Modifications	Education: Pet Scoop Ordinance
Petroleum Hydrocarbons	Street Sweeping Education: Storm Drain Stenciling Proper Materials Handling	Illicit Connections Eliminated Materials Storage and Recycling Land Use Modifications
Metals	Street Sweeping Education: Storm Drain Stenciling Proper Materials Handling	Illicit Connections Eliminated Materials Storage and Recycling Land Use Modifications
Synthetic Organics	Illicit Connections Eliminated Education: Storm Drain Stenciling Proper Materials Handling	Education: Lawn Care Materials Storage and Recycling Land Use Modifications
Temperature	Land Use Modifications	
pH	Illicit Connections Eliminated Proper Materials Handling	Materials Storage and Recycling Land Use Modifications

6.3.1.1 Solids

Both highway runoff and soil erosion can be sources of solids in urban runoff. Street sweeping can reduce solids in urban runoff by removing solids from roadways and parking lots before they can be detached and transported by runoff. The benefits associated with street sweeping depend largely on the climate. In arid regions, airborne pollutants are a serious concern, and there is a long time between storms for pollutants to accumulate[8]. In humid regions, on the other hand, frequent rainfall makes the use of sweepers between storms less practical. In colder

[8] Therefore, regular sweeping programs in these areas can potentially remove large amounts of solids from roadways.

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regions, sweeping is recommended twice per year: once in the fall after leaves fall and once in the spring in anticipation of the spring snowmelt (MPCA, 1989).

Modifying land use to preserve open space and to limit the impervious cover can also reduce solids loads. By preserving open space and maintaining vegetative cover, the amount of land cleared is limited, thus reducing the erosion potential during construction. Natural vegetated cover has less than one percent of the erosion potential of bare soil (Wischmeier and Smith, 1978).

6.3.1.2 Oxygen-Demanding Substances

Since the primary oxygen-demanding substances are organic materials (such as leaves and yard waste), BMPs that target these substances are best suited to reducing the oxygen demand in storm water. BMPs that reduce sediment loads often also reduce the loads of the organic material associated with that sediment. Pet waste is also a significant source of organic pollutants, and its control can reduce the loads of oxygen demanding substances in urban runoff. Finally, programs geared at reducing illegal dumping and eliminating illicit connections and accidental spills of materials can reduce the oxygen demand associated with these sources.

6.3.1.3 Nitrogen and Phosphorus

Nitrogen and phosphorus are prevalent in urban and suburban storm water. Nitrogen and phosphorus are natural components of soil, and can enter runoff from storm-induced erosion. Additional sources include the use of fertilizer on urban lawns and airborne deposition. Street sweeping can reduce nutrient loads by removing deposited nutrients from the street surface. Programs that focus on lawn chemical handling or replacing turf with natural vegetation also act to reduce nutrient loading. Finally, programs that educate the public or industry about illegal dumping to storm drains can result in reducing the nutrient loads associated with dumping chemicals that have high nutrient content. Energy conservation and reduced automobile use can reduce airborne nitrogen deposition.

6.3.1.4 Pathogens

Pathogens, including protozoa, viruses and bacteria, are prevalent in urban runoff. Bacteria can be found naturally in soil, and the urban landscape can produce large loads of bacteria that can be carried by runoff. Dogs in particular can be a significant source of pathogens. Thus, pet scoop ordinances and associated education are effective tools at reducing bacteria in urban runoff. Illicit connections of sewage may also be a source of pathogens, therefore eliminating these sources can effectively reduce pathogens in runoff.

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6.3.1.5 Petroleum Hydrocarbons

Petroleum hydrocarbons are present in many chemicals used in the urban environment, from gasoline to cleaning solvents. Since roadways are a major source of petroleum pollution, scheduled street sweeping can be used to remove hydrocarbon build-up prior to storm water runoff. Programs geared at preventing spills of chemicals to the storm drain, either through deliberate or accidental dumping, are effective at reducing hydrocarbon loads. Modifying the way land is developed can reduce hydrocarbon loads on both a site and a regional level by reducing the use of the automobile and replacing impervious surfaces with natural vegetation.

6.3.1.6 Metals

Metals sources in urban runoff include automobiles and household chemicals, which can contain trace metals. Street sweeping can reduce metals loads deposited on the road surface. In addition, programs that focus on reducing dumping and proper material storage can reduce accidental or purposeful spills of chemicals with trace metals to the storm drain system. Finally, modifying land use can reduce metals loads by reducing impervious cover, thus reducing total runoff containing metals, and reducing the roadway length, which is often a source of runoff containing metals.

6.3.1.7 Synthetic Organics

Much of the source of synthetic organics in the urban landscape is household cleaners and pesticides. Thus, education programs geared at reducing chemical and pesticide use, and proper storage and handling of these chemicals, can reduce their concentrations in urban runoff. In addition, land use modifications that replace turf with natural vegetation will reduce pesticide use.

6.3.1.8 Temperature

Most non-structural BMPs are not able to prevent the increase in temperature associated with urban development. One exception is the use of site designs that more closely mimic the natural hydrograph by reducing impervious cover and encouraging infiltration.

6.3.1.9 pH

The primary source of low pH in urban runoff is acid rain, and most non-structural BMPs are not used to treat this problem. BMPs that focus on proper materials handling and disposal can prevent dumping of chemicals with extremely high or low pH, but this is generally not a major problem in urban watersheds.

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6.3.2 Hydrological and Habitat Benefits

As reviewed in Chapter 4, one major impact of urbanization is induced through the conversion of farmland, forests, wetlands, and meadows to rooftops, roads, and lawns. This process of urbanization has a profound influence on surface water hydrology, morphology, water quality, and ecology (Horner et al, 1994). In this section, the hydrologic and related habitat impacts are briefly discussed as well as the potential benefits that can be achieved by managing storm water runoff using structural and non-structural BMPs.

Many of these impacts can be directly or indirectly related to the change in the hydrologic cycle from a natural system to the urban system. Figure 4-1 illustrates the fundamental effects that occur along with the development process. In the natural setting, very little annual rainfall is converted to runoff and about half is infiltrated into the underlying soils and water table. This water is filtered by the soils, supplies deep water aquifers, and helps support adjacent surface waters with clean water during dry periods. In the urbanizing conditions, less and less annual rainfall is infiltrated and more and more volume is converted to runoff. Not only is this runoff volume greater, it also occurs more frequently and at higher magnitudes. The result is that less water is available to streams and waterways during dry periods and more flow is occurring during storms. A recent study in the Pacific Northwest found that the ratio of the two-year storm to the baseflow discharge increased more than 20 percent in developed sub-watersheds (impervious cover approximately 50 percent) versus undeveloped sub-watersheds (May et al, 1997).

As a result of urbanization, runoff from storm events increases and accelerates flows, increases stream channel erosion, and causes accelerated channel widening and down cutting (Booth, 1990). This accelerated erosion is a significant source of sediment delivery to receiving waters and also can have a smothering effect on stream channel substrates, thereby eliminating aquatic species habitat. As a result, aquatic habitat is often degraded or eliminated in many urban streams. The results are that aquatic biological communities are among the first to be impacted and/or simplified by land conversion and resulting stream channel modifications. Subsurface drainage systems which frequently serve urbanized areas also contribute to the problem, by bypassing any attenuation achieved through surface flows over vegetated areas.

A unifying theme in stream degradation is this direct link with impervious cover. Impervious cover, or imperviousness, is defined as the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces in the urban landscape. This unifying theme can be used to guide the efforts of the many participants in watershed protection. Figure 6-6 visually illustrates this trend in degradation for a series of small headwater streams in the Mid-Atlantic Piedmont. Here, four stream segments, each with approximately the same drainage area, and subjected to the same physiographic conditions, respond to the effects of increased impervious cover. Similar results have been observed in the Southern United States with studies in Virginia, North Carolina and Georgia evidencing this same decline in fish and macroinvertebrate populations with increasing impervious cover (Crawford and Lenant, 1989; Weaver and Garman, 1994; Couch et al, 1996)

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Figure 6-6. Effects of Impervious Cover on Stream Quality

Sensitive Stream ➜
(Impervious Cover ≤10%)
- *Stable Channel*
- *Excellent Biodiversity*
- *Excellent Water Quality*





➜ Impacted Stream
(Impervious Cover 10-20%)
- *Channel Becoming Unstable*
- *Fair to Good Biodiversity*
- *Fair to Good Water Quality*

Restorable Stream ➜
(Impervious Cover ≈40%)
- *Highly Unstable Channel*
- *Poor Biodiversity*
- *Poor to Fair Water Quality*



Non-Supporting Stream ➜
(Impervious Cover ≈65%)
- *Poor to No Biodiversity*
- *Poor Water Quality*



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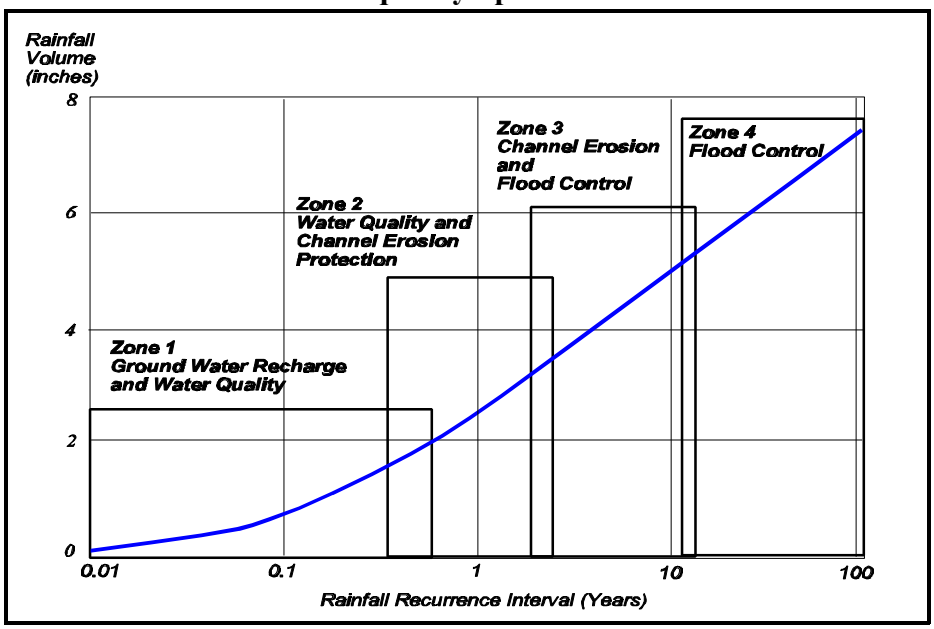
To mitigate this impact, many local and state governments have required the installation of storm water management detention basins to attenuate this increased runoff volume. It is important to recognize that the change in hydrology caused by urbanization affects more than just a single storm return interval (e.g., the two-year event). Urbanization shifts the entire "rainfall frequency spectrum" (RFS) to a higher magnitude. As illustrated in Figure 6-7, the most significant change is to the smallest, most frequent storms that occur several times per year. In the undeveloped condition, most of the rainfall from these events is infiltrated into the underlying soil. In the developed condition, much of this rainfall is runoff. As the storm return interval increases, the difference between the undeveloped and developed condition narrows. Many jurisdictions only require management of specific storms, usually the two, ten and sometimes, the one hundred year events. The two-year storm is probably the most frequently used control point along this frequency spectrum. Hence, while BMPs may do a fairly good job of managing these specific control points, there have been very few locations across the country that have specific criteria in place to manage storm water over a wide range of runoff events. Claytor and Schueler (1996) describe the RFS as:

> ...classes of frequencies often broken down by return interval, such as the two year storm return interval. Four principal classes are typically targeted for control by stormwater management practices. The two smallest, most frequent classes [Zones 1 and 2] are often referred to as water quality storms, where the control objectives are groundwater recharge, pollutant load reduction, and to some extent control of channel erosion producing events. The two larger classes [Zones 3 and 4] are typically referred to as quantity storms, where the control objectives are channel erosion control, overbank control, and flood control.

Figure 6-7. Stormwater Control Points Along the Rainfall Frequency Spectrum



Source: Claytor and Schueler, 1996

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One recent study by MacRae (1997) concluded that stream channels below storm water detention basins designed to manage the two year storm experienced accelerated erosion at three times the pre-developed rate. His findings went on to suggest that the streams were eroding at much the same rate as if no storm water controls existed.

Other jurisdictions have employed an additional level of detention storage above and beyond that required for the two year storm. This concept is often called “extended detention” (ED). McCuen and Moglen (1988) conducted a theoretical analysis of this design criteria based on sediment transport capacity of the pre-developed channel versus that with ED control. This study found ED could produce an 85 percent reduction in the pre-developed peak flow of the two-year storm. What it did not analyze, however, was the erosion potential over a wide range of storms. MacRae (1993) suggested a different storm water control criterion called “distributed runoff control” (DRC). Here, channel erosion is minimized if the erosion potential along a channel's perimeter is maintained constant with pre-developed levels. This is accomplished by providing a non-uniform distribution of the storage-discharge relationship within a BMP, where multiple control points are provided along the runoff frequency spectrum.

6.3.2.1 Benefits of BMPs to Control Hydrologic Impacts

Numerous prior studies have documented the degradation of aquatic ecosystems of urban and suburban headwater streams. As stated above, in general, the studies point to a decrease in stream quality with increasing urbanization. Unfortunately, the benefits of BMPs to protect streams from hydrologic impacts have only recently been investigated and only for a few studies.

Maxted and Shaver (1997), Jones et al (1997), and Horner et al (1997) attempted to isolate the potential beneficial influence of local storm water best management practices on the impervious cover/stream quality relationship. Horner examined the possible influence of stream-side management on stream quality as a function of urbanization. Coffman et al (1998) recently presented data on the potential hydrologic benefits of alternative land development techniques. Called the “Low Impact Development Approach,” this methodology attempts to mimic pre-developed hydrology by infiltrating more rainfall at the source, increasing the flow path and time of concentration of the remaining runoff, and providing more detention storage throughout the drainage network, as opposed to a one location at the end of the pipe.

The preliminary findings of Maxted and Shaver, and Jones et al, suggest that, for the BMPs examined, stream quality (as measured by a limited group of environmental indicators) cannot be sustained when compared to reference stream conditions. Jones assessed several BMPs by conducting biomonitoring (fish and macroinvertebrate sampling) above and below BMPs and comparing them to a reference watershed. He found that the biological community tended to be degraded immediately below BMPs as compared to the reference watersheds. One major flaw in the study was the lack of analysis in developed watersheds without BMPs. This would have compared the influence of BMPs on the aquatic community as compared to no BMPs.

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Maxted and Shaver examined eight sub-watersheds with and without BMPs. Their study also concluded that BMPs did not adequately mitigate the impacts of urbanization once watershed impervious reached 20 percent cover. While this study was useful in defining the cumulative impacts of BMPs on watersheds, several critical questions remain. First, since no sub-watersheds with less than 22 percent impervious cover were analyzed, little is known about BMP ability to protect the most sensitive species seen in less developed watersheds. Data for sub-watersheds with BMPs was collected approximately three years after data for the sub-watersheds without BMPs, so climatic/seasonal constraints may have affected the outcome as much, or more than the BMPs themselves.

Horner et al (1997) evaluated several sub-watersheds, with varying levels of impervious cover, but only tangentially related the effectiveness of BMPs to protecting stream quality. Horner found that at relatively low levels of urbanization (approximately 4 percent impervious area) the most sensitive aquatic biological communities (e.g., salmonids) were adversely affected, and stream quality degradation (as measured by a several indicators) continued at a relatively continuous rate with increasing impervious area. Horner's study demonstrates a link between urbanization and stream quality in the Puget Sound region, but since the effects of BMPs were not directly assessed, the question of whether BMPs could "raise" these thresholds could not be answered.

Horner did find a positive relationship between stream quality and riparian buffer width and quality. Here, the otherwise direct relationship of degrading stream quality with increasing impervious cover was positively altered where good riparian cover existed. In other words, increasing the buffer width and condition tended to keep the stream systems healthier.

Coffman demonstrated techniques for maintaining pre-developed hydrologic parameters by replicating the curve number and time of concentration. The analysis indicated the amount of storage required on-site to accommodate the change in site imperviousness. The benefits of this type of development, while not yet fully monitored in a field study, are likely to include increased groundwater recharge, reduced channel erosion potential, and decreased flood potential.

One major hydrologic benefit of storm water management structures is the ability to mitigate for the potential flooding associated with medium to larger storms. Storm water detention and retention facilities have been applied in many parts of the country since about 1970 (Ferguson and Debo, 1990). These facilities include wet and dry basins, as well as rooftop and parking lot detention and underground storage vaults. These *storage facilities* attempt to reduce flooding downstream from developments by reducing the rate of flow out of the particular structure being used. Although the rate of flow is reduced, the volume of flow is generally not reduced. Instead, this volume is delivered downstream at a slower rate, and stretched out over a longer time. With the exception of properly design wet ponds, these structures do not provide any water quality benefit beyond the hydrologic modifications. This technique has proved to be a successful method of suppressing flood peaks when properly applied on a watershed-wide basis.

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6.3.3 Human Health Benefits

Storm water can impact human health through direct contact from swimming or through contamination of seafood. Most human health problems are caused by pathogens, but metals and synthetic organics may cause increased cancer risks if contaminated seafood are consumed. Mercury, PCBs, and some pesticides have been linked to human birth defects, cancer, neurological disorders and kidney ailments. The risks may be greater to sensitive populations such as children or the elderly. BMPs that reduce pathogens, metals and synthetic organics will help to limit these health risks.

Economic benefits of avoiding human health problems can include swimming and recreation costs, as well as saved medical costs. One study in Saginaw, Michigan estimated that the swimming and beach recreation benefits associated with a CSO retention project exceeded seven million dollars (US EPA, 1998c). As another example, EPA initially estimated that proposed Phase II storm water controls would reduce the cost of shellfish-related illnesses by between $73,000 and $300,000 per year (US EPA, 1997d).

6.3.4 Additional and Aesthetic Benefits

Storm water BMPs can be perceived as assets or detriments to a community, depending on their design. Some examples of benefits include: increased wildlife habitat, increased property values, recreational opportunities, and supplemental uses. Detriments include: mosquito breeding, reduced property values, less developable land and safety concerns. These detriments can be mitigated through careful design.

6.3.4.1 Property Values and Public Perception

The impacts of BMPs on property values are site-specific. The presence of a structural BMP can affect property values in one of three ways: increase the value, decrease the value, or have no impact. BMPs that are visually aesthetic and safe for children can lead to increased property values. A practice becoming more prevalent is to situate developments around man-made ponds, lakes, or wetlands created to control flooding and reduce the impacts of urban runoff. Buffer zones and open areas that control runoff also provide land for outdoor recreation such as walking or hiking and for wildlife habitat. In many cases, developers are able to realize additional profits and quicker sales from units that are adjacent to such areas. A survey of residents in an Illinois subdivision indicates that residents are willing to pay between 5 percent and 25 percent more to be located next to a wet pond, but that being located next to a poorly-designed dry detention basin can reduce home values (Emmerling-Dinovo, 1995).

Safety is also a concern among the public. A childless adult may perceive a wet pond as an amenity, but a family might view it as a potential hazard to children. These concerns can be alleviated using such design features as gently sloping edges, a safety “bench” (a flat area

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surrounding a pond) and the use of dense vegetation surrounding ponds and infiltration basins to act as a barrier.

Aesthetic maintenance is also important when considering long term impacts on property values. Poorly-maintained wet ponds or constructed wetlands may be unsightly due to excess algal growth or public littering. Wet ponds and constructed wetlands can also become mosquito breeding grounds. However, mosquito problems can usually be reduced or eliminated through proper design and/or organic controls such as mosquito-eating fish. Successful designs avoid shallow or stagnant water, and reduce large areas of periodic drying, as occur in a dry detention basin (McLean, 1995). All BMPs need to have trash and debris removed periodically to prevent odor and preserve aesthetic values.

6.3.4.2 Dual-Use Systems

Since BMPs can consume a large amount of space, communities may opt to use these facilities for other purposes in addition to storm water management. Two examples are "water reuse" ponds and dual use infiltration or detention basins. In one study, a storm water pond was used to irrigate a golf course in Florida, decreasing the cost of irrigation by approximately 85 percent (Schueler, 1994b). In the southwestern United States, BMPs are often completely dry in between rain events. In these regions, it is very common to design infiltration basins or detention basins as parks that are maintained as a public open space (Livingston et al, 1997).

6.4 Review of Economic Analysis of the NPDES Phase II Storm Water Rule

The proposed storm water Phase II rule specifies that Phase II municipalities and operators of construction sites disturbing between one and five acres of land must apply for and receive a storm water permit. To meet this requirement, municipalities must develop a storm water pollution prevention plan that addresses six minimum measures[9]. Operators of construction sites are required to incorporate soil and erosion controls into their construction sites and implement a water pollution prevention plan. The analysis presented here is a summary of the most recent benefit-cost analysis prepared for the proposed Phase II storm water rule (Preliminary draft number 3). In order to address the issues raised in the public comments and during internal review, EPA gathered additional data and information to refine the analysis of potential benefits and costs conducted for the proposed Phase II rule. These data, analyses, and results are described in detail in the Preliminary Draft of the Economic Analysis of the Final Phase II Storm

[9] The six minimum measures are:

- Public Education and Outreach on Storm Water Impacts
- Public Involvement/Participation
- Illicit Discharge Detection and Elimination
- Construction Site Storm Water Runoff Control
- Post-Construction Storm Water Management in New Development and Redevelopment
- Pollution Prevention/Good Housekeeping for Municipal Operations (US EPA, 1998c).

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Water Rule ("EA"), and are summarized in the sections that follow. All cost and benefit estimates are presented in 1998 dollars.

The reader should note that the Agency continues to revise the analysis based on internal review and new data and information. EPA envisions completing the economic analysis in conjunction with the Storm Water Phase II Final Rule. Hence, all estimates are subject to future refinement.

6.4.1 Analyses of Potential Costs

This section provides an overview of the methodology used to estimate costs and pollutant loading reductions for both municipalities and construction sites subject to the final Phase II rulemaking. The specific components of the analysis are discussed in detail in the Draft Final EA. Current Agency estimates of national compliance costs, which are subject to change, are also provided.

6.4.1.1 Municipal Costs

EPA estimated annual per household program cost for automatically designated municipalities (MS4s) using actual expenditures reported by 35 Phase I municipalities. Based on census data, EPA estimated the Phase II municipal universe to be 5,040 MS4s with a total population of 85 million people and 32.5 million households. An average annual per household administrative cost was estimated to address application, record keeping, and reporting requirements, which was added to the program per household cost to derive a total average per household cost. To obtain the national estimate of compliance costs, the Agency multiplied the estimated total per household compliance cost ($9.09) by the expected number of households in Phase II communities. EPA estimates the national Phase II municipal compliance costs to be approximately $295 million (see Section 4.2.1.3 in the draft EA)[10].

6.4.1.2 Construction Costs

In estimating incremental costs attributable to the final Phase II rule, EPA estimated a per site cost for construction sites of one, three, and five acres and multiplied the cost by the total number of Phase II construction starts in these size categories to obtain a national estimate of compliance costs. The Agency used construction start data from eleven municipalities that record construction start information to estimate the number of construction starts disturbing between one and five acres of land (see Section 4.2.2.1 in the Draft Final EA).

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[10] Estimated annual per household cost of compliance ranged from $0.63 to $60.44. See Section 4.2.1.2 in the Draft Final EA for a discussion of how EPA chose the mean value of $9.09 per household. Note that the estimated per household cost does not include municipal expenditures for post-construction storm water controls.

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In estimating construction BMP costs, EPA used standard cost estimates from R.S. Means (R.S. Means, 1997a and 1997b) and created 27 model sites of typical site conditions in the United States. The model sites considered three different site sizes (1, 3, and 5 acres), three slope variations (3, 7, and 12 percent), and three soil erosivity conditions (low, medium, and high). The Agency used a database compiled by the Water Environment Federation (1992) to develop and apply BMP combinations appropriate to the model site conditions. For example, sites with shallow slopes and a low erosivity require few BMPs, while larger, steeper, and more erosive sites required more BMPs. Detailed site plans, assumptions, and BMPs that could be used are found in Appendix B-3 of the Draft Final EA. Based on the assumption that any combination of site factors are equally likely to occur on a given site, EPA averaged the matrix of estimated costs to develop an average cost for one, three, and five acre starts for all soil erodibilities and slopes. The average BMP cost was estimated to be $1,206 for a one-acre site, $4,598 for a three-acre site, and $8,709 for a five-acre site.

Administrative costs for the following elements were estimated per construction site and added to each BMP cost: submittal of a notice of intent (NOI) for permit coverage ($74); notification to municipalities ($17); development of a storm water pollution prevention plan ($1,219); record retention ($2); and submittal of a notice of termination ($17) for a total cost of $1,329 per site. From this analysis, EPA estimated total average compliance costs (BMP plus administrative) for a Phase II construction site of $2,535 for sites disturbing between one and two acres of land, $5,927 for sites disturbing between two and four acres, and $10,038 for sites disturbing between four and five acres of land.

The total per site costs were then multiplied by the total number of Phase II construction sites within each of those size categories to obtain the national compliance cost estimate. EPA estimated construction costs for 15 climatic zones to reflect regional variations in rainfall intensity and amount. Once the Phase II storm water rule is fully implemented, the total annual compliance cost is expected to be approximately $512 million (assuming 109,652 construction starts in 1998).

6.4.1.3 Pollutant Loading Reductions

To estimate municipal pollutant loading reductions for the final Phase II rulemaking, EPA used the results from a 1997 EPA draft report that calculated national municipal loading reductions for TSS based on the NURP study (US EPA, 1997d). To estimate pollutant loading reductions from Phase II construction starts, the U.S. Army Corps of Engineers developed a model based on EPA's 27 models sites to estimate sediment loads from construction starts with and without Phase II controls (US ACE, 1998). Estimating the pollutant loading reduction for TSS does not capture the full extent of potential loading reductions that result from implementing storm water controls, but provides a minimum estimate of the reductions that may result from the

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Phase II rule[11]. EPA also anticipates that the rule will result in reductions in oil and grease, nitrogen, phosphorus, pathogens, lead, copper, zinc and other metals. Estimated annual TSS loading reductions range from 639,115 to approximately 4 million tons for municipalities and 2 million to 8 million tons for construction sites assuming BMP effectiveness of 20 to 80 percent.

6.4.2 Assessment of Potential Benefits

A number of potential problems are associated with assessing the benefits from the Phase II rule, including identifying the regulated municipalities as sources of current impairment to waters and determining the likely effectiveness of various measures; difficulties in water quality modeling; difficulties in modeling construction site BMP effectiveness; and most importantly, the inability to monetize some categories of benefits with currently available data.

The national benefits of Phase II controls will depend on a number of factors, including the number, intensity, and duration of wet weather events; the success of municipal programs; the effectiveness of the selected construction site BMPs; the site-specific water quality and physical conditions of receiving waters; the current and potential use of receiving waters; and the existence of nearby "substitute" sites of unimpaired waters. Because these factors will vary substantially from site to site, data are not available with which to develop estimates of benefits for each site and aggregate to obtain a national estimate. As a result, the Agency developed national level estimates of benefits based largely on a benefits transfer approach. This approach allows estimates of value developed for one site and level of environmental change to be applied in the analysis of similar sites and environmental changes.

6.4.2.1 Anticipated Benefits of Municipal Measures

As part of an effort to quantify the value of the United States' waters impaired by storm water discharges, EPA applied adjusted Carson and Mitchell (1993) estimates of willingness to pay (WTP) for incremental water quality improvements to estimates of waters impaired by storm water discharges as reported by states in their biennial Water Quality Inventory reports[12]. Potential Phase II benefits are assumed to equal the WTP for the different water quality levels multiplied by the water quality impairment associated with Phase II municipalities multiplied by the relevant number of households (WTP x percent impaired x number of households).

The Carson and Mitchell estimates apply to all fresh water, however it is not clear how these values would be apportioned among rivers, lakes and the Great Lakes. Lakes are the water

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[11] To date, there are no national studies that estimate pollutant loading reductions due to the implementation of municipal storm water controls for the other pollutants found in storm water runoff and discharges.

[12]EPA adjusted the WTP amounts to account for inflation growth in real per capita income, inflation, and a 30 percent increase in attitudes towards pollution control.

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bodies most impaired by urban runoff and discharges, followed closely by the Great Lakes and then rivers. Hence, EPA applied the WTP values to the categories separately and assumed that the higher resulting value for lakes represents the high end of the range and the lower resulting value for rivers represents the low end of a value range for all fresh waters (i.e. high end assumes that lake impairment is more indicative of national fresh water impairment while low end assumes that river impairment is more indicative).

The extent to which impairment will be eliminated by the municipal measures is uncertain; hence, estimates are adjusted for a range of potential effectiveness of municipal measures. EPA expects that municipal programs will achieve at least 80% effectiveness, resulting in estimated annual benefits from fresh water use and passive use in the range of $67.2 to $241.2 million. The potential value of improvements in marine waters and human health benefits have not been quantified at this time.

6.4.2.2 Anticipated Benefits of Construction Site Controls

EPA estimates the benefits of construction site controls using a benefits transfer approach applying WTP estimates for an erosion and sediment control plan from Paterson et al (1993) contingent valuation (CV) survey of North Carolina residents. The adjusted WTP estimates are intended to reflect potential benefits of erosion and sediment control programs that protect all lakes, rivers, and streams. In order to transfer adjusted WTP results to estimate the potential benefits of the Phase II rule, EPA calculated the percentage of Phase II construction starts that are not covered by a state program or CZARA for each state. This percentage is multiplied by the number of households in the state and the adjusted mean WTP of $25. The results were then summed across all states and indicate that WTP for the erosion and sediment controls of the Phase II rule may be as high as $624.2 million per year.

6.4.3 Comparison of Benefits and Costs

EPA estimates the total compliance costs of the rule to be $807.2 million. The largest portion of the total cost, $512 million, is associated with erosion and sediment controls at construction sites. EPA was able to develop a partial monetary estimate of expected benefits of both the six minimum municipal measures and the construction components of the rule. The sum of these benefits ranges from $700 to $865 million annually [assuming 80 percent effectiveness of municipal programs and using the mean WTP ($25) from Paterson]. The largest portion of benefits, $624 million, are associated with erosion and sediment controls for construction sites.

6.5 Financial Issues

Effective storm water programs require both the existence of well-performing, cost-effective BMPs and sufficient funding. Financing issues are discussed extensively in other Agency

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reports and only briefly reviewed below.[13] Section 6.5.1 focuses on financing options for municipal storm water programs but does not discuss regulatory impacts on municipalities.

6.5.1 Municipal Financing of Storm Water Programs

Around the nation, local government general tax funds are the most commonly used source of funding for storm water programs. However, this may be the least suitable source of storm water program or maintenance funding. General tax revenues originate at a number of sources and are used to finance an equally diverse number of public programs, including education, police and fire protection, civil and criminal courts, and social and economic support programs. Storm water programs and maintenance must compete against a large number of other vital public programs for a very limited number of tax dollars. This problem has been compounded in recent years by tax caps and the public's general opposition to new or higher taxes.

The unreliability of general tax funds has led many communities around the country to develop storm water utilities. Storm water utilities rely on dedicated user charges related to the level of service provided. Charges are typically paid by property owners and managed in a separate enterprise fund. A variety of methods are used to determine charges, but are usually based on some estimate of the amount of storm water runoff contributed by the property, such as the total impervious surface or a ratio of impervious surface to total property area. Generally a flat rate is charged for residential properties.

There are several advantages of using utility fees to finance storm water programs. Unlike general tax revenues, utility charges are a dedicated, stable, and predictable source of funds and are not subject to state "tax cap" limitations. Also, because charges are based on the user's contribution to storm water runoff, it is often seen as more equitable or fair. Finally, utility fees provide a mechanism to incorporate economic incentives for implementation of on-site storm water management through reduced charges. For example, credits or discounts are often provided for on-site retention of storm water by nonresidential property owners. Providing such incentives creates greater flexibility by allowing each user to choose the cheaper option - paying the utility charge or implementing on-site controls. Storm water utilities are now well established as an effective financing option. As of 1991, over 100 communities across the country had instituted storm water utilities (US EPA, 1994a).

Similar to utility fees, the use of inspection or permit fees to help publicly finance storm water programs represents a relatively new application of an established component of government revenues. Often, these fees are associated with the issuance of a permit, such as a

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[13] EPA has prepared publications to assist local governments in planning for program funding (US EPA, 1994b). More recently the Agency has established an internet site with current information, the "Environmental Finance Information Network." The website address is http://www.epa.gov/efinpage/efin.htm .

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building permit, clearing permit, storm water permit, or sewer connection permit. A permit program based upon fees for annual inspections, such as a storm water discharge or storm water operating permit, can provide a continuing source of funds. However, many permit or inspection fees are a one time charge, typically when the facility is first constructed. These are generally not a good funding source for continuing storm water system maintenance.

Finally, the use of dedicated contributions from land developers may be used to finance public maintenance of storm water systems. Under this program, the local government assumes the operation and maintenance of a storm water system constructed as part of a private development. All or a portion of the estimated required funding for the O&M is obtained through a one-time contribution by the land developer to a dedicated account which is controlled by the local government. Often the developer is responsible for O&M during a "warranty period," frequently the first two years. Dedicated contributions provide a secure, dedicated funding source that is not subject to state tax cap limits. A disadvantage is that dedicated contributions are only applicable to new storm water systems.

6.6 Summary

The use of BMPs to control storm water runoff and discharges where none previously existed will ultimately result in a change in pollutant loadings, and there are indications that in the aggregate BMPs will improve water quality. The actual manner in which the loadings reductions are achieved will depend on the BMPs selected, which will determine the associated costs. The physical-chemical properties of receiving streams and consequent linkages to biologic/ecologic responses in the aquatic environment, and human responses and values associated with these changes will determine the benefits.

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ORANGE COUNTY
OC PublicWorks
Our Community. Our Commitment.

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Environmental Resources
2301 N. Glassell St.
Orange, CA 92865

Telephone: (714) 955-0600
Fax: (714) 955-0639

May 8, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

At the April 24, 2009 public hearing, the Santa Ana Regional Board held open the comment period on several land development provisions of the tentative order before it – *Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County* (Order No. R8-2009-0030). Specifically, the Board agreed to accept comments on Sections XII.C.1 and C.2, which had been revised the day of the hearing. We understand the Board intends to adopt the order at the May 22, 2009 public hearing.

The County of Orange, the Principal Permittee, is disappointed that last minute changes introduced at the hearing and subsequent to the hearing in the form of the fourth draft of the Order create a permit significantly different from the one the County came to the April 24th hearing ready to support. Nonetheless, the County welcomes the opportunity to provide additional comments on these key provisions. The Permittees were involved in the development of these comments and the cities of Anaheim, Buena Park, Cypress, Fountain Valley, Irvine, La Palma, Laguna Hills, Lake Forest, Newport Beach, Orange, Placentia, Tustin, Villa Park and Westminster have directed that they be recognized as concurring entities.

Sections XII.C.1 and C.2 pertain to land development and, specifically, "low impact development" or "LID." Prior to the April 24th hearing, the Order's land development provisions had been the subject of a series of stakeholder meetings. In our letter of February 13, 2009, we highlighted this series of meetings and noted that they had produced general areas of agreement, which include:

1. Performance standards for implementing LID BMPs, other than an EIA percentage (3-5%) are acceptable if a technically equivalent standard can be identified.

2. Sizing LID BMPs to capture the 85th percentile storm event (current DAMP criteria for water quality volume) is an acceptable alternative to EIA as a performance standard

provided that technically-based, strict, and clear feasibility criteria are developed for any project that cannot meet the LID BMP requirements.

3. Prioritized LID/SUSMP BMPs for water quality volume capture are represented by: a) infiltration BMPs; b) harvesting and reuse BMPs; and c) vegetated (or evapotranspiration) BMPs, including bioretention and biofiltration. Water quality volume not captured by LID BMPs shall be treated consistent with DAMP requirements.

Additionally, the County of Orange endorsed these general areas of agreement as "default" requirements pending development of watershed based standards through a watershed master plan (Section XII.D.5). In fact, we specifically agreed to enhanced watershed master planning requirements as part of this integrated approach.

These general areas of agreement were by and large reflected in the third draft of the Order. It is the County's position that they should continue to inform the framework of the Order's land development provisions. The changes made in the fourth draft of the Order, while deceptively small, will fundamentally alter this framework.

Attachment A presents a visual representation of the framework for land development that essentially reflects the land development provisions of the third draft of the Order. It predicates compliance on management of the 85th percentile storm volume; presumes the application of LID BMPs based upon a prioritized consideration of infiltration; capture and re-use, evapotranspiration, and bio-retention/bio-filtration and requires treatment of any residual runoff volumes for which the application of LID BMPs has been determined to be infeasible at site, sub-regional and regional scales. This framework also integrates options for water quality credits and provides for alternate compliance approaches including participation in a watershed project and contributions to an "in-lieu" fund. It also explicitly recognizes bioretention/biofiltration BMPs as LID BMPs and the continued and entirely legitimate contribution of effective structural BMPs such as constructed wetlands and detention ponds to the practice of stormwater quality management. The County's specific comments and suggestions regarding Sections XII.C.1., and X.II.C.2. which are presented below, support this framework.

Specific Comments on Sections XII.C.1 and C.2

At the April 24th hearing, the representative from U.S. EPA stated that the changes to Sections XII.C.1 and C.2 were made at EPA's request. The County understands that Section XII.C.1. was revised to address U.S. EPA's concern regarding the possibility of inordinate delay in Executive Officer approval of the required criteria for determining LID feasibility. The U.S. EPA revision removes reference to the application of the feasibility criteria. The consequence of removing the feasibility criteria is that each priority development project will need to provide the Executive Officer with project specific criteria as part of any feasibility analysis. This could subsequently result in administrative burden, additional costs and staff time as well as potential project delays. In **Attachment B** we have included proposed redline language for Section XII.C.1, making as few changes as possible, that clarifies this procedure and relates it to the update of the model WQMP.

It is less clear why U.S. EPA requested the change to Section XII.C.2. The effect of the change, however, does appear clear. It would fundamentally alter the framework discussed above. Specifically, the prioritization principle outlined in the third bullet point above would be eviscerated. As revised by U.S. EPA, any priority development project that could not meet the

performance goal by using the identified LID BMPs would have to obtain a waiver from the Executive Officer.[1] There would be no prioritization nor use of any other BMPs—LID or otherwise—without Executive Officer approval. It is not clear what effect U.S. EPA's revision would have on the BMP requirements of Section XII.B which is predicated on the use of all effective BMPs, including LID BMPs and others.

At the April 24th hearing, you and your staff agreed to add "biotreatment" to the identified LID BMPs that could be used to meet the performance goal in section XII.C.2. The Board supported this change. However, this change is not reflected in the fourth draft of the Order. While the term "bio-filter" has been added to the identified LID BMPs, a new footnote provides that bio-filtration, bio-retention or bio-treatment only may be used if other identified LID BMPs (infiltration, harvest and reuse, and evapotranspiration) are not feasible. This additional qualification is not what the Board supported at the April 24th hearing. Alternate revised language for Section X.II.C.2 is also presented in **Attachment B.** Again, making as few changes as possible, this language restores the feasibility criteria to the framework and otherwise attempts to address the County's concerns.

The new footnote, as well as U.S. EPA's other changes to Section XII.C.2, highlight a significant problem with the approach the Order has taken. Instead of allowing permittees the discretion to use whatever means they determine are effective to meet the substantive requirements of the Order, the fourth draft dictates that permittees use not just LID BMPs to meet the requirements, but a pre-selected subset of LID BMPs. That is a clear violation of section 13360(a) of the Water Code which prohibits Regional Boards from prescribing the manner in which a permittee is to comply with a permit. Eric Strecker of Geosyntec, an expert in the field, provided testimony on April 24, 2009 that this requirement is not technically sound.

Finally, your attention is drawn to a preliminary analysis of fiscal impact prepared by the City of Simi Valley with respect to the application of LID requirements to a 5.23 acre affordable housing project. This analysis provides preliminary information on the potentially significant cost impacts of retaining stormwater on site, and is included in **Attachment C**. It should be noted that a similar analysis is not available at this time for north Orange County.

Thank you for your attention to our comments. Please contact Richard Boon at (714) 955-0670 or Chris Crompton at (714) 955-0630 with any questions on this matter.

Sincerely,

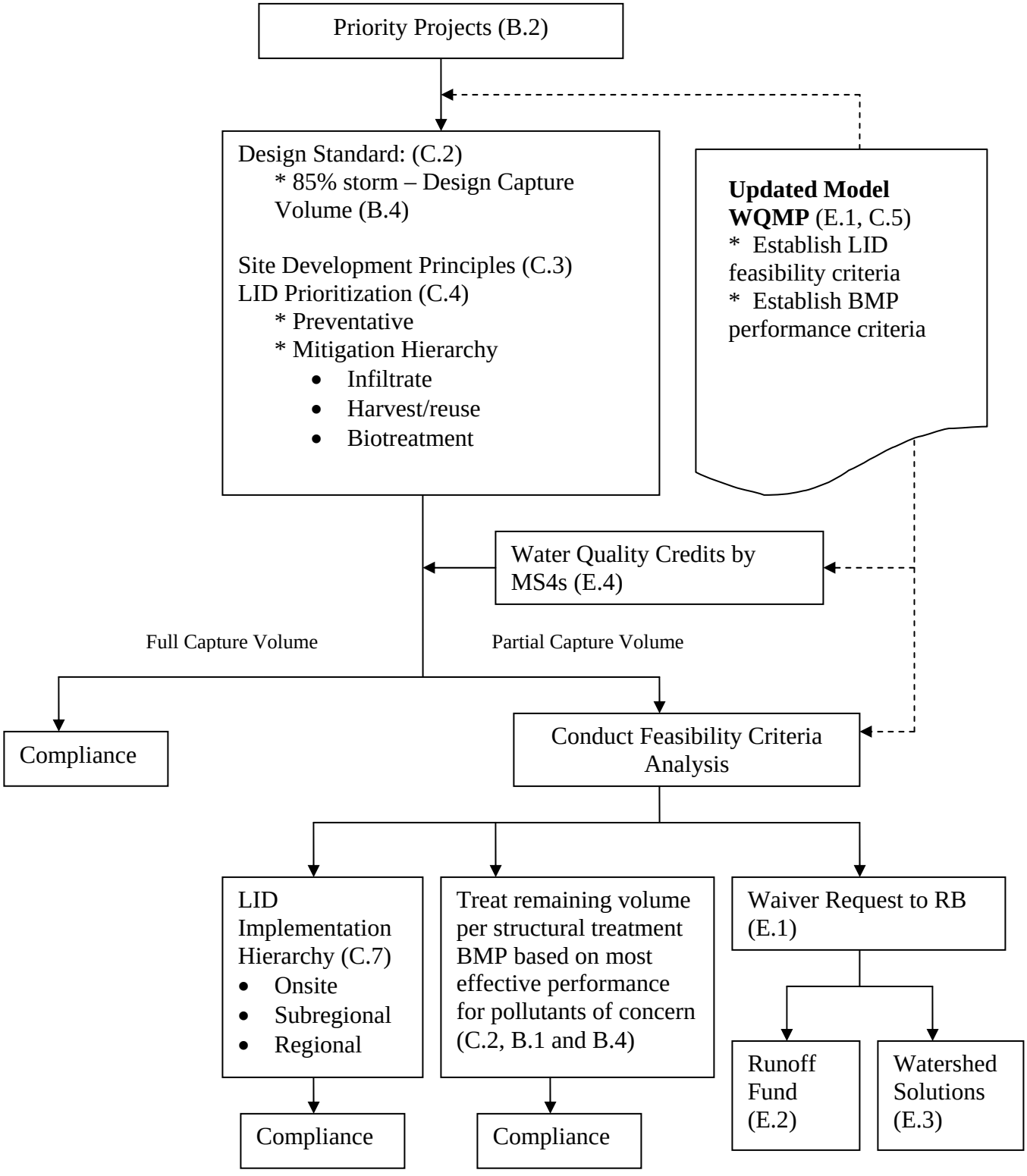
Mary Anne Skorpanich
Director, OC Watersheds Program

cc: Board Members
City Permittees

[1] During recent discussions with U.S. EPA and your staff on this issue there seemed to be some misunderstanding as to the conditions under which waivers would be required.

Attachment A:	Process Flow Chart
Attachment B:	Alternate Revised Language
Attachment C:	Letter of May 6, 2009 from City of Simi Valley to Building Industry Association – Preliminary Analysis of the Fiscal Impact to new Development by the Requirements of the Tentative Order of the Ventura County MS4 Permit

Attachment A: LID Process



NOTE: RB changes from Third to Fourth Draft in blue. Regulated community changes to Fourth Draft in red.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the model WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for review and approval by the Executive Officer[55]. As provided in Section XII.J, 90 days after approval of the revised model WQMP, p~~P~~riority development projects ~~that meet the feasibility criteria established pursuant to Section XII.E~~ shall implement the LID principles described in this section, Section XII.C. To the extent the Executive Officer has not approved feasibility criteria as provided in Section XII.E.1, the infeasibility of implementing LID BMPs shall be determined through a project-specific analysis submitted to the Executive Officer for approval.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, ~~or~~ capture, or bio-~~filter~~treat[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. ~~Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance.~~ Any portion of ~~this~~ the design capture volume that is not infiltrated, harvested and re-used, evapotranspired, ~~or~~ captured or bio-~~filtered~~treated[57] onsite by LID BMPs shall be treated and discharged using LID or ~~conventional~~ similarly effective treatment control BMPs or mitigated as set forth in Section XII.C.7, below. Projects that do not comply with this requirement shall meet the requirements established in Section XII.E. for alternative or in-lieu compliance.

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design ~~strategy~~ goal shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention,

[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

[56] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only ~~if infiltration, harvesting and reuse and evapotranspiration are not feasible~~ in accordance with the priorities specified in Section XII.C.4.

[57] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only ~~if infiltration, harvesting and reuse and evapotranspiration are not feasible~~ in accordance with the priorities specified in Section XII.C.4.

evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

a. Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

b. Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c. Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d. Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e. Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f. Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g. Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h. During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-

structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[58], New Urbanism[59] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.
6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.
7. If site conditions do not permit infiltration, harvesting and re-use, ~~and/or~~ evapotranspiration, capture, and/or biotreatment of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:
    a. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, ~~and/or~~ harvest and re-use, evapotranspire, capture, or treat at least the design capture volume.

[58] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[59] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

b. Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate, ~~and/or~~ harvest and re-use, evapotranspire, capture, or biotreat at least the design capture volume through designated ~~infiltration/treatment~~ areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire, capture, or treat at least the design capture volume.

c. Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire, capture, or treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

d. Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire, capture, or treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

CITY OF SIMI VALLEY

Home of The Ronald Reagan Presidential Library

May 6, 2009

Holly Schroeder
Chief Executive Officer
Building Industry Association - LA/Ventura Chapter
28460 Avenue Stanford, Suite 110
Santa Clarita, CA 91355

SUBJECT: PRELIMINARY ANALYSIS OF THE FISCAL IMPACT TO NEW DEVELOPMENT BY THE REQUIREMENTS OF THE TENTATIVE ORDER OF THE VENTURA COUNTY MUNICIPAL SEPARATE STORM SEWER SYSTEM PERMIT DATED FEBRUARY 24, 2009

Dear Ms. Schroeder:

As we discussed, the City of Simi Valley has performed a preliminary analysis of the fiscal impact to new development as a result of the requirements of the Tentative Order of the Ventura County Municipal Separate Storm Sewer System Permit (MS4). The analysis also included consideration of the mutual agreement between Heal the Bay (HTB), the Natural Resources Defense Council (NRDC), and the Co-Permittees. In reviewing the language of the mutual agreement, City staff indicated two possible interpretations of the agreement concerning whether or not water from pervious surfaces is allowed to leave the site.

Staff performed a hypothetical analysis based upon an actual affordable housing project constructed in the City of Simi Valley. The project was constructed by Cabrillo Development Company approximately five years ago and is located on Alamo Street between Tapo Canyon Road and Tapo Street. It included 70 units, having 34 units designated affordable, on a 5.23-acre site (227,818 sq ft) and originally costing $12,738,000 with an affordable housing subsidy of $36,300 per unit. The findings are summarized below with a more detailed summary and explanation of the analysis provided in Attachment 1.

In summary, the analysis estimated that each alternative would have increased development costs as follows.

1. Tentative Order (4th Draft) issued February 24, 2009 would have increased developer costs by $570,900 or 4.48%. The affordable housing subsidy would increase by $16,791 to $53,091.

2. Mutual agreement between HTB, NRDC, and Co-Permittees (surface water allowed to leave the site from pervious surfaces) would have increased costs by $664,000 or 5.21%. The affordable housing subsidy would increase by $19,524 to $55,824.

Paul Miller, Mayor Barbra Williamson, Mayor Pro Tem Glen T. Becerra, Council Member Steven T. Sojka, Council Member Michelle S. Foster, Council Member

2929 Tapo Canyon Road, Simi Valley, CA 93063-2199 805.583.6700 www.simivalley.org

3. Mutual agreement between HTB, NRDC, and Co-Permittees (no surface water allowed to leave the site) would have increased costs by $1,029,000 or 8.08%. The affordable housing subsidy would increase by $30,258 to $66,558.

As can be seen, the estimated additional cost of implementing the revised draft of the permit and the variations of the mutual agreement on a project with an affordable component ranged from 4.5% to 8%, or in this application to a real project a cost differential ranging from $570,900 to $1,029,000.

Should conditions become unfavorable to retain and infiltrate, it is possible that these costs could easily double this amount and thus exceed 20% of the developer's cost to construct with subsequent increases to the affordable elements.

It is important to remember that lacking a technical guidance manual and specific volume criteria and BMP sizing guidance that these numbers can only be interpreted as preliminary in nature but should still provide a good example for further discussion on the subject.

Thank you for your time. If you have any questions, please call me at 805-583-6701.

Sincerely,

Mike Sedell
City Manager

cc: City Council
City Attorney
Sam Unger, Los Angeles Regional Water Quality Control Board
Ventura County Co-Permittees
Natural Resources Defense Council
Heal the Bay

Attachment 1

PRELIMINARY ANALYSIS OF THE FISCAL IMPACT TO NEW DEVELOPMENT BY THE REQUIREMENTS OF THE TENTATIVE ORDER OF THE VENTURA COUNTY MUNICIPAL SEPARATE STORM SEWER SYSTEM PERMIT DATED FEBRUARY 24, 2009

Case 1:

Site with excellent soils conditions under design requirements of current permit language allowing surface filtration methodology. In this situation, it should be noted that a certain degree of infiltration technology could also be substituted for a portion of the project area for a nominal cost increase.

Itemization of Costs:

1. Onsite bio-filtration, 154,360 sq ft of site (all of building, and a majority of concrete and asphalt areas) @ $2.50 per sq ft of cost for treatment devices such as bio-swales, modified landscaping, etc. **$385,900**

2. Modified landscaping meeting current design methodology implied by permit with some potential for bio-filtration, storage, runoff and limited infiltration. 73,458 sq ft @ $2.50 per sq ft. **$185,000**

Total cost for a primary bio-filtration scenario under current permit - $570,900 or 4.48% of project cost.

Case 2:

Site having excellent to low to moderate soils problems with some clay near upper layers, but overall good infiltration (sand and course sand) in lower zones below 10 - 15 feet in depth. Infiltration by darcy dry wells and modified landscaping appropriate. No onsite bio-filtration necessary to comply with agreement language.

Itemization of Costs:

1. Onsite infiltration for via darcy dry wells and limited infiltration trenches as necessary depending onsite conditions. 118,000 sq ft of building rooftop and impervious surfaces not converted to impermeable surfaces. (Note: only impervious surfaces, rooftops and high travel drive asphalt areas and concrete curb and gutter not converted to impermeable surfaces were included in this calculation). Requires installing two darcy wells with associated piping and limited infiltration trenches with grading and site modifications. **$170,000**

2. Convert 34,363 sq ft of impermeable concrete and asphalt paving to permeable surface at onset. Additional cost of paving materials with associated ground preparation for porous media meeting the storage, infiltration and evapotranspiration requirements of such improvements. 34, 363 sq ft @ $9.00 per sq ft. **$309,000**

3. Modified landscaping meeting current draft design methodology and criteria. 73,459 sq ft @ 2.50 per sq ft. **$185,000**

Total cost for a primary retention scenario - $664,000 or 5.21% of project cost.

Case 3:

Site with very significant soils problems having clay or high groundwater to interfere with retention and infiltration.

Itemization of Costs:

1. Cistern and distribution system for 22 buildings having 67,575 sq ft of roof. **$220,000**

2. Porous asphalt concrete and concrete per item 2 of Scenario 2 above for 34,363 sq ft. **$309,000**

3. Modified landscaping. **$185,000**

4. Treat remaining 18% unconverted impervious area by increasing ability of all existing landscape for added treatment and increased shallow depth storage to store and effectively treat accept this added water. 125,880 sq ft @ $2.50 per sq ft. **$315,000**

Total cost for a primary retention scenario - $1,029,000 or 8.08% of project cost.

Additional Considerations:

Impact of added BMP's (under the mutual agreement) to mitigate an extremely adverse conditions for this site could likely double above costs ($1,330,000 ideal case and $2,058,000 non-ideal case-adverse soils conditions). This is an approximation. A detailed analysis was not done to arrive at this approximation. If this scenario occurs it may be more cost effective to provide offsite mitigation.

WARREN D. WILLIAMS
General Manager-Chief Engineer

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RIVERSIDE COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

May 8, 2009

Mr. Michael Adackapara
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Dear Mr. Adackapara:

Re: Comment Letter – Renewal of Waste Discharge Requirements for the Tentative Order No. R8-2009-0030, NPDES No. CAS618030 (Permit)

The Riverside County Flood Control and Water Conservation District (District) appreciates the opportunity to comment on the Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the incorporated cities of Orange County, Tentative Order No. R8-2008-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff (Permit) issued May 1, 2009. The following comments are specific to the revisions that were requested by USEPA and presented at the public hearing on April 24, 2009. The letter is divided into three sections:

1. Summary Comments and Recommendations;
2. District's Qualifications for Providing Comments on Low Impact Development (LID) Best Management Practice (BMP) criteria; and
3. Additional Supporting Information for Comments and Recommendations.

Summary Comments and Recommendations

Section XII.C.2 of the Permit stipulates that LID provisions require full retention of the 85th percentile storm volume except where retention of such volume is deemed infeasible. The District believes that defining LID to be limited to onsite retention is overly prescriptive and inconsistent with the broadly understood and implemented LID definition. *We are aware of San Bernardino County's comments refuting the infiltration centric definition of LID and are in full concurrence with them.*

The District further believes that this limited definition of acceptable LID inappropriately presumes that all project sites have the same land use, water quality and hydrologic issues; and that these issues must be addressed using the most prescriptive approach available. This approach not only discounts site specific factors (e.g.; slope stability, impervious soil conditions and project needs) that may preclude economical onsite retention, it also creates a prescriptive standard for LID that will make proactive support for LID implementation difficult, if not infeasible to engender. Additional flexibility is needed to facilitate effective, proactive and economical implementation of LID concepts.

The District is specifically concerned that:

1. The infiltration centric approach to LID ignores the substantial incidental infiltration and evapotranspiration benefits that properly designed filtration based BMPs provide;

2. The Permit precludes the Permittees from including properly engineered filtration BMPs as part of the default LID toolbox, thereby constraining the flexibility of Permittees and developers to select the most appropriate BMPs for specific site constraints and pollutants of concern; and

3. The Permit inappropriately focuses Permittees and developers on micro scale LID practices.

The District recommends that:

1. Section XII.C be reviewed and revised as necessary to recognize the goal of LID as mimicking the predevelopment site hydrology and not as a means of eliminating small storm runoff; and

2. Consistent with the above stated goal, the Permit specifically incorporates filtration and detention as part of the default LID toolbox by revising footnotes 56 and 57 to state:

   "The Permittees shall develop criteria to ensure that biofiltration, bioretention or other biotreatment systems are properly designed and constructed to maximize incidental infiltration and evapotranspiration of Vbmp."

District Qualifications for Providing Comments on Low Impact Development (LID) Best Management Practice (BMP) Criteria

The County of Riverside requested that the District research and develop a new development BMP implementation program in early 2005. The purpose of the program was to define the hydrologic design criteria, scale of BMP deployment, and design specifications necessary to ensure that new developments and redevelopment projects within the County implemented BMPs would achieve and maintain long term pollutant elimination or reduction effectiveness. This was necessary as the County is ultimately liable for the effectiveness of the deployed BMPs. The County believes it is important to avoid requiring BMPs predisposed to failure or public nuisance. By late 2005, the District had determined that vegetated BMPs (the types typically associated with LID) were likely to be the most effective in protecting the beneficial uses of receiving waters and least maintenance intensive over the life of a given project.

After consultation with Santa Ana Regional Water Quality Control Board (RWQCB) staff, the District presented recommendations to the Board of Supervisors regarding a path forward for the development of a BMP Implementation Program.

The recommendations to the Board included:

1. Requiring the use of BMPs that facilitated infiltration and retarding of peak flows from new developments;

2. Establishing numeric criteria for site design BMPs that would promote minimum implementation of LID techniques;

3. Establishing treatment control BMP substitution requirements for LID BMPs; and

4. Establishing numeric criteria (in conjunction with the Southern California Coastal Watershed Research Project's Hydromodification Study) that would allow crediting of LID BMP implementation against potential hydromodification impacts.

The District further recommended that a BMP Design Manual and public maintenance mechanism be developed to ensure the long term effectiveness of the BMPs. The Board directed the District to conduct a series of workshops with the public to further develop and refine the concept proposal.

The District held several workshops with the public and the Board of Supervisors between 2005 and 2007 to support the further development of the BMP Implementation Program. District staff also consulted with leading LID experts throughout the nation, including the authors of existing LID guidance in Denver, Colorado; Seattle, Washington; Maryland and California (Contra Costa County). In addition, the District also obtained a grant in 2006, in conjunction with Santa Ana Project Authority to convert the District's Market Street campus in Riverside into a regional demonstration and testing facility for the types of LID BMPs that were being proposed as part of the BMP Design Manual. In October 2007, Matt Yeager (PhD, San Bernardino County), in conjunction with the California Stormwater Quality Association (CASQA) and the Stormwater Monitoring Coalition (SMC), both of which the District is a member, obtained a grant to develop regional LID guidance for southern California. The District has since focused its efforts on assisting the joint CASQA/SMC effort to develop comprehensive guidance for southern California, with the intention of using that guidance to finalize the District's BMP program and incorporating the implementation program BMPs into the proposed LID Demonstration and Testing Facility.

Additional Supporting Information for Comments and Recommendations

1. The infiltration centric approach to LID ignores the substantial incidental infiltration and evapotranspiration benefits of properly designed filtration based BMPs.

   Research conducted by the American Society of Civil Engineers (ASCE), as part of their research of data in the International ASCE BMP Database, has indicated that there are significant volume losses associated with detention and filtration based BMPs. ASCE consultants speculated that the volume loss was associated with evapotranspirative and surface contact losses that are not typically considered in hydrologic BMP models and therefore ignored in BMP design. The BMP design criteria that the District has been developing is focused on design specifications that maximize the opportunities for maximizing incidental infiltration and evaporative losses in filtration based BMPs by requiring appropriate in-situ soils investigations, increasing contact time of runoff with engineered filtration media, ensuring the appropriate selection of plant pallets and properly designing subdrain systems. Further, the District's proposed LID Demonstration and Testing Facility has been specifically designed to measure and quantify the effectiveness of the proposed (and in progress) design specifications.

2. The Permit precludes the Permittees from including properly engineered filtration BMPs as part of the default LID toolbox, thereby constraining the flexibility of Permittees and developers to select the most appropriate BMPs for specific site constraints and pollutants of concern.

   USEPA's own guide to "Incorporating LID into Municipal Stormwater Programs", April 2009, EPA 901-F-09-005 states:

   "The goal of LID is to reduce runoff and to **mimic a site's predevelopment hydrology** by infiltrating, **filtering**, storing, evapotranspirating, and **detaining** storm water runoff" (emphasis added).

   As an example of potential inadvertent conflicts caused by the infiltration centric approach, the District would note that Natural Resource Defense Council (NRDC) testimony at the April 24, 2009 Public Hearing for the Permit stated that the purpose of an infiltration centric approach to LID was to ensure that water quality and hydromodification permit goals would be met. However, in addition to inappropriately specifying an overly prescriptive method of compliance, the NRDC approach would move the goal of LID from mimicking predevelopment hydrologic conditions to eliminating runoff from all but the most extreme storm events (95% of runoff events captured according to NRDC testimony). In the example provided in their slide presentation, 7% of the post-development "captured" storm events would have produced runoff in the predevelopment condition. This loss of small storm runoff may have adverse impacts on sensitive downstream habitat and unnecessarily put developers and Permittees in conflict with State and Federal regulations regarding habitat preservation. In order to address the conflict, which the District expects to be common in developing counties such as Riverside and San Bernardino, the developers and Permittees would be required to create an unnecessary administrative paper trail documenting the need to use filtration BMPs to pass what would have been natural runoff from smaller storm events through the project.

3. The Permit inappropriately focuses Permittees and developers on micro scale LID practices.

   Section XII.C.7 of the Permit focuses the Permittees on implementing LID "as close to the source as possible". Although the District believes that micro scale LID principals are an appropriate part of the LID tool kit, the District is concerned that exclusive reliance on micro scale LID will not result in sustained pollutant reduction over the long term. The District is specifically concerned that it is not administratively feasible for Permittees to consistently police individual properties (particularly residential properties) to ensure that distributed onsite LID features such as roof downspouts turned to pervious areas, porous pavements, cisterns, landscaping detention and other features are properly maintained for the entire life of a project or property.

The District, in the development of its tentative BMP implementation program has instead focused on more centralized site scale LID features such as porous landscaping detention, bioretention BMPs and other green concepts that maximize the use of common area landscaping, dual use facilities such as parks and/or LID BMPs deployed in larger publicly owned easements or parcels. The advantages of this approach are threefold:

1. The incorporation of site scale BMPs into landscaping or other multi-use features helps ensure that day-to-day vegetative and basic functional maintenance (trash and debris removal) are likely to occur by a regional entity such as a homeowners association, community service district or parks agency;

2. Site scale BMP deployment ensures that municipal BMP inspectors have specific locations to drive to for purposes of inspecting the function and maintenance of the BMPs; and

3. Site scale BMP deployment promotes the use of a public maintenance mechanism to ensure the long term treatment efficiency of the BMP (for example conducting removal and replacement of spent engineered filtration media or scarifying the bed of infiltration BMPs).

The District recognizes that micro scale LID features are an important component of a comprehensive LID strategy; however, based on the District's extensive evaluation effort, we submit that long term BMP effectiveness is dependent on having an LID BMP deployment program that supports effective and efficient BMP inspection, operation and maintenance. If BMPs that are completely dependent on site specific subsoil conditions become as numerous as roof downspouts, long term performance becomes infeasible to enforce.

Closing

Thank you for the opportunity to comment on the Permit. We appreciate your consideration of our comments and look forward to meeting with RWQCB staff to develop the 2009 Riverside County MS4 Permit. If you have any questions regarding these comments, please contact Jason Uhley at 951.955.1273.

Very truly yours,

Mark H. Wills

MARK H. WILLS
Chief of Regulatory Division

c: Riverside County Management Steering Committee
Santa Ana Region Technical Advisory Committee

AM:cw
P8/125072

SAN BERNARDINO COUNTY STORMWATER PROGRAM

A Consortium of Local Agencies

825 East Third Street
San Bernardino, CA 92415-0835
(909) 387-8112 / FAX 387-8130

Member Agencies

City of Big Bear Lake

City of Chino

City of Chino Hills

City of Colton

City of Fontana

City of Grand Terrace

City of Highland

City of Loma Linda

City of Montclair

City of Ontario

City of Rancho Cucamonga

City of Redlands

City of Rialto

City of San Bernardino

City of Upland

City of Yucaipa

County of San Bernardino

San Bernardino County Flood Control District

May 8, 2009

File: 10(NPD)-1.02

Mr. Gerard J. Thibeault, Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

RE: Fourth Draft Orange County MS4 Draft Permit Comments

Dear Mr. Thibeault:

Thank you for the opportunity to provide comments on the fourth draft MS4 NPDES Permit for the County of Orange within the Santa Ana River Watershed (draft Permit). The San Bernardino County Municipal Stormwater Program is providing these comments in the event that the Regional Board may incorporate some elements of the draft Permit into the forthcoming renewed MS4 Permit for San Bernardino County.

As specified, our comments are limited to Sections XII.C.1 & 2 of the draft Permit. Section XII contains requirements for the permittees to incorporate Low Impact Development (LID) principles into their Water Quality Management Plan (WQMP) so that LID will be implemented within all "priority" development projects. Our comments focus on two concerns: 1) lack of clarity within this very complicated section of the draft Permit, and 2) an over-emphasis on full retention of stormwater runoff on site.

Lack of Clarity

It is difficult to provide constructive comments on Section XII as provided in the fourth draft. Section XII contains numerous requirements and considerations applicable to development projects, resulting in a very complicated section with overlapping and potentially conflicting directives. This complexity makes it difficult to fully understand precisely what development projects and local agencies must comply with, and at what stage of the development review process. We have provided a few examples below to illustrate this concern. Without a full understanding of how and when these requirements are to be applied, implementation is unlikely to be successful.

The single, most-needed improvement is a flow or process diagram that charts the process of site planning, design, and approval, and identifies where or when the requirements of Section XII come into play. Once a clear diagram is developed, Section XII should be reviewed and adjusted accordingly to simplify the requirements.

For example, Section XII.B.3 states: "WQMPs shall include BMPs for source control, pollution prevention, site design LID implementation (see Section C., below) and structural treatment control BMPs," and: "The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources. However, these requirements are not fully consistent with XII.C, which specifies a requirement to retain the runoff from the design storm unless found to be infeasible, and includes 21 separate paragraphs or points for consideration in LID implementation.

Section XII.B.4 provides four options for volume-based BMP design sizing, whereas Section XII.C.2 specifies the "85th percentile storm event (design capture volume)." Does this exclude the option in XII.B.4.A.3, which is a different calculation method?

Section XII.B.5.f states: " Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic); automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities." Does this mean that projects with these conditions do not have to conduct the feasibility analysis before selecting non-infiltration BMPs?

As our final example, Section XII.C.2 seems to reference the use of feasibility criteria that will be established as required in Section XII.E. Section XII.E specifies that the principal permittee and co-permittees "shall develop **technically-based** feasibility criteria". However, the maximum extent practicable standard, as defined in Footnote 2, Page 2, states:

> "MEP is not defined in the CWA; it refers to management practices, control techniques, and system design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, **technical feasibility**, **fiscal feasibility**, public health risks, **societal concerns**, and social benefits."

Since MEP is the overarching compliance standard for the draft Permit, we suggest the feasibility criteria must include more than technical considerations, including fiscal and societal concerns.

Overemphasis on Full Retention BMPs

The main focus of the most recent proposed changes in XII.C.1 & 2 is a determination within the draft Permit of what types of so-called "LID BMPs (best management practices)" are to be preferred over others. Specifically, the proposed language limits "LID BMP" implementation to design features that retain the 85th percentile, 24-hour storm event (the design storm as specified in Section XII.B.4) on site. Other "LID BMPs," that may be effective in pollutant removal and in attenuation of increased runoff volumes and velocities, may be considered for implementation only after on-site retention BMPs have been determined to be infeasible. Common examples that are not strictly infiltration BMPs include biofiltration features and vegetated filter strips. These are effective BMPs and are part of the LID "toolbox" as described in numerous LID Manuals. These BMPs may have

flow-through designs, but also increase infiltration and promote evapotranspiration. It is really a matter of degree. However, the current draft Permit will allow such BMPs only after a "vigorous feasibility analysis", using feasibility criteria to be developed under Section XII.E.

We strongly disagree with the limitation of this approach and suggest the draft Permit be revised before adoption to allow the full range of LID implementation. If this requirement is not revised, numerous feasibility determinations will result that require considerable staff time with questionable benefits to water quality. There are numerous credible sources of guidance that support a broader concept of and approach to LID. Three examples are provided below:

- " Low Impact Development is a site design strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial, and industrial settings" (Low Impact Development Technical Guidance Manual for Puget Sound 2005).

- "LID includes specific techniques, tools, and materials. LID practices include; bio-retention facilities or rain gardens, grass swales and channels, vegetated rooftops, rain barrels, cisterns, vegetated filter strips, and permeable pavements" (California State Water Resources Control Board 2009). Of the ten listed "LID Practices," number four is "Vegetated Swales, Buffers & Strips; Tree Preservation" (http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/index.shtml).

- "The goal of LID is to reduce runoff and to mimic a site's predevelopment hydrology by infiltrating, filtering, storing, evaporating, and detaining stormwater runoff" (USEPA, Incorporating LID into Municipal Stormwater Programs, April 2009--EPA 901-F-09-005).

If you have questions regarding these comments, please contact Matt Yeager at (909) 387-8112.

Sincerely,

KEVIN BLAKESLEE, P.E., Deputy Flood Control Engineer
San Bernardino County Flood Control District

KBB:MAY: nh/ Fourth Draft Orange County MS4 Draft Permit Comments

cc:

San Bernardino County Stormwater NPDES Coordinators
Julie Rynerson-Rock, Director, San Bernardino County Land Use Services Department
Chris Crompton, County of Orange
Jason Uhley, Riverside County Flood Control and Water Conservation District
ARI Reading File

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

May 8, 2009

Mark Smythe
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3338

Dear Mr. Smythe:

Pursuant to the Santa Ana Regional Water Board's May 1, 2009 notice, the following are EPA's comments on section XII.C.2 of the May 1 "Fourth Draft" Orange County Municipal Stormwater permit.

We appreciate that there has been extremely valuable progress on this permit. A few additional changes to the permit's Low Impact Development (LID) provisions are necessary in order to provide clarity and avoid future disputes over the interpretation of these LID requirements.

1. As you know, on April 21, 2009, EPA provided suggested revisions to section XII.C.2 of the April 10 "Third Draft." Based on some of the questions raised about the edited text, in the interest of clarity, we believe section XII.C.2 should be revised to:

> "The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and reuse, capture or evapotranspire the 85th percentile storm event ('design capture volume'), as specified in Section XII.B.4.A.1 above. Compliance with the permit's LID requirements may also be achieved by implementation of the alternatives specified in section XII.C.7 or by implementation of an approved waiver under section XII.E."

2. Section XII.C.2 of the May 1 Fourth Draft uses the term "bio-filter." The exact meaning of this term is unclear, and its use may not be necessary. For example, in some circumstances there is not a distinction between infiltration and biofiltration. In some EPA guidance, "bioretention" is used as an example of an infiltration technique. While we would support the text in footnote 56, we believe additional clarification is needed if the term "bio-filter" is included. Footnote 56 refers to "properly engineered and maintained" biofiltration systems. Criteria for the design and operation of these systems should be specified to ensure that the permit does not create a loophole which allows the use of systems that are inconsistent with LID principles. These specific design and operation criteria could be included in the permit. Alternatively, the permit could be revised to require the preparation of these biofiltration criteria as part of the feasibility criteria required pursuant to section XII.E.

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3. The text in section XII.C.2 refers to section XII.C.7 as a means for compliance. Sections XII.C.7.b, c, and d require that pervious areas have the capacity to "infiltrate, harvest and re-use, evapotranspire **or treat** at least the design capture volume." (emphasis added) The term "or treat," is not clear, and may not be necessary. Again, this could create a loophole that would allow the use of systems inconsistent with LID principles. We believe "or treat" should either be deleted from this section, or it should be defined. Should the Board decide to retain this concept, the word "treat" could be revised to "biotreat." Under this scenario, the hierarchy included in footnote 56 should be applied to the use of the term "biotreat" in this section, and the design and operation criteria described in comment #2 would apply.

4. Section XII.C.2 includes references to section XII.E. We understand some parties may have concerns with the project-specific waiver provisions in section XII.E. As a fundamental matter, we believe that the number of projects requiring waivers will be relatively small. If a project cannot manage the design capture volume as described in section XII.C.2, there generally should be broad opportunities to take advantage of the compliance opportunities available under section XII.C.7 to implement LID on a sub-regional or regional basis. As currently drafted, the permit requires that waivers issued pursuant to section XII.E be approved by the Executive Officer. Although we are supportive of the existing text in section XII.E, we would be open to revisions that do not require Executive Officer approval for waivers. It would still be necessary for the principal permittee to submit feasibility criteria for the Executive Officer's approval, and for individual projects to undergo a rigorous feasibility analysis pursuant to the approved feasibility criteria. The permit could be revised to provide the responsibility for approving project-specific waivers to the principal permittee. The permit would need to require that all requests for waivers, feasibility analyses, waiver justification documentation, and waiver conclusions be included in the principal permittee's annual report to the Regional Board.

Thank you for your continued efforts to develop a clear and protective permit. If you'd like to discuss these comments, please contact John Tinger at (415) 972-3518, or Eugene Bromley at 415-972-3510.

Sincerely,

Robyn A. Stuber for D. Eberhardt

Douglas E. Eberhardt, Chief
NPDES Permits Office

OC MS4 Tentative Order No. R8-2008-0030 (R8-2009-0030)
Comments/Responses

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
1	Lake Forest	General	N/A	The Draft Permit does not have a Table of Contents	Add a Table of Contents to allow easier navigation to various sections	Comment noted. Due to time constraints, the recommendation could not be implemented.
2	Irvine, County of Orange, Anaheim, Lake Forest,	Finding A5.c	The Permittees have the authority to levy service charges, fees or assessments to pay for compliance with this order.	Assessments to pay for compliance with this order must meet voter approval	Remove Section A.5c	Permit language has been revised to reflect the need for voter approval for some assessments.
3	County of Orange-Attachment B	General	Reference to Permittees	Reference to the Permittees is inconsistent throughout the permit.	Use the recommended language.	Permit language has been revised.
4	County of Orange-Attachment B	Finding A.3, Fact Sheet page 13	MEP definition	The definition of maximum extent practicable stated in the permit and the fact sheet are different and are not consistent with the case law.	Use recommended language.	Permit language has been revised.
5	Irvine	Finding C.8 and Section XVIII.B.3	This order is intended to regulate the discharge of pollutants…from anthropogenic…sources…not… background or naturally occurring pollutants	While this finding indicates an appropriate focus of the permit, Section XVIII, which addresses selenium in rising groundwater is not consistent with Finding C.8. Selenium should be addressed under the TMDL and NSMP programs.	Revise Section XVIII to make it consistent with Finding C.8.	Permit language has been revised to describe the co-operative process that is being used to address the selenium and nutrient impacted groundwater in the San Diego Creek Watershed.
6	Irvine	Finding C.10	Regional Board recognition that the permittees may lack jurisdiction over certain discharges	While this finding appropriately identifies the legal limitations of the co-permittees, Section XVIII requires co-permittees to address selenium in rising groundwater and copper in receiving waters when it's beyond their ability to eliminate those pollutants.	Revise Section XVIII to make it consistent with Finding C.10	Permit language has been revised to describe the co-operative process that is being used to address the selenium and nutrient impacted groundwater in the San Diego Creek Watershed. The sources of copper include controllable sources such as industrial sites.
7	Irvine	Finding 16.b, Finding K.56, Section	The 2007 DAMP includes all activities the permittees propose to undertake during the next permit	This finding references the Draft 2007 Drainage Area Management Plan, which has not been reviewed by the co-permittees.	Ensure that the co-permittees have had an opportunity to review and approve the entire 2007 DAMP prior to permit adoption.	The 2007 Draft Drainage Area Management Plan (DAMP) was submitted with the ROWD on July 21, 2006 by the principal permittee.

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
		II.B.2 and Section XIX.3	term.			
8	Irvine	Finding F.18	The County's storm water conveyance systems include an estimated 400 miles of storm drains	The 2002 MS4 permit stated that there were an estimated 400 miles of storm drains in the County and that number should have increased.	Revise estimate.	Finding has been updated to current conditions.
9	Irvine	Finding G.21	This order prohibits the construction of treatment BMPs within waters of the U.S.	This language is overly broad and appears to prohibit trash booms and Natural Treatment System facilities that are installed in retrofitted channels and basins.	Eliminate or narrow the prohibition against natural and structural treatment BMPs.	As stated in the current language of the draft permit, if discharge treatment sufficiently protects the beneficial uses of the receiving water, additional polishing within waters of the U.S. may be considered. Street sweeping, catch basin inserts/filters and catch basin cleanouts result in discharges that, for the most part, protect the beneficial uses of those receiving waters. The use of trash booms primarily protects the downstream beaches. Finding 21 indicates that treatment systems within waters of the U.S. could be considered on a case-by-case basis.
10	Irvine	Finding H.30	It is anticipated that many of the inspections required under this order can be carried out by inspectors currently conducting other types of inspections for the permittees.	It should not be assumed that additional duties added to current inspections do not lead to any additional workload or City resources.	Remove that language.	The permit language does not assume that no additional workload will result from these duties being carried out by inspectors currently conducting other types of inspections, but rather identifies possible workload savings using this strategy, rather than always sending out an additional inspector to address only storm water issues.

OC MS4 Tentative Order No. R8-2008-0030 (R8-2009-0030)
Comments/Responses

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
11	Irvine	Finding I.38 and O.74	Theses findings discuss the use of debris booms within apparent waters of the U.S.	This statement would appear to violate the restriction identified in Finding G.21, prohibiting the implementation of treatment BMPs in waters of the U.S.	Please clarify.	See response to comment 9.
12	Irvine	Finding J.43	TMDLs have been established by the Regional Board for… the San Diego Creek / Newport Bay watershed.	It is the City's understanding that the San Diego Creek/Newport Bay watershed is referred to as the Newport Bay watershed.	Please clarify.	Permit language has been revised.
13	Irvine	Finding K.55	The permittees have adopted grading and erosion control ordinances, guidelines and BMPs for municipal, commercial, and industrial activities.	The co-permittees have not adopted BMPs but instead the DAMP and LIPs contain guidelines for the implementation of minimum BMPs	*Revise to read: The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of minimum best management practices (BMPs) for municipal, commercial, and industrial activities.*	Permit language has been revised.
14	Irvine	Finding L and throughout	NEW DEVELOPMENT/ SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID	Throughout the draft order there should be a distinction between the model WQMP and the project WQMP.	Please differentiate between the project and model WQMPs	Permit language has been revised.
15	Irvine	Finding L.61	Finding identifies that the Southern California Coastal Water Research Project (SCCWRP) is developing a Low Impact Development Manual for Southern California.	It is our understanding that SCCWRP is not developing this manual.	Please clarify.	Permit language has been revised.
16	Irvine	Finding L.62	Finding identifies that USEPA has determined that by limiting the effective impervious area (EIA) of a site, downstream	USEPA has not determined that prescriptively limiting EIA to 5% or less is the best way to minimize receiving water impacts in all watersheds and for all physical conditions. With	Revise this finding to recognize other white papers and information submitted to the Regional Board and revise the New Development and Significant Redevelopment provisions to use a volume	Permit language has been revised.

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
			impacts could be minimized. A limited study conducted by Dr. Richard Horner concluded that a 3% EIA standard for development in Ventura County is feasible.	regards to Dr. Horner's study, additional white papers produced in meetings regarding this Orange County permit indicate that a 3% EIA standard may be inappropriate for incorporation into this permit.	treatment performance standard for LID implementation, more specific exemption criteria for when LID may be undesirable, and establish timelines for the development of watershed plans and LID/hydromodification control standards.	
17	Irvine	Finding L.66	Finding states that if certain BMPs are not properly designed and maintained, they could become sources of groundwater pollution, nuisance, etc.	While the City supports the more stringent requirements for use of LID BMPs, if LID infiltration BMPs are used in inappropriate conditions, they may be sources of pollution or nuisance.	Revise findings to indicate technical and environmental constraints on LID infiltration BMPs.	Permit language has been revised.
18	Irvine	Finding L.67	Finding states that if the BMPs in Finding L.65 are not properly designed and maintained, they could become sources of nuisance and/or habitat for vectors.	If LID infiltration BMPs are not properly designed or maintained, they may become sources of nuisance and/or habitat for vectors.	Revise findings to indicate that LID infiltration BMPs may become sources of nuisance and/or habitat for vectors if not properly designed or maintained.	Permit language has been revised.
19	Irvine	Finding M.68	Finding discusses de minimus discharges and states that municipal de minimus discharges generally do not require separate coverage under the Regional Board's de minimus permit.	This finding can be interpreted to mean that all de minimus discharges are prohibited in the San Diego Creek/Newport Beach watershed.	The language should be clarified. Further, the City supports the County comment that all de minimus discharges should be allowed unless a finding is made that those discharges are a significant source of pollutants.	Permit language has been revised to clearly state that a separate de minimus permit is required for non-storm water discharges to the MS4 in the San Diego Creek/Newport Beach watershed.
20	Irvine	Finding M.69	Finding points out the high nitrate and/or selenium levels in the soils and/or groundwater in the San Diego Creek/Newport	LID infiltration BMPs can also potentially mobilize nitrogen and selenium.	The findings should recognize that fact.	While the comment is valid, it was not the intent of Regional Board staff to identify <u>all scenarios</u> that could lead to mobilization of nitrogen and selenium in Finding 69.

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			Bay watershed and that dewatering activities could mobilize these pollutants.			
21	Irvine	Finding N.71	The principal permittee in collaboration with the co-permittees is to develop guidelines for the competencies and training schedules for municipal storm water positions.	While training is necessary, the City wants the flexibility to design and conduct training as well as the methodology for assessing the competency of staff.	Revise this finding and add an option to enable individual co-permittees to provide in-house training using curriculum developed by the principal permittee in collaboration with the co-permittees.	Permit language has been revised.
22	Irvine	Finding O.76	The finding discusses the importance of cooperation by public agency organizations within Orange County that have an impact on storm water quality.	More needs to be done to secure the participation of some of the larger public agencies within the Newport Bay Watershed, such as UCI.	Encourage state institutions and other major dischargers in the watershed, such as UCI, to join the NSMP and other applicable watershed efforts.	Regional Board staff will continue to work with the stakeholders whose activities and/or discharge contributes to the selenium/nutrient impacts in the watershed.
23	Irvine	Finding R.83	The finding discusses the elimination of illegal discharges and illicit connections to the MS4.	The terms 'illegal' and 'illicit' should not be used interchangeably	Determine correct/consistent terminology and use throughout the permit.	Permit language has been revised.
24	County of Orange, Riverside County Flood Control	General comment	General comment	The proposed permit increases administrative burden.	Adjust the current reporting requirements rather than increasing the reporting requirements.	Draft permit amended to streamline reporting requirements.
25	Riverside County Flood Control	General comment	General Comment	The basis for the Riverside County MS4 Permit should be the 2002 Riverside County MS4 Permit, not the Draft OC MS4 permit	The basis for the Riverside County MS4 Permit should be the 2002 Riverside County MS4 Permit	Comment noted
26	San Bernardino Stormwater Program	I.B.12	Requires permittee to develop adequate guidelines for competency	This requires developing an entire training program to be placed upon the shoulders of the Principal Permittee	These competencies are in a large part already well-established by CASQA and other organizations. It would be appropriate for the	Although guidance documents have been created by various organizations, it is the

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			requirements for stormwater managers, inspectors etc.		Principal Permittee to coordinate only the training effort	responsibility of the Principal Permittee to collaborate with co-permittees to develop a competency program specific to the requirements within this permit.
27	Irvine	Section I.B.12	Develop guidelines for defining competencies of municipal managers and inspectors	The competency of staff and the outcome of any evaluation of competency are confidential	The permittee cannot commit to providing any competency evaluations or reporting on confidential documents that are part of an employees' performance.	The permit language has been revised, with the understanding that deficiencies in a permittee's program that are the result of either management or staff's lack of understanding of the program will result in enforcement actions.
28	Orange County-Attachment B, Riverside County Flood Control	III.3.	Discharge limitation/prohibition	Make the prohibitions consistent with the federal regulations.	Retain language from Order No. R8-2002-0010.	Language revised to be consistent with the federal regulations, 122.26(d)(2)(iv)(B)(1).
29	Orange County-Attachment B, Riverside County Flood Control	III.3.	Public education to reduce non-storm water discharges	Remove the requirements for public education and outreach to reduce non-storm water discharges.	Retain language from Order No. R8-2002-0010.	Reducing non-storm water discharges could possibly reduce the pollutant load to the MS4s.
30	Orange County-Attachment B, Riverside County Flood Control	III.3.	Categories of non-storm water	Irrigation water from agricultural sources.	Runoff from agricultural sources should be addressed through other programs.	Permit language has been revised.
31	Irvine	Section III.3.i	The discharges identified below need not be prohibited by the permittees if they have been determined	The wording reverses the presumption found in Federal regulations that these de minimus discharges are not significant sources unless a	No submitted recommendation was submitted for this comment.	Permit language has been revised.

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			not to be substantial contributors of pollutants to the MS4 and receiving waters.	finding is made to the contrary.		
32	Irvine	Section III.3.i.l	Discharges of potable water (i.e., fire hydrant flushing) would have to be addressed as a de minimus discharge.	Discharges from fire hydrant flushing would require capture, analysis and volumetrically and velocity controlled discharges.	Change III.3.i.l to existing de minimus permit requirements by cross-referencing that permit.	The proposed permit conditions for the discharge of fire hydrant flushing waters remain the same as the de minimus permit with regard to residual chlorine concentrations. The proposed language regarding volumetrically and velocity controlled to prevent resuspension of sediments has been revised to read "…prevent hydrologic conditions of concern in receiving waters."
33	Irvine	Section III.3.i.l and XXI.5	With regards to emergency fire fighting flows, where possible, when not interfering with health and safety issues, BMPs should be implemented.	BMPs should only be required during controlled fire exercises and/or training. BMPs should not be required, even as 'where possible' for emergency situations.	Delete sentence referring to implementation of BMPs during emergency fire fighting operations, as well as the requirement in XXI.5.	While the sensitivity of implementing BMPs during actual fire fighting activities is understood, it is not unreasonable to expect BMPs to be implemented where feasible to meet the Maximum Extent Practicable threshold for permittee action.
34	County of Orange-Attachment A, Riverside County Flood Control	III.3.i.c	Irrigation runoff from agricultural sources	Runoff from agricultural sources is exempt from NPDES requirements.	Agricultural sources should not be included in this category.	Permit language has been revised.
35	Irvine	Section III.3.i.c	Irrigation water from agricultural sources.	Agricultural sources are non-point source, are not subject to NPDES permits, and are not currently the subject of Waste	The category 'irrigation water from agricultural sources' should be amended to read 'irrigation water' and the category 'irrigation water	Permit language has been revised.

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				Discharge Requirements or a Conditional Waiver of WDRs. Federal regulations do not specify agricultural irrigation runoff as a de minimus discharge to MS4 systems.	from agricultural sources' should be addressed through other Regional Board regulatory mechanisms.	
36	SDGE	III.3	Prohibition of non-storm water discharges unless the following conditions are met:	As the permit is currently worded, there could be some misunderstanding that non-storm water discharges covered under a separate permit may be considered prohibited	Revise sentence to read: The permittees shall prohibit the following categories of non-stormwater discharges unless such discharges are authorized by a separate NPDES and/or the stated conditions below are met.	Permit language has been revised.
37	Cypress	III.3 (ii)a	Discharge Limitations/Prohibition: Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing , and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm or less, pH adjusted if necessary , and volumetrically and velocity controlled to prevent resuspension of sediments.	The Orange County Stormwater program has developed BMP Fact Sheets FP-6 – Water and Sewer Utility Operation and Maintenance, FP-7 Fire Department Activities and IC-23 Fire Sprinkler Testing/Maintenance. In the absence of any Finding that existing control efforts are inadequate,	Specific requirements for the discharges identified in Section 3.ii.a should reference these Fact Sheets	Although the information contained within the Orange County Storm water program's Fact Sheets may be consistent with the requirements illustrated within this Section of the Draft Order and have been developed in order to comply with previous iterations of the Order, the Order itself sets the requirements for compliance. Fact Sheets have been prepared as a guidance tool to be used by co-permittees.
38	State Water Resources Control Board	III.3(ii)c	Dechlorinated swimming pool discharges: reduce volume and velocity to	Is the intent to prevent resuspension of sediments in the receiving water, the MS4 or the BMP?	Clarify information concerning comment and revise paragraph heading to read "Swimming Pool Discharge"	The proposed language regarding volumetrically and velocity controlled to prevent resuspension of sediments

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			prevent resuspension of sediments			has been revised to read "…prevent hydrologic conditions of concern in receiving waters." The paragraph heading as been revised.
39	Cypress	III.3(ii)c	Dechlorinated swimming pool discharges: reduce volume and velocity to prevent resuspension of sediments	Placing numeric limits for pool discharges affirms that the City is already doing by distributing the County's "Tips for Pool Maintenance" brochure.	The City wants to be certain the intent is not to make the City test each discharge or have the City require residents to obtain permits for such.	The criteria listed in this section should be used to establish municipal codes and enforcement procedures. In most cases, we do not anticipate the need for residual chlorine testing or permitting.
40	County of Orange	Section IV of the M&RP	Program Effectiveness Assessment	Use existing and newly generated data for program assessment in accordance with the CASQA Guidance.	Make program assessment requirements consistent with the recommendations in the ROWD.	The permit provides the permittees the option of using the CASQA Guidance or other technically sound methodology.
41	Orange County-Attachment B	Section VI	Reporting of State's General Permit violations.	Permittees do not enforce the State's General Permit.	Revise language as suggested.	Enforcement requirements have not changed from the 2002 permit; this approach avoids duplicative efforts and fosters cooperation among various regulatory/local agencies.
42	Irvine	Section VI.1,VI.3, VII.1	Such legal authority must address all illegal connections and illicit discharges into the MS4s, including those from all industrial and construction sites.	The legal authority documents (ordinances, etc.) give authority to the permittee to develop a program to control illicit discharges and illegal connections, but does not set forth the specific components of the program. Legal authority should not be confused with procedures and methods to accomplish compliance.	Revise the language of this requirement to indicate the role of the DAMP and LIPs in setting forth the program to address illegal connections and illicit discharges.	Permit language has been revised.

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43	Lake Forest	VI.2	The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance	This language (progressively and decisively) creates ambiguity about what is actually required.	None offered	The language in question reflects the progressive enforcement actions as referenced in the permittee adopted Orange County Enforcement Consistency Guide.
44	Anaheim, Villa Park, Cypress	VI.2	The permittees' ordinance must include adequate legal authority to enter, inspect, gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments	Concern about search and seizure laws and the necessity to obtain a Court Order are being looked into, should the current iteration of the proposed permit language remain as is. Villa Park states: Proposed language may be viewed as a violation of 4th amendment	Therefore, in order to ensure inspections may be conducted as intended through legal authority via municipal codes, the permit language should be retooled to avoid unnecessary efforts	Permit language has been revised.
45	Irvine	Section VI.2	The permittee's ordinance must include adequate legal authority to enter, inspect and gather evidence from industrial, construction and commercial establishments.	The City agrees with the County comments that this provision could impose entry requirements on the co-permittees that violate the 4th Amendment rights of property owners	"The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments…"	Permit language has been revised.
46	Lake Forest	VI.3	"these penalties shall be issued in a decisive manner	The term *decisive* creates ambiguity about what is actually required	None offered	The term decisive was used to infer a directly definitive, results-oriented enforcement process.
47	Villa Park, Cypress, Laguna Hill	VI.6	Permittees are to provide quarterly notifications w/	Quarterly reporting of enforcement activity is an administratively burdensome	Maintain current enforcement activity reporting requirements	Reporting requirements have not changed with respect to the information to be

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			inspection results to RB, for all inspections conducted at sites covered under the Statewide General Industrial and Construction Permits.	requirement for medium and small cities with little to no staff resources.		submitted. However, the frequency has been changed. Historically, many permittees have submitted inspection information on a monthly basis or immediately following the inspection event.
48	Fullerton, Costa Mesa, Brea, Irvine	Various	Additional reporting requirements throughout various Sections	The draft Order requires additional reporting to the Regional Board staff. The City believes that adjusting the existing reporting processes rather than creating additional reporting requirements is the most effective approach to increasing transparency and accountability	None	Information collected during the (third term permit) MS4 audits, concluded that additional reporting requirements were warranted. In order to ensure compliance with data collection requirements within the permit, various reporting requirements have either been sustained or introduced accordingly
49	Orange County-Attachment B	Section VII.5	Trash Characterization	Each Permittee should not be required to characterize trash.	Principal Permittee should be responsible for this.	While trash sources may not significantly vary among municipalities, the relative quantities of trash type will vary between municipalities and even within municipalities. The purpose of this study is to focus municipal resources (education and enforcement) on the most prevalent trash sources within the municipality in an effort to avoid a possible, future trash TMDL.
50	Orange	VII.5	Permittees to review their trash control ordinance. To determine the need for	Is the intent of the Permit to have each permittee carry out this requirement? It makes no sense to have each permittee conduct a	Revise the paragraph to require the principal permittee instead of the co-permittees to conduct the county-wide study over the 5 year	Permit language has been revised. See response to Comment #49

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			any revisions/ determine sources and proper BMPs to control urban runoff. Include findings in the Annual Report	county-wide study, since trash sources do not vary significantly among municipalities	permit term to characterize trash sources	
51	Orange, Cypress, Riverside County Flood Control	VIII.2	Construction site inventory to include all sites, within each co-permittee's jurisdiction for which building or grading permits have been issued where activities at the site include …..	The first part of the paragraph requires the inventory list is limited to sites with issued building or grading permits that raise concerns regarding water quality, but later contradicts itself by stating "all sites". This would include plumbing, encroachment or other indoor permits.	Change language to make it not contradictory. Exclude the GIS requirement from construction projects within the public right of way as well.	Permit language has been revised. .
52	Irvine	VIII.2	Construction site inventory to be maintained and updated quarterly	This requirement will be burdensome and unnecessary as it will just be created to satisfy a draft tentative order. Since construction project timelines are not short enough to result in meaningful additions to the inventory within the period of three months.	Updates should only be required on a biannual basis (in September, preparatory for the rainy season and rainy season inspections).	Maintaining and updating the site inventory quarterly is to ensure that records remain current concerning the regular and constant oversight of construction activities within each permittee's jurisdiction.
53	Irvine	Section VIII.4	Each permittee shall conduct construction inspections for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program…	Water Quality Ordinances do not include a reference to project WQMPs, which are post-construction documents.	Remove parenthetical entries. "Each permittee shall conduct construction inspections for compliance with its ordinances, local permits, the Model Construction Program…"	Permit language has been revised.

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54	Riverside County Flood Control		Construction site inspection requirement to include review of the Erosion & Sediment Control Plan	In addition to requiring a significant increase in the level of training and expertise of construction site inspectors, this requirement will significantly increase the amount of time needed for each construction site inspection	Exclude requirement from the draft Riverside County MS4 permit	The current (2002) OC MS4 permit already requires, inspection staff to have sufficient expertise in construction inspection processes as they relate to water quality and storm water related issues.
55	Lake Forest	VIII.6	"[e]ach permittee shall respond to complaints received by a third party in a *timely* manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters	The term "timely" creates ambiguity about what is actually required	None offered	Response to complaints must be handled in order of severity, with respect to the sites' potential to act as a pollutant source to the MS4. Therefore, the term "timely manner" was listed with the understanding that municipal staff receiving the complaint would be properly trained and equipped to determine how potentially grievous the pollutant threat could be and address it accordingly. The setting of an arbitrary time limit (e.g., within 1 business day) could put permittees in violation of the permit by not addressing very low priority complaints in that time limit.
56	County of Orange – Attachment A	Sections VIII, IX and X	Inspection requirements	The inspection requirements are well beyond federal law.	Make requirements in the permit consistent with the federal laws and regulations.	The inspection requirements are consistent with the federal laws and regulations. See 40CFR112.26(d)(2)(F) and the MEP provisions in Clean Water Act at Section 402(p)(3)(B)(iii).
57	County of Orange – Attachment A	Sections VIII, IX and X	Inspection requirements	Requirements beyond the federal requirements tantamount to unfunded mandate.	Unfunded mandates should not be part of this permit.	The permit requirements are consistent with the federal laws and regulations and,

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						therefore, are not unfunded mandates.
58	County of Orange – Attachment A	Sections VIII, IX and X	Inspection requirements	The inspection requirements violate the fourth amendment.	Make changes to the inspection requirements consistent with the state and federal laws and regulations.	Permit language amended.
59	San Bernardino Stormwater Program	VIII,IX,X	Inspection requirements	Requirement within these sections have new specific actions, such as electronic database, to check if sites have filed NOI, photos that need to be taken and included in the database, requirements for on-site enforcement actions.	We suggest that the permittees be allowed to prioritize and take enforcement actions based on their own criteria.	While the permittees have the ability to prioritize enforcement activities based on their own criteria to a certain extent, the Regional Board still has the obligation to set a minimum standard in the permit to ensure a level of consistency amongst the permittees.
60	Orange	IX.2	Facilities Covered under the General Industrial Permit are automatically considered as High Priority and therefore are required to be inspected.	History has shown that once a facility has been inspected at least once, there is an increased awareness of water quality impacts and facilities will implement BMPs to minimize storm water and non storm water discharges.	Allow redesignation of mandatory high priority facilities based on the suite of factors in the DAMP used to rank a facility.	The criteria by which facilities are identified for coverage under the General Industrial Permit are based on either their industry's potential to pollute and/or the actual exposure of materials, wastes, or processes to storm water. This criteria alone is sufficient for a mandatory 'high' priority.
61	Irvine	Section IX.3	Industrial inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and	The written documentation, in the form of storm water pollution prevention plan, is only required for facilities with industrial storm water permits. The burden of SWPPP review for compliance with the State's General Industrial permit should remain	Please clarify the intent of the industrial facility document inspections consistent with the City's comments.	Permit language has been revised to clarify that the '… written documentation of pollutant control BMP implementation and maintenance procedures …', refers to one of the four items required to be in a permittee-

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			maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection.	with the Regional Board staff. The City's inspections should continue to assure no ICs/IDs and compliance of facilities with City water quality ordinances and requirements		prepared inspection report. Those four items include: a written review of material/waste storage procedures; the written documentation of BMP implementation; photographic documentation of evidence of discharges; and, a listing of enforcement actions resulting from the inspection.
62	Westminster	IX.6 & X.5	Electronic inspection database submittal requirement in each annual report for Industrial and Commercial inspection programs	Clarify if permittees should submit only inspection inventory or the entire inspection database for these categories.	None. Request for clarification only	Permit language has been revised to allow the submittal of all inspection documentation/information in hardcopy form if a municipality's database uses a proprietary program (not Access or Excel compatible)
63	County of Orange	Section X	Commercial inspections	The permit extends the regulatory reach of local jurisdictions without technical justification.	Unjustified inspections should not be required.	Quantifiable inspection requirements are included to ensure an equitable level of effort across all permittees.
64	Irvine	Section X.1	Each permittee shall continue to maintain and quarterly update an inventory of the types of commercial businesses listed below.	Section X.1 requires 11 new, additional categories to be added to the commercial facilities inventory. It does not make sense to increase the commercial facility inspection burden so significantly in the time of budget constraint. Further, there's no indication in the ROWD that commercial facilities are currently such significant sources of pollutants to warrant this increase in inspections.	The new categories should be deleted until such a time that these types of facilities have been determined to contribute a significant pollutant load to the MS4.	The Fact Sheet and the findings have been revised. The revised permit language requires the Principal Permittee to prioritize these new categories based on potential threat to water quality.

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65	Orange County-Attachment B	Section X.1	Municipal inspections of commercial facilities.	There are 11 new categories included in the draft permit with out any technical justification.	These resource intensive inspection requirements should be deleted.	The Fact Sheet and the findings have been revised. The revised permit language requires the Principal Permittee to prioritize these new categories based on potential threat to water quality.
66	Orange County-Attachment B	Section X.1	Commercial inspection frequencies	Some of the facilities listed under the commercial inspection program should be under the industrial program.	Move industrial type of facilities under the industrial program.	Permit language has been revised.
67	Orange County-Attachment B	Section X.2	Commercial inspection frequencies	The permit arbitrarily assigns priorities for inspections.	The Permittees should be allowed to develop a prioritization system.	Audits conducted by Regional Board staff indicated that some Permittees were ranking all their commercial facilities as “low” even though similar facilities were ranked as “high” by other Permittees.
68	Orange County-Attachment B	Section X.8	Mobile businesses	No technical basis. Difficulty in regulating mobile businesses.	Principal Permittee to develop a pilot program.	A uniform prioritization criteria and inspection requirements are acceptable alternatives. Permit language has been changed.
69	Villa Park, Yorba Linda, Tustin	X.1	Permittees to maintain and update commercial facility inventories quarterly, in a computer-based database system with all third term permit inventory criteria, as well as information on ownership, size, location, GIS w/ Lat/Longitude	Quarterly updating of the commercial facilities database and the implementation of GIS tracking of commercial fixed facilities is a burdensome requirement that for medium to small cities with little to no staff resources is not viable	Maintain current commercial facility tracking requirements	Third term permit recommended annual updating of commercial inventories with GIS tracking capabilities. During the 3rd term permit, MS4 Audits conducted by Regional Board staff indicated the need for more regimented oversight regarding commercial inventory management. Therefore this recommendation transitioned into a requirement within the fourth term permit.

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70	Laguna Hills	X.1	Permittees to maintain and quarterly update an inventory of commercial facilities within its jurisdiction.	This section should be modified to allow the permittees to update the commercial inventory annually and submit it with the annual NPDES report	The requirements within this section should not be changed from the current 3rd term permit.	The purpose of maintaining an updated inventory list is to ensure that adequate oversight controls are in place. During the 3rd term permit, MS4 Audits conducted by Regional Board staff indicated the need for more regimented oversight regarding commercial inventory management.
71	Irvine	Section X.2 and X.3	Commercial facility inspection criteria	The mandate that 10%, 40% and 50% of commercial facilities be ranked high, medium and low is not based on technical data or on demonstrated risk posed by commercial facilities.	The DAMP and LIP provisions should instead be reviewed and revised to assure that the criteria result in adequate oversight. Secondly, high ranked sites should be inspected once per permit cycle rather than once a year and medium and low site inspections be dropped.	During the third permit term, the permittees were given the opportunity to design a commercial facility ranking system based on a number of criteria including type/size of activity, potential for pollutant discharge and history of pollutant discharges. Despite this opportunity, in the most recent annual report, some permittees are reporting few or no high priority commercial sites out of hundreds to thousands of sites that met one or more of the 11 categories listed in the third term permit. The 10/40/50 breakdown should be used to ensure that the 10% of commercial facilities with the highest potential for pollutant discharge be ranked 'high' and be inspected annually, similarly for the medium and low priority rankings.

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72	OC Public Works, Huntington Beach, Costa Mesa, Orange, Brea, Westminster, Villa Park, Lake Forest, Cypress, Laguna Hills, Yorba Linda, Tustin	X.2	10% of all commercial sites (excluding restaurants) shall be ranked "high" , 40% ranked medium and the remaining 50% ranked low	This new requirement will increase the annual inspection requirements to a point where resources are incapable of complying with the requirements. The inventory should be determined solely on a risk-based instead of a mandatory curve-based criterion.	Each permittee conduct inspections of its commercial facilities as indicated below. To establish priorities for inspection, the perrmittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharges, proximity and sensitivity of receiving waters, material used and wastes generated at he site. Within 6 mos. Of the adoption of this order, the Permittees shall review their existing prioritization system, criteria and results based on the inspections and determine if any modifications are necessary. The modifications shall be completed within 6 months of the determination and reported on in the annual report.	During the 3rd term permit, MS4 Audits conducted by Regional Board staff indicated the need for more regimented oversight regarding commercial inventory management and inspections within this section. The percentages indicated within this section were developed following extensive review of inspection information within PEAs submitted by co-permittees during the 3rd term permit.
73	Irvine, Westminster	Section X.3 and X.5	Commercial facility inspection documentation	The commercial inspection section that requires photographic documentation for all aspects of the inspection is too onerous.	Photographic evidence should only be required in the case of water quality ordinance violations and only in manner consistent with local, state and federal ordinance, regulations and laws.	Photographic evidence of all aspects of commercial inspections will assist permittees in supporting the appropriate enforcement action and will provide evidence during Regional Board audits that site conditions during inspections by municipal staff, are receiving the appropriate enforcement actions, if any.

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74	County of Orange	Section X.8	Mobile businesses	A new regulatory oversight is prescribed for mobile businesses.	The permittees have already developed BMPs for these businesses; additional requirements are not warranted.	Complaints received in the Regional Board office and Board staff's field observations indicate that these discharges have not been fully eliminated and additional measures are needed to control discharges from mobile businesses.
75	Villa Park, Cypress, Laguna Hills	X.8	Mobile businesses shall implement appropriate control measures within 3 months of being notified by permittees	It's unrealistic to expect that over any period of time it would be possible for the principal permittee to notify all mobile businesses operating within the County, of minimum source controls and pollution prevention measures that they must develop and implement.	…modify the requirement to read that "…the principal permittee shall utilize all reasonable resources to notify mobile businesses…"	Permit language has been revised.
76	ProntoWash	X.8	Mobile businesses shall implement appropriate control measures within 3 months of being notified by permittees	Require mobile operators to be inspected and trained in water quality control measures during the business licensing process.	During the licensing process, the mobile operations should be inspected and the operators should be trained on water quality protection procedures.	Many municipalities currently do not issue business licenses. Listed within Section X.8, are requirements for the permittee to distribute educational materials to businesses as well as a training program requirement.
77	Lake Forest	X.8	Mobile businesses shall implement appropriate control measures within 3 months of being notified by permittees	The regular, effective practice of unannounced inspections is difficult to impossible to implement. Identifying mobile businesses is difficult because they are often not permitted or licensed. Mobile businesses are transient in nature, advertise a mobile phone number as the only means of contact and may have geographic scope of several cities or the entire region.	Remove the mobile business requirements from the draft permit and instead, require the permittees to develop their own program for implementation during the next permit cycle.	Permit language has been revised.

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78	County of Orange, Villa Park, San Bernardino Stormwater Program	Section XI	Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4 to MEP…	No technical justification for the residential program. Remove the Residential Program from the Order completely	Recognize the fact that the current public education programs are working. Remove the Residential Program from the Order completely.	Despite implementation of public education programs, residential areas continue to be a significant source of pesticides, herbicides, nutrients and nuisance flows. Additional actions are necessary to further address these problems.
79	Irvine	Section XI.2	Identification of residential areas and activities that are potential pollution sources and requiring residents to implement pollution prevention BMPs.	Many aspects of this proposed requirement are already covered by Public Education activities. Further it may require passage of new ordinances forcing residents to implement specific minimum BMPs and those types of ordinances are unpopular.	Retain the residential program as part of the Public Education section and revise the key provision in the draft permit to : "The permittees shall ~~require~~ *encourage* residents to implement pollution prevention measures via the public education and outreach Program …".	Despite implementation of public education programs, residential areas continue to be significant sources of pesticides, herbicides, nutrients and nuisance flows. Additional programs are needed to address these problems. Some changes made to the provisions.
80	Orange County-Attachment B,	Section XI.2	Residential program	The requirement for a residential program is duplicative of existing public education and outreach activities.	Avoid duplicative requirements.	Permit language has been amended.
81	Anaheim, Fullerton, Costa Mesa, Brea, Cypress, Laguna Hills, Yorba Linda, Tustin	XI.2	The permittees shall require residents to implement pollution prevention measures	Requiring residents to implement best management practices is problematic	Change the wording to state: "The permittees shall *encourage* residents to implement pollution prevention measures*."*	Permit language has been revised.
82	Cypress	XI.3	The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes.	The city is concerned with the funding for conducting collection events.	The current County of Orange Household Hazardous Waste Collection Program has been working well since its implementation and agencies continue to do a good job making residents aware of this service. Change language from "shall" to "…***should*** *facilitate the proper collection and management*."	Requirements within this section have not changed essentially from requirements within Section I.4 of the 3rd term permit.

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83	Irvine	Section XI.4	Control measure requirements for common interest areas and areas managed by Home Owner Associations.	A limited pilot HOA program has been initiated by the City to educate certain property managers on the economic and water quality benefits of improved irrigation and landscaping practices. But the draft tentative order as currently written mandates that co-permittees must develop and implement new BMPs for common interest areas, including, we presume, structural treatment control BMPs as well as source control BMPs.	Revise the first sentence of this section as follows: "The permittees shall develop ~~and implement~~ a public education and outreach component to encourage owners …".	The tentative order requires the permittees to develop and implement a public education and outreach component to encourage HOAs to implement BMPs. Nothing in that section requires permittees to build or maintain BMPs on private property.
84	Cypress, Irvine	Section XII.A.2	Inclusion of LID requirements in WQMPs.	The 6-month time frame for this requirement is too aggressive and does not allow time to collect info on watershed characteristics, stakeholder participation and the time required for adoption of the revisions by local governments.	A more reasonable time frame should be established.	Much of the groundwork for this requirement has been completed through a series of meetings between permittees, environmental NGOs and development representatives. It should be noted that this deadline refers to the default plan. Watershed specific plans can be delivered after that date. Some changes have been made to the new development section of the permit.
85	Irvine	Section XII.A.4	The first annual report following adoption of this permit must include a review of the inclusion of LID principals in the General Plan and other city documents.	This requirement is out of sync with the actual requirements for updating the DAMP, LIPs and model WQMPs.	Revise the requirements so that a single, integrated update of these documents is implemented.	Permit language has been revised.

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86	Irvine	Section XII.B.2	The list of priority development projects requiring a WQMP	Items f and g of this section would require treatment control BMPs for single-family homes, if they were large enough. This would be too much of a burden on homeowners and on City staff required to review and inspect these BMPs.	Do not require WQMPs or treatment control BMPs for single-family homes.	This permit requirement will only affect projects on hillsides with a natural slope of 25 percent or more and projects that are within 200 feet of an Area of Biological Significance (ASBS). As such these projects need the extra level of protection afforded by the development of a WQMP and implementation of appropriate control measures.
87	Irvine	XII.B.2.c	Priority Development Projects would include commercial/industrial developments greater than 10,000 square feet.	The threshold has been lowered in this permit from 100,000 square feet to 10,000 square feet.	The fact sheet should explain the basis for lowering the threshold criterion.	Fact sheet has been revised to provide basis.
88	Irvine	XII.B.2.i	Priority Development Projects would include streets, roads, highways and freeways of 5,000 square feet or more.	Road projects as small as 5,000 do not and cannot properly involve changes to the drainage facilities. Further it is not feasible to implement a 5%EIA or LID BMPs for the 85th percentile design treatment volume.	Reconsider this requirement.	The permit will be revised including the incorporation of the concepts presented in "Managing Wet Weather with Green Infrastructure: Green Streets" (U.S. EPA, 2008)
89	Irvine	XII.B.5.a	Use of structural infiltration treatment BMPs shall not cause or contribute to groundwater water quality objective exceedances.	In the Newport Bay Watershed, there are areas where the use of any infiltration BMPs will result in mobilization of nitrogen and/or selenium.	Explicitly preclude the use of LID BMPs and exempt projects from LID implementation and hydromodification control performance standards in areas with shallow groundwater, polluted groundwater, inappropriate geotechnical conditions or rising groundwater.	The current Draft Permit language already contains sufficient warnings regarding the use of infiltration BMPs, including LID-type BMPs, without having to specifically add this language.
90	NAIOP	Section XII.C	Treatment and Low Impact Development (LID) BMPs.	It appears that the permit is biased against the use of a watershed-based or regional type solutions.	Allow as much flexibility as possible in order to achieve the permit's goals across the jurisdiction regulated by the permit.	Comment noted. The permit provides sufficient flexibility for regional and sub-regional type solutions.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
91	Irvine	XII.C.1	Requirements that LID site design principals be implemented to reduce runoff to the maximum extent practicable.	The list of site design BMPs provided is a confusing mix of goals, tasks and work products that don't provide a clear basis for compliance.	Separate the provisions to distinguish between recommended site design BMPs and other goals for the new development and redevelopment program.	Permit language has been revised.
92	Irvine	XII.C.2	Requirements for source control BMP implementation.	It is not clear why the major discussion of LID also includes prescribed source control BMPs.	Section XII.C.2 should be deleted from the current section and proposed as a separate section.	While the primary focus of Section C is on LID BMP implementation, source control BMPs, particularly when they're implemented through proper site design, play a play a role in LID.
93	Irvine	XII.C.4	Conditions for the substitution of treatment control BMPs for LID measures.	One of the conditions is for EIA to be 5% or less. How does one achieve an EIA of 5% or less without implementing LID?	Delete this section.	Permit language has been revised.
94	Irvine	XII.D	Hydromodification	It is not clear how the 5% or less hydrologic impact standard would be measured and does the standard allow for dense infill and transit oriented development as required by SB 375?	Revise and clarify section.	Permit language has been revised.
95	Irvine	XII.E.2	Structural treatment control BMP requirement met by regional treatment systems.	No mention of obtaining Executive Officer determination on regional treatment systems.	Please revise to clarify the need for Executive Officer approval of common project BMPs.	Permit language has been revised.
96	Irvine	XII.G.3	Prior to occupancy, permittees shall verify through visual observation that the BMPs are operational.	It will be impossible to ascertain the operation of BMPs prior to occupancy unless it rains between construction and occupancy	Revise to verification that BMPs are built according to approved plans prior to occupancy.	Permit language has been revised.
97	Irvine	XII.H	Change of ownership and recordation	The City already has a non-recorded mechanism that tracks the transfer of long-term maintenance and operation responsibilities from a developer to an appropriate operator upon completion of	Delete reference of recording any documents and explicitly allow other methods of tracking ownership and responsibility.	Permit language has been revised.

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				development. The recordation requirement should be left to the discretion of the permittees.		
98	ConTech	Section XII	5% Effective Impervious Area (EIA)	Reliance on a 5% EIA standard is inappropriate. The water quality benefits of applying a 5% EIA standard on a site-by-site basis are unknown.	Support the approach outlined in the January 2009[1] white paper. Use delta volume (post minus pre-development) from the water quality design storm event.	Permit language has been revised based on the water quality design storm event.
99	ConTech	Section XII	Treatment and Low Impact Development (LID) BMPs.	Treatment and LID BMPs inspection and maintenance requirements are not well defined.	All water quality and/or water quantity control BMPs should have maintenance and inspection requirements.	Permit language has been revised.
100	ConTech	Section XII	Post-construction	There is no standard for selection of post-construction BMPs	Provide standards for selection of post-construction BMPs.	There are a number of handbooks (e.g., CASQA[2] BMP handbooks) available for this purpose.
101	ConTech	General	Potential pollutants of concern	Match potential pollutants with control BMPs.	The permit should require that pollutants be controlled by matching with appropriate BMPs.	There are a number of handbooks (e.g., CASQA[3] BMP handbooks) available for this purpose.
102	NRDC/OCC[4]	Section XII	Need for LID metrics	To ensure compliance with the Clean Water Act, quantifiable measures must be included.	Support the use of an EIA limitation in the permit; a 3% EIA limitation is recommended.	Comment noted. The 5% EIA metric in the permit has been replaced with a volume capture metric.
103	NRDC/OCCCI CWQ	Section XII	EIA definition	Change the EIA definition to include full onsite retention of a design storm event. EIA is not clearly defined.	The design storm should not be the delta volume from a 2-year storm event; it should be the full volume. Include a design storm volume.	The draft permit has been amended to incorporate appropriate design storm criteria.
104	NRDC/OCC	Section XII	EIA definition	The tern “percolate” is not defined.	Revise the permit such that BMPs are required to have the capacity to “infiltrate, harvest for reuse, or evapotranspire”.	Permit language has been changed.

[1] January 2009 white paper=
[2] CASQA=California Stormwater Quality Association
[3] CASQA=California Stormwater Quality Association
[4] OCC=Orange County Coastkeeper

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105	NRDC/OCC	Section XII	Waiver Provisions	Existing waiver provisions are very broad. The permit's waiver provisions should include a floor for all projects to meet.	The permit should include a provision to implement all feasible LID BMPs and must include a provision for offsite mitigation of storm water not retained onsite. The permit should define technical infeasibility. Rewrite the waiver provisions to include establishment of an "urban runoff fund". Include time limitations for the expenditure of funds.	Permit language has been revised to provide clarification.
106	NRDC/OCC	Section XII	Waiver provisions	The permit must impose limits on water quality credit system to ensure equivalent benefits within the watershed.	Having a cap of something like 50% or less of the volumetric requirement should be considered.	Waiver provisions have been revised.
107	NRDC/OCC	Section XII	Prioritize LID BMPs	A hierarchy of BMPs should be included.	Include a preferred approach of BMPs.	Permit language has been revised.
108	NRDC/OCC	Section XII	Treatment Control BMPs	LID should not be a substitute for treatment control BMPs.	Any project exercising this option should be required to provide 1:1.5 mitigation offsite.	Permit language has been revised to provide clarification.
109	NRDC/OCC	Section XII	Hydrologic conditions of concern	No waiver should be provided for discharges to engineered hardened conveyance channels.	Do not allow this waiver provision.	The waiver provision has been revised.
110	NRDC/OCC	Section XII	Priority projects	Support the inclusion of projects with a threshold of 5,000 sq ft impervious area.	Add clarifying language to Section XII.B.2.(a)	Permit language has been revised.
111	NRDC/OCC	Section XII	Groundwater Protection	The 10' separation requirement may be overly restrictive.	A 5' separation requirement may be appropriate.	The 10' separation is a conservative approach; there is an option for a case-by-case consideration of other options.
112	NRDC/OCC	Section XII	LID Metrics	A critique[5] of the January 2009 white paper (see footnote 1).	The critique provides some arguments in support of a 3-5% EIA metric and provides an analysis of some of the other findings of the January 2009 white paper (see footnote 1).	The January 2009 white paper and its critique have been considered in the revision of some of the LID provisions in the permit.

[5] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner.

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113	CICWQ[6]	Section XII	LID/Regional BMPs LID BMPs should be preferred	Support LID; regional BMPs and off-site solutions should be considered.	Both provisions are in the current draft.	Comments noted.
114	CICWQ	Section XII	LID design storm	A 2-year, 24-hour design storm is not appropriate.	Consider a design storm as specified in the DAMP.	Permit language has been revised.
115	CICWQ	Section XII	LID	LID BMPs should be the preferred approach.	LID BMPs should be required of all projects.	Permit language revised.
116	CICWQ	Section XII	HCOC	HCOC should be considered on a watershed specific basis.	A technically sound hydromodification plan should be permitted.	Permit language has been revised.
117	CICWQ	Section XII	Watershed Master Plan	Support such a plan.	Include a provision in the permit to require development of a watershed master plan or plans.	Permit language has been revised and a new section has been added.
118	NAIOP	Section XII	Watershed Master Plan	The entire issue surrounding hydromodificaton, infiltration and addressing water quality is very complex. The draft permit seems to want to approach it with a focus on a project by project basis.	Watershed Master Plans can be developed such that water resource goals can be integrated to address water quality, hydromodification, water supply and habitat issues.	Comment noted. Some changes have been made to the new/re-development section of the permit.
119	CICWQ	Section XII	Capture volume	Permit should not require make up of capture volume off site or require a fee.	Delete all requirements for off site mitigation.	The preferred option is 100% LID implementation on site. Off site mitigation is one option where full on site implementation of LID BMPS are not feasible.
120	CICWQ	Section XII	LID feasibility	Permittee should decide whether LID is feasible.	Permittees should have the option to require conventional or LID BMPs on a site-specific basis.	LID BMPs are cost effective and provides water quality and quantity benefits. As such, LID should be the preferred option. Permit does provide other options.
121	CICWQ	Section XII	LID guidance	Additional time is needed to develop LID guidance	Provide 12 months to develop LID guidance and revise WQMP.	Much of the required information is already in the WQMP and six months should be enough to consolidate readily available information.

[6] CICWQ=Construction Industry Coalition on Water Quality

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122	CICWQ	Section XII	WQMP Contents	Revise the requirements specified in the draft permit for revising the WQMP.	Delete Section XII.B.3(a) of the permit.	While some revisions to the permit have been incorporated, Section XII.b.3(a) is still applicable.
123	CICWQ	Section XII	Design volume	Capture volume should be SUSMP volume.	Delete references to 5% EIA and include a capture volume design based on the SUSMP design criteria.	The design volume has been changed to SUSMP criteria.
124	CICWQ	Section XII	HCOC	Hydromodification control strategies should be those recommended in the GeoSyntec white papers[7].	Use control strategies as defined in Attachment 4 (see footnote 7).	Some changes have been made to the permit based on this white paper and other discussions at the stakeholder meetings.
125	CICWQ, NAIPO	Section XII	Areas of agreement	1) EIA or other metrics may be used for LID. 2) Capture volume design may be based on WQMP criteria. 3) LID BMPs should be prioritized. 4) Offsite mitigation needed if on site treatment is not provided		Comments noted and agreed upon items are reflected in the revised draft.
126	County of Orange	Section XII.G	Field verification of BMPs	The requirement to inspect treatment control BMPs is burdensome.	Allow self certification and/or third party verification.	An option is added for self-certification and/or third party verification.
127	County of Orange	Section XII	LID/HCOC	The Model Water Quality Management Plan addresses LID and HCOC; additional mandates and metrics need careful consideration.	Areas of agreement: A performance standard other than the 5% EIA. Water quality design volume at 85th percentile. Prioritize LID BMPs.	LID and HCOC sections have been amended to reflect areas of agreement and to provide clarity.
128	County of Orange-Attachment A	Section XII	Land use authority/LID	The permit intrudes upon local land use authority.	Requirements, such as the 5% EIA requirement, are in contravention to the separation of powers.	As an agency of the State of California, the Regional Water Board has full legal authority

[7] Orange County MS4 Permit Stakeholder Sub-Group Examining LID BMP and Hydormodification Control Sizing Alternatives, prepared by Geosyntec for the January 27, 2009 Sub-Group meeting.

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						to implement LID requirement in this permit, including the 5% EIA requirement. Furthermore, the 5% EIA requirement was one of the options provided as a quantifiable measure for determining compliance with the LID/HCOC provisions of the permit. Other options were also provided in the permit. Providing several tools for compliance determination does not intrude into local land use authority. (The 5% EIA requirement has been amended.)
129	County of Orange-Attachment A	Section XII	Land use authority/LID	Prescribing a method of compliance is a violation of Section 13360 of the Water Code.	Do not specify a method of compliance.	As indicated above, the 5% EIA was one of the tools for compliance determination. Further, the Regional Board is well within its legal authority to determine what is included in the MEP standard.
130	Orange County-Attachment B	Section XII	New Development/re-development	Revisions to proposed land development provisions are needed.	Revise “grandfathering” provision.	Permit language has been revised.
131	Orange County-Attachment B	Section XII.A.2	WQMP guidance	Revisions should be in the LIP.	Modify permit language.	Permit language has been revised.
132	Orange County Attachment B	Section XIIA.6	CEQA review	Annual review of CEQA process is unnecessary.	Modify permit language.	Permit language has been revised.
133	Orange County Attachment B	Section XII.B.2	Commercial/industrial development	The threshold has been changed w/o technical justification.	Provide justification for changing it from 100,000 to 10,000 square feet.	Fact Sheet has been revised.
134	Orange County Attachment B	Section XII.B.2.(c)	Streets, roads and highways	The LID provision is difficult to implement.	Make it consistent with the U.S. EPA requirements.	Permit language has been revised.

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135	Orange County Attachment B	Section XII.B.2.(j)	Retail gasoline outlets	The DAMP includes BMPs for these types of facilities.	Avoid duplicative efforts.	The BMPs in the DAMP, along with LID and other requirements, should be considered for these types of facilities.
136	Orange County Attachment B	Section XII.B.3.	WQMP goals	Goals are written as specific requirements.	Revise permit language.	Permit language has been revised.
137	Orange County Attachment B	Section XII.B.5	Structural infiltration BMPs	No technical basis for the 10 feet separation for infiltration systems, light industrial category and for high vehicular traffic.	Consider the proposed regulations developed by State Board for onsite wastewater treatment systems.	Permit language provides for other options on a case-by-case basis.
138	Orange County Attachment B	Section XII.B.7	WQMP for non-priority projects	Certain non-priority projects may not require a WQMP.	A WQMP should not be required of all projects.	The permit language provides other options.
139	Orange County Attachment B	Section XII.C.1	LID design principals	The design BMPs is a confusing mix of goals, tasks and work products.	Revise the list.	Permit language has been revised.
140	Orange County Attachment B	Section XII.C.2	LID site design	Source control BMPs should not a part of this discussion.	Should delete this section.	Permit language has been revised.
141	Orange County Attachment B	Section XII.C.3	LID/EIA	5% EIA is not appropriate.	Use other LID metric.	Permit language has been revised.
142	Orange County Attachment B	Section XII.C.4	Substitution of LID/treatment controls	This provision, as written, does not appear to be correct.	Provide clarification.	Permit language has been revised.
143	Orange County Attachment B	Section XII. D.1	HCOC	An assessment of a project's impact on the hydrologic regime should not be required for all projects.	For some projects, there may not be a hydrologic condition of concern.	Permit language has been revised.
144	Orange County Attachment B	Section XII.D.2	HCOC	5% EIA should not be the metric for hydrologic conditions of concern.	Express the metric in terms of runoff volume.	The metric for hydrologic condition of concern has been changed.
145	Orange County Attachment B	Section XII.D	HCOC	An additional provision should be added to this section to include HCOC mapping as an option.	Add an interim provision till development of an appropriate LID metric.	Permit language has been revised.

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146	Irvine	XIII.J.1	The LID and hydrologic conditions of concern provisions are not applicable to projects that have an approved WQMP as of the date of adoption of this order.	Under the DAMP and LIPs, project WQMPs are prepared at a conceptual level to be used as planning documents and at a project level, to implement the concept project WQMP planning document. It is unclear whether the conceptual level WQMPs will be grandfathered in as were the land use approvals in the 2002 permit.	Revise to specify land use approvals that will determine development projects that are grandfathered and those that are not.	Permit language has been revised to further identify the level of approval/stage of planning where the requirements of this permit do not apply.
147	Irvine	XIII.3	Public education requirements include making 10 million impressions per year.	There must be a clear definition for an impression. Currently an impression can consist of anything from driving past a pollution prevention banner to and extended face-to-face interaction with a member of the public.	Consider a more effective way of evaluating the effectiveness of a public education program rather than relying on impressions. If impressions must be used, develop a standardized method of determining what qualifies as an impression.	While it is agreed that a more precise method of measuring the impacts of each and every public education interaction would be advantageous, trying to evaluate the effectiveness of City bus placards (depends on the route of the bus), City bill mailing inserts (determining percentage of inserts dumped without seeing, glanced at or actually read), etc., may be more tedious.
148	County of Orange-Attachment B	Section XIII.4	Public Education and Outreach	Requirements for annual business-related workshops may not be very useful.	Suggest modifying the language to include chamber of commerce or other outreach efforts.	Permit language has been revised.
149	County of Orange-Attachment B	Section XIV	Municipal facilities	Annual inspection requirement should be only for open channel systems.	Change annual inspection requirements to open channels only.	Permit language has been revised.
150	Irvine	XIV.7	Report on the effectiveness of debris boom	Do debris booms violate the restriction on treatment BMPs being employed in waters of the U.S.?	Clarify the Regional Board's position.	No violation exists (see Comment 9).
151	Irvine	XIV.10	Permittees shall examine opportunities to retrofit existing	A 2005 retrofit study performed by RBF Consultants has not been adopted or approved by the	The 2005 RBF Retrofit Study should not be mandated as the basis for co-permittee retrofit	The permit requires that a retrofit study be performed and a report on the study be

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			storm water conveyance systems and parks with water quality protection measures and report within 12 months of permit adoption	principal permittee, is still in draft form and co-permittees have not had the opportunity to review the draft.	programs until the co-permittees have had an opportunity to review, comment, and approve the final draft, as required in the current MS4 permit for any program developed by the principal permittee.	submitted within a year of permit adoption. If the 2005 study is still current/valid, that study could be submitted after review, and if not then a new study would have to be initiated.
152	County of Orange-Attachment B	Section XVI	Training program	Revise annual training requirement to be consistent with the County program (2 year frequency).Permittees should be given an option to have their own training programs.	Change training frequency requirements.	Permit language has been revised.
153	Irvine	XVI.2	Water quality training program curriculum	Permittees should be able to tailor their training programs. Non-management staff should not be responsible for knowing the whole storm water program, just their discrete tasks.	Revise order to allow greater flexibility in tailoring course curriculum to be appropriate to an employee's area of responsibility.	Permit language has been revised.
154	Irvine	XVI.3	Training modules should include an outline of the curriculum, a training procedure at the end and Certificate of Completion.	Mandatory training and practical application workshops should provide an alternative to a Certificate of Completion, which raises employment and labor issues.	Delete reference to testing requirements, certifications and Certificates of Completion.	Permit language has been revised.
155	Irvine	XVI.4, XVI.5 and XVI.6	At least on an annual basis, the principal permittee shall provide training to staff on Fixed Facility Model Maintenance procedures, Field Program Model Training, etc.	While this section explicitly states that the principal permittee shall provide training, where city management is competent in the storm water program, they should be allowed to provide that training in-house. Cities with a demonstrated or perceived deficiency may benefit from training provided by the principal permittee.	Revise the tentative order to allow individual cities to provide in-house training rather than participate in training administered by the principal permittee or by their consultants.	Permit language has been revised with the understanding that deficiencies in a permittee's program that are the result of either management or staff's lack of understanding about the program could result in enforcement actions.
156	Irvine	XVI.7	The principal permittee shall notify Regional Board staff at least 30	This notification requirement should not be applied to the initial training given to new	Revise the tentative order to allow documentation of training summary information in the annual report	By notifying Regional Board staff, by email, prior to conducting training, it gives

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			days prior to conducting training sessions.	employees, but only to the annual training given to all appropriate staff. Further, providing a summary training in the annual report be used in lieu of contacting Regional Board staff.	rather than notifying Regional Board staff of it's occurrence, but at minimum clarify that new employee training sessions do not require Regional Board notification.	Regional Board staff the opportunity to sit in on the training to ensure that the quality of the training meets the requirements of the permit. The Regional Board is also interested in the initial training for new storm water program employees
157	Irvine	XVI.8	Permittee shall adequately train staff within 60 days of being assigned duties related to the storm water permit.	It would be impractical for the principal permittee or their consultant to provide training within 60 days of every new co-permittee hire. If co-permittees are responsible for this training then it makes sense for co-permittees to be responsible for training existing staff.	Add an option to enable individual co-permittees to provide in-house training for new hires using curriculum developed by the principal permittee in collaboration with the co-permittees.	Permit language has been revised.
158	Irvine	XIV	None	Sections are misnumbered	No recommendation submitted.	Section numbers corrected.
159	U.S. EPA	XVIII.B.2	TMDL applicability	Although 2007 TMDL listed in this section have been adopted by the Regional Board, they have not been submitted to the State Board for approval. Until the State Board, OAL and the EPA have approved these TMDLs, they are not applicable.	Continue to implement the currently approved 2002 TMDLs until the 2007 TMDLs have been approved by the State Board, OAL and EPA	Permit language has been revised to include both 2002 and 2007 TMDLs.
160	U.S. EPA	XVIII Tables 1A/B		These tables do not accurately reflect the WLA's for urban runoff in EPA's 2002 TMDLs. Additionally, the table should clarify that the WLAs are intended to be enforceable effluent limits.	Compliance with WLAs could be required in accordance with the time frame envisioned by the Board's implementation plan, since this would be consistent with the intent of the EPA TMDLs.	Tables have been revised
161	County of Orange-Attachment A	Sections III.3.i and XVIII.B.3	Selenium in rising groundwater	The source of selenium in the rising groundwater should be considered as a non-point source	Since selenium is from a non-point source, it should not be regulated under the NPDES permit.	The release of selenium has been caused, in part, due to anthropogenic

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				and should not be subject to the NPDES permit.		hydromodification of the watershed. 40 CFR 122.26 requires the prevention of illicit discharges, which includes selenium contained in rising groundwater, into the MS4 system.
162	County of Orange-Attachment B, U.S. EPA	Section XVIII.B.3	Selenium and nutrient TMDL	Make the collaborative language more explicit.	Use suggested changes.	Permit language has been revised to describe the co-operative process that is being used to address the selenium and nutrient impacted groundwater in the San Diego Creek Watershed.
163	County of Orange-Attachment B, U.S. EPA	Section XVIII.E	Numeric effluent limits	The reference to numeric effluent limit is not accurate.	Recognize these as wasteload/load allocations.	Permit language has been revised.
164	County of Orange-Attachment A	Section XVIII.B.4	San Gabriel River metals TMDL	The permit inappropriately implements TMDLs developed by the U.S.EPA.	The requirements in the permit are for Coyote Creek; the upper reach of Coyote Creek is not listed as an impaired waterbody and therefore this requirement is inappropriate.	While the San Gabriel River metals TMDL lists the portion of Coyote Creek that lies within the Los Angeles Region, the upstream portion of Coyote Creek that lies within Orange County is one of the sources of pollutants responsible for the exceedances in the lower Coyote Creek, San Gabriel River and San Gabriel Estuary. The San Gabriel River metals TMDL contains a specific Waste Load Allocation of the MS4 discharge to the upper Coyote Creek. Moreover, the Coyote Creek TMDL was

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						promulgated by USEPA, and pursuant to 40 CFR 122.44, the Regional Board is required to incorporate this TMDL into the NPDES permit. The Regional Board does not have the authority to revisit and revise a USEPA promulgated TMDL.
165	County of Orange-Attachment A	Section XVIII.B.4	San Gabriel River metals TMDL	Since the Santa Ana Regional Board's Basin Plan does not include an implementation plan for Coyote Creek TMDL, this requirement is not consistent with the Clean Water Act and the TMDL requirements. For San Gabriel River.	This TMDL's requirements are outside the scope of authority given to the Regional Board by the Clean Water Act's NPDES program.	These TMDLs where promulgated by US EPA and notification and the opportunity to comment was given to the entities that discharge to these impacted waters. There is no state or federal law requirement that the Regional Board adopt the USEPA promulgated TMDL into the basin plan (and develop an associated implementation plan), prior to incorporating the TMDL into the NPDES permit pursuant to 40 CFR 122.26.
166	U.S. EPA	XVIII.C Tables 5a & 5b	Tables illustrating future Fecal Coliform TMDL's	These tables contain errors in that the first two rows of each table both include "TMDL for Fecal Coliform". It appears that one of these rows should present the WLA for urban runoff.	Make necessary changes in tables as deemed appropriate. Additionally, clarification language should be added to reflect that urban runoff WLA's are intended to be permit effluent limits	Tables corrected and clarification added.
167	U.S. EPA	XVIII.D.1	Diazinon and chlorpyriphos TMDLs for San Diego Creek and Newport Bay	The permit does not explicitly state that diazinon and chlorpyriphos WLAs are intended to be permit effluent limits and that the permittees shall comply with the wasteload allocations in	Add language in this section that states "The permittees shall comply with the following wasteload allocations in tables 6a and 6b." Additionally, the Fact Sheet should discuss the current compliance	Permit language has been revised.

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				tables 6a and 6b.	status of the permittees with the WLAs; given the phase-out of these pesticides within urban areas.	
168	U.S. EPA	XVIII.D.4	Sediment load allocations for Newport Bay and San Diego Creek	The permit should include firm dates for the submittal of monitoring data presenting the 10-year running averages.	The permit should include firm dates for the submittal of monitoring data presenting the 10-year running averages.	Permit language has been changed.
169	U.S. EPA	XVIII.E.2	Compliance with TMDLs	Language should be clarified for consistency with the rest of section XVIII.	Recommend revising language to read: "Based on the TMDLs, numeric effluent limits have been specified to ensure consistency with the wasteload allocations."	Permit language has been revised.
170	Irvine	XIX.B.4	"The Management Committee shall meet at least six times a year to discuss issues related to permit…"	Has the Permittee Committee's name been changed to the Management Committee?	Please clarify.	Permit language has been revised.
171	County of Orange-Attachment C	Monitoring and Reporting	Bioassessment	Integrate this requirement with the regional bioassessment programs.	Integrate monitoring programs.	Permit language has been revised.
172	County of Orange	Monitoring and Reporting	Land use correlation	This information has already been collected.	Eliminate the land use correlation element.	Permit language has been revised.
173	County of Orange	Monitoring and Reporting	Bacteriological monitoring	Intense bacteriological monitoring has been conducted for the last four years.	Reduce bacteriological monitoring requirements.	Permit language has been revised.

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	COMMENTS RECEIVED ON THE MARCH 25, 2009 DRAFT					
174	NRDC	ROWD MRP IV.2.b	Permit renewal application	The permit renewal application is incomplete as it did not include an assessment of controls.	ROWD should have included an assessment of control measures and their effectiveness in removing pollutants.	The ROWD was posted for public comments. No comments were received and we accepted it as complete after providing 30 days of public notice and review period. We believe that the requirement in the Monitoring and Reporting Section of the draft order for program effectiveness analysis is an appropriate requirement to address this issue.
175	Orange	Fact Sheet	Section IX	Fact sheet still refers to 5% EIA	Delete this reference.	Fact sheet language has been amended.
176	BIA	General	Maximum extent practicable (MEP)	Some stakeholders misrepresent the meaning of MEP.	MEP is “hortatory” (i.e., merely encouraging or exhorting) and permit requirements should be based on the real meaning of MEP.	This comment appears to take issue with characterizations of the term MEP made by other stakeholders. Thus, the comment is noted, but no substantive response is given as the Regional Board cannot speak for other stakeholders.
177	Cypress			Please give further consideration to previously submitted recommendations.		Comment noted.
178	Contech Stormwater Solutions	Finding 66 and 67	Requires proper design of BMPs	Vortex systems, filters, and catch basin inlets have no connection to groundwater and cannot therefore cause groundwater pollution.	Remove these BMPs from this finding.	The finding also references these BMPs becoming a nuisance and/or cause surface water pollution. Improper maintenance of the aforementioned BMPs can result in these problems.
179	County of Orange	Various	Reporting requirements	The County believes that the refining of existing reporting	Revise reporting requirements.	The permit has been revised giving the permittees the

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				mechanisms is the most effective approach to increasing transparency and accountability		opportunity to propose alternative reporting methodologies contingent on the approval of the Executive Officer.
180	County of Orange, Irvine, Lake Forest	Various	Deliverables and submittal dates	Compliance submittals within 6 months or with the first annual report may not provide enough time to budget and complete work.	With the exception of the hydrologic conditions of concern mapping, revise compliance dates to at least one year after permit approval.	For the majority of these deadlines, the compliance dates have been revised.
181	NRDC	III	Non-storm water discharges	Prohibit non-storm water discharges.	Include a prohibition on non-storm water discharges.	The permit provisions are consistent with the Clean Water Act and the federal regulations (40 CFR 122.26(d)(2)(iv)(B). The federal regulations state that certain types of de minimus discharges need not be prohibited from the MS4s unless they are identified by the permittees as a significant source of pollutants.. Section III.1 of the draft order prohibits all other types of non-storm water discharges.
182	Golden State Water Company	III.3	De minimus discharge requirements	Does section III.3.ii refers to discharges from all entities or just municipal permittees?	Clarify requirement.	Permit language has been amended to clarify that this section only applies to discharges from municipal permittee owned/operated facilities and activities.
183	Laguna Hills	VI.6	Construction and industrial inspections	The new requirement that cities notify the Regional Board regarding violations at sites that are State General Permittees is unwarranted	Remove this requirement.	This requirement was in previous permit (Order R8-2002-0010 – Section VI.5). Further, coordinated enforcement actions will enhance water quality and meets the MEP threshold for this MS4 permit.

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184	County of Orange	IX.10 and X.11	Coordination of inspections with Regional Board staff	The current limited resources available to both the Regional Board and permittees to conduct inspections makes coordination of these activities a priority. It is recommended that a formal framework for inspection responsibilities be established.	Revise permit accordingly.	Permit language has been added identifying this goal.
185	Laguna Hills	X.1	Quarterly update of commercial facility inventory	The City already updates it's commercial inventory on a continuous basis.	Allow permittees to constantly track facilities.	The permit has been revised to give the permittees an opportunity to devise an alternate updating methodology that's approved by the Executive Officer.
186	Huntington Beach	X.2	Prioritizing commercial sites.	Requirement will increase number of inspections 10-fold.	Allow self-inspections of commercial sites 4 of 5 years and have cities inspect once per permit term.	While analysis of the permittee's commercial site database revealed numerous commercial businesses not listed in X.1.a-s, which could probably be dropped from their inspection database without threat to water quality, the permit has been revised to lower the Medium priority percentage to 20%. In the April 10, 2009 draft, Section XII.2 provides an option for the permittees to develop a scheme for prioritization and inspection of commercial sites.
187	Laguna Hills	X.2	Prioritizing commercial sites	The assignment of arbitrary percentages for high, medium and low priority sites means if a City has already assigned 100% commercial sites a High priority, it will have to downgrade at least 40% to meet the requirement.	Permittees should be given the flexibility as to designating its facilities without being restricted by the Regional Board.	During the 3rd term permit, MS4 Audits conducted by Regional Board staff indicated the need for more regimented oversight regarding commercial inventory management and inspections

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						within this section. If the example cited by the commenter arises, certainly, having 100% High priority ranked sites would be going beyond the minimum standards set by the permit and would not be viewed as a violation. Section XII.2 provides an option to develop a scheme for prioritization and inspection of commercial sites.
188	Irvine	X.2 and 3	Inspections of commercial sites	The new 10/40/50 High/Medium/ Low commercial breakdown will require that the City perform an additional 985 inspections per year resulting in an additional annual cost of $279,700.	Make use of the 10% High priority, but only require inspections of High priority sites.	While communication with the permittee has revealed some problems with their estimates, revisions to the permit have lowered the Medium priority percentage to 20%. In addition, Section XII.2 provides an option to develop a scheme for prioritization and inspection of commercial sites.
189	County of Orange	X.2 and 3	Commercial facility inspections	The permit should provide an opportunity to develop a risk-based scheme as an alternative to current permit language.	Revise permit accordingly.	Section X.2 now provides the permittees an opportunity to develop a prioritization scheme for inspections. The commercial inspection program was introduced in the 2002 permit cycle. The permit requirements prescribed a minimum of the program's structure. As a result of permittee's implementation of the program, further prescription of a minimum program was warranted.

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						Through implementation of the program proposed in the current draft permit, a more efficient program should evolve for the next permit cycle.
190	Huntington Beach, Irvine	X.3 and X.5	Photographic documentation of commercial sites	Permit requires photos of waste & material handling BMPs which is beyond the requirement for industrial sites.	Require photos only to document violations.	Photographic documentation of waste and material handling practices will ensure that sufficiently substandard storage is appropriately documented as a violation by the permittees and will allow Regional Board staff to more accurately evaluate permittee inspection/enforcement activities during audits.
191	Orange	X.3	Commercial inspections	The proposed 10/40/50 (high/medium/low) priority breakdown will require an additional 900 inspections per permit cycle for the City.	Either maintain current flexibility or introduce the 10% mandatory 'High' priority and inspect remaining 90% as needed.	While the 900 additional inspections/permit cycle works out to 4 additional inspections a week, the priority breakdown has been adjusted to a minimum 10/20/70.
192	BIA	Section XII	CEQA	Integrate MS4 permit requirements into the CEQA documents.	Use CEQA to integrate LID principles into the project at an early stage.	We agree; there are a number of requirements in the draft permit requiring such integration (e.g., see Section XII.A.4 and 6)
193	NRDC	XII	New Development	This section should be revised to require meeting MEP standard.	Include clarifications to ensure that Permittees meet MEP standard.	Clarifications added.
194	NRDC	XII	Documents submitted for review and approval	The public should have an opportunity to review and comment on the documents submitted for approval.	Revise permit language.	Permit language revised (See Footnote 55).
195	Irvine	XII.A.7	Project approval process requirement	None	Clarify that the update of the project approval process is the same as for the DAMP finalization.	Permit language has been revised.

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196	Lake Forest	XII.B and C	Implementation of LID	Implementation of LID and hydromodification requirements will not always be feasible, in particular there is concern about implementing the USEPA's 'Green Streets' guidance document.	None	The permit addresses situations where requirements may not be feasible and provides suitable alternatives in these situations (See Section XII.E).
197	NRDC	XII.B.2	List of priority projects	Revise the list to make it clear.	Revise the list to make it clear.	List revised.
198	Orange	XII.B.2.b	New Development	By revising permit language to include subdivisions with less than 10 units, if there's a combined 10,000 sq. ft. of imperviousness, the permit may now require single family homes to be priority development projects.	Retain the language exempting subdivisions of less than 10 units.	If the threshold of 10,000 sq. ft. of impervious surface is exceeded there is the potential for a similar level of pollutant load and alteration of the hydrologic regime, whether that area is divided between 10 residential units or less than 10.
199	Orange	XII.B.2.c and j	Priority Development Project classification	It is unclear whether the 10,000 square feet refers to land area or building area.	Clarify	Permit language has been amended to indicate that 10,000 sq. ft. refers to impervious area.
200	Orange County Business Council	XII.B.2.h	WQMPs for streets	The requirement for adherence to US EPA's 'Green Infrastructure" for public streets will increase costs and may not be possible.	Remove this requirement.	The incorporation of the US. EPA guidance document was at the suggestion of some of the stakeholders. Further, XII.B.2.h only requires the incorporation of the US EPA guidance document to the Maximum Extent Practicable.
201	NRDC	XII.B.5	Infiltration systems	The specified separation needed for infiltration systems to groundwater of 10' should be revised.	Make the separation 5'.	Permit language revised.
202	Irvine	XII.B.5(a)	Structural infiltration BMPs	Structural infiltration BMPs should meet minimum requirements that they not increase seepage or exfiltration of contaminated groundwater	Clarify language.	Permit language states that infiltration systems shall not cause or contribute to groundwater water quality exceedances (Section XII.B.5.a).

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203	Orange County Water District	XII.b.5.f	LID – Infiltration requirements	Footnote 50 restricts infiltration in sites known to have soil 'and' groundwater contamination. The word 'and' should be replaced with the word 'or.'	Revise permit language.	The footnote (54 in 3rd draft) has been revised.
204	Orange County Water District	XII.B.5.f	LID – Infiltration requirements	There are some land uses that should be restricted from infiltration whether or not there is current contamination (e.g., gas stations).	Include restrictions on infiltration for sites that have a high threat to water quality	The tentative order includes restrictions on infiltration systems in high vehicular traffic areas. We believe that this restriction along with the underground storage tank regulations should provide the needed groundwater protection from infiltration systems.
205	Contech Stormwater Solutions	XII.B.5.f	Structural infiltration BMPs	In high traffic areas, infiltration BMPs should have a minimum 75 gallon spill retention capability for diesel/hydraulic fluid spills.	Add requirement.	Rather than risking groundwater contamination by spills greater than the design volume of a proposed BMP, it is more prudent to prohibit infiltration BMPs in the situations presented in XII.B.5.f.
206	Orange County Water District	XII.C	LID – Infiltration requirements	OCWD would encourage the creation of a comprehensive map of Orange County identifying areas suitable for infiltration.	Require data to be collected and a map to be prepared.	The permittees are encouraged to prepare a Watershed Master Plan (see Section XII.D.5) to address LID infiltration and hydrologic conditions of concern in a comprehensive manner. Also Section XII.E.1 of the order requires the permittees to develop feasibility criteria for implementing LID BMPs.
207	Orange County Water District	XII.C	LID – Infiltration requirements	From a management and monitoring standpoint, grouping or clustering infiltration systems on a regional basis would make sense.	Consider the grouping of infiltration systems.	Sections XII.D.5 and XII.E of the order provides an opportunity for the permittees to develop LID infiltration systems on a regional or sub-regional basis.

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208	Orange County Water District	XII.C	LID – Infiltration requirements	Data needs to be collected in Orange County to assess the potential impacts to groundwater quality due to dry wells, infiltration galleries and poorly maintained infiltrations systems.	Revise permit language.	A requirement for developing a monitoring program for the infiltration systems has been added to the tentative order (see Section XII.B.5.g).
209	Orange County Water District	XII.C	LID – Infiltration requirements	An anti-degradation analysis in terms of groundwater quality should be provided in the Order.	Revise permit language.	We do not believe that any further anti-degradation analysis is needed as the infiltration systems are required to be designed to mimic pre-development hydrologic conditions with proper controls for pollutant sources.
210	Orange	XII.C	LID requirements	Redevelopment and in-fill projects may not be able to meet the LID requirements.	Exempt redevelopment and in-fill projects from LID requirements where sites drain to hardened or engineered channels.	While permit language in the 3rd draft, acknowledges that sites for which all receiving waters are hardened do not need to meet hydrology modification requirements, LID implementation also addresses pollutant transport by reducing the runoff responsible for the transport. So were possible, LID BMPs should be implemented.
211	Irvine	XII.C	LID requirements	It should be made clear that "LID requirements do not apply to development of conceptual or project WQMPs approved prior to 12 months after permit adoption…"	Clarify language.	XII.J clearly states that the only fully grandfathered projects are those that already have an approved WQMP. For all projects for which conceptual or project WQMPs are approved after the adoption of the permit and prior 90 days after approval of the revised model WQMP must implement the provisions in Section XII of the permit to the maximum extent practicable.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
212	Irvine	XII.C	Hydrologic conditions of concern requirements	It should be made clear that "hydromodification control requirements do not apply to development of conceptual or project WQMPs approved prior to 12 months after permit adoption…"	Clarify language.	XII.J clearly states that the only fully grandfathered projects are those that already have an approved WQMP. For all projects for which conceptual or project WQMPs are approved after the adoption of the permit and prior 90 days after approval of the revised model WQMP must implement the provisions in Section XII of the permit to the maximum extent practicable.
213	Orange County Business Council	XII.C	LID requirements	The permit should make clear that capture and infiltration is not required where infeasible or impractical.	Clarify permit.	The permit already makes this clear. See Section XII.E.1.
214	CICWQ	Section XII.C.	Conventional treatment control BMPs	Conventional treatment control BMPs should be considered only as a last resort.	Require structural treatment controls only if LID BMPs are infeasible.	We agree.
215	CICWQ	Section XII.C	LID BMPs	NGOs references to more restrictive volume controls for MS4 permits are not relevant.	Most references are from guidance documents and are not included in the adopted MS4 permits.	We agree that most references are not from adopted MS4 permits. Nevertheless, some of these are useful guidance documents for implementing LID.
216	BIA	Section XII.C	LID BMPs	The Board should include filtration as an acceptable LID BMP.	Include "filtration" as an LID BMP.	We have no objection to considering filtration as a second-tier LID BMP. This should be done on a case-by-case basis.
217	BIA	Section XII.C	LID BMPs	100% on-site retention should not be mandated. Reject any "universal retention doctrine".	Allow for "natural flow doctrine".	The draft permit does not require 100% on-site retention.
218	NRDC	XII.C	LID	LID provisions should be clearly articulated with performance standards.	Revise daft permit language.	Permit language has been revised.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
219	NRDC	XII.C	LID	LID BMPs must meet the MEP standard.	Provide clarification.	Permit language revised.
220	County of Orange	XII.C.1 and 2	LID requirements	Clarifying text change recommendations were provided for these sections.	Revise permit accordingly.	Permit language has been revised to include some of the recommended changes.
221	Contech Stormwater Solutions	XII.C.2.b	LID BMPs	Permit should not limit permeable paving alternatives.	Allow alternatives to permeable concrete or porous asphalt.	Permit language has been amended.
222	Contech Stormwater Solutions	XII.C.2.b	LI D BMPs	The phrase “minimize pipes, culverts and engineered systems…” should be replaced.	Replace statement with a more general “minimize changes to the time of concentration on site.”	Recommended language has been incorporated into the permit.
223	Orange	XII.C.3	Infiltration BMPs	Dry wells are listed as an allowable BMP, but may result in groundwater contamination	Require consultation with local water district prior to approval of dry wells.	Permit language has been revised.
224	Contech Stormwater Solutions	XII.C.4	LID BMP design requirements	While the goal of LID BMPs might be capturing the 85th percentile event, it shouldn’t be a design requirement	Delete this section.	The permit already provides options for sites where conditions rule out treating the 85th percentile event through LID BMPs.
225	Contech Stormwater Solutions	XII.C.5	Treatment BMP requirements	This section does not specify any level of treatment that is required by BMPs.	Specify the treatment control BMPs must be designed to have medium or high effectiveness based on full-scale, in-field testing.	The current Model WQMP has a similar requirement and it will be carried over in the Model WQMP approved for this permit.
226	CICWQ	Section XII.C. 5 & 7	LID BMPs	The current language in provisions 5 and 7 restricts the application of all available LID BMPs. These provisions include a universal mandate to infiltrate.	Include a second tier option for biofiltration, bioretention, filter strips, etc.	We believe that the most effective LID BMPs are those that infiltrate or harvest and re-use storm water onsite. The bio-treatment types of BMPs should be considered on a case-by-case basis.
227	Contech Stormwater Solutions	XII.C.7.a-b	LID BMPs	It is overly prescriptive to dictate where BMPs should be implemented.	Delete these sections.	The intent of this permit language is to encourage mimicking natural conditions where localized detention areas address the majority of storm events.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
228	Orange County Business Council	XII.D	Hydrologic modifications	The permit should recognize that most, if not all, in-fill projects are incapable of mimicking the pre-development hydrologic regime.	Clarify permit	The permit already acknowledges that not all sites will be able to meet this requirement on-site and provides suitable alternative compliance mechanisms.
229	Orange, County of Orange	XII.D.2.b	Hydrologic Conditions of Concern (HCOC)	Second draft of the permit has added that HCOC may exist for downstream hardened channels if those channels are Waters of the U.S. In the City's experience, all conveyance channels have been considered Waters of the U.S. by the Army Corps of Engineers.	Delete the added statement.	Permit language has been revised.
230	Irvine	XII.D.2(b)	Hydrologic conditions of concern exemptions	The permit language that currently exempts hardened channels from requiring hydrologic controls should be expanded to include stabilized channels	Clarify language.	If channels are engineered and regularly maintained to ensure design flow capacity, they do not have a hydrologic condition of concern per the third draft permit language.
231	CICWQ	Section XII.D.2.(b)	HCOC	The addition of the last sentence eliminates any waivers for HCOC.	Delete the last sentence.	The last sentence has been deleted.
232	NRDC	XII.E	Alternatives and in-lieu programs	The alternatives should be better integrated.	Revise permit language.	We did not see the need for any additional changes.
233	County of Orange	XII.E.1	Alternative and In-lieu programs	Clarifying text change recommendations were provided for this section.	Revise permit accordingly.	It's the judgment of Regional Board staff that the language currently in the draft permit more accurately portrays staff's intent.
234	Irvine	XII.H	Structural treatment BMP tracking	This section requires permittees to establish a mechanism to track structural BMPs and ensure that proper easements are recorded and conveyed to new owners.	There are already procedures in place at the County Recorder's office and through permittee's WQMP approval processes that address these requirements.	If the permittees can ensure that the requirements set forth in XII.H are being addressed then XII.H is satisfied.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
235	Laguna Hills	XII.H.1	Ensure that structural treatment control information is tracked with ownership change.	Recorded information is already transferred to new owner and City should not be held responsible for keeping track of this.	Delete requirement.	If the permittees can ensure that the requirements set forth in XII.H are being addressed then XII.H is satisfied.
236	Lake Forest	XII.I.3	Structural treatment BMP database	It appears that the requirement is that all BMPs installed to date would have to be included.	Limit database to only newly constructed BMPs.	Permit language has been revised.
237	Irvine	XII.I.5	Structural treatment BMP inspections	Current permit language limits inspection of these BMPs to the dry season. Further, because the number of these BMPs will increase every year we request that the number inspected be dropped from 50% to 25%.	Revise permit	The need to ensure that the BMPs are functional during the wet season requires inspection prior to the wet season. However, the inspection quantities have been reduced to 25% per year with 100% coverage during every 4 year cycle.
238	Lake Forest	XII.I.5	Structural treatment BMP inspections	The number of these BMPs will be increasing every year, becoming burdensome.	The permit should allow self inspections or use a representative sampling	Permit language has been revised.
239	Laguna Hills	XIII.4	Commercial business training	Business owners will not attend training during the work day.	Rely on education during site visits.	Because site visits for some facilities may not occur until the end of the permit cycle, site visit education can only be one part of an overall business education system.
240	Orange	XVI.3 and 4	Permittee employee training	The requirement for testing and Certificates of Completion infringes on the City's right to set employee class specifications.	Allow attendance sheets or other proof that training has been completed in place of Certificates of Completion and allow other procedures to substitute for testing to verify an employee's understanding of the curriculum.	Section XVI.3 has been amended to include other methods of course completion.
241	NRDC	XVIII	TMDL	Specify that the wasteload allocations (WLA) are enforceable permit limits.	Make WLAs enforceable permit limits.	Permit language revised.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
242	NRDC	XVIII	TMDL	Prohibit new sources and new dischargers from discharging into 303(d) listed waters.	Include a prohibition on new sources and new dischargers into impaired waters.	First, while new development or redevelopment in an urban area may change the characteristics of the discharge entering the MS4 and hence the receiving water, each new development or redeveloped area does not constitute a new source or discharge. Further, the intent of the current MS4 permit is to address pollutant loads through an iterative BMP process. Moreover, the case primarily relied on in this comment, *Friends of Pinto Creek v. USEPA*, 504 F.3d 1007, did not involve an MS4 permit. Rather, it involved an individual NPDES permit for an individual discharger discharging directly into a water of the United States. Here, NRDC asks that the Regional Board expand the holding of that case to prohibit discharges into an MS4 system. These are two very different contexts, as the regulatory scheme/NPDES permitting requirements for an MS4 system are distinct from that of an individual discharger discharging directly into federal waters. Thus, to the extent that *Friends of Pinto Creek* is factually, distinguishable from the current situation, the holding is not applicable to this permit.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
243	County of Orange, Lake Forest	XVIII.B.10	Coyote Creek TMDL	TMDLs adopted by another Regional Board should not be applied outside their jurisdiction. Regulated entities should have the opportunity to participate and dispute the adoption of a TMDL.	The Coyote Creek TMDLs should not be included in this permit.	This TMDL was promulgated by USEPA. While the San Gabriel River metals TMDL lists the portion of Coyote Creek that lies within the Los Angeles Region, the upstream portion of Coyote Creek that lies within Orange County is one of the sources of pollutants responsible for the exceedances in the lower Coyote Creek, San Gabriel River and San Gabriel Estuary. Further, the San Gabriel River metals TMDL contains a specific Waste Load Allocation of the MS4 discharge to the upper Coyote Creek. We also note that the permittees that discharge to the listed waters were notified during the TMDL stakeholder process and commented on the TMDL at that time. See also response to comment numbers 164 and 165.
244	Lake Forest	Distribution list	None	Saddleback Valley School District was not included.	Include the school district.	The school district has been added to the list of other entities with the potential to discharge pollutants to the Orange County storm water system.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
	COMMENTS RECEIVED ON THE APRIL 10, 2009 DRAFT					
245	NRDC	XII	The permittees shall incorporate LID site design principles to reduce runoff to MEP.	The language in this Section of the tentative order requires a feasibility analysis before any LID BMP is required, as opposed to providing an "out" in situations of true infeasibility. This would mean that you would have to prove feasibility in each situation which is very problematic for many reasons and cuts against the common agreement by all that LID is generally feasible at some scale.	Modify Permit language.	During the public hearing on April 24, 2009, staff proposed a change to address this issue. This change is reflected in the 4th draft of the permit. Further changes may be made to Sections XII.C.1 & 2 based on comments on the 4th draft and any revisions will be addressed at the May 22, 2009 Regional Board meeting..
246	NRDC	XII	LID design criteria	The permit language does not require retaining the water on site from the design capture storm unless Infeasible. Rather, it says to capture and if you cannot you can use LID and conventional treatment BMPs. This doesn't seem to provide any requirement to retain the design storm when it can be done.	Change language to include a clear measurable performance standard that requires landscape-based treatment, on-site retention, and/or storage for re-use. These should be written in order to incorporate clear, enforceable LID requirements. Qualifier language such as: 'to the extent feasible' and 'as practicable' should not be used.	During the public hearing on April 24, 2009, staff proposed a change to address this issue. This change is reflected in the 4th draft of the permit. Further changes may be made to Sections XII.C.1 & 2 based on comments on the 4th draft and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
247	EPA	XII.C.1	LID BMPs	The Tentative Order states that projects that "meet the feasibility criteria" shall implement the permit's specific LID provisions. The feasibility criteria are prepared as a separate deliverable by the permittees (under section XII.E), and require EO approval. With this language, LID requirements will not apply until the permittees prepare an approvable feasibility criteria.	Modify Permit language.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
248	EPA	XII.C.2	LID criteria	As it is currently written, the tentative Ooder opens the door to allow the use of conventional treatment controls in-lieu of LID BMPs.	LID BMPs should be considered for each priority development project.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
249	Orange County Water District	XII.B.5(d)	The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 5 feet.	The Water District was concerned about the uncertainty factor in determining historic high groundwater and recommended a minimum 10 feet separation.	It would be prudent to specify a 10 feet vertical separation in the permit.	Permit language was modified in the 4th draft permit.
250	County of Orange	Finding J.52		Reference to 40 CFR citation is wrong.	Modify Permit language.	Permit language was modified in the 4th draft permit.
251	County of Orange	XVIII		Technical TMDLs (TMDLs with no implementation plans) should not be included in the permit	Delete technical TMDLs from the permit.	40 CFR 122.44(d)(1)(vii)(B) requires that this MS4 permit be consistent with the applicable waste load allocations in TMDLs and does not exempt those without implementation plans.
252	Riverside County Flood Control	Various	`	Commenter references numerous findings and permit requirements and requests that either they not be included in the Riverside County permit or be included with changes.	None	Comment noted.
253	Latham & Watkins, CICWQ,	XII.C.2 and 7	LID Implementation	Approved LID BMPs should include bio-treatment.	Modify Permit language.	Bio-filtration has been added to XII.C.2 in the 4th draft permit and may need to be added elsewhere within the permit to achieve consistency.
254	County of Orange, OC Coastkeeper, CICWQ	XII	Watershed Master Planning	Commenters support the inclusion of Watershed Master Planning and want it to be mandatory.	CICWQ supports the use of Watershed Master Plans. The County of Orange and OC Coastkeeper jointly submitted language making Watershed Master Plans mandatory.	The permit language proposed by the commenters was incorporated in Section XII.D.5
255	Prontowash	X.8	Mobile Commercial Source Program	Permit should require mobile car detailer to contain all discharge.	Revise permit language	The permit currently prohibits mobile car wash discharge as a non-storm water discharge and requires municipalities to prohibit this discharge.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
256	CICWQ	XII.C.2	LID	Provide clarification for the word "capture"; does it include bio-treatment.	Make the definition of LID consistent with the USEPA definition to include bio-treatment.	The 4th draft of the permit addresses this issue.
257	CICWQ	XII.C.3	Design "strategy"	Request replacing the word "strategy" with the word "preference"	Modify permit language.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
258	Geosyntec, County of Orange	General	Assessment of Pollutant Reductions	Response to NRDC comments	Response to NRDC comments	Comments noted.
259	Geosyntec, County of Orange	General, LID	LID Metrics	A response to Dr. Horner's critical comments on "LID Metrics in Storm Water Permitting".	Response to critical comments.	Comments noted.
260	Latham& Watkins	General, New Discharges	"New "discharges to impaired waters	A response to NRDC's comments regarding the applicability of Friends of Pinto Creek v. U.S. EPA.	Latham & Watkins analysis concludes that this case is not applicable to the Orange County MS4 permit.	Comments noted.
	ORAL COMMENTS RECEIVED AT THE APRIL 24, 2009 PUBLIC HEARING (Extracted From Audio Records, May Be Supplemented Based On Transcripts, When Available.) (Comments Reflected In Written Correspondence Not Duplicated.)					
261	City of Lake Forest	Various		Keep in mind financial considerations and maximize the flexibility of permit requirements.		Comment noted.
262	County of Riverside	Various		The County wants the opportunity to base their new permit on their old permit.		Comment noted.
263	County of Orange	XII.C.1	LID Implementation	Recommends phasing in the LID requirements over an 18-month period instead of immediately, as reflected in the U.S. EPA proposed language.	Revise implementation date to 18 months.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
264	County of Orange	XII.C.2	LID Implementation	If LID is required prior to the establishment of the feasibility criteria, as proposed in the U.S. EPA language, how do the permittees determine if LID is in fact infeasible at a site?		This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
265	County of Orange	XVIII.B.9	Coyote Creek TMDLs	The Los Angeles Regional Board should identify the load for dischargers in the Santa Ana Region. The Santa Ana Region should then determine impairment, list the impaired waters and develop TMDLs for those impaired waters. Only Santa Ana Board adopted TMDLs should be in the Santa Ana permit.	Modify Permit language.	The San Gabriel River TMDLs (including Coyote Creek) and the waste load allocations associated with those TMDLs were promulgated by the U.S. EPA and therefore this Permit must be consistent with those TMDLs as provided in 40 CFR section 122.26. Please see responses to comments number 164 and 165.
266	CICWQ	XII.C.1	LID Implementation	Put back the portion of XII.C.1, deleted in the proposed U.S. EPA language.	Modify Permit language.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
267	CICWQ, City of Irvine, County of Orange	XII.C.2	LID Implementation	Strike the language added in the U.S. EPA changes in XII.C.2.	Modify Permit language.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
268	CICWQ, Michael Recupero	XII.C	LID Implementation	Clarify that bio-filtration is consistent with U.S. EPA definition of LID	Modify Permit language.	Bio-filtration has been added to XII.C.2 in the 4th draft permit and may need to be added elsewhere within the permit to achieve consistency.
269	CICWQ	XII.C.3	LID Implementation	Replace the word 'strategy' with the word 'preference'.	Modify Permit language.	The word "strategy" may be replaced with the word "goal" as discussed at the April 24, 2009 public hearing.
270	GeoSyntec	XII.C	LID Implementation	Keeping the design storm volume on site will not always work, in many cases evapotranspiration is the key transport mechanism and replacing that with infiltration may have unintended consequences.	None	Comment noted.
271	OC Coastkeeper	XII.C	LID Implementation	This permit should have a three-pronged approach with Watershed Master Plans and an internet based information	None	Comment noted.

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				system with hydrologic data for builders and planners.		
272	City of Irvine	XII.C	LID Implementation	It should be made clear that if the design storm volume is addressed through bio-treatment and there is subsequent discharge to the MS4, no further treatment or offset is required.	Modify Permit language.	This issue is under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
273	City of Orange	XII.J.1	Pre-Approved Projects	The permit language may not include all projects that have already received approval by the municipalities.	Ensure that permit language includes all projects approved by municipalities.	The current permit language recognizes this and requires implementation of LID BMPs consistent with the MEP standard.
274	Lennar Homes	XII.C.7	Regional Treatment	Regional treatment should be allowed without a waiver requirement and without additional treatment or offset.	Modify Permit language.	The draft permit includes provisions for regional treatment. The Watershed Master Plan, Section XII.D.5, should be used as another tool to incorporate regional treatment systems.
275	Michael Recupero	XII.C.1	Feasibility criteria	Does the language proposed by U.S. EPA strike the feasibility analysis?	None	While the feasibility analysis is not eliminated, the timing of LID implementation and the approval of a model WQMP (including feasibility criteria) are under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
276	Michael Recupero	XII.C	Feasibility criteria	What will be the threshold for infeasibility and who decides it and does every project not implementing LID for the full 85th percentile 24-hour storm require a Regional Board granted waiver?	None	These issues are under review and any revisions will be addressed at the May 22, 2009 Regional Board meeting.
277	Michael Recupero	XII.B.5(d)	The vertical distance from the bottom of the infiltration system to	Supports a 10' vertical separation.	Modify Permit language.	The 4th draft permit specifies a 10-foot vertical separation.

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			the seasonal high groundwater must be at least 5 feet.			
278	San Bernardino County Flood Control District, Storm Water Program	General	Various	Commenter requests that the Orange County Permit should not be used as a template for the San Bernardino County Permit. .	None	Comments noted.
	COMMENTS RECEIVED ON THE MAY 1, 2009 DRAFT					
279	U.S. EPA	XII.C.2	LID	Language should be added to clarify that compliance with XII.C.& or XII.E meets the permit's LID requirements.	Insert "Compliance with the permit's LID requirements may also be achieved by implementation of the alternatives specified in section XII.C.7 or by implementation of an approved waiver under section XII.E" at the end of XII.C.2.	With other changes made to subsections XII.C.1 and 2, insertion of the submitted language would not have clarified the intent of this permit requirement. It is thought that the other changes made to this section have sufficiently clarified these requirements.
280	U.S. EPA	XII.C.2	LID	The meaning of the term 'bio-filter' is unclear and the use may not be necessary.	Criteria for the design and operation of these systems should be specified in the permit or should be part of the feasibility criteria required pursuant to Section XII.E.	The term 'bio-filter' has been replaced by 'bio-treatment' and the requirement that design, operation, and maintenance criteria be developed as part of the model WQMP has been added.
281	U.S. EPA	XII.C.7	LID	The term 'treat' is used repeatedly in Section XII.C.7, which sets up an inconsistency with other permit requirements.	Either 'treat' should be deleted or with Board approval, changed to 'bio-treat'.	The references to 'treat' in Section XII.C.7 have been changed to 'bio-treat' or 'bio-treatment'.
282	U.S. EPA	XII.E	Waiver Approval	With regards to project-specific waivers generated by Section XII.E, commenter believes that the number of waivers will be small. While supporting the 4th	None made.	While waiver approval per Section XII.E remains the same, if the feasibility criteria required by that section is not approved within 12 months of

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Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
				draft permit language, the commenter would be open to revisions that do not require EO approval for waivers.		permit adoption, the resulting case-by-case feasibility determination by the municipalities on proposed projects will not require EO approval, but will be submitted for Regional Board staff review 30 days prior to municipal approval.
283	Paul Singarella, Latham & Watkins	Findings	None	A Finding should be added stating that the Regional Board does not expect on-site retention of 100% of the design capture volume to be feasible in all cases and that implementation of bio-treatment will still satisfy legal requirements and provide a significant advance on the previous Order.	Insert provided Finding.	The existing Findings clearly indicate that LID itself, much less LID with 100% on-site retention may not be feasible at all sites.
284	Larry McKenny, RBF Consulting	XII.C	LID	Commenter supports the CICWQ comments and notes that the MEP standard does not dictate full retention of a design storm volume on site.	None	Comment noted.
285	County of Orange	None	None	The County notes involvement in the development of their comments by the Cities of Anaheim, Buena Park, Cypress, Fountain Valley, Irvine, La Palma, Laguna Hills, Lake Forest, Newport Beach, Orange, Placentia, Tustin, Villa Park and Westminster , as well as their concurrence with the submitted comments.	None	Comment noted.
286	County of Orange	XII.C.1	LID	While the change in Section XII.C.1 made at the Public Hearing and further in the fourth	Language was submitted by the commenter for Section XII.C.1.	Many of the changes in language, proposed by the commenter were incorporated

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
				draft were made to address the possibility that approval of the feasibility criteria may drag on, it has the possible effect of excessive administrative burden and project delays.		in the permit and are reflected in the Errata Sheet.
287	County of Orange	XII.C.2	LID	The consequence of changes to Section XII.C.2 in the fourth draft result in the need for a waiver and EO approval for any project not addressing 100% of the design storm volume through on-site LID BMPs.	Language was submitted by the commenter for Section XII.C.2.	Many of the changes in language, proposed by the commenter were incorporated in the permit and are reflected in the Errata Sheet.
288	County of Orange	XII.C.2	LID	The term 'bio-filter' was used instead of 'bio-treat'. Further, the language in footnote 56 identifies that bio-treatment can only be used if infiltration, harvest/reuse and evapotranspiration are infeasible.	Language was submitted by the commenter for Section XII.C.2 and footnote 56/57.	The term 'bio-filtration' has been used throughout Section XII.C. While much of the permit language suggested by the commenter has been used, the permit continues to require that the use of 'on-site' retention LID BMPs be implemented (where feasible) prior to the use of 'treat and release' lid BMPs.
289	NRDC/ Coastkeeper	General Comment and Section XII.C	LID	The language in the draft permit is not based on any consensus agreement among the stakeholders. There are key disagreements on certain issues.	NRDC and Coastkeeper believe that law requires a standard that retains on site the design storm whenever possible.	The draft permit language includes on site retention as the highest priority LID BMP.
290	NRDC/ Coastkeeper	Section XII.C	LID	Infiltration and reuse implements MEP requirements and is a wise policy.	Require infiltration and reuse.	Infiltration and reuse are the highest priority LID BMPs included in the draft permit.
291	NRDC/ Coastkeeper	Section XII.C.2	LID	Clarify permit language.	Use suggested permit language.	Draft permit language now includes the requested change.
292	NRDC/ Coastkeeper	Sections XII.C. 1 & 2	LID	Disagree with the inclusion of bio-filtration to meet the basic LID standard.	Remove references to bio-filtration	Permit language has been modified; it still includes bio-treatment as the lowest priority LID BMP.

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
293	NRDC/ Coastkeeper	Footnotes 56 and 57	LID	Include a design standard for bi-filtration systems.	Use suggested language to modify the footnotes.	The footnotes have been revised and the permittees are now required to include specific design criteria in the WQMP for bio-treatment systems.
294	NRDC/ Coastkeeper	Section XII.C	LID	Other sections of the permit have references to "treatment". It should be replaced with bio-treatment.	Replace references to treatment with bio-treatment.	Permit language changed.
295	City of Cypress	XII.C	LID	Consideration should be given to leaving the language in Section XII.C as existed in the third draft.	Revise permit language to reflect that proposed in the third draft.	The changes proposed in the Errata sheet for the May 22, 2009 Regional Board meeting represent an effort to allow maximum flexibility in the implementation of post-construction BMPs while maintaining a set of minimum requirements designed to insure compliance.
296	City of Irvine			Support comments made by County of Orange and CICWQ	Refer to County of Orange and CICWQ	Comment noted.
297	CONTECH	XII.C.3	LID criteria	The word "bio-filter " should be replaced with "filter" The addition of the term bio-filter appears to be excluding non-vegetative media filters, which in some cases, may prove more effective.	Replace the term Bio-filter with filter.	Wording has been changed in this case by using the term "bio-treat" or "bio-treatment"
298	City of Orange	XI.C.1	LID implementation schedule	By deleting the phrase "that meet the feasibility criteria established pursuant to Section XII.E1" within this Section, this could be interpreted as making the Permittees begin immediate implementation of LID following permit adoption.	Maintain the existing language in Section XII.C.1 in order to maintain clarity	Permit language has been revised to address this issue within this Section
299	City of Orange	XII.C.2		The proposed language change to this paragraph can be interpreted to read that projects that cannot fully infiltrate,	Delete second sentence in Section XII.C.2 "Projects that do not comply with this requirement shall meet requirements established in	Permit language has been revised.

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
				harvest, reuse or evapotranspire or capture will need to meet in-lieu programs and still require treatment by conventional BMPs.	Section XII.E for alternative and in-lieu compliance. Alternatively, adopt the County of Orange recommended language.	
300	City of Orange	(general) LID Systems		Concern has been raised about allowing only BMPs that capture the 85th percentile storm. This requirement will not allow the use of systems such as grass swales or vegetated strips. Use of these systems, under the new criteria will not be allowed, as they will be deemed only as "infiltration systems"	Comment only	Comment noted
301	CICWQ	Section XII.C	LID	Provided a marked up copy of Section XII.C	Make changes as per the marked up copy.	See revised permit language.
302	San Bernardino County Storm Water Program	Section XII	LID	Section XII lacks clarity.	Provide clarifying language or a flow chart.	Permit language amended to clarify some of the requirements.
303	San Bernardino County Storm Water Program	Section XII.B.4	Design capture volume	Does the design capture volume include all the options under Section XII.B.4?	Provide clarification.	The design capture volume only provides two of these options, "runoff produced from a 24-hour, 85th percentile storm event", as indicated in XII.B.4.A.1 and 2.
304	San Bernardino County Storm Water Program	Section XII.B.5.f	Infiltration	Is a feasibility analysis required for infiltration systems in industrial areas?	Provide clarification.	A feasibility analysis is not required for infiltration systems for the type of facilities listed under Section XII.B. 5.f.
305	San Bernardino County Storm Water Program	Section XII.C.2 And XII.E	Feasibility Criteria	Section XII.E requires the principal permittee to develop a "technically-based" feasibility criteria.	The MEP standard should be applicable here.	The co-permittees are governed by the MEP standard.
306	San Bernardino County Storm Water Program	Sections XII.C.1 & 2	Full retention	There is an overemphasis on full retention BMPs.	Consider other equally effective LID BMPs. A broader concept of LID BMPs should be included.	The permit language includes a hierarchy of LID BMPs mostly based on their effectiveness in protecting water quality and quantity.

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit 11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
307	Riverside County Water Flood Control and Water Conservation District	Section XII.C.2	On site retention	Avoid infiltration centric definition of LID.	Provide flexibility to implement proactive, effective, and economical LID BMPs.	Please note that the permit does provide other options, including bio-treatment.
308	Riverside County Water Flood Control and Water Conservation District	Section XII.C.2	On site infiltration	The permit does not allow properly designed filtration systems.	Include filtration as an option for implementing LID BMPs.	Bio-filtration is generally considered as an LID BMP and is included in the draft permit.
309	Riverside County Water Flood Control and Water Conservation District	Section XII.C.2	LID	The permit focuses on micro-scale LID	Allow broader implementation of LID BMPs.	Section XII.C.7 provides for sub-regional and regional LID implementation techniques.
310	Riverside County Water Flood Control and Water Conservation District	Section XII.C	LID	The goal should be to mimic pre-development hydrology.	Revise Section XII.C.	Section XII.C.3 notes that the design goal is to replicate pre-development hydrologic regime.
311	Riverside County Water Flood Control and Water Conservation District	Section XII.C	LID	Allow filtration and detention.	Revise Footnotes 56 and 57.	Minor changes have been made to Footnotes 56 & 57.
312	Riverside County Water Flood Control and Water Conservation District	Section XII.C	LID	The District's qualifications for submitting comments on LID	The District developed criteria for the use of LID BMPs.	Comments noted.

OC MS4 Tentative Order No. R8-2008-0030 (R8-2009-0030)
Comments/Responses

Summary of Comments and Responses on the Orange County Municipal Storm Water Permit						
11/10/08 Draft (Comments 1-173) ; 03/24/09 Draft (Comments 174-244) ; 04/10/09 Draft (Comments 245-260) ; Public Hearing (Comments 261-278) ; 05/01/09 Draft (Comments 279 – 315)						
Comment No.	**Commenting Parties**	**Section No.**	**Permit Requirement**	**Comment**	**Submitted Recommendations**	**Response**
313	Riverside County Water Flood Control and Water Conservation District	Section XII.C	LID	USEPA's guide includes filtration as an LID BMP.	Allow properly engineered filtration systems as an LID BMP.	Even though filtration per se is not included, bio-filtration is recognized as an LID BMP.
314	Riverside County Water Flood Control and Water Conservation District	Section XII.C	LID BMPs	On site vs. regional	Regional systems have many advantages, including ease of public maintenance, municipal inspections and nuisance reduction.	The permit language has provisions for regional and sub-regional systems (see Section XII.C. 7).

REPORTER'S CERTIFICATE

I, ALLISON SWANSON, CSR NO. 13377, A CERTIFIED SHORTHAND REPORTER FOR THE STATE OF CALIFORNIA, DO HEREBY CERTIFY:

THAT THE FOREGOING TRANSCRIPT OF PROCEEDINGS WAS TAKEN BEFORE ME ON April 24, 2009 AT THE TIME AND PLACE THEREIN SET FORTH, WAS TAKEN DOWN BY ME IN SHORTHAND, AND THEREAFTER TRANSCRIBED INTO TYPEWRITING UNDER MY DIRECTION AND SUPERVISION;

AND I HEREBY CERTIFY THAT THE FOREGOING TRANSCRIPT OF PROCEEDINGS IS A FULL, TRUE AND CORRECT TRANSCRIPT OF MY SHORTHAND NOTES SO TAKEN.

I FURTHER CERTIFY THAT I AM NEITHER COUNSEL FOR NOR RELATED TO ANY PARTY TO SAID ACTION, NOR IN ANYWISE INTERESTED IN THE OUTCOME THEREOF.

IN WITNESS THEREOF, I HAVE HEREUNTO SUBSCRIBED MY NAME THIS 13th DAY OF May, 2009

Allison Swanson

ALLISON SWANSON, CSR NO. 13377
CERTIFIED SHORTHAND REPORTER
FOR THE STATE OF CALIFORNIA

214

CITY OF
LA PALMA

CRWQCB - REGION 8
MES

MAY 20 2009

OFFICE OF THE DIRECTOR OF
PUBLIC WORKS/CITY ENGINEER

May 19, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of La Palma appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The recently issued Errata Sheet presents revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of La Palma supports the adoption of the Tentative Order incorporating the language of the Errata Sheet

Sincerely,

Jeff Moneda, P.E.
Public Works Director/City Engineer

Phone 714.690.3310 Fax 714.523.2141
7822 Walker Street ▪ La Palma ▪ California 90623-1771 ▪ www.cityoflapalma.org

CITY OF YORBA LINDA

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FAX (714) 986-1010

ENGINEERING / PUBLIC WORKS

CRWQCB - REGION 8
MS

MAY 20 2009

May 19, 2009

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Yorba Linda Department appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The recently issued Errata Sheet presents revised language that will establish an appropriate basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Yorba Linda Public Works Department supports the adoption of the Tentative Order incorporating the language of the Errata Sheet.

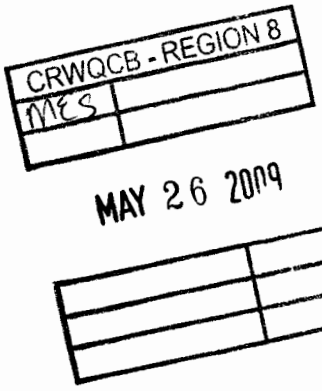
Sincerely,

CITY OF YORBA LINDA

MARK L. STOWELL
Assistant City Manager/Director of Public Works/City Engineer



City of Brea



May 21, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Brea appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Brea supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs"

Sincerely,

John Hogan

City Engineer

City Council **John Beauman** *Mayor* **Ron Garcia** *Mayor Pro Tem* **Roy Moore** *Councilmember* **Don Schweitzer** *Councilmember* **Marty Simonoff** *Councilmember*

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SARB 07099

CITY OF BUENA PARK

Department of Public Works
James A. Biery, Director

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Buena Park appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Buena Park supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs"

Sincerely,

Jim Biery, P.E.
Director of Public Works/City Engineer

CRWQCB - REGION 8
MES

MAY 26 2009

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CITY of CYPRESS

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May 21, 2009

By E-mail and U.S. Mail

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Cypress appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The attached Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Cypress supports the adoption of the Tentative Order incorporating the language of this Errata Sheet.

As stated in our previous correspondence, and as attached in the Errata Sheet, the requirements for an in-lieu program should only be triggered if a development can not treat the design captured by a combination of Low Impact Development (LID) and conventional means. We believe that it is unreasonable to require cities to treat the remaining "design capture" after LID by conventional means and require the in-lieu program. The in-lieu program should only be triggered if the "design capture" can not be treated. It appears that if the Board were to adopt otherwise, that this may be in conflict with the spirit of Section 13360 of the Water Code about prescribing methods.

Doug Bailey, Mayor
Prakash Narain, M.D., Mayor Pro Tem Phil Luebben, Council Member
Leroy Mills, Council Member Todd W. Seymore, Council Member

Thank you for your consideration in this matter. Please make this part of the record for the Board Hearing. If you have any questions, please feel free to contact me at (714) 229-6740.

Sincerely,

Douglas A. Danics, P.E.
Director of Public Works/City Engineer

Attachment: Errata Sheet

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the model WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated model WQMP shall be submitted for review and approval by the Executive Officer[55]. As provided in Section XII.J, 90 days after approval of the revised model WQMP, pPriority development projects shall implement LID principles described in this section, Section XII.C. To the extent the Executive Officer has not approved the feasibility criteria as provided in Section XII.E.1, the infeasibility of implementing LID BMPs shall be determined through project specific analyses, each of which shall be submitted to the Executive Officer, 30 days prior to municipal approval.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, ~~capture,~~ or bio-treat~~filter~~[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. ~~Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance.~~ Any portion of the design capture volume that is not infiltrated, harvested and re-used, evapotranspired, ~~captured~~ or bio-treated~~filtered~~[57] onsite by LID BMPs shall be treated and discharged using LID or ~~conventional~~ similarly effective treatment control BMPs or mitigated as set forth in Section XII.C.7, below. Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance, which shall assure at least equivalent environmental performance.

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design ~~strategy~~ goal shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention,

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[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

[56] A properly engineered and maintained bio-~~filtration, bio-retention or other bio-~~treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration ~~are~~ cannot be feasibly implemented at a project site ~~feasible~~. Specific design, operation and maintenance criteria for bio-treatment systems shall be part of the model WQMP that will be produced by the permittees.

[57] ~~A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration are not feasible.~~ See footnote 56.

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evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

SARB_017104

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[58], New Urbanism[59] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.

7. If site conditions do not permit infiltration, harvesting and re-use, ~~and/or~~ evapotranspiration, and/or bio-treatment of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:

    a. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious

[58] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[59] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate ~~and/or~~, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume.

b. Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume.

c. Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

d. Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[60])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

[60] Hydromodification is the alteration of natural flow characteristics.

CITY OF FOUNTAIN VALLEY

10200 SLATER AVENUE • FOUNTAIN VALLEY, CA 92708-4736 • (714) 593-4400, FAX: (714) 593-4498

CRWQCB - REGION 8
MES

MAY 22 2009

May 21, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter - Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Fountain Valley (City) values the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the concerns of the Permittees and stakeholder groups. The City has been recently informed that still further changes have been proposed by your staff to the Tentative Order.

The City believes that the first Errata Sheet is responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its May 8, 2009 letter. The City supports the adoption of a Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs." This version includes revised language that will establish a technically strong foundation for determining the applicability and feasibility of specific water quality management strategies for land development at the project level.

Sincerely,

Mark Lewis,
Director of Public Works/City Engineer

cc: City Manager
City Planner
Environmental Services Administrator

CRWQCB - REGION 8
MES
MAY 20 2009

CITY OF FULLERTON

Engineering Department

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Fullerton appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The recently issued Errata Sheet presents revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA, and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Fullerton supports the adoption of the Tentative Order incorporating the language of the Errata Sheet

Sincerely,

Donald K. Hoppe
Director of Engineering

GARDEN GROVE

CITY OF GARDEN GROVE

William J. Dalton
Mayor

Steven R. Jones
Mayor Pro Tem

Dina Nguyen
Council Member

Bruce A. Broadwater
Council Member

Andrew Do
Council Member

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Garden Grove appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The recently issued Errata Sheet presents revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Garden Grove supports the adoption of the Tentative Order incorporating the language of the Errata Sheet

Sincerely,

KEITH G. JONES
Director of Public Works

CRWQCB - REGION 8
MES

MAY 22 2009

City of Huntington Beach

2000 Main Street ♦ PO Box 190 ♦ CA 92648

Travis K. Hopkins, PE
Director

Department of Public Works
(714) 536-5431

May 21, 2009

via email and U.S. mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Huntington Beach appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first issued Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Huntington Beach supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMP's".

The City also supports Attachment A with modifications, which represents the LID Process which was provided in the County of Orange letter dated May 8, 2009.

Sincerely,

Tony Olmos, PE
City Engineer

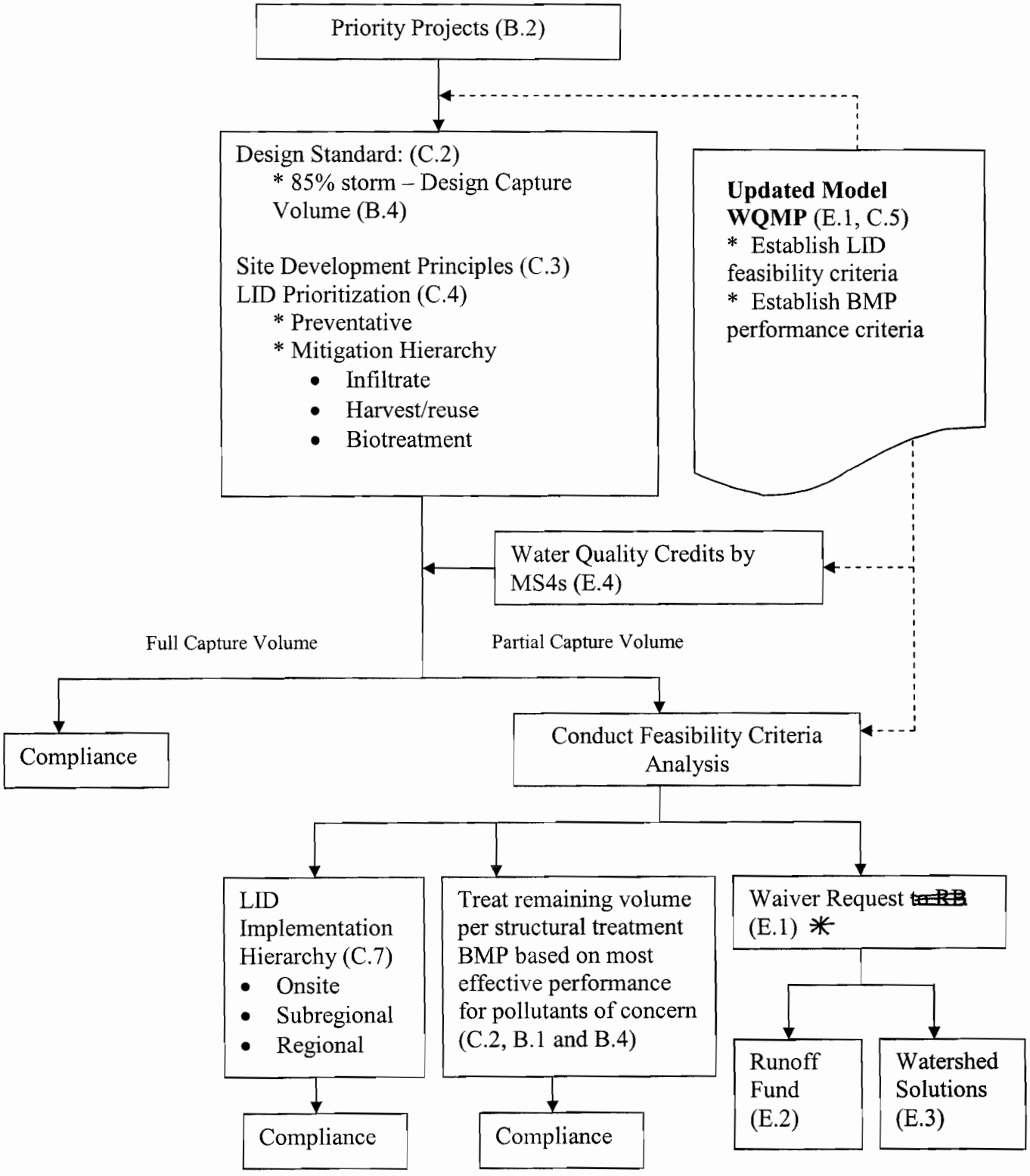
TO/TE:cs

Cc: Travis Hopkins, Director of Public Works
Terri Elliott, Principal Civil Engineer

Attachment: A LID Process

CRWQCB - REGION 8
MS3
MAY 26 2009

Attachment A: LID Process



* Treat remaining design storm volume with conventional BMPs

SARB_017111

CITY OF LAGUNA HILLS

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Laguna Hills appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Laguna Hills supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs."

It is also imperative to mention that although the City is supportive of the first errata sheet, there are still pending issues of concern in the subject Tentative Order. These issues were addressed in the second comment letter submitted to your office on 04/09/09. The City believes some of these issues would create an undue financial burden without necessarily achieving the desired water quality improvements. Nevertheless, the City is looking forward to working with your staff in achieving full compliance with the Approved Tentative Order.

Sincerely,

Kenneth H. Rosenfield, P.E.
Director of Public Works/City Engineer

24035 El Toro Road • Laguna Hills, California 92653 • (949) 707-2600 • FAX (949) 707-2633
website: www.ci.laguna-hills.ca.us



MAY 26 2009



Mayor
Mark Tettemer

Mayor Pro Tem
Peter Herzog

Council Members
Richard Dixon
Kathryn McCullough
Marcia Rudolph

City Manager
Robert C. Dunek

May 21, 2009

Via US Mail and Fax

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Additional Comments on Tentative Order No. R8-2009-0030, NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Lake Forest ("City") appreciates the continuing efforts of your staff to issue a fourth-term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. The City also appreciates your staff's attention to comments previously submitted in our correspondence dated April 9, 2009, as well as responses provided to address several issues of concern. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

Subsequent to the April 24, 2009, public hearing, the California Regional Water Quality Control Board, Santa Ana Region released an Errata Sheet. This first Errata Sheet (May 1, 2009 distribution) presented revised language that would establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs."

If you have any questions, please contact Devin Slaven, Water Quality Specialist, at (949) 461-3436.

DRUG USE IS LIFE ABUSE

25550 Commercentre Dr., Suite 100
Lake Forest, CA 92630
(949) 461-3400
City Hall Fax: (949) 461-3511
Building/Planning/Public Works Fax: (949) 461-3512

SARB 017113

Sincerely,
CITY OF LAKE FOREST

Robert L. Woodings, P.E.
Director of Public Works/City Engineer

cc: Robert C. Dunek, City Manager
Theodore G. Simon, P.E., Engineering Services Manager
Devin E. Slaven, REA, Water Quality Specialist
Chris Crompton, County of Orange, OC Public Works

C:\Documents and Settings\dslaven\Desktop\New_Tentative Permits\R8-2008-0030\SAR First Errata support.doc

CITY OF NEWPORT BEACH

PUBLIC WORKS DEPARTMENT

Stephen G. Badum, Director

May 21, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Newport Beach appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

With that said, the City of Newport Beach would request that the Permit Language be revised to reflect the first Errata Sheet, addressing Low Impact Developments which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs". We feel this should establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. We would request that footnote 56 be completely deleted and that the Board substitutes the words "should consider" for the words "shall incorporate" in Section XII.B.2.

Thank you for the opportunity to participate in the permit renewal process.

Respectfully,

David Webb
Deputy Director of Public Works/City Engineer

Cc: Dave Kiff
Steve Badum
Robert Stein
John Kappeler
File

3300 Newport Boulevard · Post Office Box 1768 · Newport Beach, California 92658-8915
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The People are the City

Mayor
GREG SOWARDS

City Administrator
TROY L. BUTZLAFF

Councilmembers:
JOSEPH V. AGUIRRE
SCOTT W. NELSON
CONSTANCE UNDERHILL
JEREMY B. YAMAGUCHI

401 East Chapman Avenue - Placentia, California 92870

CRWQCB - REGION 8
MES

MAY 22 2009

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Placentia appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Placentia supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs"

Sincerely,

Andrew R. Muth, P.E.
City Engineer

RM/mem

City of Seal Beach

CITY HALL 211 EIGHTH STREET
SEAL BEACH, CALIFORNIA 90740
(562) 431-2527 • www.ci.seal-beach.ca.us

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Seal Beach appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Seal Beach supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs"

Sincerely,

FOR Vince Mastrosimone

Director of Public Works
City of Seal Beach

CRWQCB - REGION 8
MFS

MAY 28 2009

City of Villa Park

17855 Santiago Boulevard, Villa Park, California 92861-4187
(714) 998-1500 • Fax: (714) 998-1508
www.villapark.org

CRWQCB - REGION 8
MES

MAY 22 2009

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Villa Park appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The first Errata Sheet presented revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of [GET] supports the adoption of the Tentative Order incorporating the language of the first Errata Sheet which includes explicit reference in Section XII.C.2 to "similarly effective treatment control BMPs"

Sincerely,
CITY OF VILLA PARK

Joe O'Neil, P.E.
City Engineer

C: Villa Park City Council
Don Powell, Interim City Manager
Todd Litfin, City Attorney

JIM RHEINS, Mayor • BILL MAC ALONEY, Mayor Pro Tem
DEBORAH PAULY, Councilwoman • BRAD REESE, Councilman • W. RICHARD ULMER, Councilman

City of Westminster

CIVIC CENTER
8200 WESTMINSTER BOULEVARD
WESTMINSTER, CALIFORNIA 92683
(714) 898-3311

MARGIE L. RICE
MAYOR

TRI TA
MAYOR PRO TEM

FRANK G. FRY
COUNCIL MEMBER

ANDY QUACH
COUNCIL MEMBER

TYLER DIEP
COUNCIL MEMBER

DONALD D. LAMM
CITY MANAGER

May 21, 2009

By E-mail and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Westminster appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

The recently issued Errata Sheet presents revised language that will establish a technically robust basis for determining the applicability and feasibility of specific water quality management strategies for land development at the project level. It is also responsive to the concerns of U.S. EPA and is consistent with the suggested regulatory framework proposed by the County of Orange in its letter of May 8, 2009. The City of Westminster supports the adoption of the Tentative Order incorporating the language of the Errata Sheet

Sincerely,

Marwan Youssef

Director of Public Works/City Engineer

CRWQCB - REGION 8
MES
MAY 21 2009

City of Westminster

CIVIC CENTER
8200 WESTMINSTER BOULEVARD
WESTMINSTER, CALIFORNIA 92683
(714) 898-3311

CRWQCB - REGION 8
MES
MAY 22 2009

MARGIE L. RICE
MAYOR

TRI TA
MAYOR PRO TEM

FRANK G. FRY
COUNCIL MEMBER

ANDY QUACH
COUNCIL MEMBER

TYLER DIEP
COUNCIL MEMBER

DONALD D. LAMM
CITY MANAGER

May 21, 2009

U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter, Tentative Order No. R8-2009-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

The City of Westminster appreciates the continuing efforts of your staff to issue a fourth term permit for the Orange County Stormwater Program that is responsive to the issues and concerns being raised by the Permittees and a diverse group of stakeholders. This Tentative Order is in its fourth draft and it is understood that further changes are being contemplated.

You should have already received a letter from City of Westminster in support of the first Errata sheet. Due to the fact that a second Errata sheet was released by the Regional Board staff, this letter is to clarify City's support for first Errata Sheet only, but not in support of the second Errata Sheet.

Sincerely,

Marwan Youssef

Director of Public Works/City Engineer

Construction Industry Coalition on Water Quality

Section XII.C Proposal (Tentative Order 09-30)

The Fourth Draft Permit dated April 30, 2009 does not implement the Board's direction provided to staff at the April 24, 2009 hearing. The revised draft does not make biotreatment part of the LID standard; rather, it demotes biotreatment to an inferior status that can be used only if 100 percent on-site capture of the design storm has been demonstrated to be infeasible. This is the approach espoused by NRDC and rejected by the Board at the April 24 hearing. The Fourth Draft also fails to replace the word "strategy" in Section XII.C.3 with the word "goal," another important change agreed to at the April 24 hearing. **CICWQ urges the Board to adopt the version of the permit (Section XII.C only) called "Regulated Community Proposal (May 7, 2009)," attached hereto at Attachment A, which was prepared to conform with the Board's April 24 direction and which is a consensus proposal from the regulated community.**

I. KEY MESSAGES

The attached Section XII.C, which reflects a consensus proposal of the regulated community, is submitted with reference to the following key messages:

- The Fourth Draft adopts the NRDC approach, apparently being promoted by staff for U.S. EPA Region 9. NRDC has advocated for a narrow conception of LID, requiring on-site retention of 100% of the design storm absent a demonstration of infeasibility. This is not a practicable or desirable approach, and excludes excellent biotreatment BMPs as part of the LID standard. Nor does it provide superior water quality performance, as claimed by NRDC. The Board rejected this approach on April 24.

- The regulated community approach adds biotreatment to the LID standard, but includes a preference for the narrow LID BMPs proposed by NRDC. As we said on April 24, we will achieve 100% on-site retention as a first preference, but are concerned that, in the majority of cases, biotreatment will be important to use, and runoff from the site of development to the public storm drain will occur. Our proposal reflects this approach, allowing biotreatment in accordance with the prioritization scheme of Section XII.C.4. We believe this approach is consistent with the Board's April 24 direction.

- The Fourth Draft is inconsistent with the BMP priority scheme from the stakeholder negotiations. Neither staff, NRDC, nor U.S. EPA ever rejected biotreatment during the stakeholder negotiations from December 2008 to March 4, 2009. Rather, the regulated community thought it had reached consensus that biotreatment would be part of the LID standard, available as part of a prioritization scheme. That scheme, Section XII.C.4, was added to the permit on March 24, 2009, when staff published the Second Draft permit, clearly intended to reflect the stakeholder negotiations. Section XII.C.4 also is in the Fourth Draft permit with only minor changes since it was originally inserted on March 24, 2009. Section XII.C.4 states in full:

> *The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.*

To our knowledge, no one has objected to Section XII.C.4 during the public comment periods on the permit. The Fourth Draft permit would create an end-run around this key aspect of the negotiation process.

- Narrow LID is inconsistent with U.S. EPA guidance which promotes filtration and biotreatment as part of LID. Of five U.S. EPA sources regarding LID, four included biotreatment-type terms, such as detention (i.e., slow down, treat, then release), filtration, and surface release of stormwater. In a compilation of case studies by U.S. EPA, most of 17 exemplary projects included biotreatment elements, such as bioretention, swales, wetlands, and green roofs. *See* U.S. EPA 841-F-07-006, discussed in the May 8 submittal from Mr. Eric Strecker, Geosyntec, (Attachment C). Each of two case studies described in another EPA document, *see* EPA 841-B-00-005, included the use of under-drains, and one of them specifically fed into the main storm drain system. A U.S. EPA document updated in January 2009 references additional resources, one of which refers to the many practices used to adhere to LID principles of promoting a watershed's hydrologic and ecological functions, such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. *See* EPA-560-F-07-231. A fact sheet used in conjunction with that document describes under-drains used to release treated stormwater off site, permitting planted areas to safely allow filtration of stormwater. The embrace by U.S. EPA Region 9 staff of the NRDC approach is inconsistent with the weight of the agency's pronouncements regarding LID.

- The Fourth Draft is inconsistent with SWRCB guidance. SWRCB identifies LID as a sustainable practice that benefits water supply and contributes to water quality protection, stating that, "The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall" (emphasis added). SWRCB also states that, "LID practices include; bioretention facilities or rain gardens, grass swales and channels, vegetated rooftops, rain barrels, cisterns, vegetated filter strips, and permeable pavements" (emphasis added). As can be seen, SWRCB defines LID as including filtration, detention, and bioretention, and

other practices, each of which produce runoff and would not be part of the LID standard under the Fourth Draft. In addition, SWRCB characterizes mimicking pre-development hydrology as a "goal," not an enforceable standard, which is consistent with the change in Section XII.C.3 directed by the Board on April 24, and not implemented in the Fourth Draft. *Found at*: http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/.

- Narrow LID does not achieve superior water quality. Biotreatment BMPs including natural treatment systems such as those that are part of the IRWD's Natural Treatment System can remove vast quantities of pollutant load, and provide other benefits such as habitat, flood control, and aesthetic, recreational and educational value. To relegate multi-benefit biotreatment BMPs to a status inferior to on-site retention BMPs is not justified on a water quality basis, and is bad public policy, essentially depriving the region of an extremely important and effective approach to managing water quality. Sinking water can have adverse consequences such as altering the natural flow regime of the receiving waters, depriving riparian corridors of base and storm flows, mobilizing pre-existing contamination in shallow groundwater, and causing damage from rising groundwater, etc. In addition, the Fourth Draft does not even limit infiltration BMPs to those that are "properly engineered and maintained" (which it does for biotreatment BMPs), and infiltration BMPs are prone to clogging and other maintenance problems that can reduce effectiveness. The use of infiltration, harvesting of rainwater, and evapotranspiration alone or in combination is not necessarily better from a water quality perspective, and can be less effective than biotreatment, as shown by Mr. Eric Strecker at the April 24 hearing and in the submittals from Geosyntec.

- Narrowing the use of LID to that which excludes biotreatment is not consistent with the MEP standard. Consistency with the MEP standard implies that project proponents should be provided a slate of BMP options which is robust enough to permit implementation and achieve water quality benefits in a wide variety of contexts. Therefore, consistency with the MEP standard should rule out any uncritical approach that insists upon BMPs that are neither implementable nor desirable to manage the entire design storm volume in the vast majority of cases. A narrow prescription of LID without biotreatment is such an uncritical approach, which may have superficial appeal, but is not consistent with the MEP standard and does not reflect any serious policy consideration.

- Region 9 staff's recent advocacy for NRDC's narrow LID is inconsistent with Region 9's prior positions. Region 9 told counsel for CICWQ that its main concern was to make sure conventional BMPs would not be elevated to LID status. Staff also stated that U.S. EPA was not opposed to the Regional Board using biotreatment as a LID option, which would be a position completely consistent with U.S. EPA policy. Now, the Region 9 staff are advocating for NRDC's retention standard that allows biotreatment only in cases of infeasibility as determined by yet-to-be-specified criteria. This new position is inconsistent with the Region 9's prior position, and shows clear advocacy for NRDC's narrow view of LID, rather than U.S. EPA's policy on LID.

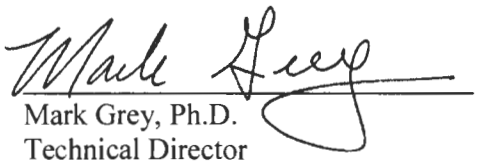
II. REQUESTED ACTIONS

We request that the Regional Board adopt the attached redline version of Section XII.C of the Draft Permit, which is consistent with the Regional Board's April 24 direction as well as with U.S. EPA and SWRCB policy and the stakeholder negotiations.

We further note that, if NRDC or any other party seeks to cross-examine or otherwise examine staff or any party, CICWQ and the Building Industry Legal Defense Foundation (BILD) would want the same opportunity. Accordingly, we respectfully request that the Regional Board recognize CICWQ and BILD as designated parties.

If you have any questions or want to discuss the content of our comment letter, please feel free to contact me at (909) 396-9993, ext. 252, (909) 525-0623, cell phone, or mgrey@biasc.org.

Respectfully,



Mark Grey, Ph.D.
Technical Director
Construction Industry Coalition on Water Quality

Description of Attachments:

Attachment A – Regulated Community Proposal (May 7, 2009), for Section XII.C
Attachment B – Rationale for Regulated Community Proposal (May 7, 2009)
Attachment C – EPA Definitions of and Guidance on Low Impact Development

Geosyntec consultants

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Memorandum

Date: May 7, 2009

To: Construction Industry Coalition on Water Quality, Mark Grey, Ph.D.

cc: Michael Adackapara
David Rice

From: Eric Strecker, P.E., and Nicole Dunn, Geosyntec Consultants

Subject: Tentative Order No. R8-2009-0030: EPA Definitions of and Guidance on Low Impact Development (LID)

BACKGROUND AND PURPOSE

There are multiple definitions of Low Impact Development that EPA has used in their documents. The National Resources Defense Council (NRDC) cited a definition to support their position that runoff from storms up to the water quality design storm be retained on site (or not allowed to surface discharge in reality). The purpose of this memo is to identify the various definitions of LID that EPA has included in guidance documents that they either prepared or participated in producing. In addition to the definition, the actual guidance has been reviewed to see if the guidance supports the definition of LID or whether in fact that biotreatment (or biofiltration) and surface discharge is in fact part of the guidance or case studies included. Finally, some additional recommendations are made regarding the state of analysis and evaluation of the practicality and results of retention requirements.

DEFINITIONS OF AND GUIDANCE REGARDING LID

In review of EPAs web site and related documents, the following EPA Reports or referenced reports include definitions of LID:

1. *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007 (EPA 841-F-07-006).* (Cited by NRDC in April 24th Hearing) http://www.epa.gov/owow/nps/lid/costs07/documents/reducingstormwatercosts.pdf
2. *Low Impact Development (LID) Literature Review, October 2000 (EPA-841-B-00-005). http://www.epa.gov/owow/nps/lid/lid.pdf*
3. *Low-Impact Development: An Integrated Environmental Design Approach (This document was prepared by the Prince George's County Maryland Department of Environmental Resources Programs and Planning Division, with assistance from EPA), June 1999.* http://www.epa.gov/owow/nps/lid/lidnatl.pdf

4. *Polluted Runoff (Nonpoint Source Pollution) Low Impact Development (LID), Last updated on Thursday, January 15th, 2009* http://www.epa.gov/owow/nps/lid/ *Additional information from linked factsheet: Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas, April 2008 (EPA-560-F-07-231)* http://www.epa.gov/brownfields/publications/swdp0408.pdf
5. *Low Impact Development (LID) and Other Green Design Strategies, Last updated on October 09, 2008* http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=124

Table 1 (at end of document) includes the definition of LID that each of these EPA or EPA referenced documents as well as information on the guidance that is included in the document that addresses whether some form of detention, filtration, and surface release of stormwater is included. Table 2 summarizes in brief form whether the definition of each document reference includes detention, filtration and stormwater release (or equivalent) in the definition and the guidance.

Table 2. Summary of Filtration and Surface Release Inclusion in LID Definitions and associated guidance.

Document/Reference	**Filtration and Surface Release**	
	In Definition	**In Guidance/ Examples**
Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007 (EPA 841-F-07-006)	No	Yes
Low Impact Development (LID) Literature Review, October 2000 (EPA-841-B-00-005	Yes	Yes
Low-Impact Development: An Integrated Environmental Design Approach (This document was prepared by the Prince George's County Maryland Department of Environmental Resources Programs and Planning Division, with assistance from EPA), June 1999	Yes	Yes
Polluted Runoff (Nonpoint Source Pollution) Low Impact Development (LID), Last updated on Thursday, January 15th, 2009 *Additional information from linked factsheet: Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas, April 2008 (EPA-560-F-07-231)*	Not Clear	Yes
Low Impact Development (LID) and Other Green Design Strategies, Last updated on October 09, 2008h	No	Not Clear

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Table 2 clearly indicates that EPA has not been and continues not to be consistent in its definition of LID on whether it includes detention, filtration (biofiltration), and release of stormwater. Some of the definitions appear to be clear one way or the other, while one is not clear. In the guidance document or other materials that are associated with a particular definition almost all include some form of detention, filtration and surface release of stormwater.

It should be noted that in EPAs definitions, they interpret infiltration as "managing on site" where in fact in many cases infiltrated waters would be expected to reach a surface water body after either shallow interflow or deeper infiltration and downstream reappearance (after filtering thru soils and obvious detention). In the definitions, EPA is clearly focused on surface hydrology, when in fact hydrology includes groundwater hydrology.

Review of Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007 (EPA 841-F-07-006)

This document merits some additional discussion, as it has been cited as showing the retention on site is feasible. In this document, Biotreatment of one form (i.e., bioretention, swales, wetland, green roofs) is presented in most of the 17 cases studies referenced. However, the document does not in most cases clearly indentify whether or not underdrains were included in these features. The Table below highlights the biotreatment elements that were included in the 17 case studies.

LID Technique	Number of case studies
Bioretention	12*
Swales	12*
Wetlands	6
Green roofs	1

* use of underdrains not indicated

Note that green roofs would have some form of underdrain or overflow and therefore would release stormwater similar to a biorention system with underdrains. Most swales also discharge well before the design storm volume has been introduced; in a few cases in the document they have been observed to infiltrate large volume of runoff. Finally, wetlands are clearly not features that retain on site up to the design storm. They either act as extended detention systems with a wet pool or a wet pond with releases during the storm event. Therefore, it is clear that this document includes biotreatment features (include regional like features – wetlands) that are identified by EPA as part cost-effective examples of LID. It is likely that some of the biorention systems may also include underdrains, but this was not provided in the guidance. Attachment 1 provides additional citations from the document that clearly show that detention/conveyance type LID features were included.

This document, while presenting some example projects that are useful, does not provide enough detail to support or not support universal on-site retention of stormwater. There are no

evaluations of projects with cisterns, including cost effectiveness. Finally, there is very little information on the overall performance of the systems, either from monitoring data or modeling.

SUMMARY

There are multiple definitions in EPA and EPA cited reports that do and do not include biotreatment-like LID features (detention/biofiltration/biotreatment and release). EPA is not consistent in their definition of LID. Second, the associated guidance with each of the definitions in almost all cases includes LID features that clearly are biofiltration/detention and surface release.

It is clear that the issue of requiring retention on site has not been systematically or technically evaluated. To date, the information has been very anecdotal with a few examples cited. Even with the examples, very little information is provided. The issue of the feasibility of "retention on site" standards needs to be evaluated on a national scale as well as locally.

Table 1. EPA Definitions of LID in EPA or EPA Referenced Documents and Guidance Elements that Include Treatment and Surface Release.

Source #	EPA or EPA Listed Document	LID definition directly from document	Additional Information
1.	*Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007 (EPA 841-F-07-006)*[i]	LID comprises a set of approaches and practices that are designed to reduce runoff of water and pollutants from the site at which they are generated. By means of ***infiltration, evapotranspiration, and reuse of rainwater***, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water.	The document notes that, "The costs might be higher because of the costs of plant material, site preparation, soil amendments, ***underdrains and connections to municipal stormwater systems***, and increased project management." NOTE: See ATTACHMENT 1 also for additional information

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Source #	EPA or EPA Listed Document	LID definition directly from document	Additional Information
2.	*Low Impact Development (LID) Literature Review, October 2000 (EPA-841-B-00-005)*[ii]	LID is a site design strategy with a goal of maintaining or replicating the predevelopment hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape. Hydrologic functions of ***storage, infiltration, and ground water recharge***, as well as the volume and frequency of discharges are maintained through the use of integrated and distributed micro-scale stormwater ***retention and detention areas***, reduction of impervious surfaces, and the lengthening of flow paths and runoff time (Coffman, 2000). Other strategies include the preservation/protection of environmentally sensitive site features such as riparian buffers,wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands and highly permeable soils. LID principles are based on controlling stormwater at the source by the use of microscale controls that are distributed throughout the site.	Two case studies shown include the use of underdrains: • Bioretention Facility Laboratory and Field Study Beltway Plaza Mall Parking Lot, Greenbelt, MD, "The depth of the system is 42" and is designed so that runoff infiltrates through the system and ***is collected by a 6-inch diameter perforated pipe underdrain, which feeds into the main storm drain system***." • Vegetated Roof Cover, Philadelphia, PA, "***Synthetic under-drain layer*** that promotes rapid drainage of water from the surface of the roof deck"

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Source #	EPA or EPA Listed Document	LID definition directly from document	Additional Information
3.	*Low-Impact Development: An Integrated Environmental Design Approach (This document was prepared by the Prince George's County Maryland Department of Environmental Resources Programs and Planning Division, with assistance from EPA), June 1999*[iii]	The primary goal of Low Impact Development methods is to mimic the predevelopment site hydrology by using site design techniques that ***store, infiltrate, evaporate, and detain runoff***. Use of these techniques helps to reduce off-site runoff and ensure adequate groundwater recharge.	The document notes that, "The use of micromanagement practices, as well as ***the use of underdrains*** to provide positive subdrainage for bioretention practices, helps to overcome many of the traditional soil limitations for the selection and use of IMPs."

Source #	EPA or EPA Listed Document	LID definition directly from document	Additional Information
4.	*Polluted Runoff (Nonpoint Source Pollution) Low Impact Development (LID), Last updated on Thursday, January 15th, 2009*[iv] *Additional information from linked factsheet: Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas, April 2008 (EPA-560-F-07-231)*[v]	LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions.	The document notes that, "There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements." The definition is from a website, which contains links to a variety of fact sheets and reports, design/guidance manuals, and information resources and centers. One of the factsheets, "Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas," discusses how buildings and other impervious surfaces can be strategically located to act as caps over contaminated areas and states, "Areas with fill caps can include soils and vegetation above the cap in the form of swales or rain gardens. If fitted with ***an under-drain system*** to release treated stormwater off site, these planted areas can safely allow filtration and evapotranspiration of stormwater. Additional features like impermeable liners or gravel filter blankets can be coupled with modified low impact development (LID) practices that safely filter stormwater without exposing the water to contaminated soils."

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Source #	EPA or EPA Listed Document	LID definition directly from document	Additional Information
5.	*Low Impact Development (LID) and Other Green Design Strategies, Last updated on October 09, 2008*[vi]	Like other alternative development strategies, LID seeks to control stormwater at its source. Rather than moving stormwater offsite though a conveyance system, the goal of LID is to restore the natural, pre-developed ability of an urban site to absorb stormwater. LID integrates small-scale measures scattered throughout the development site. Constructed green spaces, native landscaping, and ***a variety of innovative bioretention and infiltration techniques capture and manage stormwater on-site***. LID reduces peak runoff by allowing rainwater to ***soak into the ground, evaporate into the air, or collect in storage receptacles*** for irrigation and other beneficial uses.	While, the definition appears to states that LID techniques capture and manage stormwater on-site, thereby implying LID techniques only include retention and not detention, the document also states that, "In areas with slow drainage or infiltration, LID captures the first flush ***before excess stormwater is diverted into traditional storm conveyance systems***. The result is development that more closely maintains pre-development hydrology. Furthermore, LID has been shown to be cost effective, and in some cases, cheaper than using traditional stormwater management techniques."

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Attachment 1. Selected Statements in Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007 (EPA 841-F-07-006)

"For example, in lieu of a treatment pond serving a new subdivision, planners might incorporate a bioretention area in each yard, disconnect downspouts from driveway surfaces, remove curbs, and install grassed swales in common areas. Integrating small practices throughout a site instead of using extended detention wet ponds to control runoff from a subdivision is the basis of the LID approach." p. 2

NOTE: Grassed swales are typically thought of as biofiltration with some, but usually limited infiltration

"***Runoff conveyance practices.*** Large storm events can make it difficult to retain all the runoff generated on-site by using infiltration and storage practices. In these situations, conveyance systems are typically used to route excess runoff through and off the site. In LID designs, conveyance systems can be used to slow flow velocities, lengthen the runoff time of concentration, and delay peak flows that are discharged off-site. LID conveyance practices can be used as an alternative to curb-and-gutter systems, and from a water quality perspective they have advantages over conventional approaches designed to rapidly convey runoff off-site and alleviate on-site flooding. LID conveyance practices often have rough surfaces, which slow runoff and increase evaporation and settling of solids. They are typically permeable and vegetated, which promotes infiltration, filtration, and some biological uptake of pollutants. LID conveyance practices also can perform functions similar to those of conventional curbs, channels, and gutters. For example, they can be used to reduce flooding around structures by routing runoff to landscaped areas for treatment, infiltration, and evapotranspiration.
Filtration practices are used to treat runoff by filtering it through media that are designed to capture pollutants through the processes of physical filtration of solids and/or cation exchange of dissolved pollutants. Filtration practices offer many of the same benefits as infiltration, such as reductions in the volume of runoff transported offsite, ground water recharge, increased stream baseflow, and reductions in thermal impacts to receiving waters. Filtration practices also have the added advantage of providing increased pollutant removal benefits. Although pollutant build-up and removal may be of concern, pollutants are typically captured in the upper soil horizon and can be removed by replacing the topsoil." p. 4-5

Note: This description clearly includes biotreatment LID features that includes filtration and surface conveyance of runoff.

". . . bioretention areas and swales can be incorporated into the landscaping of yards, in rights of-way along roadsides, and in or adjacent to parking lots." p. 9-10

Note: Swales again are practices that typically convey and filter runoff with some infiltration and ET benefits

"2ND AVENUE SEA STREET, SEATTLE, WASHINGTON
The design reduced imperviousness, included retrofits of bioswales to treat and manage stormwater, and added 100 evergreen trees and 1,100 shrubs.14 Conventional curbs and gutters

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were replaced with bioswales in the rights-of-way on both sides of the street. . . . Hydrologic monitoring of the project indicates a 99 percent reduction in total potential surface runoff, and runoff has not been recorded at the site since December 2002, a period that included the highest-ever 24-hour recorded rainfall at Seattle-Tacoma Airport.16" p. 12-13

Note: Although this design is referred to as Bioswales, the size, depth, etc. of these systems make them more bioretention facilities than swales. Also note that at this site, it is likely that infiltration levels are fair above natural.

"**AUBURN HILLS SUBDIVISION, SOUTHWESTERN WISCONSIN**
Auburn Hills in southwestern Wisconsin is a residential subdivision developed with conservation design principles. Forty percent of the site is preserved as open space; this open space includes wetlands, green space and natural plantings, and walking trails. The subdivision was designed to include open swales and bioretention for stormwater management. . . . Stormwater savings were realized primarily through the use of vegetated swales and bioswales. These LID practices provided stormwater conveyance and treatment and also lowered the cost of conventional stormwater infrastructure." p. 13

Note: Conveyance swales were included that provided conveyance and treatment

"**BELLINGHAM, WASHINGTON, PARKING LOT RETROFITS**
The City of Bellingham, Washington, retrofitted two parking lots . . . with rain gardens in lieu of installing underground vaults to manage stormwater. . . . Flows were directed to the rain gardens by curbs. An overflow system was installed to accommodate higher flows during heavy rains." p. 14

Note: Higher flows not identified, but may or may not actually retain the water quality design storm.

"**CENTRAL PARK COMMERCIAL REDESIGNS, FREDERICKSBURG, VA (A MODELING STUDY)**
The Friends of the Rappahannock undertook a cost analysis involving the redesign of site plans for several stores in a large commercial development in the Fredericksburg, Virginia, area called Central
Park.23,24 Table 6 contains a side-by-side analysis of the cost additions and reductions for each site for scenarios where LID practices (bioretention areas and swales) were incorporated into the

existing, traditional site designs.

Table 6. Site Information and Cost Additions/Reductions Using LID Versus Traditional Designs

Name	Total BMP Area (ft^2)	Total Impervious Area Treated (ft^2)	Percent of Impervious Area Treated	Cost Additions[a]	Cost Reductions[b]	Change in Cost After Redesign
Breezewood Station Alternative 1	4,800	64,165	98.4%	$36,696	$34,785	+ $1,911
Breezewood Station Alternative 2	3,500	38,775	59.5%	$24,449	$21,060	+ $3,389
Olive Garden	1,780	31,900	59.1%	$14,885	$11,065	+ $3,790
Kohl's, Best Buy, & Office Depot	14,400	354,238	56.3%	$89,433	$80,380	+ $9,053
First Virginia Bank	1,310	20,994	97.7%	$6,777	$1,148	+ $5,629
Chick-Fil-A[c]	1,326	28,908	82.2%	$6,846	$12,540	– $5,694

[a] Additional costs for curb, curb blocks, storm piping, inlets, underdrains, soil, mulch, and vegetation as a result of the redesign.
[b] Reduced cost for curb, storm piping, roof drain piping, and inlets as a result of the redesign.
[c] Cost reduction value includes the cost of a Stormceptor unit that is not needed as part of the redesign.

"

p. 15 **Note:** Table 6 shows cost comparison of LID vs. Traditional designs and the cost additions column includes additional costs for underdrains, etc.

NOTE: Swales included

"CROWN STREET, VANCOUVER, BRITISH COLUMBIA

. . . the City relocated stormwater catch basins that would have been enclosed within the extended curb. Now, at certain intersections, the City uses the new space behind the curb to install "infiltration bulges" to collect and infiltrate roadway runoff. The infiltration bulges are constructed of permeable soils and vegetation. (The City of Portland, Oregon, has installed similar systems, which they call "vegetated curb extensions.") The catch basins are left in place, and any stormwater that does not infiltrate into the soil overflows into the storm drain system.33" p. 15

Note: These are retrofit systems and include overflows. Information not available on at what level they overflow.

"GARDEN VALLEY, PIERCE COUNTY, WASHINGTON (A MODELING STUDY)

The Garden Valley subdivision is a 9.7-acre site in Pierce County, Washington. A large wetland on the eastern portion of the site and a 100-foot buffer account for 43 percent of the site area. Designers evaluated a scenario in which roadway widths were reduced and conventional stormwater management practices were replaced with swales, bioretention, and soil amendments…The LID practices were expected to increase infiltration and reduce stormwater discharge rates, which can improve the health and quality of receiving streams." p. 17

Note: Not a real site. Included swale conveyance systems.

"KENSINGTON ESTATES, PIERCE COUNTY, WASHINGTON (A MODELING STUDY)

A study was undertaken to evaluate the use of LID techniques at the Kensington Estates subdivision,

a proposed 24-acre development consisting of single-family homes on 103 lots. The study assumed that conventional stormwater management practices would be replaced entirely by LID techniques, including reduced imperviousness, soil amendments, and bioretention areas. . . . Three wetlands and an open space tract would treat stormwater discharging from LID installations. Open space buffers were included in the design. The LID proposal also included rooftop rainwater collection systems on each house.40,41" p. 18

NOTE: Included bioretention systems and then treatment of overflow in wetlands. Not clear at what storm size overflow occurs.

"**LAUREL SPRINGS SUBDIVISION, JACKSON, WISCONSIN**
Vegetated swales and bioswales largely were used to replace conventional stormwater infrastructure and led to significant savings. Each of these factors helped to contribute to a more hydrologically functional site that reduced the total amount of stormwater volume and managed stormwater through natural processes." p. 19

Note: Swales that conveyed runoff included.

"**MILL CREEK SUBDIVISION, KANE COUNTY, ILLINOIS**
The designers used open swales as the primary means for stormwater conveyance. Coupled with other site techniques to reduce runoff volumes and discharge rates, significant savings in stormwater construction were avoided because of reduced storm sewer installation; sump pump connections; trench backfill; and catch basin, inlet, and cleanout installation." p. 20

Note: Swales that conveyed runoff included

"**POPLAR STREET APARTMENTS, ABERDEEN, NORTH CAROLINA**
The use of bioretention, topographical depressions, grass channels, swales, and stormwater basins at the 270-unit Poplar Street Apartment complex improved stormwater treatment and lowered construction costs. The design allowed almost all conventional underground storm drains to be eliminated from the design. The design features created longer flow paths, reduced runoff volume, and
filtered pollutants from runoff." p. 21

Note: Grass channels and swales included to treat (filter) and convey surface runoff

"**PRAIRIE CROSSING SUBDIVISION, GRAYSLAKE, ILLINOIS**
The Prairie Crossing subdivision is a conservation development on 678 acres, of which 470 acres is open space. The site was developed as a mixed-use community with 362 residential units and 73 acres of commercial property, along with schools, a community center, biking trails, a lakefront beach, and a farm. The site uses bioretention cells and vegetated swales to manage stormwater...The use of alternative street edges, vegetated swales, and bioretention and the preservation of natural areas all reduced the need for and cost of conventional stormwater infrastructure." p. 22

Note: Swales that treat and convey included

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"PRAIRIE GLEN SUBDIVISION, GERMANTOWN, WISCONSIN
The Prairie Glen subdivision is nationally recognized for its conservation design approach. A significant portion of the site (59 percent) was preserved as open space. Wetlands were constructed to manage stormwater runoff, and the open space allowed the reintroduction of native plants and wildlife habitat. The site layout incorporated hiking trails, which were designed to allow the residents to have easy access to natural areas.54…The use of open-channel drainage and bioretention minimized the need for conventional stormwater infrastructure and accounted for the bulk of the savings in stormwater management." p. 23

Note: Wetlands used to treat runoff; open channel drainage included in LID description

SOMERSET SUBDIVISION, PRINCE GEORGE'S COUNTY, MARYLAND
The Somerset subdivision, outside Washington, D.C., is an 80-acre site consisting of nearly 200 homes. Approximately half of the development was built using LID techniques; the other half was conventionally built using curb-and-gutter design with detention ponds for stormwater management. Bioretention cells and vegetated swales were used in the LID portion of the site to replace conventional stormwater infrastructure." p. 24

Note: Vegetated swales to treat and convey runoff included

"TELLABS CORPORATE CAMPUS, NAPERVILLE, ILLINOIS
Development of the site included preserving trees and some of the site's natural features and topography. For stormwater management, the site uses bioswales, as well as other infiltration techniques, in parking lots and other locations." p. 25

Note: Bioswales included

TORONTO GREEN ROOFS, TORONTO, ONTARIO (A MODELING STUDY)
Toronto is home to more than 100 green roofs. To evaluate the benefits of greatly expanded use of green roofs in the city, a study was conducted using a geographic information system to model the effects of installing green roofs on all flat roofs larger than 3,750 square feet. (The model assumed that each green roof would cover at least 75 percent of the roof area.) If the modeling scenario were implemented, 12,000 acres of green roofs (8 percent of the City's land area) would be installed.63 The study quantified five primary benefits from introducing the green roofs: (1) reduced stormwater flows into the separate storm sewer system, (2) reduced stormwater flows into the combined sewer system,
(3) improved air quality, (4) mitigation of urban heat island effects, and (5) reduced energy consumption.64

NOTE: Green roofs do not retain significant volumes of runoff during extended wet periods.

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[i] http://www.epa.gov/owow/nps/lid/costs07/documents/reducingstormwatercosts.pdf
[ii] http://www.epa.gov/owow/nps/lid/lid.pdf
[iii] http://www.epa.gov/owow/nps/lid/lidnatl.pdf
[iv] http://www.epa.gov/owow/nps/lid/
[v] http://www.epa.gov/brownfields/publications/swdp0408.pdf
[vi] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=124

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ATTACHMENT B – GUIDE TO PROPOSED REVISIONS TO SECTION XII.C

This attachment is a guide to the basis for the proposed changes to Section XII.C, reflected in Attachment A:

- In Section XII.C.1, the feasibility criteria language was removed likely because of U.S. EPA's concern that projects that are developed before the feasibility criteria get established would not be required to implement LID principles described in Section XII.C. However, U.S. EPA's concern with timing was not addressed by its proposed revision to C.1 of removing the feasibility criteria. The following clause, "As provided in Section XII.J, 90 days after approval of the revised model WQMP," was added to clarify that the timing of LID implementation is contingent upon approval of the revised model WQMP. The following sentence was also added to the end of Section XII.C.1, "To the extent the Executive Officer has not approved feasibility criteria as provided in Section XII.E.1, the feasibility of implementing LID BMPs shall be determined through a project-specific feasibility analysis submitted to the Executive Officer for approval." This is done in order to address that until feasibility criteria are established and approved, the feasibility of LID implementation will be made on a project-by-project basis.

- In Section XII.C.2, "bio-filter" is replaced with the word "biotreat" so as to be consistent with the remaining references of the word treat throughout Section C.

- In Section XII.C.2, "conventional" is replaced with "similarly effective" in referencing treatment control BMPs so as to eliminate the inference that low common denominator BMPs would be sufficient. Rather, similarly effective BMPs to be used means BMPs that generally are as effective as LID BMPs.

- In Section XII.C.2, Footnotes 56 and 57 each were amended to read, "A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only in accordance with the priorities specified in Section XII.C.4." Limiting the use of biotreatment to only where infiltration, harvesting and reuse, and evapotranspiration are not feasible is inconsistent with the priority scheme worked out during the stakeholder negotiations, where it was agreed that a tiered approach would be used and biotreatment was among the basket of options. Further, it is inconsistent with Section XII.C.4., which prioritizes LID principles, but includes biotreatment as an option.

- In Section XII.C.2, the sentence suggested by U.S. EPA, "Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance," is moved from the middle of the paragraph to the near end of the paragraph so that similarly effective treatment control BMPs as described in Section XII.C.7 would still be an option as a second tier of LID before having to resort to alternative or in-lieu compliance for projects that cannot implement similarly effective BMPs.

- In Section XII.C.3, the word "strategy" is replaced with the word "goal" to implement the direction that Regional Board gave staff.

- In Section XII.C.7, "evapotranspire," "capture," and "biotreat" are added for consistency because those LID options appear absent in a few instances in this section.

NOTE: RB changes from Third to Fourth Draft in blue. Regulated community changes to Fourth Draft in red.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the model WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated WQMP shall be submitted for review and approval by the Executive Officer[55]. As provided in Section XII.J, 90 days after approval of the revised model WQMP, pPriority development projects ~~that meet the feasibility criteria established pursuant to Section XII.E~~ shall implement the LID principles described in this section, Section XII.C. To the extent the Executive Officer has not approved feasibility criteria as provided in Section XII.E.1, any infeasibility of implementing LID BMPs shall be determined through a project-specific analysis submitted to the Executive Officer for approval.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, ~~or~~ capture, or bio-~~filter~~treat[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. ~~Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance.~~ Any portion of ~~this~~ the design capture volume that is not infiltrated, harvested and re-used, evapotranspired, ~~or~~ captured or bio-~~filtered~~treated[57] onsite by LID BMPs shall be treated and discharged using LID or ~~conventional~~ similarly effective treatment control BMPs or mitigated as set forth in Section XII.C.7, below. Projects that do not comply with this requirement shall meet the requirements established in Section XII.E. for alternative or in-lieu compliance.

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design ~~strategy~~ goal shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention,

[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting.

[56] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only ~~if infiltration, harvesting and reuse and evapotranspiration are not feasible~~ in accordance with the priorities specified in Section XII.C.4.

[57] A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only ~~if infiltration, harvesting and reuse and evapotranspiration are not feasible~~ in accordance with the priorities specified in Section XII.C.4.

evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

a. Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

b. Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

c. Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d. Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with biotreatment systems, where such measures are likely to be effective and technically and economically feasible;

e. Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f. Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g. Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h. During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-

structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[58], New Urbanism[59] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.
6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.
7. If site conditions do not permit infiltration, harvesting and re-use, ~~and/or~~ evapotranspiration, capture, and/or biotreatment of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:
   a. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, ~~and/or~~ harvest and re-use, evapotranspire, capture, or treat at least the design capture volume.

[58] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[59] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

b. Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate, ~~and/or~~ harvest and re-use, evapotranspire, capture, or biotreat at least the design capture volume through designated ~~infiltration/treatment~~ areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire, capture, or treat at least the design capture volume.

c. Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire, capture, or treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

d. Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire, capture, or treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

Linda S. Adams
Secretary for Environmental Protection

California Regional Water Quality Control Board
Santa Ana Region

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Arnold Schwarzenegger
Governor

A G E N D A A N N O U N C E M E N T

REGIONAL BOARD MEETING
Friday, May 22, 2009
9:00 A.M.
City of Loma Linda Council Chambers
25541 Barton Road
Loma Linda, CA

NOTICE

Changes and postponements that may occur to this agenda will be placed on our website and automatically forwarded to those who subscribe to our electronic mailing list. Anyone wishing to subscribe to our electronic agenda mailing list may do so, as follows: go to www.waterboards.ca.gov/santaana/ and choose "Email Subscriptions" from the homepage. Those who are not subscribers should visit our website prior to the board meeting date to view any changes to the agenda.

Supporting documents for agenda items are now posted on our website at least 7 days prior to the scheduled meeting. To view or download the documentation, go to www.waterboards.ca.gov/santaana/ and select the "Public Notices" page.

1. **Introductions**

2. **Public Forum** - Any person may address the Board at the commencement of the meeting on any matter within the Regional Board's jurisdiction and not related to an item that is to be considered separately. The Regional Board Chair requests that each person addressing the Regional Board observe a three–minute time limit.

3. **State Water Resources Control Board Liaison Report** - This item is for information only. No public testimony will be allowed, and the Regional Board will take no formal action.

4. **Approval of the Minutes of the Regular Board Meeting of April 24, 2009.**
{Felipa Carrillo 951/782-3285 fcarrillo@waterboards.ca.gov}

5. **Consideration of Consent Calendar Items** - Items marked with an asterisk (*) are expected to be routine and non-controversial. The Regional Board will be asked to consider these items at one time without discussion. If any interested party, Board Member or staff requests that an item be removed from the consent calendar, it will be taken up in the order shown.

*6. **Appeal of Staff's Denial of an Exemption from the Minimum Lot Size Requirement for Subsurface Disposal System Use** - Russ and Dawn Grove, 4180 Crestview Drive, Lake Elsinore, Riverside County, APN 379-300-001
{Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov}

*7 **Big Bear Lake Nutrient TMDL** - The Board will consider approval of the proposed Big Bear Lake Watershed-wide Nutrient TMDL Monitoring Plan submitted by the Big Bear Lake TMDL Task Force in compliance with the Big Bear Lake Nutrient TMDL for Dry Hydrologic Conditions.
{Hope Smythe 951/782-4493 hsmythe@waterboards.ca.gov} Resolution No. R8-2009-0043

*8. **Amendment of Waste Discharge and Producer/User Water Recycling Requirements, Order No. R8-2005-0003, for Elsinore Valley Municipal Water District – Regional Water Reclamation Facility (NPDES No. CA8000027)** - To incorporate TMDL requirements specified in Resolution No. R8-2004-0037.
{Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2009-0042

*9. **Renewal of Waste Discharge Requirements for Eastern Municipal Water District, Riverside County (NPDES No. CA8000188)** - Discharge of approximately 52.5 million gallons per day of tertiary treated wastewater to Temescal Creek.
(This item was postponed from the April 24, 2009 meeting)
{Jun Martirez 951\782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2009-0014

*10. **Rescissions** - Orders for the following facilities are proposed to be rescinded due to non-payment of annual fees or because the facility discharge has ceased, or because the project is completed and WDRs are no longer required.
{Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2009-0029

Order No.	Facility and Location	Reason for Rescission
1. R8-2004-0004	Elsinore Valley Water District, Canyon Lake Water Treatment Plant, Canyon Lake	Discharges are now regulated under the Regional Board's General De Minimus Permit
2. R8-2008-0015	Fairfield Holland Road, LP, Menifee	Project has been completed and no waste discharges are occurring at the site. WDR no longer required.
3. 84-024	Cardinal Development, Redlands Auto Care Facility, Redlands	Facility is now connected to sanitary sewer system. WDR no longer required.
4. 96-12	Lizzie Enterprises, Inc., Meat Packing Facility, 7310 Pine Avenue, Chino	Due to non-payment of Annual Fees.

11. **Presentation to the Board of the Results of the Most Recent Wasteload Allocation Analysis for the Santa Ana River** - Task Force Consultants will brief the Board on the findings of the recently completed wasteload allocation work (information item).
{Hope A. Smythe 951/782-4493 hsmythe@waterboards.ca.gov}
(This item was postponed from the March 27 and April 24, 2009 meetings).

12. **Renewal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of Orange County, Urban Storm Water Runoff Management Program (NPDES No. CAS618030)** - The Board conducted a public hearing on the tentative order on April 24, 2009. The Board agreed to accept additional comments on Sections XII.C.1 and 2 of the tentative order. Comments at this hearing will be limited to issues related to those sections. Written comments must be submitted by 5:00 pm on May 8, 2009. The Board will consider adoption of the tentative order.
{Mark E. Smythe 951/782-4998 msmythe@waterboards.ca.gov} Order No. R8-2009-0030
(This item was continued from the April 24, 2009 meeting).

13. **Regional Board Member and Executive Officer Communications** - Board Members and the Executive Officer may discuss meetings, communications, correspondence, or other items of general interest relating to matters within the Regional Board's jurisdiction. There will be no voting or formal action taken.

14. **Closed Session** - At any time during the regular session, the Regional Board may adjourn to a closed session to:

    a. consider evidence received in an adjudicatory hearing and deliberate on a decision to be reached based on that evidence (Gov. Code Section 11126(c)(3));
    b. consider the appointment, employment, evaluation of performance, or dismissal of a public employee or to hear complaints or charges brought against a public employee (Gov. Code Section 11126(a)(1));
    c. discuss significant exposure to litigation (Gov. Code Section 11126(e)(2)(B)(i));
    d. discuss whether to initiate litigation (Gov. Code Section 11126(e)(2)(C)(i)); and
    e. discuss pending litigation in the following matters (Gov. Code, § 11126, subd.(e)):
        (1) Stringfellow Hazardous Waste Site;
        (2) US EPA, Santa Ana Region v. Orange County Sanitation District (U.S. Dist. Ct., CD Cal.);
        (3) Goodrich Corporation v. California State Water Resources Control Board et al. (Los Angeles Sup. Ct. Case No. BS 110389,[consolidated with BS 110390 and BS 110391].);
        (4) In re Petitions of Kwikset Locks, Inc. (SWRCB/OCC File Nos. A-1732, 1732(a), 1732(b), 1732(c), and 1732(d));
        (5) In re Petition of Natural Resources Defense Council, Inc. (SWRCB/OCC File No. A-1883); and
        (6) In re Own Motion Review of Rialto-Area Perchlorate Contamination (SWRCB/OCC File No. A-1824).

15. **Adjournment** to the regular meeting of July 10, 2009, at 9:00 a.m., at the Orange County Sanitation District, 10844 Ellis Avenue, Fountain Valley, CA 92708.

NOTICES

Any person who has a disability and requires reasonable accommodation to participate in this Regional Board Meeting should contact Felipa Carrillo at fcarrillo@waterboards.ca.gov, or at 951/782-3285, no later than ten (10) days prior to the meeting.

Any person interested in obtaining information and/or providing input regarding pending applications for Water Quality Standards Certification under Section 401 of the Federal Clean Water Act may do so by contacting Mark G. Adelson at 951/782-3234.

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for Environmental Protection

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Arnold Schwarzenegger
Governor

ADDENDUM TO AGENDA ANNOUNCEMENT

REGIONAL BOARD MEETING
Friday, May 22, 2009

NOTICE

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Supporting documents for agenda items are now posted on our website at least 7 days prior to the scheduled meeting. To view or download the documentation, go to www.waterboards.ca.gov/santaana/ and select the item of interest.

The following items have been added to the agenda:

12A. **Hazardous Waste Incident Report** - Board staff will provide a list of hazardous waste incidents within the Region to the Board (information item).
{Kenneth R. Williams 951/782-4496 kwilliams@waterboards.ca.gov}

12B. **Underground Storage Tanks Corrective Action Plans** - Board staff will provide a list of sites where Corrective Action plans have been submitted for sites within the Region as required by the California Underground Storage Tank Regulations, Title 23, Article 11, Section 2728 (information item).
{Kenneth R. Williams 951/782-4496 kwilliams@waterboards.ca.gov}

12C. **Underground Storage Tanks Site Closure Report** - Board staff will provide a list of site closures that have occurred within the Region as required by the California Underground Storage Tank Regulations, Title 23, Article 11, Section 2728(d) (Information item).
{Kenneth R. Williams 951/782-4496 kwilliams@waterboards.ca.gov}

California Regional Water Quality Control Board
Santa Ana Region

May 22, 2009

UPDATE TO THE AGENDA

(Prepared 5-13-09)

The following item has been postponed:

*8. Amendment of Waste Discharge and Producer/User Water Recycling Requirements, Order No. R8-2005-0003, for Elsinore Valley Municipal Water District - Regional Water Reclamation Facility (NPDES No. CA8000027) Order No. R8-2009-0042

California Regional Water Quality Control Board - Santa Ana Region
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Internet Address: http://www.waterboards.ca.gov/santaana

BOARD INFORMATION SHEET

BOARD MEMBERS	APPOINTMENT CATEGORY
Carole H. Beswick, Chair	County Government
Seymour D. Van Gundy, Vice-Chair	Water Quality
William Ruh	Municipal Government
Fred Ameri	Industrial Water Use
Steven PonTell	Recreation, Fish and Wildlife
Richard A. Freschi	Water Supply
Vacant	Undesignated (Public)
Vacant	Irrigated Agriculture
Vacant	Water Quality

REGIONAL BOARD LEGAL COUNSEL

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REGIONAL BOARD SENIOR STAFF

Gerard J. Thibeault, Executive Officer
Kurt V. Berchtold, Assistant Executive Officer
Joanne E. Schneider, Environmental Program Manager
Robert L. Holub, Supervising Water Resource Control Engineer
Michael J. Adackapara, Supervising Water Resource Control Engineer
Gary D. Stewart, Chief of Compliance
Dixie B. Lass, Chief of Land Disposal
Steven D. Mayville, Chief of Enforcement
Wanda Cross, Chief of Basin Planning - Coastal Waters
Hope A. Smythe, Chief of Basin Planning - Inland Waters
Mark G. Adelson, Chief of Regional Planning Programs
Mark E. Smythe, Chief of Stormwater - Coastal
Milasol C. Gaslan, Chief of Stormwater - Inland
Jun Martirez, Chief of Permitting
Ann E. Sturdivant, Chief of SLIC/Department of Defense
Kenneth R. Williams, Chief of Pollutant Investigations
Catherine Ehrenfeld, Regional Administrative Officer
Kevin Heinemann, Information Systems Analyst
Felipa Carrillo, Executive Assistant

GENERAL STATEMENT

The primary duty of the Regional Board is to protect the quality of the waters within the Region for all beneficial uses. This duty is implemented by formulating and adopting water quality control plans for all ground and surface water bodies in the region and by prescribing and enforcing requirements on waste discharges. The specific responsibilities and procedures of the Regional Water Quality Boards and the State Water Resources Control Board are outlined in the Porter-Cologne Water Quality Control Act (Division 7, California Water Code).

The purpose of this meeting is for the Board to obtain testimony and information from concerned and affected parties and make decisions after considering the recommendations made by the Executive Officer.

Whenever possible, lengthy testimony should be presented to the Board in writing one week before the scheduled meeting and only a summary of pertinent issues should be presented orally. For each matter considered, relevant Regional Board files are incorporated into the record.

A copy of the procedures governing Regional Water Board meetings may be found at Title 23, California Code of Regulations, Section 647 et seq., and is available upon request. Hearings before the Regional Water Board are conducted pursuant to Government Code Section 11400 et seq. and 11513.

DISCLOSURE STATEMENT

All persons who actively support or oppose the adoption of waste discharge requirements or NPDES permits pending before the Regional Board, must submit a statement to the board disclosing any contribution of $250.00 or more to be used in a federal, state, or local election, made by the action supporter or opponent, or his/her agent, within the last twelve months to any Regional Board Member.

Also, all permit applications and all persons who actively support or oppose adoption of a set of waste discharge requirements and/or NPDES permits pending before the Regional Board are prohibited from making contributions of $250.00 or more to any Board member for three months following a Regional Board decision on the permit application.

RIGHT TO PETITION

Any person affected adversely by a decision of the California Regional Water Quality Control Board, Santa Ana Region (Regional Board), may petition the State Water Resources Control Board (State Board) to review the decision. The petition must be received by the State Board within thirty days of the Regional Board's meeting at which the adverse action was taken. Copies of the law and regulations applicable to filing petitions will be provided upon request to the Regional Board.

NOTE: The agenda items are numbered for identification purposes only and will not necessarily be considered in the order listed. The Public Forum item will be limited to one hour.

- - - -

ITEM NO. 12
Errata - 2

(Additions are underlined and deletions are strike-out)

1. *Order No. R8-2009-0030, Section III.3.i., Page 33*

h) Dechlorinated swimming pool discharges (Cleaning wastewater and filter backwash shall not be discharged to the MS4s);
~~h~~i) Diverted stream flows;
~~i~~i) Rising groundwaters and natural springs;
~~j~~k) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;
~~k~~l) Flows from riparian habitats and wetlands;
~~l~~m) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XXI, Provision 5);
~~m~~n) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and
~~n~~o) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

2. *Order No. R8-2009-0030, Section III.3.ii.a, Page 33 (1st sentence)*

a) The de minimus types of discharges listed in the General De Minimus Permit shall be in compliance with the terms and conditions of the Regional Board's General De Minimus Permit for Discharges to Surface Waters…

3. *Order No. R8-2009-0030, Section XII.C, Page 53*

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the model WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated model WQMP shall be submitted for review and approval by the Executive Officer[55]. As provided in Section XII.J, 90 days after approval of the revised model WQMP, p~~P~~riority development projects shall implement LID principles described in this section, Section XII.C. To the extent that the Executive Officer has not approved the feasibility criteria within 18 months of adoption of this order as provided in Section XII.E.1, the infeasibility of implementing LID BMPs shall be determined through project specific analyses,

[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting

each of which shall be submitted to the Executive Officer, 30 days prior to permittee approval.

2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, ~~capture,~~ or bio-treat~~filter~~[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. ~~Projects that do not comply with this requirement shall meet the requirements established in section XII.E. for alternative or in-lieu compliance.~~ Any portion of the design capture volume that is not infiltrated, harvested and re-used, evapotranspired~~, captured~~ or bio-treated~~filtered~~[57] onsite by LID BMPs shall be treated and discharged in accordance with the requirements~~using LID or conventional treatment control BMPs or mitigated as~~ set forth in Section XII.C.7 and Section XII.E, below.

4. Order No R8-2009-0030 Section XII.C.3, Page 53 (3rd sentence)

3. The design ~~strategy~~ goal shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff.

5. Order No. R 8-2009-0030 Section XII.C.5, Page 55 (1st sentence)

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil and groundwater contaminants (Brownfield developments),

6. Order No. R8-2009-0030 Section XII.C.7, Page 55 (1st sentence)

7. If site conditions do not permit infiltration, harvesting and re-use, ~~and/or~~ evapotranspiration, and/or bio-treatment of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:

---

[56] A properly engineered and maintained bio~~-filtration, bio-retention or other bio-~~treatment system~~s~~ may be considered only if infiltration, harvesting and reuse and evapotranspiration ~~are~~ cannot be feasibly implemented at a project site (feasibility criteria will be established in the model WQMP [Section XII.C.1] and the technically-based feasibility criteria [Section XII.E.1]) ~~feasible~~. Specific design, operation and maintenance criteria for bio-treatment systems shall be part of the model WQMP that will be produced by the permittees.

[57] ~~A properly engineered and maintained bio-filtration, bio-retention or other bio-treatment systems may be considered only if infiltration, harvesting and reuse and evapotranspiration are not feasible.~~ For all references to bio-treat/bio-treatment, see footnote 56.

7. Order No. R8-2009-0030 Section XII.C.7.a, Page 55 (3rd sentence)

a. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate ~~and/or~~, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume.

8. Order No. R8-2009-0030 Section XII.C.7.b, Page 56 (3rd sentence)

b. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume.

9. Order No. R8-2009-0030 Section XII.C.7.c, Page 56 (3rd sentence)

c. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume.

10. Order No. R8-2009-0030 Section XII.C.7.d, Page 56 (3rd sentence)

d. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume from the entire tributary area.

11. Order No. R8-2009-0030 Section XII.E.1, Page 58 (1st sentence)

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs (feasibility to be based in part, on the issues identified in Section XII.C) .

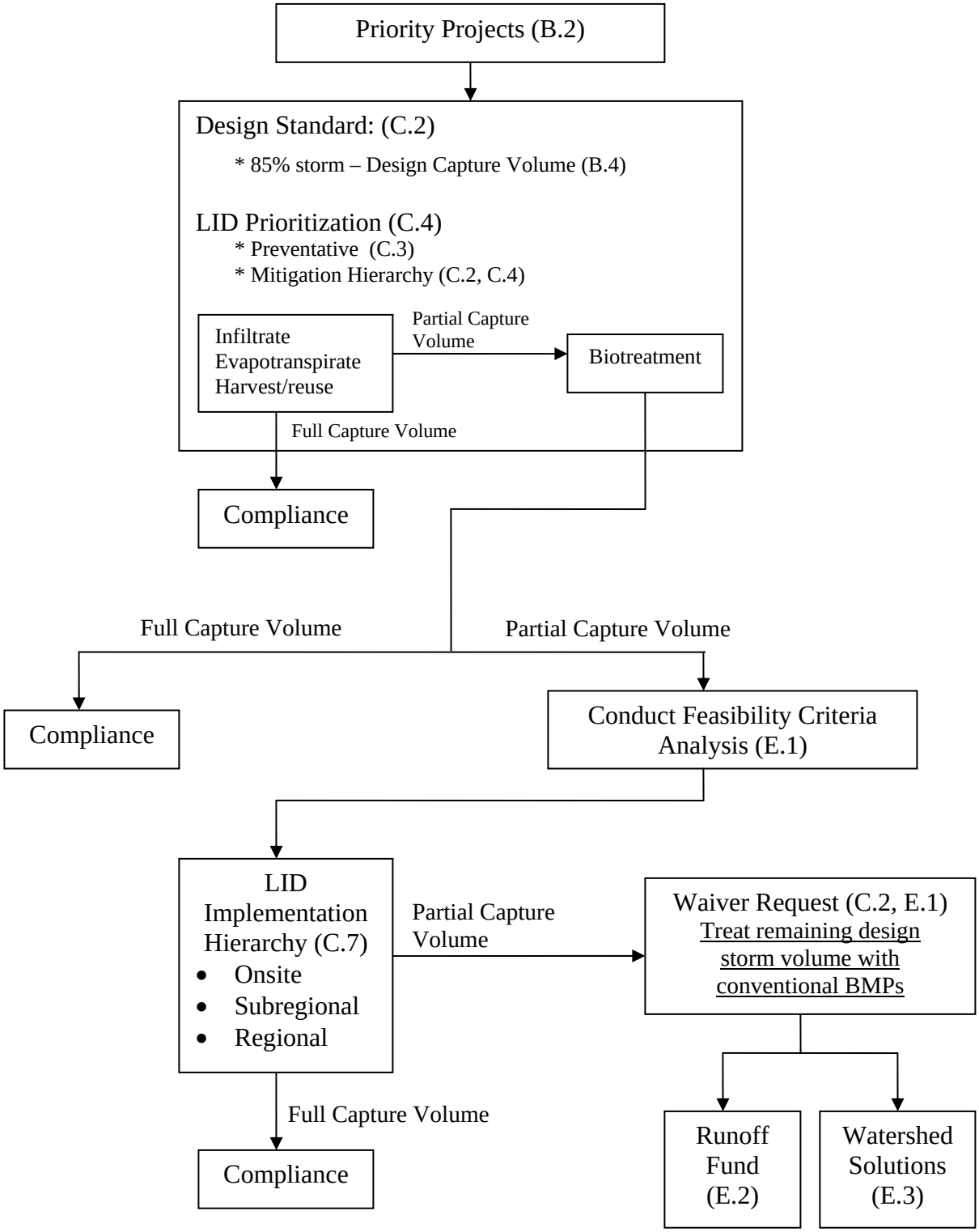
12. Order No. R8-2009-0030 Section XII.E.1, Page 58 (4th sentence)

1. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing, 30 days prior to permittee approval. ~~Waivers shall only be granted with prior approval from the Executive Officer.~~

13. Order No. R8-2009-0030 Section XVIII.B.9, Page 73 (1st sentence)

9. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement a constituent-specific source control plan~~BMPs~~ for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall be designed to ensure compliance with the following wasteload allocations:

Low Impact Development (LID) Process



CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SANTA ANA REGION

CAROLE H. BESWICK, CHAIRPERSON

In the Matter of:	)
	)
Public Hearing re: Agenda item 12, Renewal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of Orange County, Urban Storm Water Runoff Management Program (NPDES No. CAS618030)	)

TRANSCRIPT OF PROCEEDINGS

Loma Linda, California

Friday, May 22, 2009

Reported by:

MELISSA TRESSEN
CSR No. 13367

Job No.:
B1839WQRV

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SANTA ANA REGION

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TRANSCRIPT OF PROCEEDINGS taken at 25541 Barton Road, Loma Linda, California, commencing at 9:00 a.m., on Friday, May 22, 2009, heard before the CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, Santa Ana Region, reported by MELISSA TRESSEN, CSR No. 13367, a Certified Shorthand Reporter in and for the State of California, pursuant to Notice.

APPEARANCES:

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EXECUTIVE OFFICER:	Gerard J. Thibeault
ASSISTANT EXECUTIVE OFFICER:	Kurt V. Berchtold
LEGAL COUNSEL:	David Rice
ENVIRONMENTAL PROGRAM MANAGER:	Joanne E. Schneider
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CHIEF OF STORMWATER:	Mark E. Smythe
INFORMATION SYSTEMS ANALYST:	Kevin Heinemann
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Loma Linda, California, Friday, May 22, 2009

9:00 a.m.

MS. BESWICK: That brings us to item 12, which is the continued public hearing on the Renewal Waste Discharge Requirements for the County of Orange, Orange County Flood Control District, and Incorporated Cities of Orange County, Urban Storm Water Runoff Program.

I want to remind you that this meeting was -- the hearing was held open only for items -- only for Section 12.C.1 and 2. We are going to limit our conversation and discussion to just that today.

And with that, I'm going to ask Mark if he'd like to introduce the item.

MR. SMYTHE: Good morning, Madam Chair and members of the Board. As you said, we're here for part two of the public hearing. As part of the presentation today, I'm going to go through a little bit of the permit timelines since the opening of the public hearing, go through a list of the commenters, and finally, go through the second errata, which you have before you, and do a little bit of emphasis on L.I.D.

For the timeline, as you said, on April 24th, the public hearing was opened. On May 1st, Board staff

took the comments that were received prior to and at that board meeting and revised the M.S.4 permit and released a draft on that Friday, April -- or on May 1st, excuse me.

There was a week of public comment. We received 12 -- letters from 12 commenters during that time period, and on May 8th we closed the public comment for written comments on that Friday. On the following Monday, the errata sheet was released, followed by our response to comments.

And finally, a second errata sheet, the errata sheet dash two in your package was released earlier this week. By May 8th we had received comments from the following entities -- I believe all of them are here today. So rather than try and summarize their comments, I'm sure they'll be happy to share them with you later.

So based on comments from these letters and from the other conversations, teleconferences, e-mails, meetings that we've had prior to it, we came up with an errata sheet two, which incorporates the earlier errata sheet and some additional changes. So what I'll do is I will go through these.

MS. BESWICK: And, Mark, these additional changes were a result of comments you received at the meeting and subsequent to it; is that right?

MR. SMYTHE: That's correct.

MS. BESWICK: So you're responding to comments.

MR. SMYTHE: So we're responding to everything that we pretty much received prior to the last couple of days.

MS. BESWICK: Okay.

MR. SMYTHE: All right. The first one is actually outside of the C.1, C.2 area, and it has to do with the de minimus permit. In the past, when cities or county -- or the county discharge --

MR. RICE: Mark, can I stop you for a second?

MR. SMYTHE: Yes.

MR. RICE: I just want to clarify that we received a bunch of written comments up until May 8th. And that those subsequent conversations that you've had with any of the parties have been to kind of flush out what those comments were; correct?

MR. SMYTHE: That's correct.

MS. BESWICK: So it's not like you were taking new information?

MR. SMYTHE: No. It was clarification on comments that had been prepared in writing prior to May 8th.

MS. BESWICK: That's an important component of today's hearing. Thank you.

MR. SMYTHE: With regards to the de minimus permit

coverage under this permit, in the past when cities or the county discharge portable water or groundwater to their own M.S.4, they had to get coverage and pay the fees associated with our de minimus permit. These are for things like fire hydrant flushing, portable waterline flushing, groundwater pumping.

With this new permit, for the most part, these discharges are now covered under the M.S.4, and some final tweaking was necessary to get the language correct. Inadvertently, we had dropped the fact that the cities and the county did not have to prohibit dechlorinated swimming pool water discharges from residential sites, and we need to make sure that that got back into the permit.

The next changes have to do with L.I.D. This is the C.1 that was continued from last month. There are a few changes with this. First of all, we've clarified that it was model W.Q.M.P. that was being updated. A lot of this has to do with the timing of when the model W.Q.M.P. and the feasibility criteria needs to be submitted to the Executive Officer for approval.

What happens after approval, the 90-day period before this L.I.D. needs to be implemented, and what happens if, in this case after 18 months, that approval

is not forthcoming? That was one of the major issues that came out of our previous public hearing. This actually seems to have gotten pretty much settled. I don't think there are going to be any comments regarding this, although, I could be wrong.

The second issue that was coming back today was C.2, and C.2 is the one that there are still remaining issues. What I'll do is I'll point out some of the major changes that we've made to this section.

First of all, we removed the term bio-filter, something that was added as a result of the last public hearing, and have changed to bio-treat. Throughout the permit you'll see this repeated time and time again.

It requires what happens if on-site L.I.D. is not used to address the entire design storm flow. If they're not able to address the entire design storm volume on-site, then either that body has to be addressed through C.7, which is off-site L.I.D., or through the process of the in-lieu alternative program.

One of the things I need to point out is this and/or. In your errata sheet right now, it says "and." It needs to be and/or because they can either settle it through off-site, anything that they aren't dealing with on-site, or through this, or through a combination of the two, if need be. So that's why that change is

there.

And finally, one of the other issues that you'll be hearing about today is right here (indicating), is language has been added and was added with the forth draft of the permit that requires on-site L.I.D. to use infiltration, evapotranspiration, and harvest, and re-used as the priority.

When those three on-site retaining L.I.D.s are not feasible, cannot be feasibly implemented at the site, at that point you go on to look at bio-treatment systems. And I'm going to be going through the way this section has morphed over the past couple months in later slides. Some of the other changes --

MR. THIBEAULT: Mark?

MR. SMYTHE: Yes.

MR. THIBEAULT: Before you go too far, that's an important concept that you just described. Is it an accident that those three issues are listed as one priority and bio-treat is listed as a lower priority if the first three are not feasible, or is that -- that's an obvious -- or is that an obvious statement of our intent?

MR. SMYTHE: There are reasons for that, and I will be going into those in later slides. If you want me to address it now, I can.

MR. THIBEAULT: If you're going to go over it later, that's fine.

MR. SMYTHE: I will as we go to the fourth draft on this.

But to get through the rest of the errata sheet prior to getting to those concepts. The issue from the last portion of the public hearing of strategy verses preference verses goal, we've gone with goal. Where infiltration may not be feasible, some of the conditions were here.

It did not include groundwater contaminants as part of ground field development. So we added that. And as I said, bio-treatment became the term of choice, and that was used on several places. So it was added to C.7, C.7.A, C.7.B, C, D.

And then one of the issues that we have gotten in our written comments was regulated communities' concern that where we talked about on-site retention L.I.D.s not being feasible, that feasible would be up for definition, that if this went to a judge, a judge might say, well, if you can dig a hole and put in a cistern, it's feasible.

It may not work. It may not be what you want to do, but it is feasible. So we did put in language saying that feasibility would be based in part on the

issues identified within this overall L.I.D. section.

So that all those issues that are bought up in the various sections, C.4, where it talks about the priority of how to apply L.I.D., the various other sections where it talks about the concerns of L.I.D in some areas for, like, geotechnical issues, for high groundwater issues, for contaminant transport issues. All those that are in C should be taken into account when defining feasibility.

MR. PONTELL: May I ask a question?

MR. SMYTHE: Yeah.

MR. PONTELL: I guess this is something I'm still struggling with, is the word feasible verses -- if feasible does not tend to imply better. And so if it would be better even though it's feasible to handle the water in a particular way, but it would be better to do it another way, my concern is that the word feasible doesn't capture if it were better to handle it a different way.

MR. SMYTHE: And I think that's going to be one of the things discussed here is that language. And whether better becomes -- and whose opinion is it better than and what constitutes better?

MR. PONTELL: Because when you're defining feasible as based in part on all the other issues that

are identified, groundwater levels, soil condition, et cetera, it may be better if there was a half a mile away a state of the art groundwater infiltration system.

And it's better to use the storm water drain system to get the water to that system verses trying to duplicate a lesser quality system on-site. So it would be better to do something else even though it's feasible to do the former.

MR. RUH: Better is open up to interpretation. One person is saying better being delivered half a mile off site to some kind of a facility might be better to one person, that may not be to another. I think maybe we need to look at what is truly workable and what can be -- what's going to achieve the end result.

MR. SMYTHE: This conversation will be continuing.

The 12th item on the errata sheet is an important one. It changes the approval of the waivers. Should waivers be applied for, the approval will be by the permittees, rather than going to the Executive Officer for approval.

MS. BESWICK: Say that again.

MR. SMYTHE: Okay. If waivers are applied for -- if they go through -- get some of the storm -- design storm addressed through on-site B.M.P.s, some of it through off-site B.M.P.s, and then still have some

design flow that they cannot address through those and are applying for a waiver, the permittees will be approving those waivers based on criteria set up in the feasibility criteria document that you will be approving in the future -- that Jerry will be approving in the future.

MR. THIBEAULT: It will be what is submitted to the Board for approval, and the approval will proceed through whatever mechanism the Board adopts in the permit.

MR. SMYTHE: There will be a 30-day process by which Regional Board staff will have the opportunity to review those waivers before they're approved by the municipalities.

The next one is some minor tweaks for T.M.D.L. implementation that came out of the County of Orange comments and suggested language that we had received prior to the May 8th deadline that David Rice had worked with and tried to come up with some changes on.

And the final one, which is not in your errata sheet that we did receive after the May 8th, but probably needs to be included is -- and Attachment C at the end of the permit is a list of various agencies that are interested in this permit; includes community college districts, water districts, sanitation districts, school

districts and two -- or sanitation districts and water districts had not been included, and we're including them at this time.

All right. Into C.2. This is what it looked like as part of the third draft from April 10th. This is what we had going into the public -- that last public hearing startup. As part of -- as a result of E.P.A.'s threatened objection to the permit the night before, we added the following language: That the projects that do not comply with this requirement shall meet the requirements established in Section 12.E, which is the in-lieu or alternative program for alternative or in-lieu compliance.

What this meant was that anything that was not captured on-site and infiltrated harvest evapotransporated would need a waiver -- would need to go to the E -- 12.E process.

Based on the comments that were received at that public hearing, we came up with our fourth draft on May 1st, which included the E.P.A. language, added bio-filtration at that time, now bio-treatment, added bio-filtration and added this language that on-site retention L.I.D. B.M.P.s be considered prior to bio-treatment.

Here's where Staff's concern entered into

this. If a site could feasibly and, let's say to the better, infiltrate 20 percent of the design storm, they could evapotransporate 10 percent, and they could harvest and re-use 10 percent. That's 40 percent that's being addressed on-site.

The remaining 60 percent, let's say they treat through bio-treatment and then release that water. It could be that because you're having to build three different systems to address this design storm, it may be cheaper, it may be more logical to some to treat it all through bio-filtration. We've only got one system to build.

The idea of L.I.D. is to address the design storm through a wide spectrum of B.M.P.s. Staff felt that this was necessary to include this language to ensure that that wide spectrum is used whenever it's feasible to be used.

Was there anything else you wanted to add to that, Jerry?

MR. THIBEAULT: Yeah. I think the only other thing would be that this permit is based on a maximum extent practicable compliance metric. And a lot of times doing bioswales, doing grass medians, and the like is the easiest thing to do. It's just easy. Let's all do it.

But that's not to the maximum extent

practicable. That's not a high enough level of compliance. When we look at permit compliance using whatever combination as Mark described it of B.M.P.s is a -- it's more easily demonstrated to be in compliance with the M.E.P. standard. Just doing the easiest thing is not M.E.P. Doing the most effective feasible approach is M.E.P.

And so that was the basis for my earlier question to Mark. We're doing this on purpose. We're suggesting these three things are M.E.P. If you can't do the first three, then the last would be the alternative. So it's purposeful. We think it's M.E.P. We think that anything less than that is not M.E.P.

MR. RUH: Right.

MR. SMYTHE: All right. Thank you, Jerry.

So the fourth draft went out, and we received comments on Friday, May 8th. And on Monday, May 11th, we came out with the first errata sheet. Based on those comments that we received, the word "capture" was removed throughout the permit. "Filter" was changed to "bio-treat," and the language here that kicks things out to Appendix E was bumped down to here (indicating).

And what that meant was that not only could you meet the permit requirements by addressing the 85th percentile design capture volume through on-site

infiltration, harvest, and re-used and evapotransporate or bio-treatment, but also by off-site L.I.D., which is found in C.7, or by similarly effective treatment control B.M.P.s prior to going down to an in-lieu program.

Now, the reason we included this -- it was originally there as conventional with this up here (indicating). When this got moved down, this became more important because this would allow the use of, in the old word, conventional treatment to, we'll use the word "get out of," getting into an in-lieu or an alternate program. And that wasn't Staff's intent.

Our concern was in the last permit cycle, we implemented the requirements for S.U.S.M.P. requirements. We implemented the requirement for structural treatment. One of the things that we liked, one of things that we encouraged was regional treatment systems, the natural treatment systems, the constructed wetlands to address a development.

Our concern was that as set up with this language up here, if you had designed natural treatment system for existing development, for future development, or planned on using it, all of a sudden you were not only having to do the N.T.S., the Natural Treatment System, the constructed wetlands, but you were also

having to do in-lieu treatment. You were having to pay into a fund, you were having to do L.I.D. on alternate sites.

Our concern was that N.T.S. was at a level high enough that it needed special protection. And so that's why we moved that language down there (indicating). Now, things will change after additional conversations with E.P.A., and I will be showing that for the second errata sheet.

MR. PONTELL: I think what you just said is really what my goal is.

MR. SMYTHE: I know it is.

MR. PONTELL: I just want to make sure I heard that correctly.

MR. SMYTHE: Yes, you did hear that correctly.

Based on conversations with E.P.A., both John Kemmerer and staff up in San Francisco, we were able to determine that properly designed, maintained, and operated constructed wetlands such as N.T.S. would be considered bio-treatment by E.P.A.

As we saw last month and John has mentioned, you can pull up almost any E.P.A. document on L.I.D. and find the definition for L.I.D. that you want. You take it to a step further and what constitutes bio-treatment? It really goes out the door. I mean, I was doing

searches, was able to find constructed wetlands listed as an L.I.D. toolbox in certain websites, but not on other websites. So that really does raise a concern of what constitutes bio-treatment.

And with E.P.A.'s buy-in on N.T.S., Regional Board staff felt comfortable dropping this -- using L.I.D. or similarly effective B.M.P -- or treatment control B.M.P.s or mitigate us. We felt comfortable losing that because N.T.S. would fit into the slot.

I think that really was the major one. And again, feasibility criteria was actually expanded even more to include the model W.Q.M.P. and the feasibility criteria. So we're even more trying to define what -- give as much latitude as to what constitutes feasible.

Finally, what I did was I borrowed a slide from the County, adapted it, made it fit what staff believes is the intent --

MR. THIBEAULT: It's very clear.

MR. SMYTHE: -- of this portion of the permit. You guys do have it. I think you guys do have -- yeah. It gets tough on some of these.

Essentially, if you've got a priority project, you need to capture the 85th percentile design storm capture volume. What you need to do is infiltrate, evapotransporate, or harvest and re-use that design

volume. If you are able to do that -- address the full capture volume, you are in compliance. If not, you can go to bio-treatment, and that's discussed in that footnote.

If at that point you are doing your full capture volume -- if you've addressed the full capture volume through one of those two, you're in compliance. If not, you go to your feasibility criteria analysis to make sure that you weren't able to do everything up here (indicating).

At this point, if you weren't able to capture or treat the whole capture volume there, you go on to off-site L.I.D. If you're unable to address the entire storm -- design storm capture volume and those, then you go into the waiver process.

And an important thing to note is that if you are requesting a waiver, if you are unable to treat the entire design storm volume, you still need to treat what's discharging from that site through a normal S.U.S.M.P. type B.M.P.s, and in addition, because you're not doing L.I.D. on that entire storm flow or capture volume, you need to do either a runoff fund or some watershed solution to in-lieu for that portion of the design storm volume that you're not addressing here. Not for the entire thing, just for what you're not

addressing here.

MS. BESWICK: It's a good chart, Mark. It really does make sense. It's a good chart.

MR. SMYTHE: I do appreciate Richard, and I think he might have gotten it from Matt Walker. I did switch around -- this does not represent what the county wants to see, but it represents what staff believes the permit process shows.

Should I go into the other de minimus language?

MR. RICE: The de minimus language we talked about earlier?

MR. SMYTHE: Yeah.

MR. RICE: Yeah.

MR. SMYTHE: Throwing caution to the wind --

MS. BESWICK: Well, let's do that.

MR. SMYTHE: The thing that derailed us last time was last minute language additions. This issue had been brought up by a water purveyor within the Newport Bay Watershed in previous conversations. It shouldn't affect things because it's clarifying language. It's not adding any new requirements.

And what the situation is, is I explained that we have brought the de minimus permit into the M.S.4 for municipal entities. So where a municipal entity is

discharging fire hydrant water or portable water, they are no longer getting coverage under our general de minimus that applies to everybody. They're doing it under their M.S.4 permit. The exception is Newport Bay.

And the reason that Newport Bay Watershed is accepted is because of the selenium issues and the nutrient issues, the T.M.D.L. issues. It was always Staff's intent that this inclusion of the de minimus permit in Section 3 point 2.A of our M.S.4 would not include the Newport Bay Watershed. And the comments we received was it may not be interpreted that way and to clarify it.

So that language is there and would need to be included along with the errata sheet that you have before you along with the two -- the water districts and the sanitation district that I had mentioned and that and slash or in C.2 would need to be added to any errata sheet.

MS. BESWICK: I was just going to say, when you're done, why don't we leave this up since we don't have it in front of us.

MR. THIBEAULT: Is that in print anywhere?

MR. SMYTHE: Not enough copies, but we can make it though. Yeah, we can make more.

MR. THIBEAULT: Does the Board have it?

MR. SMYTHE: No, the Board does not have it. No, that's it.

MS. BESWICK: Is that it?

MR. SMYTHE: That's it for now.

MS. BESWICK: Great work. Thank you.

MR. SMYTHE: Any questions?

MS. BESWICK: Does anyone have any questions for Mark?

MR. PONTELL: Let me -- let's just go back to this feasibility issue because I'm still -- after looking at your chart, I would think that we would want to encourage communities or groups of communities to come up with multiple beneficial solutions that may not be site-specific.

And so going back to the concept of creating a wetlands that can have habitat benefits, wildlife benefits, can have a variety of other benefits that are maybe beyond the goal of this particular permit, have ended the process of handling runoff from either modifications of existing developed property or new developed property, that water was able to feed into a subregional system, it would be better than specific site-by-site solutions.

And so going back to the prioritization of, if it was feasible, to capture and infiltrate,

evapotransporate, or harvest re-use, all the water on a particular piece of property, but it was better to allow that water to go into a subregional solution, I do not see our chart allowing that to occur.

MR. SMYTHE: You know, I do apologize for being very focused on C.1 and C.2. It's kind of -- I've been obsessive for the past few weeks. There is a section in D.5, which is the watershed master plan, and Michael, I would ask you to comment a little bit more on this, but it's my understanding that this would maybe address your concern.

MR. ADACKAPARA: I think what we have done is we have provided the permittees -- actually this is a mandated requirement under Section D.5. It says the permittees are required to develop watershed master plan, and we are hoping that concerns, just like what Mr. PonTell expressed, will be completely addressed in the watershed master plan.

MR. PONTELL: So in the event there's a watershed master plan, then that would allow for --

MR. SMYTHE: It's page 57.

MS. BESWICK: Thank you. It's D.4? Is that what I heard?

MR. SMYTHE: D.5.

MR. ADACKAPARA: D.5, pages 57 and 58.

MS. BESWICK: So it's addressed elsewhere in the permit, Steve. Do you see where that is?

What we're talking about in 12.C.1 and 2 is not going to address your concern to the extent that it's going to be addressed in this portion of the print out.

MR. THIBEAULT: Or it already has been addressed. I think, Mr. PonTell, that this Board has always expressed its support for regional systems, and I'm not sure how anybody could say that a proposal to use a regional or subregional system that achieves the same net results, would not be acceptable.

I can't imagine that because everything would be based on is it an equivalent level of capture, harvest re-use, evapotransporation then what would be achieved on-site? If it's the equivalent of what would be achieved on-site, how would it not be a compliant approach?

MR. SMYTHE: I wouldn't want to come before you arguing against something like that.

MS. BESWICK: And it would be out of character for you to do that.

MR. THIBEAULT: The Board has expressed that on the record many times.

MR. PONTELL: Thank you.

MS. BESWICK: Other questions for Mark?

MR. RUH: Just very quickly, Madam Chair and for the public, I unfortunately will have to leave. I have a meeting in Diamond Bar at 12:15. So I'll need to leave about 11:15. It's unfortunate. It's due to the weekend and the time frames. Hopefully we'll be able to --

MS. BESWICK: That's really a problem because we need to take a vote today, and you're our quorum. Thanks for the update, but I'm not sure that I can get us through it that fast. We'll try.

MR. RUH: Hopefully we can do what we need to. Thank you.

MS. BESWICK: Thanks, Mark.

Before we open this, I'd like to ask for David to give us some procedural comments, if you would.

MR. RICE: Thank you, Madam Chair. Before we move on to what I expect to be a very lively, and hopefully very short discussion, we need to handle a little bit of housekeeping.

As you know, at the April 24th meeting you closed the hearing -- the Board closed the hearing and accepted -- allowed comments on two very specific sections in the permit written comments up until May 8th.

And we have received -- and actually you have received directly several late comments, and so we need to figure out how the Board would like to address those and deal with those comments. I'd like to give you maybe two general possibilities, and they get more complicated --

MS. BESWICK: Do you want me to just tell you what my inclination is?

MR. RICE: Please do.

MS. BESWICK: I've said at the April 24th meeting we would not take comments after May 8th, and we won't.

MR. RICE: Okay. Well, then that clears up at least one procedural issue. And to the extent that any of the Board members did directly receive any comments from parties here and did read them, please disregard those in consideration -- in rendering your decision on the permit.

And I would like to raise one other issue. The errata sheet did include changes not only to the portions that were left open for comment -- written comment until May 8th, but also to other areas of the permit, and I expect that some folks here would like to make comments on those errata changes to other portions of the permit.

And as the hearing is currently designed and

scheduled, the Board is going to allow comments only on sections 12.C.1 and 12.C.2. The Board is under no obligation to consider any comments to any other parts of the permit, even those that there were errata changes made to.

But I expect that there will be some parties in the audience who would like to make comments. They may certainly ask if the Board will allow comments on other portions of the permit, but it's certainly within the Board's discretion to neither accept or reject those.

MS. BESWICK: Let me comment to my colleagues with your -- see how you feel about this. My inclination again is to treat those other items as not something we would focus on today.

It is the norm for us to have the staff bring to the Board potential changes based on input that they received from the time that we first hear something, and we take action on it. And that's the case in my mind today that we are being asked as a Board to deal with some of these things based on Staff's comments.

So my intent, unless anyone disagrees with it, is to limit the conversation to the items that we agreed that we were going to be discussing today.

MR. RUH: Absolutely.

MS. BESWICK: Part of my reason for that is, I really am not going to allow this permit to be opened up for an entire discussion again. I don't see how we avoid that unless we stick to the rules we set for ourselves in April.

MR. RUH: I concur.

MR. FRESCHI: I concur.

MR. PONTELL: Can we make a motion to limit public comment to one minute per person?

MS. BESWICK: Let me tell you what. I'm going to be watching the clock. I've been through your cards. No, I won't hear 10 minute presentations. No, there won't be powerpoints. No, there won't be -- we'd like you to try and make three minute comments.

We have had a very thorough discussion of these things on April 24th. We -- I think are pretty clear about what's being proposed today. So I'm going to be a little firmer than you might be used to me being at a meeting, but you'll find I can be.

So we'll begin with -- David, did you have anything else you wanted to say?

My only other comment then is just to remind you, we're only talking about the issues that we said we would talk about. We are not going to entertain late comments. The three minute thing -- we understand

bio-treatment. We don't need to be re-educated to it. We got a very complete picture on the 24th.

With that -- with those comments, I would ask Mary Ann Skorpanich if she would like to begin. And please know, I'm going to watch the clock, and at three minutes I'm going to ask people to stop.

MS. SKORPANICH: With all due respect, we'd like to just change the order a little bit.

MS. BESWICK: Absolutely. However you'd like to do it.

Is this Richard then?

MR. BOON: Yes.

MS. BESWICK: Identify yourself for the court reporter.

MR. BOON: Richard Boon. I represent the County of Orange, which is the principal permittee for the Orange County Storm Water Program. I'm responsible for managing the countywide elements of the Orange County Storm Water Program. Our presentation, I do have a powerpoint presentation. I would ask that as a principal permittee --

MS. BESWICK: Not today.

MR. BOON: This is a really -- we're focused on C.1 and C.2. It is a critical issue.

MS. BESWICK: I'm not going to hear it. We're not

going to have time for a 10 minute powerpoint presentation.

MR. BOON: It won't be 10 minutes.

MS. BESWICK: You can have three.

MR. BOON: We can try to get through it in three.

MS. BESWICK: So let's really focus on the highlights. And I have to say, I'm a little skeptical when I see this many pages of powerpoint that we're going to make it in three. So I wouldn't bother with -- I'd move right on to what you really want to say.

MR. BOON: Obviously, as you observed, reaching consensus has proven to be very difficult. The permittee positions over the course of consideration of this permit, April 24th we were prepared to support adoption of the permit, but we withdrew our support following an errata sheet that was presented to us on April 24th.

May 19th, we were again prepared to support the permit adoption, and we regret that we had to withdraw our support following another errata sheet.

Our main point today is that L.I.D. and traditional structural B.M.P.s are similarly effective protecting water quality. We've examined the performance of B.M.P.s extensively in Orange County. We had a consultant report prepared by R.B.F. and an expert

from the University of Texas in 2003, updated significantly in 2005, and it recommended for use in Orange County a variety of B.M.P.s, both traditional structural and types that would be considered low impact development.

The permittee position is that we support the prioritization of B.M.P.s of L.I.D. and S.U.S.M.P B.M.P.s, but that a water quality volume that cannot be captured by L.I.D. B.M.P.s should be, for a project proponent, be able to be treated using standard or traditional S.U.S.M.P. type B.M.P.s.

Now Mac Walker with Larry Walker Associates is going to present a study that underscores that point.

MR. WALKER: Do I have three minutes?

MS. BESWICK: Yes, you do.

MR. WALKER: Next slide, please.

What we basically did was, we wanted to look -- have a side by side comparison of low impact development strategies verses what we call traditional or conventional B.M.P.s. So what this means is, we took three case studies, and in the first case study, the 100 percent L.I.D. retention, that's the one you get to pass. You don't have to get a waiver.

Case two is if you have 50 percent L.I.D. on-site, but you had to treat the rest before leaving,

you have to get a waiver.

And finally, the third case where we just couldn't do L.I.D., we went with traditional B.M.P.s. Again, you have to have a waiver for those -- case two and three.

So what we did is, is we set up a continuous simulation model. We took a site -- next slide, please -- and we looked at the loadings off of this acreage, 2.7 acres. It's a commercial site runoff coefficient about .74, and we ran -- we calculated the loads coming off that site using the rainfall data for Orange County. We used 10 years of data.

So we plugged in the data, calculated the loads coming off that site for each of those three cases that we talked about.

One other thing I want to point out here is, when we talk about conventional or traditional B.M.P.s, we're talking about a detention basin, and we assume that the water coming out of the well-designed maintained detention basin was going to be around 40 milligrams per liter. And we used total suspended solids as our surrogate to look at.

And the next slide is really the slide we want to present. It's a little bleached out here. I'm going to point out -- the green line is the site without any

controls. That's what we had before S.U.S.M.P., no treatment controls, nothing. The yellow line is case three. That's where we can't do any L.I.D. on-site, but we're using all that water, and we're sending it through a conventional treatment control B.M.P.

Case one, which is the blue line, which is the best performing scenario, is L.I.D. 100 percent. You may say, well, how could that be? Because L.I.D. is retaining it on-site.

What it is, is your standard is to capture and retain the three quarters inch storm. In California where we have that frontal-type rainfall events, you get storms that come in back to back, and you end up using the capacity of the L.I.D. on-site, and the rest of it has to go and be discharged off-site without treatment.

So the bottom line is our overall removal -- solids removal for conventional treatment is 78 percent, while the L.I.D., 100 percent L.I.D. strategy, is only 83 percent. That's a five percent difference. Although, in your scenario, we have to go and get a waiver for that five percent.

Sorry. Are my three minutes --

MS. BESWICK: Getting close.

MR. WALKER: This is important stuff.

MS. BESWICK: I agree, but you need to move it

along.

MR. WALKER: I appreciate that.

Just to keep this in context, we did a sensitivity analysis where we changed some of the input, and the bottom line is it still kind of came real close. The best case scenario is L.I.D. verses traditional verses suspended solids was within one percent overall. This is for 10 years of data, by the way. We are within one percent. The best case for L.I.D. in this -- in these sensitivity was 10 percent difference. It's really bracketed. It's a very small window.

So anyway, the bottom line is we feel that a waiver is inappropriate -- or not inappropriate, but maybe not consistent with the ability of traditional B.M.P.s well-designed and maintained to treat and discharge good water quality.

MR. THIBEAULT: I think that what Mr. Taylor -- or Mr. Walker just showed us looks sort of like -- if you can look at the case three at -- I don't know, 1,100 kilograms and the L.I.D. at 700 kilograms, it looks like maybe what you've demonstrated to us is, it's about 40 percent better to use full L.I.D. than it is the conventional -- just using your data.

MR. WALKER: That's not the way I would look at it.

MR. THIBEAULT: I think it's what the graph shows

us. And you have kind of a scale issue here, too, by having such a large -- or is it small -- scale. It doesn't really differentiate the three cases very clearly when there is a significant difference between the three.

MR. WALKER: Well, I would maybe not agree with you.

MS. BESWICK: And that's okay.

MR. WALKER: I wouldn't agree with you. I suppose that's up for another time.

MS. BESWICK: Thank you.

MS. SKORPANICH: So what we're arguing today is for re-inclusion of similarly effective treatment control B.M.P.s back into the language in Section C. Our position is that this is the N.P.D.S. program. It is to control the discharge of pollutants, and we see L.I.D. and support L.I.D. as a means toward that end, but not an end unto itself.

We feel that the exclusion of that particular phrase then puts a punitive mitigation on projects where it has been deemed infeasible to be able to do this on-site and to have to go through a waiver, still do the treatment of that 85th percentile storm, but do mitigation in addition to it.

We are trying to argue here that a project

should not be penalized because it's using things that are similarly effective where it's infeasible to do it on-site.

Next slide, please.

And again, that's -- next slide. One more.

And so we're arguing for this phrase to be reinserted in there. There really has not been a technical basis for why L.I.D. should be the end as opposed to the means in this particular case. And we think that those similarly effective B.M.P.s where it's infeasible to do the L.I.D. on-site should not have to go through the waiver provision.

Am I out of time?

MS. BESWICK: That's it.

MS. SKORPANICH: Thank you.

MS. BESWICK: Thank you.

Do we have someone following on in that, or may I just continue through the cards that I have?

MR. CARLSTEDT: I believe my card is next.

MS. BESWICK: Are you Tim? It is Tim. Thank you.

MR. CARLSTEDT: My name is Tim Carlstedt. I'm an Environmental Counsel for the County of Orange. Good morning.

Just as a procedural matter, as usual, we just want to make sure that all the County's written

submittals have been included in the administrative record. I have a complete copy set here. I would just ask to present them to make sure it's in the record.

On the legal issues, I just want to follow up with the technical presentation that's been made with a legal justification for making this change to the permit language. And, again, the only change is just by adding this one additional phrase it would put traditional, similarly effective treatment control B.M.P.s back into the mix without requiring a waiver or some kind of payment -- and/or some kind of payment into an in-lieu fund or runoff fund.

There's two legal -- at least two legal basis for adding this language back. The first, I'm sure you're familiar with Water Code Section 13360A, which prohibits the Regional Board from prescribing the matter of compliance with a standard.

So in other words, you can set the standards, the standard here is M.E.P., the permittees have the discretion as to how to meet that standard. And there's been a lot of discussion here. If you have good so-called traditional B.M.P.s, why should you be penalized from using them? That's a pragmatic question, but legally, the Water Code prohibits the Water Board from telling permittees how to meet a standard.

If you have similarly effective options, permittees should be able to use any one of those options in their toolbox. They shouldn't be penalized by having to seek a waiver and paying some kind of in-lieu fund when there's not a justification for it.

The second basis is it's arbitrary. If there hasn't been established that this sub set of L.I.D. or L.I.D. generally is always superior to S.U.S.M.P. treatment control B.M.P.s. And by the way, S.U.S.M.P. treatment control B.M.P.s are throughout Section 12.B, 12.G, 12.I.

The permit is premised on permittees using these types of treatment control B.M.P.s, and yet now, 12.C.1 and 2 would seem to say that you can't use them unless you get a waiver and pay some money. So it's arbitrary. That's a legal basis for adding this language back in, which would make the permit not arbitrary.

With the last minute of my presentation I was going to ask permission to address the technical T.M.D.L. issue, that had been tweaked with respect to Coyote Creek T.M.D.L.s, but I understand that that is not to be accepted.

I appreciate your time, and that's my two minutes.

MS. BESWICK: Thank you very much.

John Kemmerer.

MR. CARLSTEDT: Were there any questions?

MS. BESWICK: Let me stop before John comes up. Does anyone have any questions for the permittee? Because that really was their presentation. It seems very clear.

MR. KEMMERER: Thank you, Madam Chair. Again, John Kemmerer with E.P.A. I'm an associate director of the water division in E.P.A. Region 9. We're working very closely with the Regional Boards across the state and with the State Board on storm water permits, and I want to really commend the work that your staff has done on this permit, which I believe is really a model for how low impact development can be addressed for permits really across the state and country.

I think it's important not to lose site -- of one of the reason -- there's a lot of reasons why we're encouraging L.I.D. and why the staff here are putting L.I.D. provisions in this permit because of the many benefits of L.I.D.

In situations where we have these drought conditions across the state, infiltration into groundwater is a really huge benefit, and I just think that having an L.I.D. section in this permit and having

these clear provisions in this permit on L.I.D. is very critical.

I want to -- we definitely support the changes made in errata sheet two. I think the version that the staff have come up with is actually much superior than what I provided three days before the last hearing, and so we would definitely endorse the permit as written. I want to respond real quick --

MS. BESWICK: John, I can't stand it. Three days before? How about the night before? Oh, nevermind.

MR. KEMMERER: It wasn't the night before.

I guess what I want to also point out is that I'm a little concerned about the last presentation about saying that if you can't contain the storm water on-site, you need to go to a waiver. I think your staff have come up with a really clear and detailed and flexible process for how you comply with the L.I.D. section.

And if you cannot contain the storm water on-site, there are a number of options in 12.C.7 for doing subregional or regional solutions here. I definitely agree with Jerry's analysis of the fact that using L.I.D. and trying to use these on-site containment approaches is M.E.P. -- is consistent with the M.E.P. approach. And so the idea of prioritizing those on-site

methods is a benefit.

And I also just want to echo Mark's comments earlier about the big variability in the definitions on what bio-treatment are. I think you got -- your permit here has a really clear approach that's laid out where you're now going to be able to define exactly what you wanted to define bio-treatment as in the W.Q.M.P. document that's prepared.

I think there's been a huge amount of work done by everybody involved in this, and I really encourage you to adopt this today. I think it's a very flexible and detailed and thorough approach.

MS. BESWICK: Thank you.

Bart Lounsbury.

MR. LOUNSBURY: Good morning, Madam Chair and members of the Board. I am Bart Lounsbury with the Natural Resources Defense Council. I will skip my powerpoint today to try to make this go a little bit more quickly.

Basically, you'll hear the same concern from us that we mentioned last time, which is that we think this should be an on-site retention standard for the reasons mentioned by staff, that that is a superior treatment method. It can ensure that no pollution flows off-site.

And this is not an argument as I think people have mentioned today about the definition of L.I.D. It's an argument about the most effective treatment B.M.P.s, and that means retention. It is more effective, even as the County's consultant studies showed, it's still more effective than conventional treatment B.M.P.s no matter the margin we're talking about.

That's necessary then for this permit to meet the M.E.P. standard. And in fact, you probably all know that recently the Ventura County M.S.4 permit was adopted by the L.A. Regional Board. That has an on-site retention standard that does not include bio-treatment as an option.

It requires, essentially, the retention on-site of the 85th percentile storm with off-ramps for situations of technical infeasibility, which is what we've always advocated. This permit draft with the errata sheet is close to that except that it allows bio-treatment, which we don't support.

So overall in looking at this, I would just say that if you look through the flow chart that staff have come up with, we fully support that flow chart except where it includes bio-treatment. We think that that should be something permittees can do on-site to

deal with any sort of discharge that they may have or toward the on-site retention standard that we would advocate, but that some sort of off-site mitigation or in-lieu fee payment should be required for that portion that is bio-treated.

But otherwise, we think that flow chart very well summarizes what's necessary to meet the M.E.P. standard here. We certainly would not support anything like the County recently proposed here that would allow similarly effective treatment B.M.P.s to be installed on-site. That's, in our opinion, subject to far too much discretion.

The term bio-treatment, as people have mentioned, is highly variable. It has many definitions, and that's what makes us worried. If you say on-site retention, you need to keep it on-site. You know what's happening. It's staying on-site, it's infiltrated, evapotranspired, or re-used.

If you allow bio-treatment, you just don't know how effective these B.M.P.s are going to be. And I'm sure that in the study you just saw, the most effective conventional treatment B.M.P.s were chosen, and they still did not perform as well as L.I.D. retention B.M.P.s.

So that's our perspective. Thank you for the

opportunity to testify today.

MS. BESWICK: Thank you.

Mary Lynn Coffee, followed by Peter Herzog.

MS. COFFEE: Good morning. I'm here on behalf of the City of Irvine. The City believes it's critical that all water quality control L.I.D. bio-treatment B.M.P.s remain available in the toolbox for use for treat and release of water on-site in accordance with the prioritization that's set forth in C.4 and C.7, but without a waiver. We think that's what the flow chart says. If that's what it says, we support that flow chart.

With respect to the prioritization under C.4 and C.7, we believe it's critical that a broad variety of factors can be considered as defined as feasibility factors. And those factors need to include not only what we think of as technical feasibility, like high groundwater and impermeable soils and the potential for mobilization for groundwater pollutants, and the potential for geotechnical hazards, but also need to broadly consider environmental factors and environmental policy factors like the need for infill development compliance with S.P.375, encouragement of redevelopment of brownfield sites and the potential for sort of excessive costs as well in light of these social and

environmental goals and a comparison of the water quality benefit achieved in light of any costs in that regard.

So if all of those things -- including, I might add, whatever the master plan says and whatever adverse effects may be created for reclaimed water production. I do think we have to look at the potential for adverse affects on reclaimed demand with on-site retention, and take that into account as well. If those all constitute feasibility factors, then we're in support of this approach as well.

The only thing we would add is that we're not quite clear -- there's been a lot of discussion this week about what the various errata versions say and what the flow chart says. So if that could be clarified on the record today. So we all know how to interpret it when we're going forward to develop the revised model W.Q.M.P., I think it would be very, very helpful for the permittees.

And finally, I might mention, we did have a conference call with staff to clarify performance based compliance with the E.P.A. technical waste load allocations that have been included in this permit, and staff had indicated in that conversation that they were going to make some changes --

MS. BESWICK: We're now stepping away from the item that we were to be discussing today. I'm sorry.

MS. COFFEE: If they could clarify what they mean because they were going to make changes in the permit per the conference call, and they didn't happen. So we are really unclear on where they stand.

MS. BESWICK: Then maybe huddle up with staff while you're here today, and see if you can get an answer to that. Because it's not something we are going to be entertaining at this point.

Is Peter Herzog here?

MR. HERZOG: Yes. Good morning, Madam Chair and members of the Board. My name is Peter Herzog. I'm the Mayor Pro Tem of Lake Forest. Came here today for one purpose, and it seems like it's changed dramatically.

Back when we met in April, you were on the third version, and it seems like the only thing that has happened since the April hearing is confusion. So at this juncture I think the only prudent recommendation is to adopt the third version.

Because since then there's been discussions, there's been changes, and as was just pointed out, there's even confusion existing, and I have to admit in trying to follow this, I'm not really sure that we know what's going on.

I think Board Member PonTell was extremely on point when he said that you need the maximum flexibility. I can tell you particularly under the current dynamics in this state that for cities to propose and complete public works projects, we need maximum flexibility.

And the concept of retaining on-site everything that's from a road is essentially not feasible. And so this is in C.2. And so the key thing is we need bio-treatment. We need it on-site and off-site. We need that bio-treatment, and we need it badly.

Secondly, as I mentioned, I do think you need to adopt the third version at this point. I will also point out -- and because you'll hear a lot more about bio-treatment and why it is so important --

MS. BESWICK: We're really clear on that. It's included and it's a part of this --

MR. HERZOG: Well, from listening in the audience and the way the record stands now, what we have is a conflict between Section C and Section D. And having been travelers for many years, you can ride a truck through that confusion. The fact that you have bio-treatment in one area and not in another area, that creates confusion.

MS. BESWICK: I think the bio-treatment goes all the way through the document now.

MR. HERZOG: No. Actually -- because if you look at the C Section, but then you look at Footnote 56, all of a sudden bio-treatment is changed. Footnote 56 creates confusion. It creates confusion that's going to cause a lot of trouble.

If D.5 is what you really want to do, then just make C consistent. That's all you need to do. Then it's clear that bio-treatment can occur on and off-site, we can use reasonable sources, and we can actually move forward with really focusing on the best way to achieve clean water. That's what everybody's objective is.

I do have to comment for the record, moving on to the process, our city is in the Newport Bay Watershed. There has been language that was presented -- it was on the screen for a couple of minutes. My public works director and my water quality specialist from the City of Lake Forest is here.

We tried to talk about what about that, and we don't know. We don't know if it's good, bad, or indifferent. Here is another last minute change that we're supposed to try to address, yet we're being told we can't talk about it.

And in 15 years as a public official and having gone through many meetings through a variety of committees and commissions that I'm on, I have never heard, ever, that you close comments May 8th, and that nobody is allowed to provide written comments after that or that something that appears today cannot be commented upon. I'm just stunned.

MS. BESWICK: Let us respond to that.

MR. THIBEAULT: The need to comment on something that doesn't change for your city is -- it's hard to understand why that is a due process issue for you. As you know from reading it and your public works director knows very clearly, that doesn't change anything for your city. Nothing changes.

MR. HERZOG: Well, Mr. Thibeault, I don't know. I talked to them directly, and we don't know that. We should been given the prudent opportunity to look at it, consult it. I have never heard of a public process where things come up at the last second like they did in April and now, where you can't comment on them. That's just unheard of.

MR. THIBEAULT: Nothing changes.

MR. HERZOG: Well, I'm just for the record indicating that to me, the process that has been laid down today by your attorney is inappropriate, is not

supportable, and quite frankly, it really defies the public process that should exist to really come to grips with getting a permit that everyone agrees on.

You will hear all the technical stuff, and I'm not going to go back into it, but I wanted to put that on the record because I am just stunned.

MR. THIBEAULT: I would just also put on the record, Mr. Mayor, that that is incorrect, that nothing changes.

MR. HERZOG: Well -- and this is what lawsuits are made of.

MR. THIBEAULT: Yes, sir.

MR. FRESCHI: I have a question.

MS. BESWICK: Yes, please.

MR. FRESCHI: Mr. Thibeault, you said nothing changes. I'm not quite sure I understand what that means, but it sounds like what we're saying is that we're not going to pay attention to the testimony.

MR. THIBEAULT: No, sir. What it means is that the proposal made for the Newport Bay Watershed addresses de minimus discharges in the watershed that are in line with the existing policy that is already in place adopted by this Board. And so that language simply clarifies that nothing has changed with respect to what is being proposed for discharges within that watershed.

MR. FRESCHI: And while I have you --

MR. THIBEAULT: Is that okay?

MR. FRESCHI: Yes.

MS. BESWICK: And do you want to see that -- do you want us to bring that text up again? Oh, there it is. I'm sorry. It is up. I thought it was on a different slide.

MR. FRESCHI: I would like you to comment on the resolution that was proposed by Orange County. There was -- I don't see anything wrong with Orange County's resolution that was up on the sheet. I'd like to understand exactly where you're coming from.

MS. BESWICK: Can we finish the -- can you hold that question and let us finish. That's a very good question. It's one I have sitting here, too, and I have notes on it, but if you don't mind, I'd like to get through the -- is that all right?

MR. FRESCHI: Yes.

MS. BESWICK: So if we could just finish up with the public hearing part. That's a point that I think we need to discuss.

Vaikkol Allen, and that's going to be followed by Jason Uhley.

MR. ALLEN: Good morning. My name is Vaikkol Allen with Contech Storm Water Solutions. I'll be as brief as

possible here.

There seems to be an assumption here made on the part of some of the prior presenters that if the 85th percentile storm is not infiltrated or retained on-site, then somehow we have not met the L.I.D. standard, or we have failed in our obligation there.

I just want to reorient a little bit just to say that L.I.D. really is a process of -- it's a process of prioritizing runoff production and simulating predevelopment hydrology where ever possible in a developed situation.

I think the permit in its current form, especially with the additions suggested by the County do a good job of that. It prioritizes on-site retention. You need to do that where ever it's feasible. And if that's not feasible for whatever reason, there needs to be options left for managing that storm water prior to a waiver.

Where I differ, and what I think is a new comment you haven't heard yet is the term bio-treatment. I don't feel like that's a sufficiently useful or precise term. As noted before, it can encompass a wide variety of things, some of which are less effective, definitely less effective, and you'll see this in the testimony that are provided as written comments.

Then some conventional treatment controls, for example, sand filters have no biological component, yet are more effective for important pollutants like phosphorus, total suspended solids, total copper, total zinc then would be filter strips or soils, which would be considered bio-treatment.

So to go to bio-treatments or bio-filtration and excluding conventional controls, it actually violates the M.E.P. standard. I think that point has been made, and I just want to echo that there.

So my final summary, I would just say that bio-treatment I think is an inappropriate word to include there. It should just say treatment of pollutants of concern to the maximum extent practicable or of pollutants of concern on-site with moderate or highly effective B.M.P.s.

Something to that effect that is a performance qualifier as opposed to just whether or not it has something green in it. And that's really all bio-treatment does for you. Just ensures that there's something biological, which has really little to do with performance.

Thank you.

MS. BESWICK: Jason, followed by Matt Yeager.

MR. UHLEY: Good morning, Madam Chair and members

of the Board. My name is Jason Uhley. I'm with Riverside County Flood Control Water Conservation District.

What I'd like to simply propose today is an amendment to Footnote 56 to simply change it to require that filtration B.M.P.s be maximized or that maximized infiltration and evapotransporation opportunities within those B.M.P.s. And in support for that I'd like to quote a 2007 E.P.A. study that says, "Filtration practices offer many of the same benefits as infiltration, such as groundwater recharge, increasing stream base flow, and reductions in thermal impacts to receiving waters."

And our own county has been working on putting together an L.I.D. design manual for several years now, and one of the critical components of that manual was integrating site design with the L.I.D. concepts using the B.M.P. criteria, and we came to the same conclusion that the Mayor did, that we need to have filtration as part of that default package.

And one of the things we are trying to do to make sure we get effective B.M.P.s is we're designing an L.I.D. B.M.P. testing and demonstration facility. And really the whole purpose of that facility is to figure out how to maximize the infiltration and

evapotransporation benefits of filtration based B.M.P.s.

And so with that expertise, I ask that you consider a change to footnote 57 (sic) to simply state, instead of being negative in terms of -- prove the negative with the feasibility analysis, just state that your filtration B.M.P.s have to maximize infiltration and evapotransporation.

Come at it from a more positive approach. The permittees can develop B.M.P. design guidance that they can give to you to demonstrate that they've done that. And it makes it easier for us to implement these L.I.D. requirements.

I'm also a bit concerned with the feasibility criteria in that the way I read it, it would only allow for consideration of on-site issues, such as soil conditions and high groundwater. But there's also an issue because you'll be eliminating small storm discharges with an on-site retention policy that you may need to consider impacts to things like vernal pools.

Another example would be Lake Elsinore where we're trying to maximize the amount of water that's coming into the lake. And I'm not sure that that policy right now is addressed. I think a simple solution to that is to simply change Footnote 56 to be proactive and require filtration B.M.P.s to maximize infiltration and

evapotransporation.

Thank you.

MS. BESWICK: Question.

MR. THIBEAULT: Jason, so are you thinking that in the submittal of a feasibility study that your suggestions wouldn't be part of what you had proposed to us -- when it comes to Riverside County, I would expect the same sort of feasibility study to be designed. Where you would propose to us things like, hey, we need water in Lake Elsinore. That's really important. And I would expect that given everything that's happened, we would go, yeah, that's a good idea. We need that.

MR. UHLEY: That's another question. Is this feasibility study only on a site-by-site analysis, or can it be done -- we can draw a conclusion that says to the Santa Jacinto Watershed, we need water to Lake Elsinore. That's a factor.

MR. THIBEAULT: I would expect for any of the counties to make it a county-wide feasibility study where you look at all of the issues that affect feasibility for all development in field, brownfields, V.O.C. plumes. Anything like that should be included as part of the feasibility analysis.

I would expect yours to be different, but along the same lines as what we would look for from

Orange County.

MR. UHLEY: And that's clarifying. I was envisioning that this was a project-by-project type of evaluation that was being set up.

MS. BESWICK: I think that's a lot of people's perception.

MR. THIBEAULT: I think feasibility is important because there are some things that are more important than perhaps infiltrating runoff in a certain spot. Jason brings up a great point about Lake Elsinore. I agree, and I would be very receptive to that if that was brought to us and asked for the Board's support in that. Because having some on-site reinvention in a very small groundwater basin that is not very efficient for water supply is less important than maintaining other important beneficial uses.

MR. PONTELL: Not to speak in complete self-interest, but I would be very disappointed since the groundwater and the lake water in Big Bear are two completely separate systems. If all the water was diverted and the groundwater -- and we ended up with a dry lake, probably not very good.

Thank you.

MR. SMYTHE: I think the thing here is that the criteria itself will be region-wide, county-wide. The

application of that criteria, the analysis of that criteria will then be applied on a site -- or project-by-project basis.

MR. UHLEY: Thank you. But I would also still like you guys to consider the proactive rewrite of footnote 56 with regard to application of filtration based B.M.P.s, but thank you for the clarification. That is helpful.

MS. BESWICK: Matt Yeager, followed by Andrew Henderson.

MR. YEAGER: Good morning. This is Dr. Matt Yeager. I'm saying that for maximum impact. I'm representing the San Bernardino County Storm Water Program today and the 16 cities and the County in the flood control district.

And again, we are commenting. This is not our permit, and we're not attempting to negotiate on behalf of anyone. We have some ideas about what our permit may look like based on this discussion. I don't think this whole feasibility L.I.D. discussion is probably going to be fully heard again.

So I think -- the first thing I'd like to say is that although we may not agree with everything that's been said today by Orange County and by everybody else, we haven't had a chance to analyze that. It's been a

very compressed time frame.

We do support Orange County's analysis and assessment of their own situation, and generally, would tend to support their suggestions for modifying the permit. And I also would like to say after having heard Jason's comment that we definitely would support any kind of modification to Footnote 56, which makes it more -- what I would say implementable.

And also, we had talked previously about a more regional approach to feasibility, and I think that makes a lot of sense. And also, I would like to say we do not, as a program, we do not support the need for feasibility analysis for applying the L.I.D. process as a whole.

And what I mean by the L.I.D. process is the process which has been developed by the L.I.D. center in Maryland over a 10-year period. It's a process applied to sites, and it does a constraints and opportunities analysis, and it has feasibility built into it.

So the other question about the feasibility analysis is in the interim before we have it approved region wide, this will be applied on a site-by-site.

So I would suggest if there's a fair amount of potential administrative burden on cities and government staff -- other state staff in dealing with these

feasibility analysis. And I don't know what the benefit is really going to be there in terms of water quality.

So I think -- finally, I would just like to say that I'm concerned about the overall processes some others have mentioned. I would be curious -- I don't know what my rights are, but I'd be really curious to understand what comments were made after May 8th because right now, I don't know what they are, and I don't know what you guys have been asked to disregard.

Finally, on the flow chart, I really appreciate the fact that the flow chart was prepared. I think is does help us to try and understand, but it's still a very complicated program -- just this development program. I don't think it's clear. I'm not understanding it fully either, even though the flowchart is here.

A specific question is: You have a box on the flow chart that says, "conduct feasibility criteria analysis E, point 1." You've also got up in the top box, which is where the initial L.I.D. application comes in. You've got a box called bio-treatment, and then I believe in the revised, which I just saw today, which wasn't here before, but it was sent to me by e-mail, was different. It now references Footnote 56.

My question is: Is the feasibility analysis E,

point 1 the same as we're talking about this bio-treatment, which refers to 56 -- Footnote 56? If it's the same -- that's what I interpret, but that's not what the flowchart sent out really says. Again, clarity would be really nice.

Thank you.

MS. BESWICK: Thanks.

All right. Andrew Henderson. Andrew, we're not going to have time for more than three minutes. So if you're going to do a powerpoint --

MR. HENDERSON: Well, I thought I had one, but I don't. I apologize to the court reporter --

MS. BESWICK: But it's amazing how much you can convey verbally without having to show us something. You'll be good.

MR. HENDERSON: Well, I do want to apologize to the court reporter because I know as a former litigator I used to make them cry.

I'm Andy Henderson. I'm here representing the Construction Industry Coalition on Quality. You're probably used to seeing Mark Gray, who is on vacation, and he asked me to step in instead of him to make a number of points.

And first he would want me to certainly thank you and the staff for all your hard work on these issues

and all the state workers who have really worked, I think, heroically on trying to reach agreement and by and large with one exception that is now reflected in the first sentence of Footnote 56.

Let me start by saying that the building industry -- and I'm also the Vice President General Counsel of the Building Association of Southern California, and we're very much in favor of the impetus to move towards low impact development.

We're used to the California Environmental Quality Act, C.E.Q.A., trying to lower impacts of development all the time. We welcome the addressing that low impact development through this body, and, in fact, we have recommended that this body should promulgate or recommend to the local governments a threshold of significance for hydro-modification and these other things that are currently being addressed now through what is more a command and control means.

And as champions for low impact development, we feel that it's extremely important that we keep on the table and keep -- it's probably the best tool available, bio-treatment, because it is in many circumstances far preferable to an uncritical application of retention and for evapotransporation, re-use, and infiltration.

One example would be Rancho Mission Viejo, which recently went through a major revision with the blessing of endangered habitats league. And the conclusion there was that they were going to try to build on the land that is least pervious, and they did that because that's the way to best maintain the water cycle and the natural flows of water.

If you now were to layer on top of that the requirements that are reflected in footnote A, in particular the first sentence of footnote A, you'd have a wrong headed mandate, which is to the extent feasible, you've got to retain water on-site when the whole plan was designed to build on the sites that were naturally impervious so that you could maintain and mimic the natural hydrology.

So we very much believe bio-treatment needs to be on the table. I heard Madam Chair say that bio-treatment is throughout the permit, but the first sentence of Footnote 56 relegates it to a poor step-child in relation to the other, which must be done wherever it's feasible.

And it's that question of feasibility that is so problematic because it would be feasible for me to rent a Hummer and drive here today, but I drove my Prius instead. It would be economically, technically, and

legally feasible for me to drive a Hummer here, but it's environmentally far more preferable for me to drive my Prius, which I did. And it's that problematic word of infeasibility -- or feasibility.

So we have asked for, in various ways, that that question of feasibility be addressed. First, we think you could do without Footnote 56. The first sentence of it, in particular, by saying you have to do X, Y, and Z if it's feasible, and then if you can't do it, you have to move on to the more preferable tool is problematic.

So if there's a way to just remove it -- or otherwise to change Footnote 56 to say that -- something to the effect that a properly engineered and maintained bio-treatment system may be considered only in accordance with the priorities specified in Section 12.C.4. Something like that would do it.

Another thing you could do is say that you would use bio-treatment where the on-site retention is infeasible or where the bio-treatment is an environmentally preferred alternative at the site.

So there are ways that you can address this and elevate bio-treatment to the level where it belongs, which is in many circumstances the best tool available.

I want to finally point out that our stance on

this is completely consistent with both the E.P.A. definition of L.I.D. and the State's definition of L.I.D., both of which say that the aim of L.I.D. is to mimic the predevelopment hydrology -- well, you're not going to do that. If you say anywhere you can, you change the hydrology if it's feasible to do so, you're not going to be trying to mimic the predevelopment hydrology. So you're stepping away from both the U.S. definition and state definition of L.I.D.

You're also stepping away from a 2000 year doctrine called the National Flow Doctrine at Law, which since Ancient Rome has said that you should try to -- when you develop property, you should try to maintain the natural flow as much as possible. In fact, you have an obligation to do so.

MS. BESWICK: I'm going to ask you to stop there. Again, we heard a good discussion about that at our last meeting. We understand it clearly.

MR. HENDERSON: Okay. Thank you.

MS. BESWICK: Eric Strecker, followed by Paul Singarella.

MR. STRECKER: Obviously, I'm not going to go through the whole presentation. I would have liked to today. My name is Eric Strecker with Geosyntec Consultants, and I'm here from Portland, Oregon today.

I'm going to skip through the highlights from my last presentation to the Board that I gave you and focus on just a couple of things. I think if we look at a more sustainable strategy, it's really all of these things that we want to be looking at in terms of what is the most desirable combination, not simply looking at what is feasible, which has been highlighted here.

I think Board Member PonTell highlighted there's lots of benefits to some of the bio-treatment-type systems. I thought some pictures would be good to look at. This a bio-retention system in Sacramento County.

MS. BESWICK: We're really -- we've had this. I'm just saying, spend your time on things we haven't already been over.

MR. STRECKER: I'll just show a few pictures here of different systems out there that I think provides some aesthetics and habitat benefits, fresh water marshes included.

The other thing I wanted to draw your attention to is just -- I'll go right to the last map here. We did some analysis of feasibility of infiltration, and this is showing an overlay of where we have the soils to do it, where we have industrial areas, where we have contamination considerations, steep

slopes, and depths to groundwater of less than 10 feet.

Bottom line is, about 23 percent of the County is probably available for infiltration, which is a significant component. But you're going to have another almost 80 percent, but that's not a viable technology. Then you're into capture and use, because evapotransporation is going to be fairly limited as a loss mechanism, and then we're into building tanks and things like this.

After your hearing, I visited E.P.A. They have cisterns that capture an inch of runoff from their roof. They were dry because -- they weren't even diverting water into those because they can't use it now for irrigation. Their own sign said it takes about 10 days to drain those things. My bet is those are bypassing off it.

So again, I think the key issue here is in thinking about Footnote 56, what I'd like to see is what is the most desirable combination of those things that we can do that gives us the best outcome verses prioritizing one over another. So maybe this hits on what Mac was trying to say, too.

We did an example 100 acre catchment where I showed the T.S.S. loadings to receiving waters would be less under bio-retention scenario with toilet flushing

and irrigation verses cistern and re-use, and I'd actually have lower concentrations in this particular case.

So -- and then I also think we just have to think about the sustainability and the carbon footprint if we get into putting tanks and treatment pumps and treatment systems and the rest of that on a micro-scale.

So bottom line is that I think we need to think about keeping the appropriate mix of tools in the toolbox and really taking -- so this word feasibility, I think you're hearing that it gives a lot of people heartburn here. And let's get that down to what are the most desirable combinations of things that we should do.

Thank you.

MS. BESWICK: Thank you. Those are good points.

Paul Singarella.

MR. SINGARELLA: Thank you, Madam Chair and other members of the Board. Paul Singarella, and I'm here today on behalf of the Orange County Business Council.

I have two points: One procedural and one substantive. On the procedural side, we were actually quite surprised on May 11 because the prior comment period had closed on May 8, and on May 11 we saw for the first time -- because it was first introduced on May 11 -- this Footnote 56, which we thought was

actually a 180 degree turn from the permit and the proceeding that we had in front of you on April 24.

The reason that we thought it was a 180 degree turn is that it introduced for the first time this feasibility demonstration in the way of using the kinds of B.M.P.s that Eric Strecker just showed you up on the screen. Those are really great B.M.P.s, natural treatment system B.M.P.s, bio-treatment B.M.P.s. There was no gate to get to those types of B.M.P.s, and actually have runoff from the site during the design storm prior to May 11.

That gate was introduced on May 11 after the prior public comment period was closed. We looked at that introduction of that footnote -- it's only a footnote, but it's a big footnote -- and it really turned things around. And our estimation what you've got -- and I hate to say this, but I think you have a major permit amendment here as defined under the Federal Clean Water Act.

It's that substantial, and I think, Madam Chair, that's what you're seeing. That's what you saw this week. That's why you saw people trying to communicate with you to say, oh, my gosh. Why are we spending so much time here trying to save the good, trying to save these good B.M.P.s? Why is such an

obstacle to using bio-treatment B.M.P.s being introduced at the 11th hour? That's how we see it.

So I want to make that procedural point for the record. It's a formal objection to the process, Madam Chair.

On substance, the issue is bio-treatment. Again, the issue is, is it going to be part of compliance, or are you going to have to earn your way to it through some kind of a process, whether it's just a feasibility analysis or it's a feasibility analysis plus a waiver or a feasibility analysis plus a waiver plus a fee. We don't know. Leaving here today, we don't know.

What we will know is, if you approve this permit as proposed, is that access to the public storm drain for new development, for new streets and highways, for new infrastructure is fundamentally changed. And the way it's fundamentally changed is that you can no longer avail yourself of the public storm drain for the design storm volume without getting something else -- something in addition to what you've needed before today.

At a minimum it's feasibility, and it may be more, and we don't understand it. We don't know why, as a matter of policy, you would create that roadblock. We don't think it's a smart way to go here. I'd be glad to

make an offer of proof to you as to why we think feasibility is such an important issue here and why it's the wrong term, but I'd have to ask for Madam Chair's -- for an extra minute to do so.

MS. BESWICK: Take the extra minute.

MR. SINGARELLA: Thank you.

First of all, the term feasibility is -- it's just -- it's the wrong term. It's too limited. We have to look at water quality performance. We have to look at desirability. It may simply not be desirable to go with on-site retention in all instances. It may be feasible to do so, but it may not be desirable.

Number two, why set such a bar to bio-treatment? Why are you relegating these fantastic B.M.P.s that should be promoted? Why are you relegating them to an inferior status to on-site retention B.M.P.s? It makes no sense to us.

Number three, feasibility is not defined. I was very heartened to hear the Executive Officer talk about his concept of feasibility. But the reality is, it's not defined. There's no place where we can find it in the permit. That's one of the reasons that C.I.C.W.K. offered a finding to the Board and at the same time to the public earlier this week is to allow some definition of that very important term, if you can

retain it.

And finally, number four, we're very concerned because we see it in defensive projects when we're doing E.I.R. work under C.E.Q.A. We're very concerned that this is going to slide and that feasibility today is going to turn into something totally unintended tomorrow. We're going to be living with this permit for seven years.

MS. BESWICK: Okay. I think the feasibility issue has been addressed, and I thank you for that.

MR. SINGARELLA: Thank you, Madam Chair.

MS. BESWICK: Kristine Murray.

MS. MURRAY: Madam Chair, members of the Board, thank you for your time. I represent the Orange County Business Council today, and we're also represented by Latham Watkins. So I do concur with all of Paul's comments.

My comments are also process and substance as well. With regard to process, we did submit a letter yesterday to your Chief Counsel, Mr. Rice, electronically asking that it be considered because it was based on changes post the May 8th public comment period. And we felt due process was that our comments should be considered, which I respectfully request, and I have an original copy of our letter signed by our

president and C.E.O., and I would respectfully request it be submitted into the record with your consideration.

MS. BESWICK: What's the date on your letter?

MS. MURRAY: It's May 21st, but it's based on comments since the May 8th --

MS. BESWICK: I understand that, but one of the reasons is that -- were you at our last hearing?

MS. MURRAY: I was. And on April 24th we did submit a hearing -- a letter to you as well, and we were also represented by Latham Watkins and their submission by May 8th. So that qualifies our involvement.

MS. BESWICK: I understand that. It's just that it is frustrating to get things the day before a meeting always. You can understand that, I'm sure. And so that's what we were trying to avoid. And it's not like you just got the document. That's, as much as anything, it's just kind of respect for the process.

MS. MURRAY: And Madam Chair, I do have --

MR. PONTELL: May I just ask a question?

All of the testimony we're receiving today is going into the record; correct?

MS. BESWICK: Of course.

MR. PONTELL: So can she read the letter, and then it would be on the record by definition.

MS. BESWICK: She can submit it to us.

MS. MURRAY: Thank you very much.

MS. BESWICK: Or no, I can't. If I do that -- yeah, you're right. I can't do it.

MR. PONTELL: But if it's not a long letter, just read it.

MS. BESWICK: Well, the same problem applies, I think.

MR. RICE: Well, you certainly have the ability to accept --

MS. BESWICK: True.

MR. PONTELL: All this is testimony.

MS. BESWICK: If you'd like to read your letter, read your letter.

MS. MURRAY: I'm happy to read my letter. Thank you.

Honorable members, the Orange County Business Council, representing the largest employers in Orange County and the public agencies, cities, and counties major stake holder community impacted by this permit respectfully requests some small, but what we consider very important changes to the draft permit to delete newly introduced Footnotes 56 and 57, which would reintroduce your direction -- reinforce your direction from the April 24th hearing that bio-treatment with off-site runoff is part of the L.I.D. standard.

We would also request -- and this paragraph does speak to something that you said you will not be consider today, but it's part of our letter -- substitute the words "should consider" for the words "shall incorporate" in sections 12.B. to .H so that the federal green streets guidance is not improperly transformed into new unbedded enforceable standards for street and highway projects in Orange County.

These critical changes would enable the City to support the permit unequivocally and are described below.

One, to make bio-treatment and off-site runoff part of the L.I.D. standard rather than an exception available only after proving infeasibility of off -- I'm sorry -- infeasibility of on-site retention.

At the April 24th hearing you provided staff with direction to add bio-treatment and off-site runoff to the L.I.D. standard rather than making it available only after proving infeasibility of on-site retention. The revisions to the proposed permit do not accomplish this objective and add qualifications and obstacles to the use of bio-treatment.

As the cities have discussed with staff for the last several months, bio-treatment B.M.P.s are the best -- are some of the best available B.M.P.s to

improve urban runoff. We ask you to revise the proposed permit so that the runoff from these public works projects can occur without a demonstration that on-site retention of the design capture volume is infeasible.

This could be accomplished by deleting Footnotes 56 and 57 and reinforce your direction from the April 24th hearing that bio-treatment with off-site runoff is part of the L.I.D. standard, not something that can occur only after infeasibility is proven, a waiver is granted, or a fee is paid.

The permit is proposed -- will propose a great and unnecessary burden on public works projects and creates impediments for projects as small as 5,000 square feet to drain to the public storm drain where the runoff is intended to go.

It is infeasible to retain 100 percent of the design capture volume on-site for most projects. At a time when budgets have been slashed and infrastructure funding is scarce, we strongly urge you to revise the proposed permit as described above.

Our second point speaks to the do not make federal -- we request that you not make federal --

MS. BESWICK: Can you summarize? We're running past the three minutes.

MS. MURRAY: Absolutely, Madam Chair, thank you.

Our second point is to the green street gardens, and I understand you're not accepting that today. So I'll move on. We remain -- I would just like to say that the Orange County Business Council remains committed to the protection of water quality and appreciate in advance your attention to these vitally important issues. We look forward to responding to any comments or questions today at this hearing, but we do respectfully request that you make these considerations, and we would urge that you remove item -- Footnotes 56 and 57.

We do think they're substantial, and they were made post the May 8th comment period. We ask for your consideration of that with due respect from the Lucy Dunn, our President and C.E.O.

Thank you.

MS. BESWICK: Thank you.

Mike -- I'm not sure. Is it Recupero?

MR. RECUPERO: Thank you, Madam Chair. Mike Recupero on behalf of the City of Anaheim, Santa Ana, and Newport Beach.

Just for clarification purposes, I have three letters here that were e-mailed, and I understand those are not being accepted. Is the Board now saying that it is not accepting evidence to be -- letters to be lodged

in during this hearing?

MS. BESWICK: That's right. If you'd like to tell us the content of the letter, feel free.

MR. RECUPERO: Okay. I would.

MS. BESWICK: Can you summarize for us, though?

MR. RECUPERO: I can.

All three cities are consistent with what the comments have been today, believing that Footnote 56 and the use of the term feasibility is a substantial change to the permit. I think it's regrettable that they're not given the opportunity to explain why in writing.

I think it would be very helpful -- I don't know if it's possible -- to look at the flowchart very quickly because I think there might be a fix that I could share with you that I think the Board would be very interested in.

MS. BESWICK: We've got it in front of us. You want to just go ahead and describe it? We all have it in front of us.

MR. RECUPERO: Please.

If you look at the top, there are four B.M.P.s. There's three on the left, and then there's bio-filtration over on the right. When everybody saw that flowchart, they understood exactly what you said at the April 24th hearing, that bio-treatment was an

acceptable L.I.D. component.

The problem is Footnote 56 used the term feasibility, and the feasibility analysis is a term of art in your permit because there's a different feasibility analysis that has to happen.

And that is, when a city can't do L.I.D., they're saying we need your okay to use non-L.I.D. This is a feasibility that says, "Can you or can you not use L.I.D., generally?" There's a different and smaller prioritization process that is supposed to take place at the top of the box, and that is to go from the three B.M.P.s on the left to bio-treatment on the right.

And the concern is, now, just to get to bio-treatment, the cities are going to have to go through a separate feasibility analysis that is referenced down below in analysis E.1.

It is a substantial difference, and I think if the Board would address that -- frankly, I don't think it was Staff's intent to use the term feasibility in Footnote 56 and trigger E.1. I think those are two different analysis.

From the City's perspective, they should have the authority to prioritize those best management practices. We get the fact that you don't want everyone to default to all bio-treatment. We've heard it 20

times. I don't think that's the intent, but it's also not the intent to require cities when they have a road project, a library, or something else to have to come and do a full on feasibility analysis to this Board.

And it should be done -- it should be done in-house with regard to the best management practices. The use of L.I.D. generally, is it a different analysis? We understand that, but I think it would be helpful if you would clarify those two things.

Thank you.

MS. BESWICK: Thank you. Well, that's the extent of the comment cards that I have. I'm just going to do one thing.

I want to get back to the point about the request for the contemplation of adding back in some language. I've asked Jerry about that. Would it be okay if I had Jerry make some comments, and then see if that clarifies?

So I'm actually closing the public hearing, and we'll move onto -- if you'd like to make comments or Mark would like to make comments on some of things we've heard -- I think that -- well, go ahead. I think there's some real confusion here that needs to be addressed.

MR. THIBEAULT: Right. I think there's some real

confusion, too, and this is just a response to comments, Madam Chair. I just want to make that clear.

People have said repeatedly that this is -- that Footnote 56 is something new that was added to the permit, and we all know that that's not true. Footnote 56 has been there --

MS. BESWICK: Been there since the beginning.

MR. THIBEAULT: Well, it's at least been there since the May 1st draft, and I'm not so sure we'd object to going back to the May 1st draft if people don't like the clarifying language in the subsequent drafts, Mark, but I will read the earlier draft just to make sure you all know what it says.

"A properly engineered and maintained bio-filtration, bio-retention, or other bio-treatment system maybe considered only if infiltration, harvesting and re-use and evapotransporation are not feasible." That's the end.

So what we've done -- attempted to do, is to make it more clear -- more easy for everyone to comply by identifying that we assume that this process of identifying the treatment options or the retention options, the L.I.D. options, will be part of the feasibility study that we expect to have submitted by the permittees, by the principal permittee and all the

co-permittees.

MR. SMYTHE: And as well as being part of the model W.Q.M.P. process.

MR. THIBEAULT: And as part of the model W.Q.M.P., exactly. And so I guess I just have a hard time understanding the testimony today indicating that Footnote 56 is somehow, you know, changed and is being imposed on, on the co-permittees because it's always been there. But it's been in a more restrictive, harder-to-comply-with structure. And so if --

MS. BESWICK: Maybe you need to speak to why it's easier to comply with.

MR. THIBEAULT: Well, what we are suggesting in the latest draft is that it's a process that's part of the model W.Q.M.P., as Mark just said, Section 12.C.1 and the feasibility criteria in Section 12.E.2 are also part of the process. And then specific design, operation, and maintenance criteria for bio-treatment systems shall be part of the model W.Q.M.P. We expect them to submit it to us.

MR. PONTELL: Jerry, I think that's probably one of the things that gives me the most comfort. And I guess it's -- within 12 months of adoption of this order, the permittee shall update the W.Q.M.P. to incorporate L.I.D. principles.

Well, L.I.D. principles are an evolving science. And so to the extent the permittee and the permittee's associates are able to identify the best practices for low impact development that maximize accomplishing all the goals as laid out in the permit, and that's something that they are going to be designing and developing, what those principles are.

But I do have two questions associated with that. It says that it will be submitted to the Executive Officer. So we did have some conversation about if the Executive Officer does not accept what is submitted, what is that appeal process?

MR. THIBEAULT: The appeal process is currently in -- proposed in the permit would be to the State Board. If you want it to be appealed back to you, we can certainly do that.

MR. PONTELL: I would want to entertain that. So just put that on the table for discussion because -- and I do think especially with regard to the fact that Orange County gets to be the guinea pig, but San Bernardino and Riverside are right behind.

So I would think that if over the next 12 months, the permittee is coming up with the L.I.D. principles that can best accomplish the overall goals -- and I think everybody understands what the overall goals

are, and to the extent the Executive Officer, the permittee, and staff are able to work those out, great.

And I think that will then create a lot of information for subsequent permits. To the extent they're not, I would think a discussion with the Board would be mutually beneficial for all of the future permittees.

So essentially it seems to me that there is some direction. There is some indication of prioritization, but there is nothing cast in stone with regard to what the solutions are to the extent the permittee is coming back with their determination of the application of L.I.D. and whatever other solutions may be able to be incorporated into that permit.

I did have a second question, though, with regard to -- maybe explain the waiver process. So if somebody needs a waiver, is that an onerous obstacle over which to -- is it an expensive process? Is it a timely -- now, I'm talking about when it talks about a waiver of a specific application -- of a specific project where a waiver is required.

MR. THIBEAULT: Michael.

MR. ADACKAPARA: In answer to your first question, actually, when the principle criteria is developed and the water quality management plan is submitted to us, we

are going to publicly notice that. And if there are any significant issues based on the comments we receive, I think the intent -- Staff's intent is to bring that to the Board at that point.

To answer your second question -- I forgot. What was the question?

MR. PONTELL: The waiver.

MS. BESWICK: The waiver question.

MR. ADACKAPARA: The waiver process will also be established in the feasibility criteria, and it's not going to come back to the Board or it's not going to come back to us. It will be the permittee who are going to actually decide whether they want to grant the waiver or not. And the criteria will be established during the water quality management plan divisions.

MR. PONTELL: That's what I thought. Thank you.

MS. BESWICK: Now, do you want to get into your -- the question that was asked, if you remember, Jerry, by -- who was it that asked the question?

MR. FRESCHI: A couple things. Last month we discussed this appeal process, and I was expecting that we would find that in this document today. That's one observation. The other one is, on the one hand it looks like this is being rushed because everyone has to hurry up, but realize that this was suggested, and it was

promulgated in November of last year.

So there has been a long time for people to make the comments absent item 56 and 57. But I'm uncomfortable approving this today because there's so much misunderstanding.

And we think it's clear, staff thinks it's clear, but the people that are affected by it aren't clear. We haven't defined what the waiver process really is. We haven't indicated the review process by staff, and I still need to have Jerry explain to me what's wrong with adding the words that --

MR. THIBEAULT: We'll get to that.

MS. BESWICK: What I need to tell you is that our court reporter needs a break. I need to give her five minutes. We'll break until noon, and then pick right up on that question.

(Recess)

MS. BESWICK: We were right in the middle of a question, and I think that Jerry was ready with an answer.

MR. THIBEAULT: Yes. Thank you, Madam Chair.

We specifically --

MS. BESWICK: Oh, Steve's not here. I thought Steve was in the room.

MR. THIBEAULT: I thought he was, too.

MS. BESWICK: Let's go back -- so we're back to answering the question that Steve -- that was asked earlier about the old language.

MR. THIBEAULT: Right. The question Mr. Freschi asked had to do with why the words "similarly effective" were removed from the latest version C.1, C.2, and it's for exactly the same reason that you've heard over and over again this morning. It wasn't very clear. It wasn't well-defined. It means too many things.

So this is an attempt to be really clear about what the staff proposal is for M.E.P., maximum extent practicable. See, you haven't been involved in a storm water permit before, and so they operate under a different standard than most other N.P.D.S. permits. Those are typically numerical standards.

Storm water permits operate under M.E.P., maximum extent practicable. M.E.P. is a moving target over the years in an attempt to achieve the highest level of storm water control pollutants -- to control the pollutants from storm water that can be achieved.

So what we are suggesting is that M.E.P. in this case is not a similarly effective bar that has to be achieved. It's do these L.I.D. principles first. If that doesn't work, do bio-treatment, which is one of the L.I.D. things, but what we're suggesting is less -- it

should be lower on the priority scale.

And then if that doesn't work, then you go to the next thing that is going to be part of -- and I will respond to another comment as I continue to answer that question -- and that is feasibility and the feasibility study and the report and everything else that's been brought up over and over again, we expect the co-permittees to propose to us what they would like to do for a waiver program, for feasibility, for their evaluation of L.I.D. principles.

Some of the comments I think are confusing because they don't recognize what we've been telling them all along, that we expect them to come to us with a proposal. We're not telling them how to do it. Let them come to us.

So this Footnote 56, that is such a center of controversy, I think was set up -- and if we have to argue it in court, we will, but Footnote 56 is clearly making it easier for them to come to us with a proposal for compliance.

Now, the earlier version, I think, is hard to comply with. It's not as clear as what Mark and the other staff members have put together. It's been in there all along. This is easier to comply with. This is clearer. We expect them to come to us with what they

propose.

I don't know if anybody from Lake Forest is still here, but just to clarify what we talked about earlier with respect to the language that is still on the screen, Madam Chair, this language makes it clear that compliance with the permit, with the de minimus permit, R82009 dash 003 remains in effect. Nothing changes for Newport Bay Watershed.

That language for the Newport Bay Watershed says, "Proposed waste water de minimus discharges as defined above within the San Diego Creek/Newport Bay Watershed that do not contain nutrients, selenium, or other T.M.D.L. pollutants of concern at levels that pose a threat to water quality or beneficial uses may apply for coverage under this order."

This addition that staff has put in here simply means that it's a status quo with respect to those discharges.

MR. FRESCHI: Thank you for clearing those issues up. I didn't recognize a difference between the storm water permit, which you were talking about before. And I appreciate your clarification. Perhaps that helped some of you other individuals who aren't as experienced as I am -- who are as inexperienced as I am.

Thank you.

MS. BESWICK: I'm just wondering how important that language is.

MR. THIBEAULT: The importance would be if that language wasn't there -- and, Joanne, help me if I misstate this -- if that language is removed, then the coverage that is allowed under the de minimus permit would be excluded.

MS. SCHNEIDER: This language is strictly intended as a clarification to make sure that no de minimus discharger with discharges -- those de minimus discharges into the Newport Bay Watershed would assume pursuant to the earlier language, that they simply needed to comply with the terms and conditions of the general de minimus permit.

In fact, the general de minimus permit makes clear that where de minimus discharges within the watershed includes selenium, nutrients, or other pollutants of T.M.D.L. concern, they would not be authorized under the general de minimus permit, and they would have to get separate regulatory coverage.

MS. BESWICK: Which should not be a surprise in light of what we've been doing on selenium.

MS. SCHNEIDER: This should not be a surprise whatsoever. We simply wanted to make that differentiation more explicit, lest there be any doubt.

MS. BESWICK: I guess it stunned me to learn that the public works department in that region was surprised by this. To me it was -- but that's why I asked the question about does it need to be there. Your point is to try and make it clearer, to help people comply, to refer, I guess, to other work that's being done in this area.

MR. THIBEAULT: Is it fair to say that this is non-regulatory? This is just clarifying? Because the regulatory natures are --

MS. SCHNEIDER: That is correct. We are merely clarifying the purpose of established orders by this Regional Board.

MS. BESWICK: That's what I thought I understood, but I was very surprised by the reaction that we got with a threat of a lawsuit and so on and so on over something that seemed clarifying and not surprising.

Thank you for that.

That's why I was looking still puzzled.

MR. THIBEAULT: Are there any other questions to the Board?

MS. BESWICK: I want to make sure -- are we comfortable on the waiver issue? Do you all really feel comfortable now with how the waiver process works?

MR. RUH: Yes.

MS. BESWICK: If we understand it, then hopefully others do, too. Steve, what else?

MR. PONTELL: Just to kind of echo what I was saying earlier, I understand the concern with us presupposing, predetermining what may be a higher and better solution when maybe it's not the best solution for accomplishing our overall goals.

So as long as -- and I've read through the permit, and I do believe that there's plenty of language that actually suggests and allows for a variety of alternatives that would meet the overall goal of the permit that are not necessarily site-specific, and it may not even necessarily be infiltration, harvesting, re-used -- and re-used and then evapotransporated.

I mean, in my reading of the permit, there's an enormous amount of flexibility. I do think -- I actually think that Footnote 56 helps the primary permittee because I do think the word feasibility is -- it does open it -- it has -- it could potentially have a variety of meanings.

It opens a pretty wide door, but, correct me if I'm wrong, the new language in Footnote 56 says, "Feasibility criteria will be established in the model permit that's going to be coming back from the permittee."

So what we're doing is we're asking the permittee to define feasibility and to define the waiver process and to identify what the L.I.D. solutions are. It may very well be that the L.I.D. solutions that are proposed include bio-treating in a variety of different formats.

So we're not presupposing what the L.I.D. solutions are. We're not presupposing the definition of feasibility, and we're not presupposing the waiver. We're asking that within the next 12 months, let's create a process that is accomplishing those. Is that -- would you say that's an accurate interpretation of the goal?

MR. SMYTHE: Absolutely.

MR. THIBEAULT: I agree.

MS. BESWICK: That was helpful. I think the more we restate these things, the better. I was stunned to hear it come up today that someone even for a moment thinks we're still talking about full containment on-site. So these things do need clarification.

MR. PONTELL: One last comment. The striking of the language in item two where essentially we changed it to L.I.D. B.M.P.s shall be treated and discharged in accordance with the requirements set forth in Section 12.C.7 and Section 12.E below --

MS. BESWICK: It's actually and/or Section 12.E below.

MR. PONTELL: -- accomplishes the same thing as what it said previously, which is it shall be treated and discharged using L.I.D. or similarly effective treatment controlled B.M.P.s or mitigated as set forth in Section 12.C.

As long as -- and I do understand the concern, but similarly effective treatment control B.M.P.s could be L.I.D. solutions as proposed by the permittee. If essentially they come back and say, here is a L.I.D. solution that is as effective if not more so than X, Y, Z, then that would be something that would be submitted in the Model Water Quality Permit; correct?

MR. THIBEAULT: Yes.

MR. PONTELL: And then the Executive Officer would review it, and if the Executive Officer liked it or didn't like it, there would be an opportunity for additional conversation.

MR. SMYTHE: Or to come back to you.

MS. BESWICK: Yes. And I was going to comment that Member Freschi had mentioned at our last meeting that -- and I thought we had agreed, he thought we had agreed. I think he remembers correctly that things on appeal would come back to this Board, and that would be our

first way of dealing with an appeal.

If we find that it's technically beyond this Board's willingness to be addressing it, we could move it on -- could we move it on? I shouldn't assume that. Could we move it on? We'd have to deal with it.

MR. THIBEAULT: Yes, you would have to deal with it. The next step in the petition process would be to the State Board.

MS. BESWICK: So we would have to deal with it and either deny it or approve it. I just want to be really clear on what the process is going to be as these things come. And who knows exactly even what would be appealed at this point.

MR. FRESCHI: Or we could table it and pass it on to the state; right?

MS. BESWICK: No. We have to deny it to get it to go to the state. So I guess my concern last time was, does that create -- and we won't know until it happens, actually. I was trying to be, I guess, more efficient for the Applicant rather than coming here and just moving right up there, but I'm not sure that that's the best solution, and we may have to find out as we go along.

MR. PONTELL: I would prefer within our region, to the extent possible, that we keep an opportunity to have

a say. It's theoretically possible to disagree with our Executive Officer.

MS. BESWICK: Imagine. Whoever that person might be. So that is what we're contemplating now is that the appeal would come back to the Board.

MR. THIBEAULT: So what we'll do if that's part of your motion to consider the order is to make the changes necessary and they're editorial changes to accomplish what you've directed.

MS. BESWICK: Are there other comments or questions that anybody has?

I'm just going through my notes real quick.

Would someone like to attempt a motion?

MR. RUH: I'm going to say one thing. We have a stake holder process that has served us well for many years with this Board. It is a model for other boards. Other boards wish they had the collaboration from their stake holders that we have.

I hope that in the future, as we move forward with other permits, be either these permits or others, that the stake holder process will continue as it has done, other than this one, to continue to work well, where these agreements and disagreements are ironed out before they come to the Board, and we don't have the Board and Board members trying to rewrite the permits.

I think that -- personally, I think it's a waste of every public agency here to sit through and keep rewriting something that could have been done at the stake holder process, and I hope that in the future everybody will be able to come together and reason and respect that process, and that what we see before us is something that can be worked out that everybody's pretty much agreed on, as we've done in the past.

Thank you.

MS. BESWICK: When you think about it -- when you look at what we -- out of all this huge permit, that it's pretty amazing that we are dealing just with these limited -- these limited issues, and it has been an amazing process.

MR. SMYTHE: It's actually 37,000 words.

MS. BESWICK: I'm sorry?

MR. SMYTHE: It's 37,000 words, the permit is.

MS. BESWICK: Right. So we're doing pretty well in terms of what we are up against. It can't be expected that we are going to get complete consensus on something. That would be great if we could, but it's not possible.

MR. PONTELL: I would attempt a motion.

MS. BESWICK: Okay. Give it a shot.

MR. PONTELL: Looking forward to the permittee's

input over the next 12 months on the creation of the specific L.I.D. standards that would be incorporated into the future approval process, looking forward to the permittee's definition of the term feasibility, and looking forward to the permittee's definition of the waiver process, I would move approval of order number R82009 dash 0030.

MS. BESWICK: With the errata sheet.

MR. PONTELL: With the most recent errata sheet.

MS. BESWICK: And the change of and/or, and we added -- remember we added or in number two --

MR. PONTELL: And with the changes as indicated on the errata sheets --

MS. BESWICK: Perfect.

MR. PONTELL: -- and with the appeal being changed to come to the Board of Directors.

MS. BESWICK: And that piece as well.

MR. THIBEAULT: On your motion, Mr. PonTell, with the errata sheets before you, number two, Mark points out that we have the and/or that we need to put in Section 12.C.2.

MS. BESWICK: He just did that.

MR. THIBEAULT: And then adding the water districts and the sanitation districts.

MS. BESWICK: On the appendix.

MR. RICE: I think that you should hand the sheet to Steve, and he can make his motion again, just for clarification.

MR. PONTELL: Further clarification of my motion will include and/or in 12 dot C dot 2 adding water district, sanitation districts --

MR. RICE: I hate to bother you again.

Would you mind just starting from the very top because there was a lot of interim discussion between the start of the motion --

MR. PONTELL: Do I have to go through looking forward to?

MR. RICE: That would be up to you.

MR. PONTELL: I would move approval order number R8 dash 2009 dash 0030 based on errata sheet two as presented by staff today with the following changes: Adding and slash or in 12 dot C dot 2, adding water districts and sanitation districts to attachment three.

The de minimus permit language is laid out on the overhead screen in three dot two little i's dot A, and not just in footnote 55, but where ever appropriated in the ordinance indicate that appeals go to the Board of Directors.

MS. BESWICK: Is there a second?

MR. GUNDY: Second.

MS. BESWICK: Now, any discussion on the motion?

MR. RUH: When you have the appeal going to the Board for this, remember, you're setting precedent for everything else, and I really question that.

MS. BESWICK: Yes. Do you have a clarifying question?

MR. THIBEAULT: A clarifying question: Would you be expecting us to review it first, and if there were no issues, we could approve it?

MR. PONTELL: Yes.

MS. BESWICK: Oh, absolutely.

MR. THIBEAULT: But then if there are issues, then they would be brought to the Board.

MR. PONTELL: The permittee has the opportunity to appeal.

MS. BESWICK: To appeal, but are we talking about --

MR. PONTELL: Hopefully that won't be necessary.

MS. BESWICK: We're appealing a permit?

MR. PONTELL: No, the denial. If the Executive Officer denies the Model Water Quality Permit as being, over the next 12 months, being developed by the permittee, the permittee has the opportunity to appeal it to the Board -- to our Board and then ultimately to the State Board.

MS. BESWICK: Should we deny the appeal.

MR. PONTELL: Should we deny it.

MR. FRESCHI: I thought that was pretty much what we agreed to last month.

MS. BESWICK: Right. I just want to be sure that everybody was clear about what we were agreeing to. And I wanted to make sure that you were clear about what we were agreeing to --

MR. THIBEAULT: I am now.

MS. BESWICK: -- since it wasn't in the original proposal.

Anything else?

MR. FRESCHI: I just might add, being the newbie on the Board, that having from November of last year until now to submit all your complaints and make these -- and have these stake holder meetings to make changes, I think that's pretty reasonable. That's all. I think it's pretty reasonable.

You had a lot of time, and you folks are experts at this. I'm surprised that we had all the contentiousness that we had today.

MS. BESWICK: Well, except that last month --

MR. FRESCHI: Realizing that you had since November to do it.

MS. BESWICK: But the last month has been a

moving -- you know, new things evolving. But the other piece of it is that at some point it's up to us to make decisions, and that's what today was about.

MR. PONTELL: And if I can also make a comment is I think that the staff for the Water Quality Board, the permittee, all the affected agencies, the construction industry, the N.R.D.C. -- I very much appreciate the amount of energy and effort and just the quality of thinking going into this. And at the end of day it is my perception that everybody has the same goal.

So I think what gives me comfort is over the next 12 months, we have the opportunity -- you have the opportunity to continue to, you know, refine how this is going to play out. And things will continue to change. This is very much a moving target.

So thank you, everybody, very much for all the time and energy that's been invested in this.

MR. FRESCHI: And I would like to second those remarks, and I was -- in not bringing it up because you certainly are accurate in that.

MS. BESWICK: If there are no other comments, then I'm going to call for the question and ask all those in favor to say aye.

BOARD MEMBERS: Aye.

MS. BESWICK: Any opposed?

We don't need a roll call.

That takes care of that. Thank you, everyone, staff, all of you who have been working through this. That's greatly appreciated.

And I think that concludes our agenda.

(Board meeting adjourned at 12:21 p.m.)

REPORTER'S CERTIFICATE

I, ALLISON SWANSON, CSR NO. 13377, A CERTIFIED SHORTHAND REPORTER FOR THE STATE OF CALIFORNIA, DO HEREBY CERTIFY:

THAT THE FOREGOING TRANSCRIPT OF PROCEEDINGS WAS TAKEN BEFORE ME ON April 24, 2009 AT THE TIME AND PLACE THEREIN SET FORTH, WAS TAKEN DOWN BY ME IN SHORTHAND, AND THEREAFTER TRANSCRIBED INTO TYPEWRITING UNDER MY DIRECTION AND SUPERVISION;

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I FURTHER CERTIFY THAT I AM NEITHER COUNSEL FOR NOR RELATED TO ANY PARTY TO SAID ACTION, NOR IN ANYWISE INTERESTED IN THE OUTCOME THEREOF.

IN WITNESS THEREOF, I HAVE HEREUNTO SUBSCRIBED MY NAME THIS 13th DAY OF May, 2009

Allison Swanson

ALLISON SWANSON, CSR NO. 13377
CERTIFIED SHORTHAND REPORTER
FOR THE STATE OF CALIFORNIA

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bio-treatment. We don't need to be re-educated to it. We got a very complete picture on the 24th.

With that -- with those comments, I would ask Mary Ann Skorpanich if she would like to begin. And please know, I'm going to watch the clock, and at three minutes I'm going to ask people to stop.

MS. SKORPANICH: With all due respect, we'd like to just change the order a little bit.

MS. BESWICK: Absolutely. However you'd like to do it.

Is this Richard then?

MR. BOON: Yes.

MS. BESWICK: Identify yourself for the court reporter.

MR. BOON: Richard Boon. I represent the County of Orange, which is the principal permittee for the Orange County Storm Water Program. I'm responsible for managing the countywide elements of the Orange County Storm Water Program. Our presentation, I do have a powerpoint presentation. I would ask that as a principal permittee --

MS. BESWICK: Not today.

MR. BOON: This is a really -- we're focused on C.1 and C.2. It is a critical issue.

MS. BESWICK: I'm not going to hear it. We're not

going to have time for a 10 minute powerpoint presentation.

MR. BOON: It won't be 10 minutes.

MS. BESWICK: You can have three.

MR. BOON: We can try to get through it in three.

MS. BESWICK: So let's really focus on the highlights. And I have to say, I'm a little skeptical when I see this many pages of powerpoint that we're going to make it in three. So I wouldn't bother with -- I'd move right on to what you really want to say.

MR. BOON: Obviously, as you observed, reaching consensus has proven to be very difficult. The permittee positions over the course of consideration of this permit, April 24th we were prepared to support adoption of the permit, but we withdrew our support following an errata sheet that was presented to us on April 24th.

May 19th, we were again prepared to support the permit adoption, and we regret that we had to withdraw our support following another errata sheet.

Our main point today is that L.I.D. and traditional structural B.M.P.s are similarly effective protecting water quality. We've examined the performance of B.M.P.s extensively in Orange County. We had a consultant report prepared by R.B.F. and an expert

from the University of Texas in 2003, updated significantly in 2005, and it recommended for use in Orange County a variety of B.M.P.s, both traditional structural and types that would be considered low impact development.

The permittee position is that we support the prioritization of B.M.P.s of L.I.D. and S.U.S.M.P B.M.P.s, but that a water quality volume that cannot be captured by L.I.D. B.M.P.s should be, for a project proponent, be able to be treated using standard or traditional S.U.S.M.P. type B.M.P.s.

Now Mac Walker with Larry Walker Associates is going to present a study that underscores that point.

MR. WALKER: Do I have three minutes?

MS. BESWICK: Yes, you do.

MR. WALKER: Next slide, please.

What we basically did was, we wanted to look -- have a side by side comparison of low impact development strategies verses what we call traditional or conventional B.M.P.s. So what this means is, we took three case studies, and in the first case study, the 100 percent L.I.D. retention, that's the one you get to pass. You don't have to get a waiver.

Case two is if you have 50 percent L.I.D. on-site, but you had to treat the rest before leaving,

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Case two is if you have 50 percent L.I.D. on-site, but you had to treat the rest before leaving,

you have to get a waiver.

And finally, the third case where we just couldn't do L.I.D., we went with traditional B.M.P.s. Again, you have to have a waiver for those -- case two and three.

So what we did is, is we set up a continuous simulation model. We took a site -- next slide, please -- and we looked at the loadings off of this acreage, 2.7 acres. It's a commercial site runoff coefficient about .74, and we ran -- we calculated the loads coming off that site using the rainfall data for Orange County. We used 10 years of data.

So we plugged in the data, calculated the loads coming off that site for each of those three cases that we talked about.

One other thing I want to point out here is, when we talk about conventional or traditional B.M.P.s, we're talking about a detention basin, and we assume that the water coming out of the well-designed maintained detention basin was going to be around 40 milligrams per liter. And we used total suspended solids as our surrogate to look at.

And the next slide is really the slide we want to present. It's a little bleached out here. I'm going to point out -- the green line is the site without any

controls. That's what we had before S.U.S.M.P., no treatment controls, nothing. The yellow line is case three. That's where we can't do any L.I.D. on-site, but we're using all that water, and we're sending it through a conventional treatment control B.M.P.

Case one, which is the blue line, which is the best performing scenario, is L.I.D. 100 percent. You may say, well, how could that be? Because L.I.D. is retaining it on-site.

What it is, is your standard is to capture and retain the three quarters inch storm. In California where we have that frontal-type rainfall events, you get storms that come in back to back, and you end up using the capacity of the L.I.D. on-site, and the rest of it has to go and be discharged off-site without treatment.

So the bottom line is our overall removal -- solids removal for conventional treatment is 78 percent, while the L.I.D., 100 percent L.I.D. strategy, is only 83 percent. That's a five percent difference. Although, in your scenario, we have to go and get a waiver for that five percent.

Sorry. Are my three minutes --

MS. BESWICK: Getting close.

MR. WALKER: This is important stuff.

MS. BESWICK: I agree, but you need to move it

along.

MR. WALKER: I appreciate that.

Just to keep this in context, we did a sensitivity analysis where we changed some of the input, and the bottom line is it still kind of came real close. The best case scenario is L.I.D. verses traditional verses suspended solids was within one percent overall. This is for 10 years of data, by the way. We are within one percent. The best case for L.I.D. in this -- in these sensitivity was 10 percent difference. It's really bracketed. It's a very small window.

So anyway, the bottom line is we feel that a waiver is inappropriate -- or not inappropriate, but maybe not consistent with the ability of traditional B.M.P.s well-designed and maintained to treat and discharge good water quality.

MR. THIBEAULT: I think that what Mr. Taylor -- or Mr. Walker just showed us looks sort of like -- if you can look at the case three at -- I don't know, 1,100 kilograms and the L.I.D. at 700 kilograms, it looks like maybe what you've demonstrated to us is, it's about 40 percent better to use full L.I.D. than it is the conventional -- just using your data.

MR. WALKER: That's not the way I would look at it.

MR. THIBEAULT: I think it's what the graph shows

us. And you have kind of a scale issue here, too, by having such a large -- or is it small -- scale. It doesn't really differentiate the three cases very clearly when there is a significant difference between the three.

MR. WALKER: Well, I would maybe not agree with you.

MS. BESWICK: And that's okay.

MR. WALKER: I wouldn't agree with you. I suppose that's up for another time.

MS. BESWICK: Thank you.

MS. SKORPANICH: So what we're arguing today is for re-inclusion of similarly effective treatment control B.M.P.s back into the language in Section C. Our position is that this is the N.P.D.S. program. It is to control the discharge of pollutants, and we see L.I.D. and support L.I.D. as a means toward that end, but not an end unto itself.

We feel that the exclusion of that particular phrase then puts a punitive mitigation on projects where it has been deemed infeasible to be able to do this on-site and to have to go through a waiver, still do the treatment of that 85th percentile storm, but do mitigation in addition to it.

We are trying to argue here that a project

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We are trying to argue here that a project

should not be penalized because it's using things that are similarly effective where it's infeasible to do it on-site.

Next slide, please.

And again, that's -- next slide. One more.

And so we're arguing for this phrase to be reinserted in there. There really has not been a technical basis for why L.I.D. should be the end as opposed to the means in this particular case. And we think that those similarly effective B.M.P.s where it's infeasible to do the L.I.D. on-site should not have to go through the waiver provision.

Am I out of time?

MS. BESWICK: That's it.

MS. SKORPANICH: Thank you.

MS. BESWICK: Thank you.

Do we have someone following on in that, or may I just continue through the cards that I have?

MR. CARLSTEDT: I believe my card is next.

MS. BESWICK: Are you Tim? It is Tim. Thank you.

MR. CARLSTEDT: My name is Tim Carlstedt. I'm an Environmental Counsel for the County of Orange. Good morning.

Just as a procedural matter, as usual, we just want to make sure that all the County's written

this is completely consistent with both the E.P.A. definition of L.I.D. and the State's definition of L.I.D., both of which say that the aim of L.I.D. is to mimic the predevelopment hydrology -- well, you're not going to do that. If you say anywhere you can, you change the hydrology if it's feasible to do so, you're not going to be trying to mimic the predevelopment hydrology. So you're stepping away from both the U.S. definition and state definition of L.I.D.

You're also stepping away from a 2000 year doctrine called the National Flow Doctrine at Law, which since Ancient Rome has said that you should try to -- when you develop property, you should try to maintain the natural flow as much as possible. In fact, you have an obligation to do so.

MS. BESWICK: I'm going to ask you to stop there. Again, we heard a good discussion about that at our last meeting. We understand it clearly.

MR. HENDERSON: Okay. Thank you.

MS. BESWICK: Eric Strecker, followed by Paul Singarella.

MR. STRECKER: Obviously, I'm not going to go through the whole presentation. I would have liked to today. My name is Eric Strecker with Geosyntec Consultants, and I'm here from Portland, Oregon today.

I'm going to skip through the highlights from my last presentation to the Board that I gave you and focus on just a couple of things. I think if we look at a more sustainable strategy, it's really all of these things that we want to be looking at in terms of what is the most desirable combination, not simply looking at what is feasible, which has been highlighted here.

I think Board Member PonTell highlighted there's lots of benefits to some of the bio-treatment-type systems. I thought some pictures would be good to look at. This a bio-retention system in Sacramento County.

MS. BESWICK: We're really -- we've had this. I'm just saying, spend your time on things we haven't already been over.

MR. STRECKER: I'll just show a few pictures here of different systems out there that I think provides some aesthetics and habitat benefits, fresh water marshes included.

The other thing I wanted to draw your attention to is just -- I'll go right to the last map here. We did some analysis of feasibility of infiltration, and this is showing an overlay of where we have the soils to do it, where we have industrial areas, where we have contamination considerations, steep

slopes, and depths to groundwater of less than 10 feet.

Bottom line is, about 23 percent of the County is probably available for infiltration, which is a significant component. But you're going to have another almost 80 percent, but that's not a viable technology. Then you're into capture and use, because evapotransporation is going to be fairly limited as a loss mechanism, and then we're into building tanks and things like this.

After your hearing, I visited E.P.A. They have cisterns that capture an inch of runoff from their roof. They were dry because -- they weren't even diverting water into those because they can't use it now for irrigation. Their own sign said it takes about 10 days to drain those things. My bet is those are bypassing off it.

So again, I think the key issue here is in thinking about Footnote 56, what I'd like to see is what is the most desirable combination of those things that we can do that gives us the best outcome verses prioritizing one over another. So maybe this hits on what Mac was trying to say, too.

We did an example 100 acre catchment where I showed the T.S.S. loadings to receiving waters would be less under bio-retention scenario with toilet flushing

and irrigation verses cistern and re-use, and I'd actually have lower concentrations in this particular case.

So -- and then I also think we just have to think about the sustainability and the carbon footprint if we get into putting tanks and treatment pumps and treatment systems and the rest of that on a micro-scale.

So bottom line is that I think we need to think about keeping the appropriate mix of tools in the toolbox and really taking -- so this word feasibility, I think you're hearing that it gives a lot of people heartburn here. And let's get that down to what are the most desirable combinations of things that we should do.

Thank you.

MS. BESWICK: Thank you. Those are good points.

Paul Singarella.

MR. SINGARELLA: Thank you, Madam Chair and other members of the Board. Paul Singarella, and I'm here today on behalf of the Orange County Business Council.

I have two points: One procedural and one substantive. On the procedural side, we were actually quite surprised on May 11 because the prior comment period had closed on May 8, and on May 11 we saw for the first time -- because it was first introduced on May 11 -- this Footnote 56, which we thought was

State of California
California Regional Water Quality Control Board
Santa Ana Region

Minutes of the May 22, 2009 Board Meeting
City of Loma Linda Council Chambers
25541 Barton Road
Loma Linda, CA

1. Chair Beswick called the meeting to order at 9:10 a.m.

Board Members Present	**Board Members Absent**
Carole Beswick, Chair	Fred Ameri
Seymour Van Gundy, Vice-Chair	
William Ruh	
Steven PonTell	
Richard Freschi	

Staff Members Present

Gerard J. Thibeault, Executive Officer
Kurt V. Berchtold, Assistant Executive Officer
David Rice, Regional Board Counsel
Joanne Schneider, Environmental Program Manager
Michael J. Adackapara, Supervising Water Resource Control Engineer
Robert L. Holub, Supervising Water Resource Control Engineer
Mark E. Smythe, Chief of Storm Water (Coastal Waters)
Hope Smythe, Chief of Basin Planning (Inland Waters)
Milasol Gaslan, Chief of Storm Water (Inland Waters)
Marc Brown, Environmental Scientist
Cindy Li, Engineering Geologist
Maria Macario, Water Resources Control Engineer
Keith Elliott, Water Resources Control Engineer
Kevin Heinemann, Staff Information Systems Analyst
Felipa Carrillo, Executive Assistant

Public Attendance

Ian Adam, Fuscoe Engineering
Mark Baker, Contech
Tim Carlstedt, Co. of Orange
Mary Lynn Coffee, Nossaman LLP
Terry Friedman, Menifee
Peter Herzog, City of Lake Elsinore
A3 Holmon III, City of Garden Grove
Bart Lounsbury, NRDC
Kristine Murray, OC Business Council
Mike Recupero, Rempu
Paul Singarella, Latham & Watkins
Ron Smith, SWPPP Services
Jason Uhley, Riverside Co. Flood Control
Ken Watkins, Menifee
Howard Wen, Fuscoe Engineering
Mark Wildermuth, Wildermuth Env.
Michael Yang, City of Irvine
Vaikko Allen, Contech
Richard Boon, Co. of Orange
Jessica Chin, City of Riverside
James Fortuna, County of Orange
Andrew Henderson, CICWQ
Daniel Hsieh, City of Westminster
John Kemmerer, U.S. EPA
Larry McKenney, RBF Consulting
Trung Phan, City of Fullerton
Grant Sharp, Co. of Orange
Mary Ann Skorpanich, Co. of Orange
Eric Strecker, Geosyntec/CICWQ
Gonzalo Vasquez, Cypress
Mack Walker, Larry Walker Assoc.
Howard Welpon, City of Yorba Linda
Marsha Westropp, OCWD
Bob Woodings, City of Lake Forest
Matt Yeager, San Bernardino Co.

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2. Public Forum

Terry Friedman and Ken Watkins, both from Menifee, expressed to the Board their disappointment with the Regional Water Quality Control Board staff in addressing their concerns regarding a package sewage treatment plant at Wilderness Lakes RV park for the last eighteen months.

Staff said a number of inspections have been made, and that the treatment plant has had two operational failures in the past 18 months, but is currently operating properly. Wilderness Lakes has been informed and is aware they need to upgrade the plant to make sure it is reliable, or connect to the EMWD sewer.

3. State Water Resources Control Board Liaison Report

Tam Doduc, State Board Liaison, reported that the Recycled Water Policy, the draft Construction General Statewide Storm Water Permit, the draft Water Quality Enforcement Policy and the draft Once-through Cooling (OTC) Policy may be up for consideration by the end of this year. Ms. Doduc stated that the OTC Policy is a very important policy for every coastal region, and it will be very helpful for the State Board to establish a State policy for OTC.

4. Approval of the Minutes

Action: It was moved by Member Ruh, seconded by Member Freschi, and unanimously approved that the Minutes of the April 24, 2009 Board Meeting be approved as presented.

Agenda Update: It was noted that Item No. 7 had errata and Item No. 8 had been postponed.

5. Consent Calendar

*6. **Appeal of Staff's Denial of an Exemption from the Minimum Lot Size Requirement for Subsurface Disposal System Use for Russ and Dawn Grove**

*7. **Big Bear Lake Nutrient TMDL – Resolution No. R8-2009-0043**

*9. **Renewal of Waste Discharge Requirements for Eastern Municipal Water District, Riverside County (NPDES No. CA8000188) - Order No. R8-2009-0014**

*10. **Rescissions - Order No. R8-2009-0029**

Action: It was moved by Member Ruh, seconded by Member Freschi, and unanimously approved that the Board adopt Resolution No. R8-2009-0043 as amended by errata, Order No. R8-2009-0014, Order No. R8-2009-0029, and approve the exemption from the minimum lot size requirements requested by Russ and Dawn Grove.

11. **Presentation to the Board of the Results of the Most Recent Wasteload Allocation Analysis for the Santa Ana River**

Mark Wildermuth, consultant for the Nitrogen/TDS Task Force, presented this item.

Mr. Wildermuth's presentation described in detail the efforts by him and his associates to perform an updated analysis of the Nitrogen and TDS Wasteload Allocations included in the Basin Plan for the Santa Ana River and its major tributaries. The Nitrogen and TDS Wasteload Allocations were established more than 20 years ago and need to undergo periodic review and updates to address ever changing conditions. The presentation included several calibration scenarios regarding stormwater, hydrologic studies, and Nitrogen and TDS Wasteload Allocations.

The Wasteload Allocations are implemented through permit limitations in the NPDES permits issued to each of the publicly owned treatment works (POTWs) that discharge to the Santa Ana River or its major tributaries. Mr. Wildermuth said a proposed basin plan amendment will be prepared.

Staff said that this was the latest product that came from the stakeholder process.

12. **Renewal of Waste Discharge Requirements, County of Orange, Orange County Flood Control District, and Incorporated Cities of Oran,ge County, Urban Storm Water Runoff Management Program (NPDES No. CAS618030) - Order No. R8-2009-0030**
Information concerning this item is contained in a verbatim transcript of the proceedings.

At the last meeting of April 24, 2009, the Board extended the public comment period on Section XII.C of the permit to May 8, 2009, and agreed to continue the public hearing to the May 22, 2009 meeting for Section XII.C only of the permit.

Mark Smythe, Chief of Storm Water (Coastal Waters), presented the comments that were submitted on Sections XII.C.1 and C.2 of the permit that had been received prior to May 8, 2009, plus Errata Sheet 2.

Mr. Smythe discussed in detail the changes in the Errata Sheet, which included changes in the language that allows the use of biotreatment systems as Low Impact Development (LID) BMPs if the other LID BMPs (infiltration, evapotranspiration and harvest/reuse) are not feasible. Staff recommended adopting the permit with the changes included in Errata Sheet 2, the inclusion of de-chlorinated swimming pool water as a non-storm water discharge that is not necessarily prohibited and that the appeal process for Executive Officer decisions, with regards to this permit, is to go to the Regional Board for consideration.

The Board received testimony from USEPA, NRDC, County of Orange, Latham and Watkins, Nossaman LLP, Riverside and San Bernardino County storm water program managers, Geosyntec, CICWQ, Larry Walker Associates, Contech, Orange County Water District and Rempu.

Speakers:

Richard Boon, Malcolm Walker, Mary Ann Skorpanich, Tim Carlstedt, John Kemmerer, Bart Lounsbury, Mary Lynn Coffee, Peter Herzog, Vaikko Allen, Jason Uhley, Matt Yeager, Andrew Henderson, Eric Strecker, Paul Singarella, Kristine Murray and Mike Recupero.

At the conclusion of the testimonies, the Board closed the public hearing on the permit. Some discussion among the Board members took place to clarify the appeal process.

Action: It was moved by Member PonTell, seconded by Member Van Gundy, and unanimously approved that the Board adopt Order No. R8-2009-0030 as amended by: Errata Sheet 2; replacing "or" with "and/or" in the second sentence of Section XII.C.2; adding the Mesa Consolidated Water District and Costa Mesa Sanitary District to Attachment 3; adding clarifying language regarding the non-applicability of the permit's de minimus permit language in Section III.3.ii.a to certain discharges in the

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Newport Bay watershed; changing the LID waiver granting authority to the permittees; and, adding language clarifying that should the Executive Officer's decisions regarding document submittals and waivers be challenged by the permittees or the public, that challenge shall be brought before the Regional Board for consideration.

12A. **Hazardous Waste Incident Report**

Information item.

12B. **Underground Storage Tanks Corrective Action Plans**

Information item.

12C. **Underground Storage Tanks Site Closure Report**

Information item.

13. **Regional Board Member and Executive Officer Communications**

None.

14. **Closed Session**

None

15. **Adjournment**

The meeting was adjourned at 12:25 p.m., to the regular Board meeting of July 10, 2009 at 9:00 a.m., at the Orange County Sanitation District, 10844 Ellis Avenue, Fountain Valley, CA.

Respectfully submitted:

GERARD J. THIBEAULT
Executive Officer

/fc

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State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2009-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards. The Basin Plan also incorporates by reference all State Board water quality control

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

    a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order, where voter approval is needed, the permittees should strive to gain voter approval[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the County of Orange, Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561).

facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illicit[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illicit connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552.

beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect illicit discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County Flood Control system includes an estimated 740 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on

Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

Inland Surface Streams

Santa Ana River, Reaches 1 and 2

Aliso Creek (tributary to Santa Ana River)

Carbon Canyon Creek (tributary to Santa Ana River)

Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

Silverado Creek (tributary to Santiago Creek)

Black Star Creek (tributary to Santiago Creek)

Ladd Creek (tributary to Santiago Creek)

San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

San Joaquin Freshwater Marsh (tributary to San Diego Creek)

Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

Santa Ana Delhi Channel (tributary to Newport Bay)

Big Canyon Wash (tributary to Newport Bay)

Buck Gully

Los Trancos Creek

Coyote Creek (tributary to San Gabriel River)

Other tributaries to the above listed rivers, creeks and channels

Bays, Estuaries, and Tidal Prisms

Anaheim Bay and Seal Beach National Wildlife Refuge

Sunset Bay

Bolsa Bay and Bolsa Chica Ecological Reserve

Upper and Lower Newport Bay

Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects (CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new

developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. Each watershed has unique receiving water issues, land uses, topography, soils and stream stability and habitat issues. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants (e.g., Orange County Flood Control Master Plan, Irvine Ranch Water District Natural Treatment System Master Plan, Orange County Watershed Plans, Nutrient and Selenium Management Program, etc.). As recommended in the 2008 National Academy of Sciences Report on Urban Stormwater Management, this order provides an option for the permittees to develop and implement watershed master plans integrating water quality, hydromodification, water supply and habitat protection issues. The Regional Board recognizes that a watershed master plan should integrate all other related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary. The

Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. Inspection requirements, including criteria for prioritization of facilities for the inspection, were included in the third term permit. The construction and industrial inspection programs in the third term permit had established criteria/examples. However, the commercial inspection program only included a preliminary list of types of facilities to be inspected. Further refinements to the commercial inspection program are included in this order and these include: moving mobile businesses into their own program; including eating establishments (previously their own pilot program); and the addition of some key categories, not included on the 3rd term permit list. It should also be noted that some of these additional categories are directly related to current categories or identified in the Model Urban Runoff Program[11] and all of the additional categories are proposed for inclusion in other Southern California MS4 permits. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB

[11] Model Urban Runoff Program, prepared by the City of Monterey, California Coastal Commission, et. al., revised February 2002 by California Coastal Commission.

411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[12]. The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[13].

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvements in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, “Management Guidelines for Use of Fertilizers and Pesticides”. The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers

[12] Unified Annual Progress Report, 2005-2006, Page C-11-31.

[13] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII.

and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Stagnant water trapped in trash and debris creates breeding conditions for disease vectors (e.g., mosquitoes). Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[14]. Bioaccumulation of pollutants, present

[14] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996.

in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms. If not properly designed and maintained, urban storm water treatment systems could provide breeding areas for disease vectors, such as mosquitoes, which are a public health concern (e.g., West Nile Virus).

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illicit discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

Seal Beach (listed for enteroccocus, PCBs);

Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

Peters Canyon Channel (listed for DDT, toxaphene);

Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the

Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban

runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[15] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[16].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control

[15] Attachment 2 to Resolution No. R8-2007-0024.

[16] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed.

the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. NPDES regulations at 40 CFR 122.44(d)(vii)(B) require that permits be consistent with wasteload allocations approved by U. S. EPA. This order requires the permittees to comply with the urban runoff/storm water wasteload allocations specified in (1) Regional Board-adopted and USEPA approved TMDLs (including TMDLs for nutrients, fecal coliform, diazinon and chlorpyrifos); (2) Regional Board-adopted TMDLs that are approved by the State Board and State Office of Administrative Law and that are thereby effective (approval of organochlorine compounds TMDLs by the State is pending); and, (3) USEPA-promulgated TMDLs (including toxics TMDLs for the Newport watershed). Continuation of water quality/biota monitoring and analysis of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff, compliance with the wasteload allocations and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[17] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[18]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[19].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of best management practices (BMPs) for municipal, commercial, and industrial activities.

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[17] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile,* EPA 841-R-92-001; Office of Water, Washington, DC.

[18] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[19] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States. Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[20] (LID) BMPs are effective storm water management tools that minimize adverse impacts on storm water runoff quality and quantity resulting from urban developments. The Southern

[20] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

California Monitoring Coalition (SMC), including the project lead agency, the San Bernardino County Flood Control District, in collaboration with SMC member Southern California Coastal Water Research Project (SCCWRP) and the California Storm Water Quality Association (CASQA), with funding from the State Water Resources Control Board and CASQA, is developing a Low Impact Development Manual for Southern California. A preliminary draft of this manual indicates that effective implementation of site design LID BMPs should occur during the earliest stages of planning such as site assessment, environment review and site planning. This manual will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the manual as a resource to implement LID techniques. This order requires the project proponents to first consider preventative and conservation techniques (e.g., preserve and protect natural features to the maximum extent practicable) prior to considering mitigative techniques (structural treatment, such as infiltration systems). The mitigative measures should be prioritized with the highest priority for BMPs that remove storm water pollutants and reduce runoff volume, such as infiltration, then other BMPs, such as harvesting and re-use, evapotranspiration and bio-treatment should be considered. These LID BMPs must be implemented at the project site in a manner consistent with the maximum extent practicable standard. Where LID BMPs are not feasible at the project site, more traditional, but equally effective control measures should be implemented.

62. The USEPA has determined that LID/green infrastructure can be a cost-effective and environmentally preferable approach for the control of storm water pollution and will minimize downstream impacts by limiting the effective impervious area of development. LID and the reduction of impervious areas may achieve multiple environmental and economic benefits in addition to reducing downstream water quality impacts, such as enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency and other community benefits, such as aesthetics, recreation, and wildlife areas. USEPA has reviewed studies[21] that have evaluated the percent EIA[22] concept (also see the SCCWRP study[23]). The limited study conducted by Dr. Richard Horner[24] concluded that a 3% EIA standard for development is feasible in Ventura County. EPA believes that EIA is a reasonable metric for incorporating LID principles into storm water permits and EPA supports

[21] See for example the analysis prepared by Dr. Richard Horner entitled, "Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County" submitted to the Los Angeles Regional Board by NRDC.

[22] EIA=effective impervious area. These are areas where little or no infiltration of storm water occur, such as paved areas.

[23] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area.

[24] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated).

other equally effective metrics for compliance determination. A review of the analysis of the LID metrics in storm water permitting[25] and its critique[26] indicates that there are certain shortcomings in specifying a percentage EIA as a metric. A series of stakeholder meetings[27] conducted after issuance of the first draft of this order concluded that other equally effective metrics could be used to quantify implementation of LID. It was generally agreed by the stakeholders that a numeric metric, such as a metric based on a specified volume capture may be an equally effective metric. A 5% EIA metric was included in the first draft of this order. The second draft replaces the 5% EIA metric with a volume capture metric based on the design volume specified in the WQMP.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The model WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the model WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate project WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP, and the priority project threshold for commercial/industrial developments has been changed to 10,000 square feet, making it consistent with the threshold for residential subdivisions. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The project WQMPs are required to include a discussion on how LID principles are incorporated into the project. Section 7.II-3.2.4 of the WQMP requires identification of hydrologic conditions of concern (HCOC). An HCOC exists when a site's hydrologic regime is

[25] Low Impact Development Metrics in Stormwater Permitting, Prepared for the Ventura Countywide Stormwater Quality Management Program and the Orange County Stormwater Program by Geosyntec Consultants and Larry Walker Associates with Assistance from Hawks and Associates (January 2009).

[26] Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting" by Dr. Richard Horner (undated, submitted by NRDC on February 13, 2009).

[27] The stakeholder group included representatives from Permittees, NRDC, Orange County Coastkeeper, BIA/CICWQ, The Irvine Company, Regional Board staff, USEPA and a number of consultants and attorneys.

altered and there are significant impacts on downstream channels and aquatic habitats, alone or in conjunction with impacts of other projects. Currently, new development and significant re-development projects are required to perform this assessment and incorporate appropriate BMPs to ensure existing hydrologic conditions are maintained. Certain jurisdictions have employed HCOC mapping efforts to assist developers in identifying areas where HCOC conditions exist. Within six months of adoption of this order, the permittees are required to conduct an HCOC mapping to identify HCOC areas in the permitted area.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. Treatment control BMPs include vortex systems, catch basin inserts, detention basins, infiltrations areas (including LID-based), retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and managed, these systems could be sources of pollutants and could become a nuisance and/or cause the spreading of surface water pollution, and those treatment systems with a hydraulic connection to groundwater (e.g., detention basins, infiltration systems, constructed wetlands, etc.) could be sources of groundwater pollution. Restrictions placed on urban runoff infiltration in this order (Section XII.B.5.) are based on recommendations provided by the U.S. EPA Risk Reduction Laboratory. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 66 could create a nuisance and/or habitat for vectors[28] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County

[28] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants. There are other site conditions that limit the applicability of infiltration, including site soils, contaminant plumes, potential mobilization of naturally occurring contaminants such as selenium, high groundwater levels, etc. Such factors should be considered in the design and implementation of storm water control measures.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[29] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required, see Finding 69), as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illicit discharges[30] to the MS4s; and (3) enact the necessary legal authority to effectively

[29] E.g., R8-2003-0061,as amended by R8-2004-0021.

[30] Illicit Discharge means any discharge to the municipal separate storm system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all discharges that contain non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a model WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. Based on the results of the audits performed during the 3rd term permit, a number of permit requirements have been incorporated into the current permit. While the 2001 DAMP listed criteria by which co-permittees were to assess the priority ranking of commercial sites, a number of co-permittees had interpreted those criteria in such a manner as to ensure that only a very small number of sites would be ranked 'High' and in some cases, all commercial sites within a municipality were ranked 'Low,' resulting in the least number of inspections possible. To address this situation, commercial site ranking now requires that a minimum 10% of the sites with the highest potential for pollutant discharge, be ranked 'High' and next 40% of highest potential sites be ranked 'Medium,' for inspection purposes.

72. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. In the event that co-permittees want to design their own training program, it should be prepared in collaboration with the principal permittee, and at a minimum, should contain all information present in the principal permittee-prepared training program. The permittees are required to document procedures used to determine the defined

competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

73. This order includes wasteload allocations for those constituents for which either the U.S. EPA has promulgated or the Regional Board has established TMDLs. Federal regulations (40 CFR 122.44(d)(vii)(B)) require that the Permits be consistent with the applicable wasteload allocations in the TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

74. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

75. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

76. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that

established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

77. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

78. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

79. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

80. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed

inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

81. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal activities that could impact water quality. This order requires implementation of LID techniques. If not properly designed and maintained, some of the LID BMPs could provide breeding areas for vectors. Public education and outreach materials should include a discussion on the association between disease vectors, urban runoff, storm water treatment control and LID BMPs.

82. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

83. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather

monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLICIT DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

84. Illicit discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illicit discharges and illicit connections. The program also facilitates public reporting of illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illicit discharges to the MS4s and to take appropriate enforcement actions.

85. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illicit connections and illicit discharges, to control spills, to require compliance with local water quality ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

86. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area.

87. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

88. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

89. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

90. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

91. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

92. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.

7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee and attend at least 75% of the meetings each calendar year.

2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illicit connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
    i. The discharges identified below need not be prohibited by the permittees unless such discharges are identified either by the permittees or by the Executive Officer as a significant source of pollutants. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
        a) Discharges composed entirely of storm water;
        b) Air conditioning condensate;
        c) Irrigation water;
        d) Passive foundation drains;
        e) Passive footing drains;

f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Dechlorinated swimming pool discharges (Cleaning wastewater and filter backwash shall not be discharged to the MS4).

i) Diverted stream flows;

j) Rising ground waters and natural springs;

k) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

l) Flows from riparian habitats and wetlands;

m) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XXI, Provision 5);

n) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

o) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges from permittee owned and/or operated facilities and activities unless the stated conditions are met:

a) For discharges outside the Newport Bay watershed the de minimus types of discharges listed in the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001 (General De Minimus Permit), shall be in compliance with the terms and conditions of the General De Minimus Permit. Separate coverage under the General De Minimus Permit is not required. For discharges within the Newport Bay watershed, separate permit authorization for these de minimus discharges will be required when the discharges contain selenium, nitrogen or other pollutants at levels of concern.

b) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[31] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

[31] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

c) Discharges from lawn, greenbelt and median watering and other irrigation runoff from non-agricultural operations[32]: These discharges shall be minimized through a Model Municipal Activity Maintenance Program designed to control irrigation runoff.

d) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[33] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

e) Construction dewatering wastes: The maximum daily concentration limit for total suspended solids shall not exceed 75mg/l, sulfides 0.4mg/l, oil and grease15mg/l, total petroleum hydrocarbons 0.1mg/l.

f) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.

5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).

6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.

7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of pollution, contamination or nuisance, as those terms are defined in Section 13050 of the Water Code.

[32] Non-agricultural irrigation using recycled water must comply with the statewide permit for Landscape Irrigation Using Recycled Water and the State Department Health guidelines.

[33] See previous footnote.

8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.
2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.
3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

   a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

   b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

   c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

   d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

   So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water

limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illicit connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The Permittees' ordinance must include adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.
3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a

decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow-up inspection.

4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.
5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.
6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis[34] and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)
7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):
   a) Sewage (also prohibited under the Statewide SSO order[35]);
   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;
   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;
   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;
   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

[34] The reporting schedule may be revised with the approval of the Executive Officer.

[35] State Board WQO No. 2006-0003.

f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[36];

g) Discharges of runoff from the washing of toxic materials[37] from paved or unpaved areas;

h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

i) Pet waste, yard waste, litter, debris, sediment, etc.; and,

j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLICIT CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illicit connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illicit connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.
2. The permittees shall control the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.
3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illicit Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.

[36] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

[37] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. At least once during the permit term, the principal permittee shall characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report.
6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.
7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.
2. Each permittee shall continue to maintain and update (at least on a biannual basis, once in September and the second update in May) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites, as described above, shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude [in decimals] or NAD83/WGS84[38] compatible formatting), inspection data, etc.
3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites

[38] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.

4. Each permittee shall conduct construction site inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:

   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;

   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

   c) Visual observation for non-storm water discharges and potential pollutant sources;

   d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

   e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an

inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.
7. All violations shall be notified as per Section XVII.
8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.
9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitude/longitude (in decimals) or NAD83/WGS84[39] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.

[39] See Footnote 38.

3. Each permittee shall conduct industrial facility inspections, subject to limitations on municipal action under the constitutions of California and the United States, for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.
4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.
5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.

10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period[40].

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction[41]. As required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[42] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

   Commercial facilities may include, but may not be limited to[43]:

   a) Transport, storage or transfer of pre-production plastic pellets.
   b) Automobile mechanical repair, maintenance, fueling or cleaning;
   c) Airplane maintenance, fueling or cleaning;
   d) Marinas and boat maintenance, fueling or cleaning;
   e) Equipment repair, maintenance, fueling or cleaning;
   f) Automobile impound and storage facilities;
   g) Pest control service facilities;
   h) Eating or drinking establishments, including food markets and restaurants;
   i) Automobile and other vehicle body repair or painting;
   j) Building materials retail and storage facilities;
   k) Portable sanitary service facilities;
   l) Painting and coating;
   m) Animal facilities such as petting zoos and boarding and training facilities;
   n) Nurseries and greenhouses;
   o) Landscape and hardscape installation;
   p) Pool, lake and fountain cleaning;
   q) Golf courses;
   r) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
   s) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

[40] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

[41] The inventory update schedule may be revised with the approval of the Executive Officer.

[42] See Footnote 38.

[43] Mobile cleaning services are addressed in X.8, below.

2. Each permittee shall conduct, or require to be completed, inspections of its commercial facilities as indicated below and subject to limitations on municipal action under the constitutions of California and the United States. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 12 months of adoption of this order, the permittees shall develop a prioritization and inspection schedule for the commercial facilities in Section X.1 for review and approval by the Executive Officer. Until that plan is approved, the following minimum criteria must be met for prioritization of commercial sites for inspections: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[44]; 20% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct, or require to be completed, commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.

4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.

5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or

[44] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.

7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the permittees shall develop a mobile business pilot program. The pilot program shall address one category of mobile business from the following list: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape and furniture cleaning; mobile high pressure or steam cleaning. The pilot program shall include at least two notifications of the individual businesses operating within the County regarding the minimum source control and pollution prevention measures that the business must implement. The pilot program shall include outreach materials for the business and an enforcement strategy to address mobile businesses. The permittees shall also develop and distribute the BMP Fact Sheets for the selected mobile businesses. At a minimum, the mobile business Fact Sheets should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated.
9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, continue to conduct annual inspections that address:
    a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;
    b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;
    c) Parking lot, alley, sidewalk and street areas to verify that floor mats, mops, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas or discharged to the MS4;
    d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,
    e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

    All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.
10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period[45].

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s consistent with the maximum extent practicable standard so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.
2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall encourage residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[46] and USDA's Backyard Conservation Program[47].
3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.
4. Within 18 months of adoption of this order, the permittees shall develop a pilot program to control pollutant discharges from common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape

[45] An appropriate framework for inspection coordination will be developed by Regional Board staff and the permittees.

[46] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[47] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

Performance Certification Program[48] to encourage efficient water use and to minimize runoff[49].

5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[50].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.
2. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. Within 18 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.
3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.
4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies,

[48] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[49] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[50] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. The permittees shall review their planning procedures and CEQA document preparation processes at the time of DAMP finalization and no later than 24 months after adoption of this order, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

   a) Potential impact of project construction on storm water runoff;

   b) Potential impact of project's post-construction activity on storm water runoff;

   c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

   d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

   e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

   f) Potential for significant increases in erosion of the project site or surrounding areas.

   g) Potential decreases in quality and quantity of recharge to groundwater.

   h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process in conjunction with preparation of the DAMP finalization, consistent with the guidance for conceptual

or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.
2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance with the approved Model WQMP and shall incorporate LID principles in the WQMP.
   a. All significant redevelopment projects, where significant redevelopment is defined as projects that include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in the addition or replacement of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in the addition or replacement of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.
   b. New development projects that create 10,000 square feet or more of impervious surface (collectively over the entire project site) including commercial, industrial, residential housing subdivisions (i.e., detached single family home subdivisions, multi-family attached subdivisions (town homes), condominiums, apartments, etc.), mixed-use, and public projects. This category includes development projects on public or private land, which fall under the planning and building authority of the permittees.
   c. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).
   d. Restaurants where the land area of development is 5,000 square feet or more.

e. All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

f. Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[51] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

g. Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

h. Streets, roads, highways and freeways of 5,000 square feet or more of paved surface shall incorporate USEPA guidance, "Managing Wet Weather with Green Infrastructure: Green Streets" in a manner consistent with the maximum extent practicable standard. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

i. Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

j. Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

3. WQMPs shall include BMPs for source control, pollution prevention, site design, LID implementation (see Section C., below) and structural treatment control BMPs. For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, vector minimization and control measures, and a funding source or sources for its operation and maintenance. WQMPs shall include control measures for any listed pollutant[52] to an impaired waterbody on the 303(d) list such that the discharge shall not cause or contribute to an exceedance of receiving water quality objectives. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

[51] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows.

[52] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

c) Minimize storm water contact with pollutant sources;

d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances.

f) The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources.

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

A. Volume

Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[53]; or,

2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

[53] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

   a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

   b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

   c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050.

   d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

   e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

   f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic) automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[54].

   g) Within 18 months of adoption of this order, the principal permittee shall develop a pilot program to monitor the impact of groundwater infiltration systems on the quality of groundwater. This monitoring program may be conducted by: (1) analyzing the quality of the runoff prior to infiltration; (2) by monitoring the quality of the infiltrate through the vadose zone; or (3) by monitoring groundwater quality upstream and downstream of the infiltration systems. The results of the pilot study shall be submitted with the next annual report.

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of

[54] This restriction applies only to sites that are known to have soil and/or groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. Within 12 months of adoption of this order, the permittees shall update the model WQMP to incorporate LID principles (as per Section XII.C) and to address the impact of urbanization on downstream hydrology (as per Section XII.D) and a copy of the updated model WQMP shall be submitted for review and approval by the Executive Officer[55]. As provided in Section XII.J, 90 days after approval of the revised model WQMP, priority development projects shall implement LID principles described in this section, Section XII.C. To the extent that the Executive Officer has not approved the feasibility criteria within 18 months of adoption of this order as provided in Section XII.E.1, the infeasibility of implementing LID BMPs shall be determined through project specific analyses, each of which shall be submitted to the Executive Officer, 30 days prior to permittee approval.
2. The permittees shall reflect in the WQMP and otherwise require that each priority development project infiltrate, harvest and re-use, evapotranspire, or bio-treat[56] the 85th percentile storm event ("design capture volume"), as specified in Section XII.B.4.A.1, above. Any portion of the design capture volume that is not infiltrated, harvested and re-used, evapotranspired or bio-treated[57] onsite by LID BMPs shall be treated and discharged in accordance with the requirements set forth in Section XII.C.7 and/or Section XII.E, below.

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[55] The Executive Officer shall provide members of the public with notice and at least a 30-day comment opportunity for all documents submitted in accordance with this order. If the Executive Officer, after considering timely submitted comments, concludes that the document is adequate or adequate with specified changes, the Executive Officer may approve the document or present it to the Board for its consideration at a regularly scheduled and noticed meeting. If there are significant issues that cannot be resolved by the Executive Officer, the document will be presented to the Board for its consideration at a regularly scheduled meeting.

[56] A properly engineered and maintained bio-treatment system may be considered only if infiltration, harvesting and reuse and evapotranspiration cannot be feasibly implemented at a project site (feasibility criteria will be established in the model WQMP [Section XII.C.1] and the technically-based feasibility criteria [Section XII.E.1]). Specific design, operation and maintenance criteria for bio-treatment systems shall be part of the model WQMP that will be produced by the permittees.

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[57] For all references to bio-treat/bio-treatment, see footnote 56.

3. The permittees shall incorporate LID site design principles to reduce runoff to a level consistent with the maximum extent practicable standard during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The design goal shall be to maintain or replicate the pre-development hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime through site preservation techniques and the use of integrated and distributed micro-scale storm water infiltration, retention, detention, evapotranspiration, filtration and treatment systems as close as feasible to the source of runoff. Site design considerations shall include, but not be limited to:

   a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; preserve trees; minimize compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

   b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize paving, minimize runoff by disconnecting roof leader and other impervious areas and directing the runoff to pervious and/or landscaped areas, minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable materials; minimize pipes, culverts and engineered systems for storm water conveyance thereby minimizing changes to time of concentration on site; utilize rain barrels and cisterns to collect and re-use rainwater; maximize the use of rain gardens and sidewalk storage; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

   c) Preserve wetlands, riparian corridors, vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

   d) Use properly designed and well maintained water quality wetlands, bio-retention areas, filter strips and bio-filtration swales; consider replacing curbs gutters and conventional storm water conveyance systems with bio-treatment systems, where such measures are likely to be effective and technically and economically feasible;

   e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

   f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) During the early planning stages of a project, the LID principles shall be considered to address pollutants of concern identified in the Watershed Action Plans and TMDL Implementation Plans, and the LID BMPs shall be incorporated into the sites conceptual WQMP.

4. The selection of LID principles shall be prioritized in the following manner (from highest to the lowest priority): (1) Preventative measures (these are mostly non-structural measures, e.g., preservation of natural features to a level consistent with the maximum extent practicable standard; minimization of runoff through clustering, reducing impervious areas, etc.) and (2) Mitigation (these are structural measures, such as, infiltration, harvesting and reuse, bio-treatment, etc. The mitigation or structural site design BMPs shall also be prioritized (from highest to lowest priority): (1) Infiltration (examples include permeable pavement with infiltration beds, dry wells, infiltration trenches, surface and sub-surface infiltration basins. All infiltration activities should be coordinated with the groundwater management agencies, such as the Orange County Water District); (2) Harvesting and Re-use (e.g., cisterns and rain barrels); and (3) Bio-treatment such as bio-filtration/bio-retention.

5. Even though the LID principles are universally applicable, there could be constraining factors, such as: soil conditions, including soil compaction, saturation (e.g., hydric soils) and permeability, groundwater levels, soil and/or groundwater contaminants (Brownfield developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), naturally occurring contaminants (e.g., selenium in the soil and the groundwater in the Newport Bay Watershed), etc. In such cases, the LID principles could be integrated into other programs, such as: Smart Growth[58], New Urbanism[59] or regional or sub-watershed management approaches. Also see Section E, below, for alternatives and in-lieu programs.

6. The LID BMPs shall be designed to mimic pre-development site hydrology through technically and economically feasible preventive and mitigative site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality.

[58] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[59] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

7. If site conditions do not permit infiltration, harvesting and re-use, and/or evapotranspiration, and/or bio-treatment of the design capture volume at the project site as close to the source as possible, the alternatives discussed below should be considered and the credits and in-lieu programs discussed under Section E, below, may be considered:

   a. Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest, evapotranspire and/or bio-treat and re-use at least the design capture volume.

   b. Implement as many LID principles as possible at the project site close to the point of storm water generation and infiltrate and/or harvest and re-use at least the design capture volume through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from impervious areas should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume.

   c. Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate and/or harvest and re-use the design capture volume. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume. (Also see discussion on hydrologic conditions of concern, below.)

   d. Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to infiltrate, harvest and re-use, evapotranspire and/or bio-treat at least the design capture volume from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[60])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

   e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected.

   c) The site infiltrates at least the runoff from a two-year storm event. The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

[60] Hydromodification is the alteration of natural flow characteristics.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

5. The permittees shall address the hydrologic conditions of concern on a watershed basis by preparing a Watershed Master Plan as described below:

   The Watershed Master Plans shall integrate water quality, hydromodification, water supply, and habitat for the following watersheds: Coyote Creek-San Gabriel River; Anaheim Bay-Huntington Harbour; Santa Ana River; and Newport Bay-Newport Coast. Components of the Plan shall include: (1) maps to identify areas susceptible to hydromodification including downstream erosion, impacts on physical structure, impacts on riparian and aquatic habitats and areas where storm water and urban runoff infiltration is possible and appropriate; and, (2) a hydromodification model to make available as a tool to enable proponents of land development projects to readily select storm water preventive and mitigative site BMP measures.

   The maps shall be prepared within 12 months of the adoption of this order and a model Plan for one watershed shall be prepared within 24 months of adoption of this order. The model Plan should specify hydromodification management standards for each sub-watershed and provide assessment tools. In the preparation of the model Plan, the permittees are encouraged to use currently available information from other sources such as: (1) Orange County Flood Control Master Plan; (2) Irvine Ranch Water District's Natural Treatment System Master Plan; (3) Orange County Watershed Plans; (4) Nutrient and Selenium Management Program; (5) TMDL and 303(d) Listing information from the U.S. EPA and/or the Regional Board, and (6) and water districts.

   The model Watershed Master Plan shall be submitted to the Executive Officer for approval. Watershed Master Plans shall be completed for all watersheds 24 months after approval of the model Watershed Master Plan.

   The Watershed Master Plans shall be designed to meet applicable water quality standards and the Federal Clean Water Act.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop technically-based feasibility criteria for project evaluation to determine the feasibility of implementing LID BMPs (feasibility to be based in part, on the issues identified in Section XII.C). This plan shall be submitted to the Executive Officer for approval. Only those projects that have completed a vigorous feasibility analysis as per the criteria developed by the permittees and approved by the Executive Officer should be considered for alternatives and in-lieu programs. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same

level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, a waiver of the BMPs may be granted. All requests for waivers, along with feasibility analysis including waiver justification documentation, must be submitted to the Executive Officer in writing, 30 days prior to permittee approval.

2. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects and the urban runoff fund shall be expended for water quality improvement or other related projects approved by the Executive Officer within two years of receipt of the funds. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

3. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.

4. The permittees may establish a water quality credit system for alternatives to infiltration, harvesting and reuse, evapotranspiration, and other LID BMPs and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification and treatment control BMPs should be included in the annual report for each year. Any credit system that the permittees establish

should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

a) Redevelopment projects that reduce the overall impervious footprint

b) Brownfield redevelopment

c) High density developments (>7 units per acre)

d) Mixed use and transit-oriented development (within ½ mile of transit)

e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses

f) Regional treatment systems with a capacity to treat flows from all upstream developments

g) Contribution to an urban runoff fund (see 1, above)

h) Offsite mitigation or dedications within the same watershed

i) City Center area

j) Historic Districts and Historic Preservation areas

k) Live-work developments

l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.
4. The permittees may accept self-certification or third-party certification of BMPs from State licensed professional engineers.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding. The operation and maintenance plans for all post-construction structural treatment controls should include specific vector control mitigation measures to avoid and/or minimize vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments, including requirements for vector control. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.
3. The permittees shall develop a database with information regarding each structural treatment control BMP installed after adoption of this order. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.
4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.
5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 25% of priority development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within every four year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record. The permittees may accept inspections conducted and certified by state licensed professional engineers in lieu of permittee inspections.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan. The above provisions shall be implemented in a manner consistent with the maximum extent practicable standard for all other projects 90 days from the date of approval of the revised model WQMP (per Section XII.C.1). The Regional Board recognizes that full implementation may not be feasible for certain projects which have received tentative tract or parcel map or other discretionary approvals.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.
2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.
3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.
4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections.

Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. Some of these outreach activities could be conducted through the chamber of commerce or other similar establishments. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.
6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.
7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.
2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public

agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.

3. The permittees shall conduct inspections of open channel systems at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:

   a) Parking facilities;

   b) Flood management and storm water conveyance systems (open channels);

   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and

   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.

4. All applicable public agency staff shall be trained as specified under Section XVI.

5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:

   a) Conduct annual integrated pest management self-audits;

   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

   c) Provide proper training to municipal and contract staff involved in the above activities;

   d) Within one year of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within one year of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall

submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.
12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.
13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.
14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.

4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XVI. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.
2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program. Each permittee may develop its own training program curriculum consistent with the general principles discussed in this and the next paragraph. The training program should be coordinated with the Orange County Vector Control District to insure that vector control issues related to post-construction BMPs are incorporated into the training curriculum.
3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing or other procedure at the end of the training program to determine that the trainees have acquired the requisite knowledge in the storm water program to carry out their duties and proof of completion of training, such as Certificate of Completion, attendance sheets or other proof that training has been completed. .
4. At least every two years, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation

and a final test to verify that the material has been properly reviewed and understood. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.

5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above. The permittees have the option to develop and conduct their own training program as indicated in Paragraph 2, above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections[61].
2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

[61] The reporting schedule may be revised with the approval of the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs that the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

1. As required under a consent decree, in 2002, the EPA promulgated technical TMDLs for toxic pollutants in San Diego Creek and Newport Bay, including metals, organochlorine compounds, selenium and organophosphate pesticides. EPA and the Los Angeles Regional Water Quality Control Board established technical TMDLs for metals in Coyote Creek. Technical TMDLs do not include implementation plans or compliance schedules.
2. In collaboration with stakeholders, Regional Board staff are developing revised TMDLs that are expected to supplant the toxics TMDLs promulgated by EPA for the Newport watershed. The TMDLs will include implementation plans and compliance schedules. Implementation plans for the Coyote Creek TMDLs are also being developed.
3. In summary, work related to the following established TMDLs is ongoing:
   a) Metals (San Diego Creek and Newport Bay (including Rhine Channel))
   b) Metals (Mercury, Chromium) (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay; also see Paragraphs 5 and 6, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)
4. The permittees in the Newport Watershed shall comply with the wasteload allocations specified in the established TMDLs and shown in Tables 1 A/B/C, 2 A/B/C/D and 3. These wasteload allocations shall remain in effect unless and

until alternative wasteload allocations are established in TMDLs approved by the Regional Board, State Board, Office of Administrative Law and EPA.

Tables 1 A/B/C/D – Urban Runoff Waste Load Allocations for Metals (TMDLs promulgated by U.S. EPA)[62]

A- San Diego Creek and Tributaries – Concentration based TMDL

	Base flows (<20 cfs) Hardness- 400 mg/L		Small flows (21-181 cfs) Hardness- 322 mg/L		Med. flows (182-815 cfs) Hardness- 236 mg/L		Large Flows (>815 cfs) Hardness- 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd (ug/L)	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu (ug/L)	50	29.3	40	24.3	30.2	18.7	25.5
Pb (ug/L)	281	10.9	224	8.8	162	6.3	134
Zn (ug/L)	379	382	316	318	243	244	208

B- Newport Bay

Cd *	Cu	Pb	Zn
9,589 lbs/yr	3,403 lbs/yr	17,638 lbs/yr	174,057 lbs/yr

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume)

C- Rhine Channel

Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

D- Concentration-based Dissolved Metal TMDLs, WLAs and LAs for Newport Bay

	Dissolved saltwater TMDLs and allocations which apply to direct discharges to the bay, including storm drains/channels and metals loading associated with boats	
	Acute	Chronic
Cd* (ug/L)	42	9.3
Cu (ug/L)	4.8	3.1
Pb (ug/L)	210	8.1
Zn (ug/L)	90	81

* (Applies to Upper Bay only, estimated as 40% of Newport Bay volume).

[62] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

Tables 2 A/B/C/D – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs promulgated by U.S. EPA)[63]

A- San Diego Creek and Tributaries

Total DDT	Chlordane	Dieldrin	PCBs	Toxaphene
302.8 g/yr	220.3 g/yr	183.4 g/yr	177.7 g/yr	6.2 g/yr

B- Upper Newport Bay

Total DDT	Chlordane	PCBs
207.4 g/yr	120.5 g/yr	609.7 g/yr

C – Lower Newport Bay

Total DDT	Chlordane	Dieldrin	PCBs
76.3 g/yr	12.6 g/yr	4.45 g/yr	303.3 g/yr

D – Rhine Channel

	Total DDT	Chlordane	Dieldrin	PCBs
WLA	0.7 g/yr	0.1 g/yr	0.13 g/yr	4.1 g/yr

Table 3 – Urban Runoff Waste Load Allocation for Selenium – San Diego Creek and Tributaries

(TMDL promulgated by U.S. EPA)[64]

Base flows (<20 cfs)	Small flows (21-181 cfs)	Med. flows (182–814 cfs)	Large Flows (>814 cfs)
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr

5. The Regional Board adopted TMDLs, including an implementation plan, for organochlorine compounds in September 2007. These TMDLs must be submitted for approval by the State Board, Office of Administrative Law and EPA. These TMDLs have not yet been submitted to the State Board for its approval. However, stakeholders in the watershed are already taking steps to implement the TMDLs through a Toxicity Reduction and Investigation Program (TRIP) that will address the organochlorine compounds and other toxic pollutants, including metals, in the Newport Bay watershed. These TMDLs will become effective upon approval by the State Board and Office of Administrative

[63] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

[64] From Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, U.S. EPA – Region 9, established June 14, 2002.

Law but will not supplant the EPA organochlorine compounds TMDLs until they are approved by EPA. Accordingly, upon approval of the Regional Board-adopted organochlorine compounds TMDLs by the State Board and the Office of Administrative Law, the permittees shall comply with both the EPA and Regional Board wasteload allocations specified in Tables 2 A/B/C/D and Table 4, respectively. In accordance with the Regional Board TMDLs, compliance with the allocations specified in Table 4 shall be achieved as soon as possible but no later than December 31, 2015. Upon approval of the Regional Board-approved organochlorine compounds TMDLs by EPA, the applicable wasteload allocations shall be those specified in Table 4.

Table 4 – Urban Runoff Waste Load Allocations for Organochlorine Compounds (TMDLs approved by Santa Ana Regional Water Quality Control Board)[65]

	Total DDT	Chlordane	Total PCBs	Toxaphene
San Diego Creek	128.3 g/yr			1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.8 g/yr	
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	

6. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated the Toxicity Reduction and Investigation Program (TRIP) consistent with the Regional Board-approved implementation plan for the organochlorine compounds TMDLs. Recognizing the difficulties inherent in measuring the allocations presented in Table 4, the permittees shall evaluate the monitoring results with the targets shown in Tables 5A/B and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay and include water column, sediment and fish tissue monitoring. The permittees may use current monitoring locations.

[65] From Resolution No. R8-2007-0024, Table NB-OCs-10.

Tables 5 A /B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[66]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l
Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	
Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

7. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs and that are intended to replace the EPA TMDLs. The permittees within the Newport Bay watershed shall continue to participate in the development and implementation of these TMDLs. This Order will be reopened to incorporate revised allocations based upon TMDLs, including implementation plans, for metals and selenium approved by the Regional Board, State Board and Office of Administrative Law. As for the organochlorine compounds, the EPA promulgated allocations for these constituents will also remain in effect unless and until EPA approves the Regional Board's TMDLs for these constituents.

8. Selenium is a naturally occurring element in the soil but its presence in surface waters in the Newport Bay watershed is largely the result of changes in the hydrologic regime as the result of extensive drainage modifications. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column.

[66] From Resolution No. R8-2007-0024, Table NB-OCs-4.

The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive selenium (and nitrogen) management plans, which are expected to form the basis, at least in part, for the selenium implementation plan (and a revised nutrient TMDL implementation plan). A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. A proposed Cooperative Watershed Program that will fulfill applicable requirements of the selenium TMDL implementation plan must be submitted by the stakeholders covered by this order within 24 months of adoption of this order, or one month after approval of the selenium TMDLs by OAL, whichever is later. The Program must be implemented upon Regional Board approval. As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste discharge requirements or waivers of waste discharge requirements.

9. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement a constituent-specific source control plan for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall be designed to ensure compliance with the following wasteload allocations:

Table 6 – Municipal Storm Water Wasteload Allocations - Coyote Creek

	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

10. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper,

lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 7 – Numeric Targets - Coyote Creek

(total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[67]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

C. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 8A – Fecal Coliform TMDL and Allocations for Newport Bay

To be achieved no later than December 30, 2013

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2013	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

[67] Based on saltwater CTR criterion in San Gabriel River estuary.

Table 8B – Fecal Coliform TMDL and Allocations for Newport Bay

Before December 30, 2019

Urban Runoff Waste Load Allocation for Fecal Coliform	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

The permittees shall comply with the wasteload allocations for urban runoff in Tables 8A and 8B in accordance with the deadlines in Tables 8A and 8B. Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the Watershed Action Plans to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete the ongoing source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within twelve months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.

3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL IMPLEMENTATION PLANS AND COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are included in the TMDLs (Tables 9A and 9B are extracted from the Implementation Plan[68]). The permittees in the Newport Bay Watershed shall comply with the allocations in Tables 9 A and B.

Table 9A

Diazinon and Chlorpyrifos Allocations for San Diego Creek*

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Acute	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

Table 9B

Chlorpyrifos Allocations for Upper Newport Bay*

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1

Chronic means 4-consecutive day average

* Pursuant to the TMDLs, compliance with these allocations was achieved no later than December 1, 2007

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

[68] Attachment to Resolution No. R8-2003-0039.

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 10 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[69]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[70]	2007 Summer Allocation (Apr-Sept)[71]	2012 Winter Allocation (Oct-Mar)[72]
Newport Bay Watershed	lbs/year TN[73,74]	lbs/season TN	lbs/season TN	lbs/season TN
Urban runoff	277,131[75]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

Table 11 - Annual Total Nitrogen Load Allocations for San Diego Creek, Reach 2 During Non-Storm Conditions.[76]

	2012 Allocation lbs/day TN[77]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent

[69] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[70] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[71] See previous footnote.

[72] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[73] TIN = (NO3+NH3).

[74] TN = (TIN + Organic N).

[75] Estimated annual average (summer and winter loading).

[76] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9d. Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[77] Compliance to be achieved no later than December 31, 2012. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

monitoring data indicate that these target load allocations have been already met).

Table 12 - Annual Total Phosphorous Load Allocations For The Newport Bay Watershed[78]

	2002 Allocation lbs/year TP[79]	2007 Allocation lbs/year TP[80]
TMDL	86,912	62,080
Urban areas	4,102	2,960

The permittees shall comply with the waste load allocations for urban runoff in Tables 10, 11 and 12 in accordance with the schedules in Tables 10, 11 and 12. Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

   Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at San Diego Creek at Campus, starting from year 2000 and based on a 10-year running average. The data from this monitoring is to be submitted annually on February 27.

[78] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9c. Compliance dates are as soon as possible but no later than December 31 of the years specified (Table 5-9a of Resolution No. 98-9, as amended).

[79] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[80] See previous footnote.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determinations shall be based on monitoring within the receiving waters. For sediment TMDLs, compliance determination shall be based on monitoring in the Creek.
2. Based on the TMDLs, effluent limits have been specified to ensure consistency with the wasteload allocations. If the monitoring results indicate an exceedance of the wasteload allocations, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that an exceedance has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
    a) Review of the formal training needs of municipal employees
    b) Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.
3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.

2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:

   a) Each permittee's expenditures for the previous fiscal year,

   b) Each permittee's budget for the current fiscal year,

   c) A description of the source of funds, and

   d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.
5. Within one year of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.

6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,
   d) To incorporate any requirements imposed upon the permittees through the TMDL process.
2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on April 1, 2014 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR

122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:

a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;

b) Changes in land use and/or population including land use map updates;

c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).

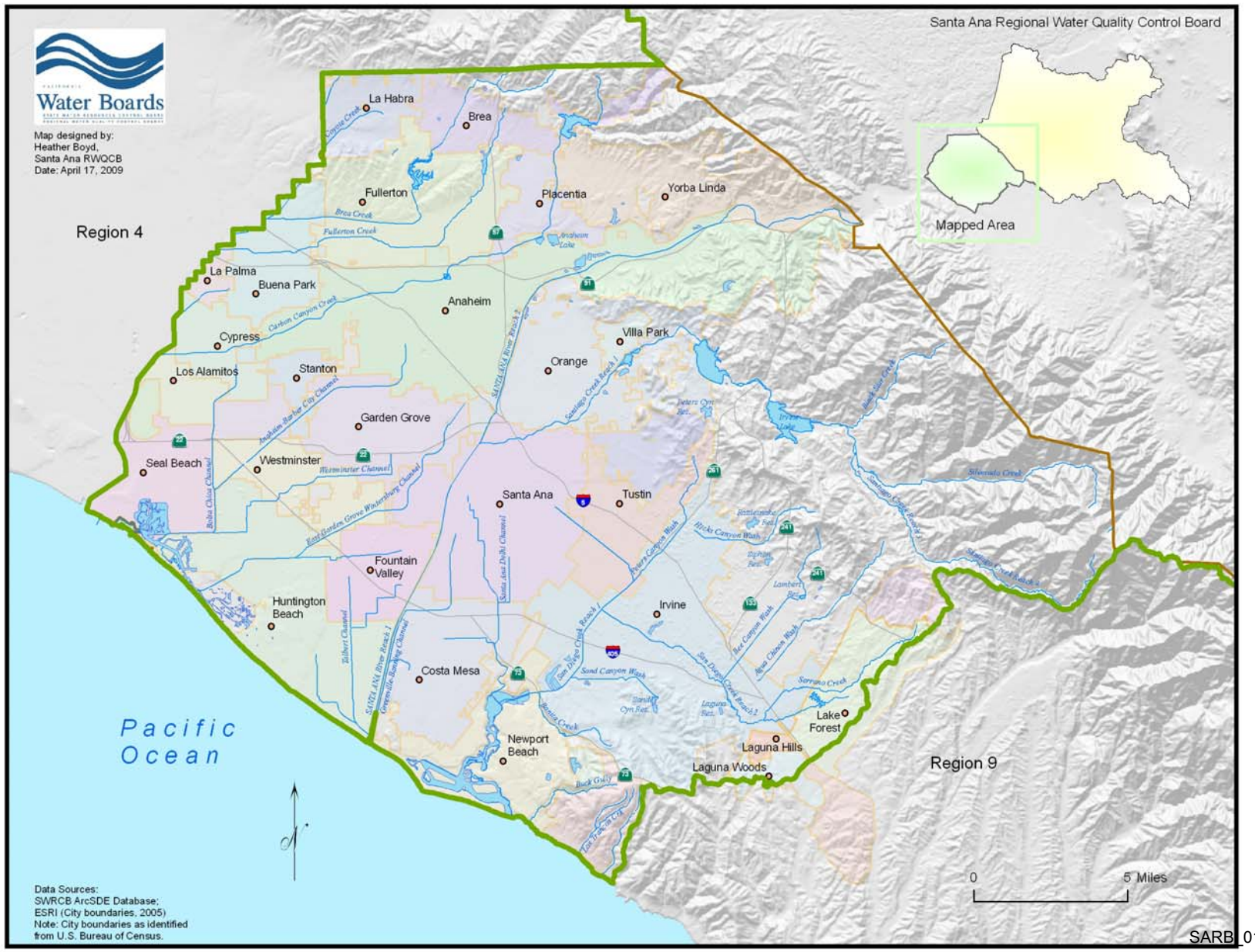
3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

4. Order No. R8-2002-0010 is hereby rescinded.

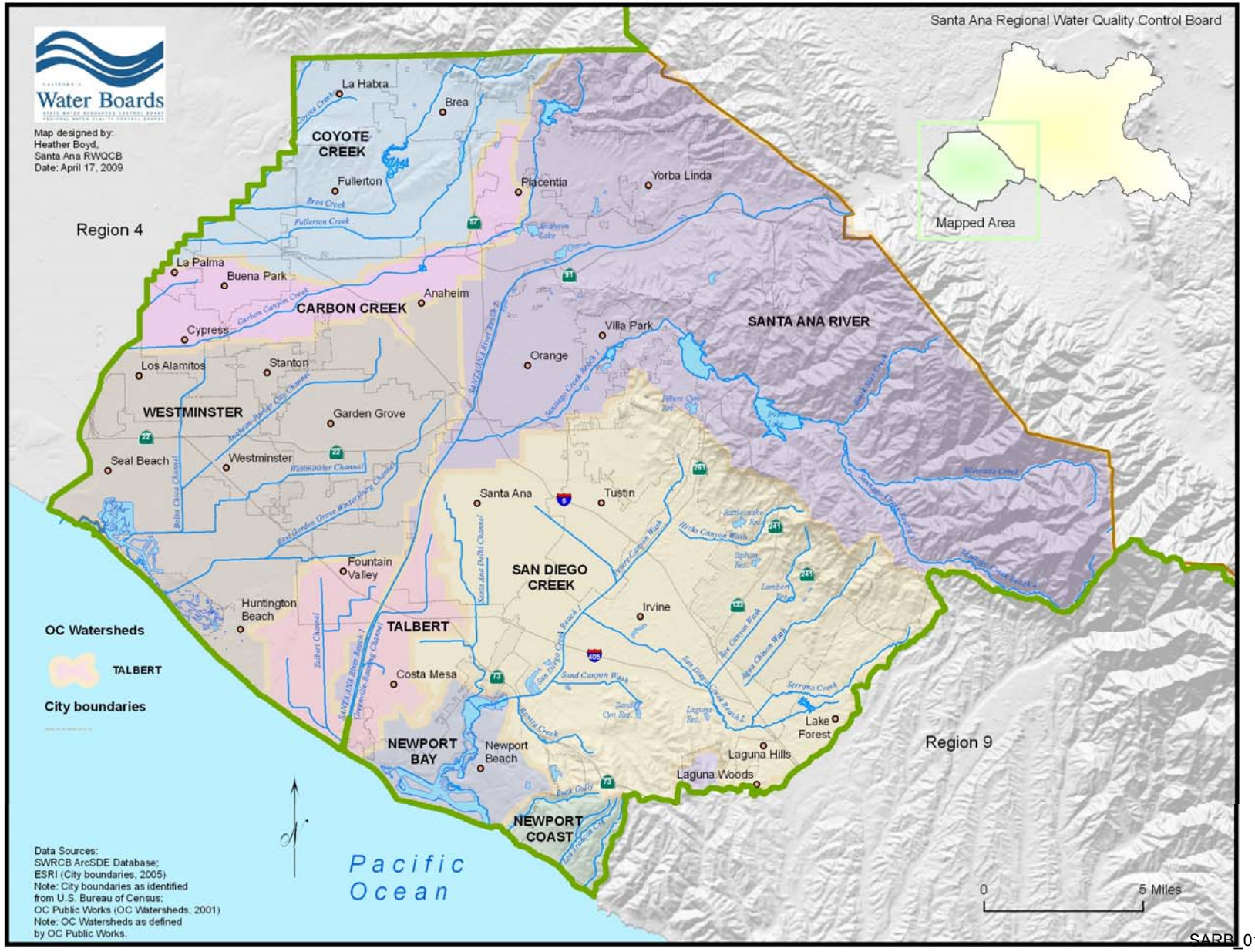
I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on May 22, 2009.

Gerard J. Thibeault
Executive Officer

Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities **Attachment "A"**
Area wide Urban Storm Water Runoff



Order No. R8-2009-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities **Attachment "B"**
Area wide Urban Storm Water Runoff



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Order No. R8-2009-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District
Ocean View Union High School District
Orange Unified School District

Placentia Unified School District
Saddleback Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
Mesa Consolidated Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Costa Mesa Sanitary District
Orange County Water District
Metropolitan Water District

State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2009-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County within the Santa Ana Region
Areawide Urban Storm Water Runoff

I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment: The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Currently weekly channel monitoring is conducted in San Diego Creek and Santa Ana-Delhi channels by both Orange County Environmental Health and the Orange County monitoring program. The Executive Officer is authorized to allow the permittees to integrate their monitoring efforts with other bacteriological/pathogen monitoring programs.

f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region. The Executive Officer is authorized to allow the permittees to integrate this element of the monitoring program with the regional bioassessment monitoring initiative being coordinated by the Southern California Monitoring Coalition.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment. The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Within 24 months of adoption	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Public education workshops	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Twice/year	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Within 6 months of adoption	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Within 6 months of adoption	Annual Report
Evaluate the need for additional debris control measures	Within 12 months of adoption	Annual Report
Complete Public Awareness Survey	July 1, 2012	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Annually	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business pilot program	Within 12 months of adoption	Annual Report
Residential common interest area/HOA pilot program	Within 18 months of adoption	Annual Report

Develop a guidance document for preparing conceptual WQMP	Within twelve months of adoption	Annual Report
Review planning documents to ensure water quality protection	Within 24 months of adoption	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	November 15
Provide training to public agency staff and to contract field operations staff	Once in two years/3 per permit term	November 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	November 15
Evaluate the DAMP	Annually	November 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	November 15

Ordered by _____
Gerard J. Thibeault
Executive Officer

DECLARATION OF SERVICE BY EMAIL

I, the undersigned, declare as follows:

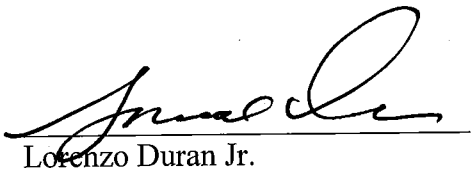
I am a resident of the County of Sacramento and I am over the age of 18 years, and not a party to the within action. My place of employment is 980 Ninth Street, Suite 300, Sacramento, California 95814.

On August 11, 2016, I served the:

Administrative Record on Permit – Orange County R8-2009-0030
Santa Ana Region Water Permit, 09-TC-03
California Regional Water Quality Control Board, Santa Ana Region,
Order No. R8-2009-0030
County of Orange, Orange County Flood Control District, Cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Huntington Beach, Irvine, Lake Forest, Newport Beach, Placentia, Seal Beach and Villa Park, Claimants

By making it available on the Commission's website and providing notice of how to locate it to the email addresses provided on the attached mailing list.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct, and that this declaration was executed on August 11, 2016 at Sacramento, California.



Lorenzo Duran Jr.
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COMMISSION ON STATE MANDATES

Mailing List

Last Updated: 8/10/16

Claim Number: 09-TC-03

Matter: Santa Ana Regional Water Permit - Orange County

Claimants: City of Anaheim
City of Brea
City of Buena Park
City of Costa Mesa
City of Cypress
City of Fountain Valley
City of Fullerton
City of Huntington Beach
City of Irvine
City of Lake Forest
City of Newport Beach
City of Placentia
City of Seal Beach
City of Villa Park
County of Orange
Orange County Flood Control District

TO ALL PARTIES, INTERESTED PARTIES, AND INTERESTED PERSONS:

Each commission mailing list is continuously updated as requests are received to include or remove any party or person on the mailing list. A current mailing list is provided with commission correspondence, and a copy of the current mailing list is available upon request at any time. Except as provided otherwise by commission rule, when a party or interested party files any written material with the commission concerning a claim, it shall simultaneously serve a copy of the written material on the parties and interested parties to the claim identified on the mailing list provided by the commission. (Cal. Code Regs., tit. 2, § 1181.3.)

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